

Paramedics and Emergency Medical Technicians' Perspectives on Innovation in Prehospital Trauma Care: A Qualitative Study in Saudi Arabia

Naif Harthi

nharthi@jazanu.edu.sa

Jazan University

Fayez Mutairan Alanazi

Saudi Red Crescent Authority

Layan S. Al-Subaie

King Saud bin Abdulaziz University for Health Sciences

Shujaa D. Alyami

Saudi Red Crescent Authority

Amera Alrasheedi

Saudi Red Crescent Authority

Ziyad Darraj

Jazan University

Mohmmad A. Alharthi

Jazan University

Omar Harrash

Jazan University

Abdullah Harrash

Jazan University

Ateeq Almuwallad

Jazan University

Hussin Albargi

Jazan University

Rayan Jafnan Alharbi

Jazan University

Fayez Alruqi

Jazan University

Keywords: ambulance clinicians, emergency medical services, innovation, prehospital trauma care, qualitative research, Saudi Arabia

Posted Date: July 7th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9866787/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Title page

Title: Paramedics and Emergency Medical Technicians' Perspectives on Innovation in Prehospital Trauma Care: A Qualitative Study in Saudi Arabia

List of authors and institutional addresses:

Naif Harthi^{1*}, Fayeze Mutairan Alanazi², Layan S. Al-Subaie³, Shujaa D. Alyami⁴, Amara Alrasheedi⁵, Ziyad Darraj¹, Mohammad A. Alharthi¹, Omar Harrash¹, Abdullah Harrash¹, Ateeq Almuwallad¹, Hussin Albargi¹, Rayan Jafnan Alharbi¹, Fayeze Alruqi¹

¹ Emergency Medical Services Programme, Department of Nursing, College of Nursing and Health Sciences, Jazan University, Jazan, Saudi Arabia. ² Saudi Red Crescent Authority, Riyadh, Saudi Arabia. ³ Department of Emergency Medical Services, College of Applied Medical Sciences, King Saud bin Abdulaziz University for Health Sciences, Al-Ahsa, Saudi Arabia. ⁴ Saudi Red Crescent Authority, Najran, Saudi Arabia. ⁵ Saudi Red Crescent Authority, Eastern Province, Saudi Arabia.

Corresponding author:

Name: Naif Harthi

Email: nharthi@jazanu.edu.sa

Phone number: +966557684253

Abstract

Background: Innovation may improve prehospital trauma care by addressing problems encountered during emergency responses. However, little is known about how Saudi ambulance clinicians perceive innovation, what influences its implementation, or which developments they consider relevant to trauma care. This study explored ambulance clinicians' perspectives on innovation in prehospital trauma care in Saudi Arabia.

Methods: We conducted a qualitative study using semi-structured interviews with ambulance clinicians from the Saudi Red Crescent Authority. Participants were purposively

recruited from six cities to include paramedics and emergency medical technicians with differing durations of experience. Interviews were conducted and transcribed in Arabic, translated into English and independently back-translated before analysis. Data were analysed using the framework method, with findings charted against four research questions concerning perceptions, barriers, facilitators and potential innovations.

Results: Fourteen ambulance clinicians participated: eight paramedics and six emergency medical technicians, with experience ranging from two months to 25 years. Participants viewed innovation as practical improvement intended to address problems in prehospital trauma care, rather than solely as invention of new technology. They identified frontline experience as a source of innovation ideas and expressed willingness for retained proposals to be reported where these could benefit patients and ambulance services. Barriers included limited training and awareness, unclear routes for progressing ideas, inadequate feedback and recognition, resource and workforce constraints, equipment reliability and restricted ambulance space. Facilitators included structured training, funding and resources, supportive leadership, national readiness for innovation, transparent submission processes, recognition and communication between frontline clinicians and decision-makers. Participants described innovations already in practice, including mechanical cardiopulmonary resuscitation devices, powered stretchers, digital documentation, tranexamic acid, mechanical ventilation and specialised vehicles. Proposed developments included improved haemorrhage control, digital trauma handover, live video and remote support, artificial intelligence-assisted decision support, drones, improved dispatch, traffic-control integration, ambulance redesign and interagency coordination.

Conclusion: Saudi ambulance clinicians perceived innovation as relevant to improving prehospital trauma care and considered themselves potential contributors to its development. Innovation should be supported through transparent mechanisms for submitting and acknowledging ideas, appropriate training and structured evaluation. The proposed solutions represent frontline-informed priorities for development and assessment, rather than interventions ready for routine implementation.

Keywords: ambulance clinicians; emergency medical services; innovation; prehospital trauma care; qualitative research; Saudi Arabia

Introduction

Prehospital trauma care is a critical component of emergency medical services (EMS), requiring ambulance clinicians to assess, stabilise and transport injured patients under time-critical conditions (1,2). In Saudi Arabia, trauma and motor vehicle collisions remain major reasons for prehospital emergency responses, with the Saudi Red Crescent Authority (SRCA) responding to 95,372 road traffic accidents between 2016 and 2020 (3,4). Effective care requires rapid decision-making, appropriate interventions and timely coordination with hospital services (5–7). Improving prehospital trauma care is therefore important for reducing avoidable delays, supporting patient safety and strengthening the wider trauma care pathway (5,8).

Innovation may improve prehospital trauma care by developing, adapting and implementing clinical practices, technologies and service processes that address challenges encountered during emergency responses (9–11). In time-critical trauma care, these may include equipment and protocols to support safe interventions and decision-making, digital systems to improve information transfer, and training approaches to support the safe use of new practices (9–14). Saudi healthcare transformation under Vision 2030, including digital health expansion and efforts to improve quality and efficiency, provides opportunities to develop and evaluate such innovations (15,16).

However, successful innovation depends on more than the availability of new technologies, equipment or organisational initiatives (3,11). Ambulance clinicians work in complex, time-critical environments and are well placed to identify practical needs, implementation barriers and opportunities for service improvement (3,6,8). Their involvement can help ensure that innovations are relevant to frontline trauma care, feasible in the prehospital environment and supported by appropriate training, leadership and organisational processes (3,17). Evidence remains limited on Saudi ambulance clinicians' perceptions of innovation in prehospital trauma care and the factors influencing its implementation in routine practice. This qualitative study therefore explored their perspectives and identified barriers, facilitators and potential innovations relevant to improving trauma care delivery. It addressed the following research questions:

1. How do Saudi paramedics and emergency medical technicians (EMTs) perceive innovation in prehospital trauma care?

2. What barriers influence the implementation of innovative practices in prehospital settings?
3. What factors facilitate the implementation of innovative practices in prehospital settings?
4. What innovative approaches or tools have been, or could be, integrated to enhance prehospital trauma care delivery in Saudi Arabia?

Methods

Study design and setting

This qualitative interview study explored Saudi ambulance clinicians' perspectives on innovation in prehospital trauma care. Participants were recruited from the SRCA ambulance services in Riyadh, Jeddah, Al-Ahsa, Tabuk, Najran and Jazan. The SRCA is the principal provider of public prehospital emergency care in Saudi Arabia, providing free ambulance services across the Kingdom (18). Recruiting participants from several cities enabled the study to capture perspectives from ambulance clinicians working across different geographical and operational contexts.

Recruitment and sample

Participants were Saudi frontline ambulance clinicians employed by the SRCA, including paramedics who held bachelor's degrees in EMS and EMTs who held diploma-level qualifications (17). Participants were eligible if they currently delivered prehospital emergency care and had experience of responding to trauma patients. Purposive sampling was used to obtain perspectives from ambulance clinicians with different professional roles and durations of service across the included cities. Online interviews enabled recruitment from different operational settings.

Data collection procedures

Online semi-structured interviews were conducted via Zoom between October 2025 and February 2026, lasting approximately 45 to 60 minutes. Interviews were undertaken by NH, FMA, ZD and OH, following coordination with participants by the recruitment and coordination team. The interview schedule was developed from the study questions and informed by NH's professional experience in prehospital care. Following three pilot interviews and input from the methodological development team and participants, the schedule was refined, resulting in three versions (**Supplementary File 1**). Reflective notes were recorded after each interview to identify emerging issues and assess data sufficiency.

Use of Arabic language

Interviews were conducted and transcribed in Arabic to allow participants to describe their experiences in their preferred language (19,20). Before analysis, each transcript was forward translated into English by a bilingual member of the recruitment and coordination team and independently back-translated into Arabic by another bilingual member of the team (20–22). Any discrepancies identified through back-translation were reviewed and resolved to retain the intended meaning of participants' accounts (20–22). Quotations selected for presentation in the manuscript were checked against the original Arabic transcripts before reporting. Where participants used English clinical or technical terms during the interviews, these terms were retained in English in the translated quotations (21,23).

Data analysis

Data were analysed in English using the translated transcripts after completion of forward translation and independent back-translation. The framework method involved familiarisation, development of a thematic framework, indexing, charting and interpretation (24–26). The lead researcher reviewed the translated transcripts and reflective notes to identify initial concepts relevant to the study questions. The analytical framework developed from the early interviews was refined as analysis progressed. The framework was then applied across the dataset, and findings were charted in matrices organised according to the four research questions (**Supplementary File 2**). MAXQDA software was used to support data management and coding due to its compatibility with the Arabic language (27).

The use of structured matrices and an iterative analytical process provided an audit trail from participants' accounts to the final themes and subthemes (28–30).

Research team roles

The research team was organised into three groups according to their roles in the study. The recruitment and coordination team comprised LSA, SDA, AA, MAA and AH. Members of this team supported participant recruitment from their allocated cities or geographical areas, facilitated communication between potential participants and the interviewing team, and undertook translation of the interview transcripts. Each transcript was forward translated into English by one bilingual member of this team and independently back-translated into Arabic by another bilingual member before analysis. The interviewing team comprised NH, FMA, ZD and OH, who conducted the semi-structured interviews and documented relevant issues emerging during data collection. The methodological development team comprised NH, AM, HA, RJA and FA, who contributed to the development and refinement of the study design, methodology and interview questions. NH oversaw the study process and coordinated the contributions of the three teams. All authors reviewed and approved the final manuscript.

Rigour and trustworthiness criteria

Lincoln and Guba's trustworthiness criteria were used to guide study rigour (30,31). Credibility was supported through iterative refinement of the interview schedule following pilot interviews and participant feedback (31). Dependability and confirmability were enhanced by maintaining reflective notes and using structured matrices to document the progression from participants' accounts to the final themes and subthemes (26,31). Transferability was supported by recruiting ambulance clinicians from several Saudi cities with different professional roles and durations of service (30,31).

Ethical statement

Ethical approval was obtained from the Standing Committee for Sabbatical Leaves, Publication and Research Ethics at Jazan University, Saudi Arabia (Reference No. REC-

46/03/1197). Participants received study information and provided informed consent before interview. Participation was voluntary, with withdrawal permitted before data analysis. Interviews were anonymised using participant identification codes, and potentially identifying information, including ambulance station details, was removed before reporting. Electronic data were stored on an encrypted, password-protected system accessible only to the research team. Following the interviews, participants who proposed innovation ideas were asked to confirm their agreement for these ideas to be reported. All ideas retained in the study findings were approved for publication. Specific details that a participant requested should remain confidential were excluded.

Results

Fourteen ambulance clinicians were interviewed: eight paramedics and six EMTs from Riyadh, Jeddah, Al-Ahsa, Tabuk, Najran and Jazan. Their experience in prehospital care ranged from two months to 25 years; 12 were male and two were female. Participant characteristics are presented in Table 1.

