The impact of pre-hospital emergency medical services on the outcomes of patients with burn: a systematic review and meta-analysis

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Abstract

Burn injuries are a worldwide health issue, significantly burdening healthcare facilities. Specialized burn centres are only sometimes available near the site of burn injury. First aid greatly impacted the outcomes of burns by evaluating the severity of the burn and associated injuries. Pre-hospital Emergency Medical Services (EMS) have more remarkable contributions to healthcare systems. We aimed to reveal the interventions provided by the EMS staff on the scene of burn injuries and the impact of these interventions on the outcomes of burn injuries. Furthermore, the study aimed to identify areas for improvement in pre-hospital burn care. A systematic literature review was carried out from inception to 1st July 2023 using twelve databases. All original articles that included patients with burn injuries who received the necessary pre-hospital care by EMS staff were included. Nine articles comprehending 6149 patients with burn injuries were retrieved. The analysis revealed that EMS interventions significantly improved the outcomes of burn management. This included better control for pain and vital parameters, and lower mortality risk. The EMS provided analgesic administration, cooling of the burn wound, and the necessary urgent therapies. However, the study identified a need for better EMS training in assessing burn severity and managing burn injuries effectively. Enhancing EMS providers' knowledge and skills in pre-hospital burn management could substantially improve patient outcomes and reduce the burden on healthcare systems. Improving the understanding of EMS providers towards burn care can minimize the risk of burn-related poor outcomes and reduce the burden on healthcare facilities.

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Introduction

Burn injuries are a worldwide health issue, significantly burdening healthcare facilities.[1] Most burn injuries are caused by unintentional exposure to high temperatures. This includes hot liquids, hot solids, or gases.[1] Burn injuries result in a long-term negative impact on the mental health, physical health, and quality of life among burn survivors.[1] In 2019, more than eight million new burn cases were identified, resulting in more than seven million patients living with disabilities and approximately 111,000 deaths.