Table 1: Characteristics of study participants

<i>No.</i>	<i>ID</i>	<i>Position</i>	<i>Gender</i>	<i>City</i>	<i>Experience years</i>
1	A1	Paramedic	Male	Jazan	6 years
2	A2	Paramedic	Male	Riyadh	6 years
3	A3	EMT	Male	Riyadh	12 years
4	A4	EMT	Male	Riyadh	12 years
5	A5	EMT	Male	Najran	17 years
6	A6	Paramedic	Male	Tabuk	5 years - 6 months
7	A7	Paramedic	Male	Riyadh	25 years
8	A8	EMT	Male	Jazan	11 years
9	A9	EMT	Male	Najran	13 years
10	A10	Paramedic	Male	Al-Ahsa	1 year – 6 months
11	A11	EMT	Male	Tabuk	15 years

12	A12	Paramedic	Female	Jeddah	3 years – 7 months
13	A13	Paramedic	Female	Jeddah	2 years
14	A14	Paramedic	Male	Al-Ahsa	2 months

201

202 Participants described their understanding of innovation, factors influencing its
 203 implementation, and innovations already in use or proposed for future development. Four
 204 domains were identified: conceptualising innovation in prehospital trauma care; barriers to
 205 innovation adoption; enablers of innovation implementation; and innovation across clinical,
 206 digital and system domains. **Table 2** summarises the domains and subthemes, while
 207 **Supplementary File 2** presents the thematic matrices and supporting quotations.

208

209 **Table 2: Themes and Subthemes**

<i>Research questions</i>	<i>Domains</i>	<i>Themes and/or their (subthemes)</i>
1. How do Saudi paramedics and EMTs perceive innovation in prehospital trauma care?	Conceptualising innovation in prehospital trauma care	1.1 Innovation as essential progress and problem-solving in prehospital care
		1.2 Innovation as enhancement of existing ideas rather than purely new invention
		1.3 Innovation as practical tools, protocols, and emerging technologies
		1.4 Need for clearer organisational awareness of innovation concepts and processes
		1.5 Innovation as a frontline contribution to improving trauma care
2. What barriers influence the implementation of innovative practices in prehospital settings?	Barriers to innovation adoption	2.1 Limited training, awareness and readiness
		2.2 Unclear governance, limited feedback and underuse of research
		2.3 Resistance to change, limited motivation and concerns about recognition
		2.4 Funding, resource, workforce and workload constraints
		2.5 Equipment reliability, usability and ambulance ergonomic constraints
3. What factors facilitate the implementation of innovative practices in prehospital settings?	Enablers of innovation implementation	3.1 Training initiatives and structured preparation before implementation
		3.2 Availability of funding and resources
		3.3 Governmental support and national readiness for innovation
		3.4 Knowledgeable and experienced leadership
		3.5 Formal initiatives and clear routes for submitting ideas
		3.6 Recognition, motivation and supportive supervision
		3.7 Open communication between frontline clinicians and administration

4. What innovative approaches or tools have been or could be integrated to enhance trauma care delivery in Saudi Arabia?	Innovation across clinical, digital, and system domains	4.1 Innovations already integrated into prehospital practice: 4.1.1 Mechanical CPR compressors (LUCAS) 4.1.2 Stretchers and safe patient handling solutions 4.1.3 Advanced monitoring and multifunctional devices 4.1.4 Intraosseous access 4.1.5 Improved splinting and limb stabilisation tools 4.1.6 Tourniquet improvements and haemostatic innovations 4.1.7 Digital documentation systems and trauma pathways 4.1.8 Tranexamic acid 4.1.9 Mechanical ventilators in ambulances 4.1.10 Specialised and rapid-response vehicles 4.2 Innovations proposed for future integration: 4.2.1 Innovations for bleeding control beyond tourniquets 4.2.2 Technologies to support difficult intravenous access 4.2.3 Improved communication and trauma networking 4.2.4 Live video, portable ultrasound, and remote clinical support 4.2.5 Artificial intelligence-enabled decision support 4.2.6 Drones and early scene support 4.2.7 Innovations to reduce response and transport delays 4.2.8 Improving dispatch intelligence and pre-arrival information 4.2.9 Upgrading ambulance design and ergonomics 4.2.10 Unified control and interagency response 4.2.11 Supply access and equipment readiness 4.2.12 Scene access, extrication support and night-time casualty identification
---	--	--

210

211 1. How do Saudi paramedics and EMTs perceive innovation in prehospital trauma care?

212 Participants perceived innovation as the development or improvement of tools, protocols
213 and service processes to address practical problems in prehospital trauma care, reduce
214 delays and support safer decision-making. They considered that innovation could involve
215 adapting existing ideas for routine practice, rather than only introducing new technologies,
216 and that frontline clinicians could contribute ideas arising from their experience. However,
217 participants identified a need for clearer organisational understanding of innovation,
218 transparent routes for developing ideas and appropriate recognition of staff contributions.

219

220 **1.1 Innovation as essential progress and problem-solving in prehospital care**

221 Participants considered innovation necessary for maintaining and improving the quality of
222 prehospital trauma care as clinical practice and technology develop. They reported that it
223 could improve safety, reduce errors and support timely decision-making in the assessment
224 and management of injured patients. Innovation was particularly relevant to practical
225 challenges encountered in time-critical care, including limited ambulance space and the
226 complexity of managing severely injured patients. Participants considered frontline
227 ambulance clinicians well placed to identify changes that could improve assessment,
228 treatment and transport across the trauma pathway.

229

230 “Innovation is essential in all aspects of medicine. Medical care must continuously evolve
231 and improve”. (Interviewee A1, paramedic, Jazan)

232 “Innovation means coming up with a new method or approach that helps improve the
233 targeted service... In EMS, our focus is on reducing time... so innovations support that.”
234 (Interviewee A10, paramedic, Al-Ahsa)

235

236 **1.2 Innovation as enhancement of existing ideas rather than purely new invention**

237 Several participants distinguished innovation from invention. They described innovation as
238 improving or adapting an existing idea in response to problems identified during prehospital
239 practice, rather than necessarily creating a completely new product. Participants considered
240 this particularly relevant to trauma care, where established tools or processes may need
241 modification to make them more practical and effective in the field. Participants considered
242 an idea to become innovative when it was developed into a solution that could be applied in
243 routine practice. They reported that experience of working in the field helped ambulance
244 clinicians recognise limitations in current equipment or procedures and identify practical

improvements. Innovation was therefore viewed as an incremental, experience-informed process intended to make trauma care safer and more effective.

“Innovation means developing or improving an existing idea. It’s not necessarily a completely new invention”. (Interviewee A5, EMT, Najran)

“Innovation comes after invention... it becomes something we actually use in practice”. (Interviewee A9, EMT, Najran)

1.3 Innovation as practical tools, protocols, and emerging technologies

Participants identified equipment, protocols and medications as practical forms of innovation in prehospital trauma care. They described devices to support haemorrhage control, splinting and other trauma interventions, alongside changes in clinical protocols such as the introduction of tranexamic acid (TXA). Participants viewed these developments as ways of improving the care provided by ambulance clinicians during trauma responses. Participants also identified digital systems and improved communication as potential forms of innovation. They described the value of transferring information between ambulance clinicians and receiving hospitals to support preparation before patient arrival and improve coordination of care. Some participants identified emerging technologies, including artificial intelligence (AI), as potential means of supporting clinical decision-making, but emphasised that innovations must be practical at the scene and implemented consistently across ambulance teams.

“It could be tools, maybe something to help with bleeding control... It could also be protocols, for example, the recent introduction of tranexamic acid”. (Interviewee A12, paramedic, Jeddah)

“Innovations that go beyond the existing manual tools... Like splints that are more advanced than the manual ones”. (Interviewee A14, paramedic, Al-Ahsa)

1.4 Need for clearer organisational awareness of innovation concepts and processes

Some participants reported uncertainty about how innovation was understood and managed within the SRCA. They suggested that ambulance clinicians needed clearer information about what constituted innovation, how ideas could be submitted and how proposals would be assessed and progressed. Participants perceived transparent processes and feedback as important for encouraging frontline clinicians to contribute ideas arising from their practice.

“I would create awareness sessions about innovation... explaining what innovation means and how it works... Everything should be clear and transparent”. (Interviewee A4, EMT, Riyadh)

“There’s no dedicated place or department for innovations, no clear channel where someone with an idea can present it”. (Interviewee A13, paramedic, Jeddah)

1.5 Innovation as a frontline contribution to improving trauma care

Participants considered frontline ambulance clinicians a potential source of innovation in prehospital trauma care. Their experience enabled them to identify limitations in current practice and propose solutions relating to haemorrhage control, communication, decision support, dispatch, equipment readiness, patient access and ambulance design. Some participants were willing to share their ideas to improve ambulance services or benefit injured patients, while others emphasised the role of field experience in refining innovations for routine care. Ambulance clinicians therefore viewed themselves as contributors to innovation as well as users of new practices. However, they also reported that concerns about acknowledgement and ownership could discourage the sharing of ideas. Only ideas that participants agreed could be reported were included in this study; specific details that one participant wished to keep confidential were excluded.

300 “I do not have a problem if the research produces ideas that benefit society and benefit the
301 patient”. (Interviewee A5, EMT, Najran)

302 “From a field perspective, I can explain how an innovation could help in real situations. I can
303 also provide my own field-based ideas that could help improve the innovation”.
304 (Interviewee A14, paramedic, Al-Ahsa)

305

306 **2. What barriers influence the implementation of innovative practices in prehospital** 307 **settings?**

308 Participants identified individual, organisational and operational barriers to innovation,
309 including limited training and awareness, unclear routes for progressing ideas, inadequate
310 feedback and recognition, resistance to change, resource and workload pressures, and
311 practical difficulties in using innovations within the ambulance environment.

312

313 **2.1 Limited training, awareness and readiness**

314 Participants reported that inadequate or inconsistent training limited the implementation of
315 innovations in prehospital trauma care. Without structured preparation, clinicians described
316 uncertainty and reduced confidence in using new equipment or protocols during time-
317 critical care. Although some received practical training before using particular devices, those
318 joining after implementation often relied on written instructions or informal learning.

319 Participants also reported limited awareness of what constituted innovation and how ideas
320 could be progressed within the organisation. Greater awareness and consistent training
321 were therefore considered necessary to support engagement with innovation and its safe
322 use across ambulance teams.

323

324 “Not everyone is familiar with the trauma pathway... some staff don’t have full awareness of
325 the system or protocols”. (Interviewee A12, paramedic, Jeddah)

“When new things are introduced, there isn’t enough training... sometimes, when there’s no training, we don’t use new equipment and lack of confidence is an issue”. (Interviewee A13, paramedic, Jeddah)

2.2 Unclear governance, limited feedback and underuse of research

Participants reported uncertainty about how innovation ideas were managed within the SRCA, including where proposals should be submitted, how they would be assessed and whether they could progress to implementation. They considered clear submission routes, transparent review and timely feedback important for encouraging further contributions from frontline clinicians. Participants also perceived limited communication between ambulance clinicians and administrative decision-makers, which could prevent service development from addressing challenges encountered during trauma care. Greater frontline involvement and more consistent use of evidence were therefore considered necessary to support relevant innovation in prehospital trauma care.

“There’s no dedicated place or department for innovations, no clear channel where someone with an idea can present it”. (Interviewee A13, paramedic, Jeddah)

“Even if you submit an idea, it might take 6 or 7 months going from email to email”.
(Interviewee A12, paramedic, Jeddah)

2.3 Resistance to change, limited motivation and concerns about recognition

Participants reported that resistance to change could limit the adoption of innovation, particularly where clinicians preferred established approaches or were reluctant to use new equipment or protocols. They considered that resistance might be reduced by explaining the purpose of an innovation, addressing concerns and formally supporting its use in routine care. Motivation was also influenced by encouragement, recognition and trust. Participants described concern that ideas might not be acknowledged or could be progressed without appropriate credit, while slow or unclear organisational responses further discouraged engagement. They therefore considered supportive leadership, recognition of contributors

and clear processes for assessing and progressing ideas important for sustaining innovation in prehospital trauma care.

“Some colleagues resist change... they prefer to stick to traditional methods and oppose new technologies”. (Interviewee A2, paramedic, Riyadh)

“If you propose an idea, they might dismiss it... or later you might see your idea turned into something by someone else”. (Interviewee A9, EMT, Najran)

“There’s nothing truly motivating, nothing official... even something small, like a certificate of appreciation, could make a difference”. (Interviewee A13, paramedic, Jeddah)

2.4 Funding, resource, workforce and workload constraints

Participants reported that funding, resource availability and workforce capacity influenced the consistent implementation of innovation in prehospital trauma care. Limited funding could restrict the purchase and maintenance of equipment, while uneven availability of innovations across ambulance teams and regions reduced access in practice. Some specialised response vehicles were reported to be limited in number or unable to operate regularly because appropriately trained staff were unavailable. Participants also identified workload as a barrier, as immediate operational demands limited clinicians’ capacity to learn about new approaches or contribute ideas for service improvement.

“You can’t expect someone to innovate when they’re under constant work pressure”.
(Interviewee A11, EMT, Tabuk)

“Funding the idea yourself is tough. If you invest time and money and then they tell you your innovation isn’t helpful or worthwhile, it’s discouraging”. (Interviewee A9, EMT, Najran)

2.5 Equipment reliability, usability and ambulance ergonomic constraints

Participants identified reliability, usability and suitability for the ambulance environment as barriers to implementing innovative equipment. Malfunctioning devices, including battery-dependent equipment that could fail without warning, were reported to delay care and reduce confidence in subsequent use. Participants also considered some devices impractical where they required lengthy preparation or could not be applied to particular patients, including those with larger body size. Limited ambulance space and restrictive vehicle layouts further constrained the use of new equipment, particularly when managing unstable or difficult-to-move trauma patients. Innovations were therefore considered more likely to be adopted where they were reliable, quick to use and suited to the practical demands of prehospital trauma care.

“Some barriers might be the complexity of using or setting up the device... Or the device might not suit every patient”. (Interviewee A10, paramedic, Al-Ahsa)

“I’ve had some social and family responsibilities... those circumstances haven’t given me the opportunity”. (Interviewee A9, EMT, Najran)

3. What factors facilitate the implementation of innovative practices in prehospital settings?

Participants identified practical training, adequate resources, supportive leadership and clear organisational processes as facilitators of innovation in prehospital trauma care. They also emphasised national support for innovation, recognition of staff contributions and effective communication between frontline clinicians and decision-makers.

3.1 Training initiatives and structured preparation before implementation

Participants identified practical training as necessary for the safe and confident use of innovations in prehospital trauma care. They considered that preparation should explain the purpose, indications and application of new tools or protocols, using approaches such as

online materials, videos, device training, workshops and scenario-based learning. Training should also be repeated and available across ambulance stations to prepare clinicians joining after implementation and maintain readiness for changes in practice.

“Any new innovation... requires thorough training provided by the institution”. (Interviewee A10, paramedic, Al-Ahsa)

“They welcomed questions and sent out a lot of videos and courses before implementation”. (Interviewee A3, EMT, Riyadh)

3.2 Availability of funding and resources

Participants reported that funding and operational resources were required to support innovation in prehospital trauma care. They described financial support as necessary for developing ideas, purchasing or maintaining equipment and implementing innovations across ambulance teams. Some participants also suggested that linking frontline clinicians with organisations able to fund or support innovation could help develop practical solutions arising from field experience.

“Without financial support, your idea won’t succeed”. (Interviewee A14, paramedic, Al-Ahsa)

“Linking innovators with funding organisations helps bring these ideas to life”. (Interviewee A2, paramedic, Riyadh)

3.3 Governmental support and national readiness for innovation

Participants viewed governmental support and national healthcare development as facilitators for innovation in prehospital trauma care. They perceived that the wider emphasis on innovation in Saudi Arabia could support the introduction of new technologies and service improvements within ambulance care. Some participants considered that

opportunities for sharing ideas had increased and that developments likely to benefit patient care would receive support.

“Our government ensures that we have access to the latest innovations... if a new technology benefits patient care, they make sure it is available to us as soon as possible”.
(Interviewee A1, paramedic, Jazan)

“There has been noticeable progress in recent years in Saudi Arabia”. (Interviewee A14, paramedic, Al-Ahsa)

3.4 Knowledgeable and experienced leadership

Participants identified leadership that understood frontline practice as important for supporting innovation. Clinically experienced leaders were considered better able to recognise relevant ideas, support implementation and engage staff, particularly when informed by developments in other healthcare systems. Participants also valued experienced ambulance clinicians who could identify operational needs, develop ideas arising from challenging cases and communicate them to decision-makers. Frontline involvement was considered essential for assessing whether proposed innovations were practical and safe for routine use. Participants therefore viewed knowledgeable leadership and frontline expertise as complementary in developing clinically relevant innovation in prehospital trauma care.

“Leaders who studied abroad and experienced advanced medical practices overseas often introduce these innovations when they return”. (Interviewee A2, paramedic, Riyadh)
“People with 15 or 20 years in the field, with connections across various regions, could help facilitate innovation”. (Interviewee A6, paramedic, Tabuk)

3.5 Formal initiatives and clear routes for submitting ideas

Participants identified accessible and transparent routes for submitting ideas as facilitators of innovation. Formal mechanisms, including meetings with senior leaders, communication channels and electronic submission initiatives, were considered useful for enabling ambulance clinicians across different regions to contribute suggestions arising from practice. However, awareness of these mechanisms and feedback following submission appeared to vary. Participants considered transparent review, timely feedback and acknowledgement of contributors necessary to sustain engagement with organisational innovation activities.

“The Vice President hosts periodic meetings, and if we have a suggestion or idea, we can present it directly”. (Interviewee A3, EMT, Riyadh)

“They had an annual initiative where anyone with an idea or innovation could submit it via email”. (Interviewee A4, EMT, Riyadh)

3.6 Recognition, motivation and supportive supervision

Participants considered supportive supervision and recognition of staff contributions important for sustaining engagement with innovation. They reported that clinicians were more likely to share and develop ideas in environments where supervisors listened to frontline concerns and encouraged improvement. Financial rewards, formal awards, certificates of appreciation, training opportunities and acknowledgement through performance assessment were identified as ways of recognising contributors. Participants therefore considered both supportive working relationships and formal recognition necessary to demonstrate that innovation was valued and encourage further involvement.

“They offer awards for those who propose ideas... there are material prizes for innovators.” (Interviewee A4, EMT, Riyadh)

“If the environment is positive, then ideas will come out. Supportive people around you help you express your ideas and help develop them”. (Interviewee A14, paramedic, Al-Ahsa)

3.7 Open communication between frontline clinicians and administration

Participants identified communication between frontline clinicians and administrative decision-makers as an important facilitator for innovation. They reported that ambulance clinicians encounter practical challenges during trauma responses that may not be apparent to those outside the field. Participants suggested that accessible routes for sharing concerns and proposed solutions could help align service developments with frontline needs, including improved trauma handover and coordination with receiving hospitals.

“Discussing field challenges with supervisors and decision-makers is crucial. When we communicate these issues effectively, solutions can be developed”. (Interviewee A1, paramedic, Jazan)

“Listen to our field-based solutions, like improving the handover process”. (Interviewee A8, EMT, Jazan)

4. What innovative approaches or tools have been or could be integrated to enhance trauma care delivery in Saudi Arabia?

Participants identified innovations already introduced into prehospital practice and further developments that could address remaining challenges in trauma care. Existing innovations included equipment and approaches supporting resuscitation, patient movement, monitoring, vascular access, limb stabilisation, haemorrhage control, documentation, treatment and emergency response. Proposed innovations addressed bleeding control, vascular access, communication with hospitals, remote clinical support, decision-making, dispatch, scene access, ambulance design and interagency coordination.

4.1 Innovations already integrated into prehospital practice

Participants described the benefits and practical limitations of innovations already integrated into prehospital trauma care, including devices and approaches supporting resuscitation, patient handling, monitoring, vascular access, limb stabilisation, haemorrhage control, documentation, treatment and emergency response:

520

521 **4.1.1 Mechanical CPR compressors (LUCAS)**

522 Participants described mechanical CPR compressors as a useful innovation during
523 resuscitation in the prehospital environment. They reported that delivering manual chest
524 compressions in a moving ambulance could be difficult because of limited space, transport
525 conditions and staffing constraints. Participants reported that the LUCAS device could
526 maintain chest compressions during transfer, particularly when staffing was limited, while
527 enabling clinicians to perform other interventions, including airway management, vascular
528 access and medication administration. However, they reported limitations relating to device
529 weight and suitability for different patient body sizes, particularly where the device could
530 not be applied effectively to larger patients. Participants also suggested that training was
531 required to support appropriate integration of the device with other resuscitation
532 interventions.

533

534 “It allows the paramedic to focus on airway management or medication while the machine
535 handles compressions”. (Interviewee A10, paramedic, Al-Ahsa)

536 “Its main limitation is for obese patients... so we go back to manual CPR for heavier
537 patients”. (Interviewee A8, EMT, Jazan)

538

539 **4.1.2 Stretchers and safe patient handling solutions**

540 Participants described electric or hydraulic stretchers as useful innovations for reducing the
541 physical demands of moving trauma patients. They reported that manual lifting, particularly
542 of heavier patients, could contribute to back pain and injury among ambulance clinicians.
543 Participants perceived that powered stretcher systems reduced the need for manual lifting
544 and supported safer movement and loading of patients into ambulances. Participants also
545 identified limitations to powered stretcher systems. They reported that some stretchers
546 were themselves heavy and could remain difficult to manoeuvre in restricted spaces or
547 when transporting patients from upper floors. Participants identified a need for further

solutions to reduce the physical demands of moving very heavy patients, particularly from locations involving stairs, restricted access or difficult extrication.

“Many ambulance workers experienced lower back pain due to lifting heavy patients. Now, we have an electric stretcher... which has significantly reduced these issues”. (Interviewee A2, paramedic, Riyadh)

“There is one negative, the stretcher is very heavy, extremely heavy”. (Interviewee A14, paramedic, Al-Ahsa)

4.1.3 Advanced monitoring and multifunctional devices

Participants described multifunctional monitoring and defibrillation devices as useful innovations in prehospital care. They reported that combining physiological monitoring, electrocardiography and defibrillation functions within a single device reduced the need to use multiple items of equipment during assessment, transport and resuscitation. However, participants also noted that these devices could be heavy or difficult to move at challenging scenes, which limited their practicality outside the ambulance.

“When transporting a cardiac arrest case, you only need one device. It has everything; defibrillation, monitoring, BP; all in one”. (Interviewee A9, EMT, Najran)

“The LifePak now delivers electric shocks, performs ECGs on site, and functions as a vital signs monitor. It replaced multiple devices”. (Interviewee A8, EMT, Jazan)

4.1.4 Intraosseous access

Participants described intraosseous access as a useful innovation for trauma patients with major haemorrhage or shock when peripheral intravenous access was difficult to obtain. They reported that intraosseous access could allow fluids or medications to be administered without repeated attempts at peripheral cannulation. However, one participant described

concerns about the reliability of battery-dependent equipment, particularly where a device could lose power without a visible warning during a time-critical response.

“In severe bleeding cases, it was impossible to find a vein... in under a minute, you bypass vein hunting and begin treatment directly via the bone”. (Interviewee A8, EMT, Jazan)
“The device battery runs out, and there’s no indicator showing how much charge is left”.
(Interviewee A14, paramedic, Al-Ahsa)

4.1.5 Improved splinting and limb stabilisation tools

One participant described improved splinting devices as a practical innovation for stabilising limb injuries in confined environments. He reported that newer splints were easier to apply than rigid alternatives, particularly when patients remained trapped inside vehicles or access was restricted. The participant considered these devices useful for enabling earlier stabilisation of injured limbs before extrication and transport.

“These are used especially for trauma cases where patients are trapped inside vehicles... You can apply splints before the Civil Defense arrives”. (Interviewee A8, EMT, Jazan)

4.1.6 Tourniquet improvements and haemostatic innovations

Participants described improved tourniquets and haemostatic dressings as innovations intended to support haemorrhage control in prehospital trauma care. They reported that newer tourniquet designs could be easier to apply and more suitable for severe limb injuries, including traumatic amputations. Haemostatic dressings were considered potentially useful for wounds where tourniquets could not be applied. However, participants expressed uncertainty about whether these dressings were consistently available across ambulance stations.

“This one is stronger... very durable... and effectively slows the bleeding in amputation cases”. (Interviewee A8, EMT, Jazan)

“This dressing causes rapid clotting... sometimes there’s bleeding in an area where a tourniquet can’t be applied”. (Interviewee A14, paramedic, Al-Ahsa)

4.1.7 Digital documentation systems and trauma pathways

Participants identified tablet-based electronic patient care reporting as an important innovation in prehospital practice. Compared with paper-based reporting, electronic documentation provided a more structured record of assessment and treatment and enabled information to be shared with receiving hospitals before arrival, supporting preparation for trauma patients. However, participants reported that newer versions could provide less useful pre-arrival information and increase the time required for documentation. Although integrated trauma pathways supported classification and destination decisions, they were not always straightforward to use in practice. Participants suggested that better integration of ambulance and hospital records could improve access to relevant patient information and continuity of trauma care.

“We now receive dispatches through the iPad, with the full case file, location, and everything... That iPad idea was a huge leap forward”. (Interviewee A7, paramedic, Riyadh)

“There’s a pathway in the tablet... I select: stable case, emergency case, or critical case. That data is sent to the designated hospital”. (Interviewee A13, paramedic, Jeddah)

4.1.8 Tranexamic acid

Participants described TXA as a medication-related innovation for managing bleeding in prehospital trauma care. They reported that TXA had been introduced into ambulance practice and perceived it as potentially useful for patients with significant haemorrhage. However, participants reported that its use was limited by inconsistent availability and the time needed for preparation when ready-to-use formulations were unavailable. One

participant also reported that short transport times to trauma centres could reduce the perceived practicality of administering TXA before hospital arrival.

“Tranexamic acid... helps clot formation... it’s a very beneficial and simple innovation”.

(Interviewee A10, paramedic, Al-Ahsa)

“TXA helps by forming clots at the bleeding site... I’ve given it before... but it’s not provided in large quantities”. (Interviewee A14, paramedic, Al-Ahsa)

4.1.9 Mechanical ventilators in ambulances

Participants described mechanical ventilators as an innovation that extended the capability of ambulance clinicians to manage critically unwell trauma patients during transport. They reported that the introduction of ventilators required specialised training and provided an option for supporting patients requiring advanced respiratory care. However, participants also identified practical limitations, including the time needed to prepare ventilator settings and the limited opportunity to use the device during short journeys to hospital.

“The introduction of ventilators in ambulances... We received specialised training... which helped us operate the ventilators effectively”. (Interviewee A2, paramedic, Riyadh)

“It takes time to adjust settings like weight and the number of breaths”. (Interviewee A7, paramedic, Riyadh)

4.1.10 Specialised and rapid-response vehicles

One participant described several SRCA specialised vehicles as operational innovations relevant to prehospital trauma care. He reported that Rapid Intervention Vehicles, including Ubayyah and Khuzam, could reach incidents before standard ambulances and provide initial assessment and essential equipment while further transport support was arranged. Khuzam and Al-Taamer were described as vehicles designed to support access in difficult terrain, including desert, off-road, mountainous or rocky environments. He also identified Tuwaiq as

a larger response vehicle intended to expand transport capacity during incidents involving multiple casualties. However, he reported that the availability and routine operation of these vehicles varied between regions and could be limited by the number of trained staff available to operate them.

“They speed up response time and reduce reliance on ambulances”. (Interviewee A14, paramedic, Al-Ahsa)

“Khuzam is designed for rough terrain, desert or off-road environments”. (Interviewee A14, paramedic, Al-Ahsa)

4.2 Innovations proposed for future integration

Participants proposed innovations to address continuing challenges in prehospital trauma care, including approaches to improve haemorrhage control, vascular access, hospital communication, remote clinical support, decision-making, dispatch, scene access, ambulance design, equipment readiness and interagency coordination. These proposals were generally presented as practical responses to problems encountered during trauma care:

4.2.1 Innovations for bleeding control beyond tourniquets

Participants identified haemorrhage control as an area requiring further innovation in prehospital trauma care. They reported that tourniquets could be difficult to manage during prolonged transfers and were not suitable for bleeding from non-limb injuries. Participants suggested alternative approaches for temporarily controlling severe external bleeding before hospital arrival, particularly where tourniquets could not be applied. One participant proposed a wound-closure device for large bleeding wounds as an idea requiring further development and evaluation.

“If there were something other than a tourniquet that could help us, especially for long-distance calls, it would be very helpful”. (Interviewee A4, EMT, Riyadh)

“My idea is a stapler with sterile clips that temporarily closes the wound until the patient reaches the hospital”, (Interviewee A10, paramedic, Al-Ahsa)

4.2.2 Technologies to support difficult intravenous access

Two participants proposed technologies to support intravenous access when cannulation was difficult during prehospital care. They described situations in which patient condition, including active seizures or severe illness, could delay intravenous access and the administration of treatment. One participant suggested that a handheld vein-visualisation device could help ambulance clinicians identify suitable veins more quickly in challenging cases. These devices were viewed as potential aids to clinical practice rather than alternatives to existing skills or established vascular-access approaches.

“There are devices that help the technician insert an IV line... maybe a handheld scanner”.
(Interviewee A3, EMT, Riyadh)

4.2.3 Improved communication and trauma networking

Participants identified communication between ambulance clinicians and receiving hospitals as requiring further development. They considered timely and direct transfer of clinical information important for hospital preparation and coordinated trauma handover, but reported that existing routes could be indirect, unreliable or require information to be repeated on arrival. Better digital integration and clearer reception processes were considered important for reducing delays and supporting continuity of care. Participants also proposed stronger links between ambulance services, receiving hospitals and specialist trauma centres, including remote specialist advice for smaller hospitals managing complex injuries before transfer. One participant suggested that a designated handover process or staff role could reduce delays when receiving clinicians were occupied with immediate treatment.

714

715 “I wish the iPad could automatically send all the data to the hospital before we even arrive”.

716 (Interviewee A7, paramedic, Riyadh)

717 “Sometimes we wait 20 minutes, half an hour, sometimes even an hour, just to complete

718 the handover”. (Interviewee A7, paramedic, Riyadh)

719

720 **4.2.4 Live video, portable ultrasound, and remote clinical support**

721 Participants described live video and portable ultrasound as possible approaches to remote

722 clinical support during prehospital trauma care. One participant suggested that live video

723 from the scene could allow medical oversight and advice during complex incidents, and that

724 ultrasound images could potentially be transmitted to a trauma centre for review. However,

725 another participant questioned the practicality of portable ultrasound in ambulance care,

726 considering that it could distract from immediate assessment and treatment when definitive

727 imaging would subsequently be undertaken in hospital.

728

729 “The dispatcher should be able to activate a live video... allowing the medical director to see

730 the scene live and guide the field team in real time”. (Interviewee A5, EMT, Najran)

731

732 **4.2.5 Artificial intelligence-enabled decision support**

733 Participants identified the AI as a possible future innovation for supporting prehospital

734 trauma care. They suggested that AI integrated into electronic systems could provide

735 prompts or structured guidance during assessment and help clinicians manage information

736 in high-pressure situations. However, one participant expressed concern that reliance on AI

737 during active clinical care could reduce opportunities for clinicians to develop independent

738 judgement. Participants therefore described potential roles for AI both as a limited decision-

739 support tool during care and as a post-event learning resource for reviewing cases and

740 supporting reflection.

741

742 “The AI provides an initial assessment or suggestion... It gives you a guideline to follow”.

743 (Interviewee A10, paramedic, Al-Ahsa)

745 **4.2.6 Drones and early scene support**

746 One participant proposed drones as a potential means of providing early support before an
747 ambulance arrived at the scene. He suggested that drones could carry essential equipment,
748 such as first aid supplies or an automated external defibrillator, particularly where long
749 distances or traffic congestion delayed ambulance response. However, he considered
750 drones an adjunct rather than a replacement for ambulance clinicians, particularly in major
751 trauma where direct assessment and clinical decision-making were required.

753 “Long distances and traffic congestion are major problems. A drone could be the solution”.

754 (Interviewee A7, paramedic, Riyadh)

756 **4.2.7 Innovations to reduce response and transport delays**

757 Participants identified traffic congestion and long transport distances as important
758 challenges for time-critical trauma care. They proposed system-level approaches to improve
759 access and transport, including traffic-control integration, designated emergency lanes in
760 congested cities and expanded air ambulance provision for rural or remote areas.

761 Participants recognised that wider use of air transport would require appropriate resources,
762 trained staff and operational support.

764 “If the operations control room was linked to traffic lights... to automatically open
765 intersections for ambulances, it would significantly reduce time”. (Interviewee A3, EMT,

766 Riyadh)

768 **4.2.8 Improving dispatch intelligence and pre-arrival information**

Participants reported that accurate pre-arrival information was important for preparing for trauma responses. They described difficulties when dispatch information contained limited clinical detail or when incident locations were inaccurate, which could reduce preparation and delay arrival at the scene. Participants suggested that more complete case information, accurate location sharing and reliable digital dispatch could help clinicians prepare equipment and plan initial care before arrival at the scene.

“When I get a trauma call, I want to know the details so I can mentally prepare and know what equipment and interventions to get ready”. (Interviewee A4, EMT, Riyadh)
“The biggest problem we face is location accuracy... We arrived late because the location was not accurate”. (Interviewee A14, paramedic, Al-Ahsa)

4.2.9 Upgrading ambulance design and ergonomics

Participants identified ambulance design and cabin ergonomics as areas requiring further innovation. They reported that older vehicles and restricted interior layouts could affect reliability and limit the ability of ambulance clinicians to undertake multiple interventions during transport. Participants suggested that newer ambulance models and improved cabin organisation could support the practical use of equipment and enable safer, more efficient delivery of care during complex trauma cases.

“Many ambulances aren’t set up in a way that allows you to do more than one thing at a time”. (Interviewee A12, paramedic, Jeddah)

4.2.10 Unified control and interagency response

One participant proposed closer coordination between ambulance services and traffic police to improve access and safety at trauma scenes. He reported that bystanders and crowding around road traffic collisions could obstruct ambulance access and delay care. He suggested

796 that joint dispatch or a unified control centre could coordinate attendance by traffic police
797 and ambulance teams, enabling crowd control and improving access to injured patients.

798

799 “I hope that for every accident, a traffic police unit is dispatched alongside the Red
800 Crescent... through a unified control centre”. (Interviewee A8, EMT, Jazan)

801

802 **4.2.11 Supply access and equipment readiness**

803 Participants identified supply availability and equipment readiness as areas for future
804 innovation. One participant proposed a hospital-based self-service system through which
805 ambulance clinicians could rapidly obtain essential supplies between calls, while
806 acknowledging potential barriers relating to cost, approval and coordination with hospitals.
807 Another participant identified shortages, inadequate restocking and equipment failure as
808 barriers to care, and considered portable, readily accessible equipment particularly valuable
809 when patients were located away from the ambulance.

810

811 “This vending machine would be in the hospital... You’d select what you need and scan your
812 ID card to take it”. (Interviewee A7, paramedic, Riyadh)

813 “The idea is to improve response speed... the paramedic could just grab what they need and
814 move on to the next case”. (Interviewee A7, paramedic, Riyadh)

815

816 **4.2.12 Scene access, extrication support and night-time casualty identification**

817 Participants identified scene access and casualty identification as areas requiring further
818 innovation, particularly at road traffic collision scenes involving entrapment or multiple
819 casualties. One participant reported that ambulance clinicians may be unable to access or
820 treat trapped patients until Civil Defence completes extrication, and suggested that a simple

tool for minor entrapment could support earlier access where appropriate. Participants also described difficulties identifying casualties during night-time incidents, particularly when patients had been ejected from vehicles. They suggested that improved scene illumination or area-scanning equipment could assist clinicians in identifying injured patients at complex scenes.

“If there was a simple tool that could help us free the patient when the entrapment is not extremely severe, that would solve a major issue”. (Interviewee A14, paramedic, Al-Ahsa)

“I wish there were something that scans the whole area around us, shows how many patients there are”. (Interviewee A14, paramedic, Al-Ahsa)

Discussion

To our knowledge, this is the first qualitative study in Saudi Arabia and the wider Middle East to explore ambulance clinicians’ perspectives on innovation in prehospital trauma care. The participants viewed innovation as a practical response to frontline challenges, extending beyond new technologies to include clinical, digital and system-level improvements. They identified training, resources, leadership, communication, organisational processes and operational suitability as key influences on implementation. Their proposed innovations addressed recurring challenges in haemorrhage control, trauma handover, dispatch, patient access and ambulance design. Participants viewed innovation as a practical response to frontline problems rather than simply the introduction of new technologies. This aligns with evidence that implementation in EMS depends on whether new practices address operational needs and whether clinicians are supported to use them in routine care (11,32–34). Saudi evidence on prehospital ultrasound similarly indicates that implementation requires attention to feasibility, training and integration with emergency department care. Abbas et al. (2020) identified support for the feasibility of ultrasound use in Saudi ambulances and the importance of training and communication with emergency departments (35), while Alsulami et al. (2024) identified cost, environmental constraints and lack of training as barriers to implementing prehospital ultrasound within the SRCA (3). Our findings extend this evidence by showing that ambulance clinicians identified innovation

needs across clinical interventions, communication, handover, dispatch, vehicle design and interagency response. This suggests that frontline ambulance clinicians should therefore be involved in setting priorities for innovation, while proposed developments should undergo structured assessment and evaluation before routine implementation (32,36,37).

Participants identified training as central to implementing innovation safely and consistently. They reported reduced confidence in using new equipment or practices when preparation was limited or when training was unavailable to clinicians joining after implementation. This finding is consistent with international evidence on the implementation of new practices in EMS. A systematic review of prehospital evidence-based guideline implementation identified educational and organisational approaches as relevant, although evidence on their effectiveness was limited (11). A five-state United States study implementing a prehospital traumatic pain management guideline used standardised training and implementation plans, but found difficulty in monitoring training and achieving consistency across EMS systems (34). More recently, a scoping review identified training and education as key factors influencing implementation in EMS systems (32). In Finland, a new prehospital anaesthesia protocol was implemented using lectures, simulation, skills stations, cognitive aids and continuing support, with sustained improvement in protocol-related performance indicators (33). Innovation in prehospital trauma care therefore requires structured training and continuing support to ensure safe and consistent use across ambulance teams.

Participants identified organisational processes as important determinants of innovation. They reported that uncertainty about how ideas should be submitted and progressed, together with limited feedback and recognition, could discourage frontline engagement. This finding is consistent with international evidence that employee-driven innovation in healthcare requires organisational resources, management support, an enabling culture and mechanisms for developing staff ideas, while bureaucracy and poor responsiveness may prevent progress (38,39). Studies involving frontline healthcare staff further indicate that innovations are more likely to progress when organisations engage stakeholders, adapt proposals to the local context and provide transparent, responsive processes and adequate resources (40–42). This accords with the proposition that frontline voice alone is insufficient unless organisations enable ideas to move towards implementation (43). Innovation in Saudi

882 prehospital care therefore requires clear submission routes, transparent assessment and
883 feedback to frontline contributors.

884 Participants identified access to usable and reliable resources as important determinants of
885 innovation in routine prehospital care. They reported that consistent use depended on
886 equipment being available, well maintained and suited to the confined, time-critical
887 ambulance environment. This finding is consistent with international prehospital evidence.
888 Finnish paramedics identified treatment equipment and information technology as
889 development priorities, but reported that limited organisational support and frontline
890 involvement constrained implementation (36). A recent scoping review similarly identified
891 organisational and resource-related factors as influences on the implementation of new
892 practices in EMS systems (32). Studies of specific technologies also highlight the importance
893 of usability and integration with clinical workflow. In Germany, the acceptability and
894 perceived effectiveness of prehospital telemedicine were associated with usability,
895 supporting a user-centred approach to implementation (44). A US qualitative study of
896 clinical decision support in EMS identified workflow disruption, alert burden, real-time
897 documentation, trust and over-reliance as considerations for implementation (45).
898 Innovations in Saudi prehospital trauma care should therefore be evaluated for usability,
899 reliability, operational fit and potential clinical benefit.

900 Participants identified national support and local leadership as facilitators of innovation.
901 They perceived that healthcare transformation in Saudi Arabia created opportunities to
902 improve ambulance care, but required local leadership to translate national priorities into
903 practice. This is consistent with Vision 2030 healthcare reforms, which emphasise digital
904 health, workforce capability, quality improvement and patient safety (15,46). International
905 evidence similarly indicates that healthcare organisations are more likely to innovate when
906 they have clear strategic direction, supportive leadership, an enabling organisational climate
907 and committed staff (39). Studies of healthcare innovation implementation have also
908 identified staff engagement, adaptation to local context and empowering, collaborative
909 leadership as important for successful change (40,47). Innovation in Saudi prehospital
910 trauma care therefore requires leadership that aligns national transformation priorities with
911 frontline clinical needs and experience.

912 Participants identified haemorrhage control as an area for innovation. Although tourniquets,
913 haemostatic dressings and TXA were available in practice, participants reported limitations
914 relating to availability, preparation and bleeding not amenable to tourniquet use. This is
915 consistent with recent evidence suggesting that tourniquets and haemostatic agents may
916 help control severe external bleeding, although comparative evidence is limited and their
917 effects on mortality and transfusion requirements remain uncertain (48,49). Evidence
918 relating to prehospital TXA also supports a cautious approach. A recent systematic review
919 and meta-analysis found reduced 24-hour mortality without a significant increase in venous
920 thromboembolism, but no significant improvement in longer-term or overall mortality while
921 a joint position statement recommended limiting prehospital TXA to adult trauma patients
922 with clinical signs of haemorrhagic shock, administered within three hours of injury (50,51).
923 Haemorrhage-control innovations in Saudi prehospital trauma care therefore require
924 reliable availability, clear indications, appropriate training and evaluation in routine practice.

925 Participants identified communication and digital information transfer between ambulance
926 clinicians and receiving hospitals as priorities for innovation. They reported that incomplete
927 information transfer and delayed handover could disrupt continuity of care and prolong
928 ambulance turnaround times. This finding is consistent with a systematic review of
929 handover from EMS to emergency departments, which identified information loss,
930 duplication, delays, technological difficulties and limited feedback as barriers to effective
931 transfer of care (52), and with a scoping review of trauma handover practices, which
932 identified communication failures, inconsistent processes and system-level barriers at the
933 ambulance–hospital interface (8). Recent international evidence also supports the potential
934 value of better pre-arrival communication while emphasising the importance of
935 implementation (53,54). A UK mixed-methods study found that prehospital pre-alerts could
936 support emergency department preparation for time-critical patients, but that variable
937 guidance, differing expectations and limited feedback contributed to inconsistent practice
938 (53). A recent scoping review also identified limited evidence on person-centred handover
939 guidance between emergency care practitioners and emergency department professionals,
940 despite the need for structured, clinically relevant information transfer (54). Digital
941 innovation in Saudi prehospital trauma care should therefore support timely, relevant and

structured information transfer for trauma reception and handover, without adding operational delays.

Participants described mechanical cardiopulmonary resuscitation (CPR) compressors, mechanical ventilators and powered stretchers as innovations supporting the practical delivery of prehospital care. They considered these devices useful for enabling concurrent interventions during resuscitation, providing respiratory support during transport and reducing the physical demands of patient movement. Evidence relating to mechanical CPR indicates that these perceived operational advantages should be distinguished from patient outcome benefit (55,56). A recent umbrella review and updated systematic review found no definitive evidence that mechanical CPR improves return of spontaneous circulation, survival or favourable neurological outcomes compared with manual compressions, although it may be useful when high-quality manual CPR cannot be delivered (56). A further meta-analysis of out-of-hospital cardiac arrest found no significant improvement in return of spontaneous circulation or survival to discharge, although survival to hospital admission may improve based on very low-certainty evidence (55). These findings are consistent with current resuscitation guidance, which does not recommend routine mechanical CPR but allows its consideration in selected circumstances where manual compressions may be difficult or unsafe to perform (57). Evidence relating to powered stretchers is more supportive of staff-safety benefits: studies have reported reduced biomechanical demands during stretcher handling and reductions in patient-handling injury rates following the introduction of power-lift stretchers (58,59). Prehospital mechanical ventilation may support consistent ventilatory care after advanced airway insertion, but requires device-specific training, appropriate monitoring and awareness of potential adverse events during transport (60,61). These innovations should therefore be evaluated according to their intended purpose, recognising potential benefits for staff safety and operational capability even where improved patient outcomes have not been demonstrated.

A further finding was that ambulance clinicians considered frontline practice to be a source of innovation. They proposed solutions to problems encountered during trauma care and, in some cases, agreed to their ideas being reported because they believed these could benefit patients and improve ambulance services in Saudi Arabia, with potential relevance beyond the local setting. Similar findings have been reported in other healthcare settings, where

973 frontline staff have generated ideas addressing operational and patient-care problems and
974 contributed to their development through structured innovation initiatives (62,63).
975 Research on nurse-led innovation has also shown that clinicians may develop solutions in
976 response to barriers to delivering high-quality care, but require support to develop and
977 disseminate these solutions more widely (64). Wider evidence on employee-driven
978 innovation indicates that staff contributions are more likely to progress when organisations
979 provide responsive processes, opportunities for development and appropriate recognition
980 (38,41,42). Participants' concerns about acknowledgement and ownership reinforce the
981 need for transparent processes that respect frontline contributions. The proposed solutions
982 should therefore be regarded as clinician-generated priorities for development and
983 evaluation, rather than new or proven interventions.

984 Participants proposed live video, portable ultrasound and AI to support clinical decision-
985 making, while recognising potential effects on practicality and professional judgement.
986 Evidence on prehospital telemedicine suggests that it can provide remote clinical assistance,
987 but that implementation depends on usability, acceptability and integration with routine
988 workflow (44,65). Evidence for prehospital point-of-care ultrasound (POCUS) remains
989 promising but incomplete. A recent scoping review found that trauma was the most
990 frequently studied indication, but that evidence was dominated by feasibility studies with
991 limited evaluation of clinical outcomes (66). A UK helicopter EMS study found that
992 prehospital POCUS could be implemented with acceptable image quality when supported by
993 training, governance, image archiving and continuous feedback. Saudi evidence has similarly
994 identified training needs, cost and environmental constraints as considerations for
995 implementation within the SRCA (3,67). Evidence relating to AI remains at an earlier stage. A
996 scoping review of AI in prehospital emergency care in low- and middle-income countries
997 identified limited evidence and a need for locally relevant evaluation (68), while a
998 qualitative study of clinical decision-support systems in EMS similarly identified workflow
999 disruption, usability, trust and avoidance of over-reliance as important design
1000 considerations (45). These suggest that remote clinical support, POCUS and AI should
1001 therefore be evaluated within Saudi ambulance services for feasibility, safety, training
1002 requirements and effects on clinical decision-making before routine use in trauma care.

Participants proposed system-level innovations to improve access to injured patients and reduce delays, including enhanced dispatch information, traffic-control integration, specialised response resources, drones and closer interagency coordination. This suggests that they viewed innovation as extending beyond clinical equipment to the wider organisation of emergency response. Their proposal for drone-supported scene response is consistent with reviews identifying potential roles for unmanned aerial vehicles in delivering time-critical equipment or medicines and supporting communication and situational awareness at remote or inaccessible scenes (69,70), while highlighting the need to address safety, regulation and integration with existing EMS systems (71). The need for improved dispatch information is supported by evidence that dispatch models vary substantially and may have limited accuracy in identifying injured patients requiring critical prehospital resources (72–74). Participants' proposals for traffic-control integration are consistent with approaches using route optimisation, traffic-signal pre-emption and lane prioritisation to reduce emergency vehicle travel time. However, their feasibility and effectiveness in routine trauma response require evaluation before implementation (75,76). Proposed coordination with traffic police is relevant to evidence that police may influence prehospital trauma care through scene access and clearance, although effects on patient outcomes remain unclear (77). System-level innovations in Saudi prehospital trauma care should therefore be evaluated for feasibility, safety, coordination requirements, effects on response time and potential patient benefit before routine implementation.

Taken together, these proposals show that frontline experience can identify priorities for innovation in prehospital trauma care. However, they do not demonstrate that the proposed solutions are feasible, effective or ready for implementation. As many involve interactions between clinical practice, technology, organisational processes and receiving services, they require stakeholder involvement, assessment of local context, feasibility testing and evaluation before wider adoption (37,78). These findings support the development of a structured, frontline-informed innovation programme in Saudi ambulance services, with transparent processes for acknowledging, prioritising and evaluating proposed solutions before their introduction into routine trauma care.

Strengths and limitations

This study has several strengths. It included ambulance clinicians from six Saudi cities, with representation from both paramedics and EMTs and a wide range of experience in prehospital care. This enabled exploration of innovation across different professional and operational contexts within the SRCA. The study also identified both innovations already encountered in practice and solutions proposed by clinicians in response to problems experienced during trauma care. Conducting interviews in Arabic enabled participants to describe their experiences in their preferred language, while forward translation, back-translation and checking of selected quotations supported accurate reporting of their accounts. A further strength was the explicit confirmation obtained from participants regarding publication of the innovation ideas retained in the findings, with specific details removed where a participant requested that these should not be disclosed.

This study also has limitations. Only two participants were female, which may limit representation of female ambulance clinicians' perspectives, although this may reflect the relatively small number of women currently working in Saudi prehospital care (79,80). All participants were employed by the SRCA, so the findings may not be transferable to clinicians working in other private or military ambulance services. Although participants were recruited from six cities, ambulance clinicians in other regions who did not participate may have identified different challenges or proposed valuable innovations not captured in this study. Participants who agreed to take part may also have had a greater interest in innovation than clinicians who did not participate, leading to greater emphasis on innovation opportunities and proposed solutions. Finally, this study explored clinicians' perceptions and ideas; it did not assess the feasibility, safety, cost or effectiveness of any specific innovation. The proposed solutions should therefore be regarded as priorities for further development and evaluation rather than recommendations for immediate implementation.

Implications for policy and practice and future research priorities

The findings suggest that innovation in Saudi prehospital trauma care should be developed through a structured and frontline-informed process. Participants identified practical limitations in current care and proposed solutions based on their experience of managing

trauma patients. The SRCA should consider establishing a clear innovation pathway that enables clinicians to submit proposals, receive feedback and contribute to development and evaluation, while ensuring appropriate acknowledgement and confidentiality where required. New practices or technologies should be supported by training, continuing support and assessment of usability, safety, maintenance needs and fit with routine ambulance care. The proposed clinical, digital and system-level innovations should be viewed as priorities for future evaluation rather than recommendations for immediate adoption. A staged programme involving ambulance clinicians, patients, trauma teams, SRCA leaders and partner agencies could prioritise proposals, assess feasibility, pilot selected innovations and evaluate clinical, operational and economic outcomes. This would enable Saudi ambulance services to develop frontline-generated ideas transparently and safely in response to identified trauma-care needs.

Conclusion

Saudi ambulance clinicians perceived innovation as a practical means of improving prehospital trauma care and identified clinical, digital and system-level developments relevant to problems encountered during routine practice. They also contributed ideas for potential solutions, indicating that frontline clinicians may have an important role in identifying priorities for service development. However, implementation was considered to depend on training, reliable resources, supportive leadership, clear organisational processes and suitability for the prehospital environment. Saudi ambulance services should establish transparent processes for receiving, acknowledging, developing and evaluating frontline-generated innovation ideas. The solutions identified in this study should not be considered established interventions, but priorities for evaluation to determine their feasibility, safety, acceptability, cost and potential contribution to improving trauma care.

Abbreviations

AI: Artificial intelligence; CPR: Cardiopulmonary resuscitation; EMS: Emergency medical services; EMT: Emergency medical technician; POCUS: Point-of-care ultrasound; SRCA: Saudi Red Crescent Authority; TXA: Tranexamic acid

Acknowledgement

We thank all ambulance clinicians who participated in this study for sharing their experiences of innovation in prehospital trauma care. We are particularly grateful for their willingness to contribute frontline-generated ideas for improving ambulance services and care for injured patients, and for permitting the reporting of the ideas retained in this manuscript. The authors gratefully acknowledge the funding of the Deanship of Graduate Studies and Scientific Research, Jazan University, Saudi Arabia, through project number: RG24-S0114.

Author contributions

NH conceived the study, developed the study design and methodology, contributed to refining the interview questions, oversaw the research process, coordinated the study teams, conducted interviews, analysed the data and drafted the manuscript. FMA, ZD and OH conducted interviews and contributed to data collection. LSA, SDA, AA, MAA and AH contributed to participant recruitment and coordination across the included geographical areas, and undertook forward translation and independent back-translation of the interview transcripts before analysis. AM, HA, RJA and FA contributed to developing and refining the study design, methodology and interview questions. All authors critically reviewed and approved the final manuscript and are accountable for the accuracy and integrity of the work.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was funded by the Jazan University, Saudi Arabia.

Declarations

Ethical approval and informed consent to participate

Ethical approval was obtained from the Standing Committee for Sabbatical Leaves, Publication and Research Ethics at Jazan University, Saudi Arabia (Reference No. REC-46/03/1197). The study was conducted in accordance with local legislation and institutional requirements. Participants received the study information before the interview and

provided informed consent to participate. Participation was voluntary, and participants were informed that they could withdraw before data analysis. Interviews were anonymised using participant identification codes, and potentially identifying information was removed before reporting.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study, including interview audio files, transcripts and translated transcripts, are not publicly available due to ethical and confidentiality considerations. The findings are presented anonymously, and potentially identifying information has been removed. Reasonable requests for access to anonymised data may be directed to the corresponding author, subject to ethical approval and institutional requirements.

Competing interests

The authors declare that they have no competing interests.

References

1. Huang W, Wang TB, He YD, Zhang H, Zhou XH, Liu H, et al. Trends and characteristics in pre-hospital emergency care in Beijing from 2008 to 2017. *Chin Med J (Engl)*. 2020;133(11):1268–1275.
2. Harthi N, Goodacre S, Sampson FC. Optimising prehospital trauma triage for older adults: challenges, limitations, and future directions. *Front Med*. 2025 Apr 22;12:1569891.
3. Alsulami M, Almukhlifi Y, Alsulami A, Al Nufaiei ZF, Alruwaili A, Alanazy A. Implementing Prehospital Ultrasound at the Saudi Red Crescent Authority: Perceived

- 1154 Barriers and Training Needs. J Multidiscip Healthc [Internet]. 2024;17:2871–8.
 1155 Available from: <https://pubmed.ncbi.nlm.nih.gov/38881755/>
- 1156 4. Alghnam S, Alghamdi M, Alzahrani S, Alzomai S, Alghannam A, Albabtain I, et al. The
 1157 prevalence of long-term rehabilitation following motor-vehicle crashes in Saudi
 1158 Arabia: a multicenter study. BMC Musculoskelet Disord. 2022 Mar 3;23(1):202–202.
- 1159 5. Almuwallad A, Harthi N, Albargi H, Siddig B, Alharbi RJ. Exploring Saudi paramedics’
 1160 experiences in managing adult trauma cases: a qualitative study. BMC Emerg Med
 1161 [Internet]. 2024 Dec 1;24(1):1–11. Available from:
 1162 <https://link.springer.com/articles/10.1186/s12873-024-01145-0>
- 1163 6. Harthi N, Goodacre S, Sampson F, Alharbi R. Research priorities for prehospital care of
 1164 older patients with injuries: scoping review. Age Ageing. 2022 May 1;51(5):1–9.
- 1165 7. Harthi N, Goodacre S, Sampson FC, Chowdhury S. The Characteristics of Older Injured
 1166 Patients Attended by Ambulances in Saudi Arabia: A Retrospective Cohort Study.
 1167 Emerg Heal Serv J [Internet]. 2025 Jul;2(2):56–64. Available from:
 1168 [https://journals.lww.com/ehsj/fulltext/2025/07000/the_characteristics_of_older_inj](https://journals.lww.com/ehsj/fulltext/2025/07000/the_characteristics_of_older_injured_patients.5.aspx)
 1169 [ured_patients.5.aspx](https://journals.lww.com/ehsj/fulltext/2025/07000/the_characteristics_of_older_injured_patients.5.aspx)
- 1170 8. Harthi N, Almuwallad A, Albargi H, Alharbi RJ, Alyami RA, Al Ruwaithi AA, et al.
 1171 Trauma handover practices between ambulance clinicians, emergency department
 1172 staff and trauma teams: scoping review. BMC Emerg Med 2026 261 [Internet]. 2026
 1173 Jan 27;26(1):57-. Available from: [https://link.springer.com/article/10.1186/s12873-](https://link.springer.com/article/10.1186/s12873-026-01480-4)
 1174 [026-01480-4](https://link.springer.com/article/10.1186/s12873-026-01480-4)
- 1175 9. Kim JY, Kim OH. Recent Advances in Prehospital and In-Hospital Management of

- 1176 Patients with Severe Trauma. J Clin Med [Internet]. 2025 Apr 1;14(7):2208. Available
1177 from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11989688/>
- 1178 10. Zhang Z, Brazil J, Ozkaynak M, Desanto K. Evaluative research of technologies for
1179 prehospital communication and coordination: a systematic review. J Med Syst. 2020
1180 Apr 3;44(5):1–14.
- 1181 11. Fishe JN, Crowe RP, Cash RE, Nudell NG, Martin-Gill C, Richards CT. Implementing
1182 Prehospital Evidence-Based Guidelines: A Systematic Literature Review. Prehospital
1183 Emerg care [Internet]. 2018 Jul 4;22(4):511–9. Available from:
1184 <https://pubmed.ncbi.nlm.nih.gov/29351495/>
- 1185 12. Abellsson A, Rystedt I, Suserud BO, Lindwall L. Mapping the use of simulation in
1186 prehospital care - a literature review. Scand J Trauma Resusc Emerg Med [Internet].
1187 2014 Mar 18;22(1). Available from: <https://pubmed.ncbi.nlm.nih.gov/24678868/>
- 1188 13. Syeed MS, Poudel N, Ngorsuraches S, Veettil SK, Chaiyakunapruk N. Characterizing
1189 attributes of innovation of technologies for healthcare: a systematic review. J Med
1190 Econ [Internet]. 2022 Dec 31;25(1):1158–66. Available from:
1191 <https://www.tandfonline.com/doi/pdf/10.1080/13696998.2022.2140591>
- 1192 14. Bhati D, Deogade MS, Kanyal D. Improving Patient Outcomes Through Effective
1193 Hospital Administration: A Comprehensive Review. Cureus [Internet]. 2023 Oct
1194 26;15(10). Available from: [/pmc/articles/PMC10676194/](https://pmc/articles/PMC10676194/)
- 1195 15. Mani ZA, Goniewicz K. Transforming Healthcare in Saudi Arabia: A Comprehensive
1196 Evaluation of Vision 2030's Impact. Sustain 2024, Vol 16, Page 3277 [Internet]. 2024
1197 Apr 15;16(8):3277. Available from: <https://www.mdpi.com/2071->

1198 1050/16/8/3277/htm

1199 16. Suleiman AK, Ming LC. Transforming healthcare: Saudi Arabia's vision 2030 healthcare
1200 model. *J Pharm Policy Pract* [Internet]. 2025;18(1):2449051. Available from:
1201 <https://pmc.ncbi.nlm.nih.gov/articles/PMC11753010/>

1202 17. Harthi N, Goodacre S, Sampson FC, Binhotan M, Alotaibi AS. Paramedics and
1203 emergency medical technicians' perceptions of geriatric trauma care in Saudi Arabia.
1204 *BMC Emerg Med*. 2025 Jan 9;25(1):1–15.

1205 18. Alanazy ARM, Fraser J, Wark S. Emergency medical services in rural and urban Saudi
1206 Arabia: a qualitative study of Red Crescent emergency personnel' perceptions of
1207 workforce and patient factors impacting effective delivery. *Health Soc Care*
1208 *Community* [Internet]. 2022 May 30;30(6):4556–63. Available from:
1209 <http://www.ncbi.nlm.nih.gov/pubmed/35634803>

1210 19. Al-Amer R, Ramjan L, Glew P, Darwish M, Salamonson Y. Language translation
1211 challenges with Arabic speakers participating in qualitative research studies. *Int J Nurs*
1212 *Stud*. 2016 Feb 1;54:150–7.

1213 20. Chen HY, Boore JRP. Translation and back-translation in qualitative nursing research:
1214 methodological review. *J Clin Nurs*. 2010 Jan;19(1–2):234–9.

1215 21. Aloudah NM. Qualitative research in the Arabic language. When should translations
1216 to English occur? A literature review. *Explor Res Clin Soc Pharm* [Internet].
1217 2022;6:100153. Available from: <https://doi.org/10.1016/j.rcsop.2022.100153>

1218 22. Dolan HR, Alvarez AA, Freylersythe SG, Crane TE. Methodology for Analyzing
1219 Qualitative Data in Multiple Languages. *Nurs Res* [Internet]. 2023 Sep 1;72(5):398–

- 1220 403. Available from: <https://pubmed.ncbi.nlm.nih.gov/37625183/>
- 1221 23. Regmi K, Naidoo J, Pilkington P. Understanding the processes of translation and
1222 transliteration in qualitative research. *Int J Qual Methods*. 2010 Mar;9(1):16–26.
- 1223 24. Ritchie J, Lewis J. *Qualitative research practice : a guide for social science students*
1224 *and researchers*. SAGE. London : SAGE; 2003.
- 1225 25. Ritchie J SL. Qualitative data analysis for applied policy research. In: Bryman A BR,
1226 editor. *Analysing qualitative data*. London: Routledge; 1994. p. 194–207.
- 1227 26. Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for
1228 the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res*
1229 *Methodol*. 2013;13(1):1–8.
- 1230 27. Aloudah NM, Scott NW, Aljadhey HS, Araujo-Soares V, Alrubeaan KA, Watson MC.
1231 Medication adherence among patients with type 2 diabetes: a mixed methods study.
1232 *PLoS One*. 2018 Dec 1;13(12):e0207583–e0207583.
- 1233 28. Ahmed SK. The pillars of trustworthiness in qualitative research. *J Med Surgery, Public*
1234 *Heal [Internet]*. 2024 Apr 1;2:100051. Available from:
1235 <https://www.sciencedirect.com/science/article/pii/S2949916X24000045>
- 1236 29. Hackett A, Strickland K. Using the framework approach to analyse qualitative data: a
1237 worked example. *Nurse Res*. 2019 Sep 21;26(2):8–13.
- 1238 30. Lincoln YS, Guba EG. But is it rigorous? Trustworthiness and authenticity in
1239 naturalistic evaluation. *New Dir Progr Eval [Internet]*. 1986;(30):73–84. Available
1240 from: <http://doi.wiley.com/10.1002/ev.1427>

- 1241 31. Shenton K. Strategies for ensuring trustworthiness in qualitative research projects.
1242 Educ Inf. 2004 Jan 1;22(2):63–75.
- 1243 32. Chiu YC, Liu CH, Chiu YL, Wang LW, Chen HL, Yang CW. The Influencing Factors of
1244 Implementation in Emergency Medical Service Systems - A Scoping Review.
1245 Prehospital Emerg care [Internet]. 2025;29(5):659–69. Available from:
1246 <https://pubmed.ncbi.nlm.nih.gov/39088818/>
- 1247 33. Ångerman S, Kirves H, Nurmi J. Multifaceted implementation and sustainability of a
1248 protocol for prehospital anaesthesia: a retrospective analysis of 2115 patients from
1249 helicopter emergency medical services. Scand J Trauma, Resusc Emerg Med 2023 311
1250 [Internet]. 2023 Apr 30;31(1):21-. Available from:
1251 <https://link.springer.com/article/10.1186/s13049-023-01086-w>
- 1252 34. Adelgais KM, Sholl JM, Alter R, Gurley KL, Broadwater-Hollifield C, Taillac P.
1253 Challenges in Statewide Implementation of a Prehospital Evidence-Based Guideline:
1254 An Assessment of Barriers and Enablers in Five States. Prehospital Emerg Care
1255 [Internet]. 2019 Mar 4;23(2):167–78. Available from:
1256 <https://www.tandfonline.com/doi/abs/10.1080/10903127.2018.1495284>
- 1257 35. Abbas I, Shakhreet BZ, Alghamdi A, Wali B, Alelyani B, Alshehri T. Feasibility of using
1258 ultrasound in ambulances in Saudi Arabia. World J Radiol [Internet]. 2020 Dec
1259 28;12(12):302–15. Available from: <https://pubmed.ncbi.nlm.nih.gov/33510854/>
- 1260 36. Rinkinen T, Kinnula M, Nordquist H. Technological development roles and needs in
1261 pre-hospital emergency care from the advanced level paramedics' perspective. Int
1262 Emerg Nurs [Internet]. 2024 Mar 1;73:101406. Available from:

- 1263 <https://www.sciencedirect.com/science/article/pii/S1755599X24000016>
- 1264 37. Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new
1265 framework for developing and evaluating complex interventions: update of Medical
1266 Research Council guidance. *Int J Nurs Stud* [Internet]. 2024 Jun 1;154:104705.
1267 Available from:
1268 <https://www.sciencedirect.com/science/article/abs/pii/S0020748924000178>
- 1269 38. Cadeddu SBM, Dare LO, Denis JL. Employee-Driven Innovation in Health
1270 Organizations: Insights From a Scoping Review. *Int J Heal policy Manag* [Internet].
1271 2023;12(1). Available from: <https://pubmed.ncbi.nlm.nih.gov/37579391/>
- 1272 39. van den Hoed MW, Backhaus R, de Vries E, Hamers JPH, Daniëls R. Factors
1273 contributing to innovation readiness in health care organizations: a scoping review.
1274 *BMC Heal Serv Res* 2022 221 [Internet]. 2022 Aug 5;22(1):997-. Available from:
1275 <https://link.springer.com/article/10.1186/s12913-022-08185-x>
- 1276 40. Wutzke S, Benton M, Verma R. Towards the implementation of large scale
1277 innovations in complex health care systems: views of managers and frontline
1278 personnel. *BMC Res Notes* [Internet]. 2016 Jun 28;9(1):327. Available from:
1279 <https://pmc.ncbi.nlm.nih.gov/articles/PMC4924288/>
- 1280 41. Taylor R, Fuller A, Halford S, Lyle K, Teglborg AC. Translating employee-driven
1281 innovation in healthcare: Bricolage and the mobilization of scarce resources. *Public*
1282 *Money Manag* [Internet]. 2021 Jul 4;41(5):376–86. Available from:
1283 <https://www.tandfonline.com/doi/abs/10.1080/09540962.2020.1824408>
- 1284 42. Kerrissey M, Satterstrom P, Pae J, Albert NM. Overcoming walls and voids: Responsive

- 1285 practices that enable frontline workers to feel heard. Health Care Manage Rev
1286 [Internet]. 2024 Apr 1;49(2):116–26. Available from:
1287 <https://pubmed.ncbi.nlm.nih.gov/38345339/>
- 1288 43. Satterstrom P, Vogus TJ, Jung OS, Kerrissey M. Voice is not enough: A multilevel
1289 model of how frontline voice can reach implementation. Health Care Manage Rev
1290 [Internet]. 2024 Jan 1;49(1):35–45. Available from:
1291 <https://pubmed.ncbi.nlm.nih.gov/38019462/>
- 1292 44. O’Sullivan S, Krautwald J, Schneider H. Improving the introduction of telemedicine in
1293 pre-hospital emergency medicine: understanding users and how acceptability,
1294 usability and effectiveness influence this process. BMC Emerg Med [Internet]. 2024
1295 Dec 1;24(1). Available from: <https://pubmed.ncbi.nlm.nih.gov/38992613/>
- 1296 45. Bai E, Zhang Z, Xu Y, Luo X, Adelgais K. Enhancing prehospital decision-making:
1297 exploring user needs and design considerations for clinical decision support systems.
1298 BMC Med Inform Decis Mak [Internet]. 2025 Dec 1;25(1):1–12. Available from:
1299 <https://link.springer.com/articles/10.1186/s12911-024-02844-1>
- 1300 46. Alasiri AA, Mohammed V. Healthcare Transformation in Saudi Arabia: An Overview
1301 Since the Launch of Vision 2030. Heal Serv Insights [Internet]. 2022;15. Available
1302 from:
1303 https://scholar.google.com/scholar_url?url=https://journals.sagepub.com/doi/pdf/10.1177/11786329221121214&hl=ar&sa=T&oi=ucasa&ct=ufr&ei=Wb0lavupM5GrieoPw6XzwAY&scisig=AFyMTJUAoLy8CRLzq3obUpYGGQ4v
1304
1305
- 1306 47. Thapa A, Gyawali P, Kalauni D. Leadership strategies to foster innovation in

1307 healthcare organizations of the UK: a systematic review. BMC Health Serv Res
 1308 [Internet]. 2026 Jan 18;26:222. Available from:
 1309 <https://pmc.ncbi.nlm.nih.gov/articles/PMC12896025/>

1310 48. Trentzsch H, Goossen K, Prediger B, Schweigkofler U, Hilbert-Carius P, Hanken H, et al.
 1311 Stop the bleed " - Prehospital bleeding control in patients with multiple and/or severe
 1312 injuries - A systematic review and clinical practice guideline - A systematic review and
 1313 clinical practice guideline. Eur J trauma Emerg Surg [Internet]. 2025 Dec 1;51(1).
 1314 Available from: <https://pubmed.ncbi.nlm.nih.gov/39907772/>

1315 49. Cirocchi R, Prigorschi D, Properzi L, Matteucci M, Duro F, Tebala GD, et al. Is the Use
 1316 of Tourniquets More Advantageous than Other Bleeding Control Techniques in
 1317 Patients with Limb Hemorrhage? A Systematic Review and Meta-Analysis. Medicina
 1318 (Kaunas) [Internet]. 2025 Jan 1;61(1). Available from:
 1319 <https://pubmed.ncbi.nlm.nih.gov/39859075/>

1320 50. Barrett WJ, Kaucher KA, Orpet RE, Champion EM, Goodloe JM, Fischer PE, et al.
 1321 Tranexamic acid in trauma: A joint position statement and resource document of
 1322 NAEMSP, ACEP, and ACS-COT. J Trauma Acute Care Surg [Internet]. 2025 Sep
 1323 1;99(3):357–63. Available from: <https://pubmed.ncbi.nlm.nih.gov/40842057/>

1324 51. Li Y, Tian M, Zhong W, Zou J, Duan X, Si H. Prehospital tranexamic acid decreases early
 1325 mortality in trauma patients: a systematic review and meta-analysis. Front Med
 1326 [Internet]. 2025;12. Available from: <https://pubmed.ncbi.nlm.nih.gov/40160319/>

1327 52. Troyer L, Brady W. Barriers to effective EMS to emergency department information
 1328 transfer at patient handover: A systematic review. Am J Emerg Med [Internet]. 2020

- 1329 Jul 1;38(7):1494–503. Available from:
- 1330 [https://www.sciencedirect.com/science/article/pii/S0735675720302655?casa_token=Zwz9MmZKUGEAAAAA:XwpjPKnwUK6hWQXUUPAVFop0ib1zthQMrKxoVibT6eHLdn](https://www.sciencedirect.com/science/article/pii/S0735675720302655?casa_token=Zwz9MmZKUGEAAAAA:XwpjPKnwUK6hWQXUUPAVFop0ib1zthQMrKxoVibT6eHLdnGNGB6RuDnHgYAI53F_l223jN31)
- 1331
- 1332
- 1333 53. Sampson FC, Long J, Coster J, O’Hara R, Pilbery R, Bell F, et al. Exploring the use of
- 1334 pre-hospital pre-alerts and their impact on patients, Ambulance Service and
- 1335 Emergency Department staff: a mixed-methods study. *Heal Soc care Deliv Res*
- 1336 [Internet]. 2026 Apr;14(9):1–46. Available from:
- 1337 <https://pubmed.ncbi.nlm.nih.gov/42010986/>
- 1338 54. Lange S de, Heyns T, Filmalter C. Clinical practice guidelines for person-centred
- 1339 handover practices in emergency departments: a scoping review. *BMJ Open*
- 1340 [Internet]. 2024 Oct 1;14(10):e082677. Available from:
- 1341 <https://bmjopen.bmj.com/content/14/10/e082677>
- 1342 55. Zhu X, Fu J. Efficacy of mechanical against manual method in cardiopulmonary
- 1343 resuscitation for out-of-hospital cardiac arrest: A meta-analysis. *Exp Ther Med*
- 1344 [Internet]. 2024 Oct 16;28(6). Available from:
- 1345 <https://pubmed.ncbi.nlm.nih.gov/39478734/>
- 1346 56. El-Menyar A, Naduvilekandy M, Rizoli S, Di Somma S, Cander B, Galwankar S, et al.
- 1347 Mechanical versus manual cardiopulmonary resuscitation (CPR): an umbrella review
- 1348 of contemporary systematic reviews and more. *Crit care* [Internet]. 2024 Dec 1;28(1).
- 1349 Available from: <https://pubmed.ncbi.nlm.nih.gov/39080740/>
- 1350 57. Kleinman ME, Buick JE, Huber N, Idris AH, Levy M, Morgan SG, et al. Part 7: Adult

1351 Basic Life Support: 2025 American Heart Association Guidelines for Cardiopulmonary
 1352 Resuscitation and Emergency Cardiovascular Care. *Circulation* [Internet]. 2025 Oct
 1353 22;152(16_suppl_2):S448–78. Available from:
 1354 /doi/pdf/10.1161/CIR.0000000000001369?download=true

1355 58. Lad U, Oomen NMCW, Callaghan JP, Fischer SL. Comparing the biomechanical and
 1356 psychophysical demands imposed on paramedics when using manual and powered
 1357 stretchers. *Appl Ergon* [Internet]. 2018 Jul 1;70:167–74. Available from:
 1358 <https://pubmed.ncbi.nlm.nih.gov/29866307/>

1359 59. Pryce R, Weldon E, McDonald N, Sneath R. The effect of power stretchers on
 1360 occupational injury rates in an urban emergency medical services system. *Am J Ind*
 1361 *Med* [Internet]. 2024 Apr 1;67(4):341–9. Available from:
 1362 <https://pubmed.ncbi.nlm.nih.gov/38356274/>

1363 60. Baez AA, Qasim Z, Wilcox S, Weir WB, Loeffler P, Golden BM, et al. Prehospital
 1364 Mechanical Ventilation: An NAEMSP Position Statement and Resource Document.
 1365 *Prehospital Emerg care* [Internet]. 2022;26(sup1):88–95. Available from:
 1366 <https://pubmed.ncbi.nlm.nih.gov/35001824/>

1367 61. Pinto-Villalba RS, Leon-Rojas JE. Reported adverse events during out-of-hospital
 1368 mechanical ventilation and ventilatory support in emergency medical services and
 1369 critical care transport crews: a systematic review. *Front Med* [Internet]. 2023;10.
 1370 Available from: <https://pubmed.ncbi.nlm.nih.gov/37877027/>

1371 62. Jung OS, Jackson J, Majmudar M, McCree P, Isselbacher EM. Engaging frontline
 1372 employees using innovation contests: Lessons from Massachusetts General Hospital.

1373 Healthcare [Internet]. 2022 Jun 1;10(2):100615. Available from:
 1374 <https://www.sciencedirect.com/science/article/abs/pii/S2213076422000045>

1375 63. Jung OS, Begum F, Dorbu A, Singer SJ, Satterstrom P. Ideas from the Frontline:
 1376 Improvement Opportunities in Federally Qualified Health Centers. J Gen Intern Med
 1377 [Internet]. 2023 Oct 1;38(13):2888–97. Available from:
 1378 <https://pubmed.ncbi.nlm.nih.gov/37460922/>

1379 64. Rigtering C, Spaans LJ, de Jong JPJ. How to bridge the nurse innovation–diffusion gap?
 1380 An in-depth case study of Create4Care. Front Public Heal [Internet]. 2023;11.
 1381 Available from: <https://pubmed.ncbi.nlm.nih.gov/37601181/>

1382 65. Schröder H, Beckers SK, Borgs C, Sommer A, Rossaint R, Grüßer L, et al. Long-term
 1383 effects of a prehospital telemedicine system on structural and process quality
 1384 indicators of an emergency medical service. Sci Reports 2024 141 [Internet]. 2024 Jan
 1385 3;14(1):1–12. Available from: <https://www.nature.com/articles/s41598-023-50924-5>

1386 66. Warren J, Tamhankar O, Toy J, Schlesinger SA, Liu YT. Use of Ultrasound in the
 1387 Prehospital Setting: A Scoping Review. JACEP Open [Internet]. 2025 Apr
 1388 1;6(2):100086. Available from:
 1389 <https://www.sciencedirect.com/science/article/pii/S268811522500044X>

1390 67. Naeem S, Aziz S, Hirst T, Strobel J, Mulvey JM, Lang A, et al. Implementation of
 1391 prehospital point-of-care ultrasound using a novel continuous feedback approach in a
 1392 UK helicopter emergency medical service. Scand J Trauma Resusc Emerg Med
 1393 [Internet]. 2025 Dec 1;33(1). Available from:
 1394 <https://pubmed.ncbi.nlm.nih.gov/39905531/>

- 1395 68. Mallon O, Lippert F, Stassen W, Ong MEH, Dolkart C, Krafft T, et al. Utilising artificial
1396 intelligence in prehospital emergency care systems in low- and middle-income
1397 countries: a scoping review. *Front Public Heal* [Internet]. 2025 Jun 20;13:1604231.
1398 Available from: <https://doi.org/10.17605/OSF.IO/9VS2M>,
- 1399 69. Surman K, Lockey D. Unmanned aerial vehicles and pre-hospital emergency medicine.
1400 *Scand J Trauma Resusc Emerg Med* [Internet]. 2024 Dec 1;32(1). Available from:
1401 <https://pubmed.ncbi.nlm.nih.gov/38287437/>
- 1402 70. Rahim F, Qasim NH. A systematic literature review of drones in emergency medicine:
1403 practical applications, legal challenges, and future directions. *Drone Syst Appl*
1404 [Internet]. 2025 Dec 15;13:1–13. Available from:
1405 <https://cdnsiencepub.com/doi/pdf/10.1139/dsa-2024-0072?download=true>
- 1406 71. Zhang Y, Cao J, Ye S. Unmanned aerial vehicles in prehospital emergency care: current
1407 evidence, technological advances, and future perspectives. *Front public Heal*
1408 [Internet]. 2026 Jan 13;13. Available from:
1409 <https://pubmed.ncbi.nlm.nih.gov/41607887/>
- 1410 72. Bohm K, Kurland L. The accuracy of medical dispatch - a systematic review. *Scand J*
1411 *Trauma Resusc Emerg Med* [Internet]. 2018 Nov 9;26(1):94. Available from:
1412 <https://pmc.ncbi.nlm.nih.gov/articles/PMC6230269/>
- 1413 73. Owen P, Kirby K, Hannah J, Crouch R, Hyde P, Voss S. Prehospital critical care
1414 dispatch: a scoping review (PHASE). *Scand J Trauma Resusc Emerg Med* [Internet].
1415 2025 Dec 1;33(1):140. Available from:
1416 <https://pmc.ncbi.nlm.nih.gov/articles/PMC12351921/>

- 1417 74. Nicoletta V, Robitaille-Fortin M, Bélanger V, Mercier É, Harrisson J. Performance
1418 measures of the medical priority dispatch system in an urban basic life support
1419 system. *Scand J Trauma Resusc Emerg Med* [Internet]. 2025 Dec 1;33(1). Available
1420 from: <https://pubmed.ncbi.nlm.nih.gov/40399996/>
- 1421 75. Yu W, Bai W, Luan W, Qi L. State-of-the-Art Review on Traffic Control Strategies for
1422 Emergency Vehicles. *IEEE Access* [Internet]. 2022;10:109729–42. Available from:
1423 <https://ieeexplore.ieee.org/document/9916277>
- 1424 76. Alruwaili M, Ali A, Almutairi M, Alsahyan A, Mohamed M. LSTM and ResNet18 for
1425 optimized ambulance routing and traffic signal control in emergency situations. *Sci*
1426 *Reports* 2025 151 [Internet]. 2025 Feb 19;15(1):6011. Available from:
1427 <https://www.nature.com/articles/s41598-025-89651-4>
- 1428 77. Salhi RA, Iyengar S, da Silva Bhatia B, Smith GC, Heisler M. How do current police
1429 practices impact trauma care in the prehospital setting? A scoping review. *J Am Coll*
1430 *Emerg Physicians open* [Internet]. 2023 Jun 1;4(3). Available from:
1431 <https://pubmed.ncbi.nlm.nih.gov/37229183/>
- 1432 78. O’Cathain A, Croot L, Duncan E, Rousseau N, Sworn K, Turner KM, et al. Guidance on
1433 how to develop complex interventions to improve health and healthcare. *BMJ Open*
1434 [Internet]. 2019 Aug 1;9(8). Available from:
1435 <https://pubmed.ncbi.nlm.nih.gov/31420394/>
- 1436 79. Alobaid A, Gosling C, Mckenna L, Williams B. Saudi female paramedics’ perceptions of
1437 challenges in the workplace: a qualitative study. *Int Emerg Nurs*. 2022 Jul
1438 1;63:101176.

1439 80. Alalwan MA, Alshammari T, Alawjan H, Alkhayat H, Alsaleh A, Alamri I, et al.
1440 Electrocardiographic interpretation by emergency medical services professionals in
1441 Saudi Arabia: A cross sectional study. PLoS One [Internet]. 2023 Oct
1442 1;18(10):e0292868. Available from:
1443 <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0292868>
1444

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1.docx](#)
- [Additionalfile2.docx](#)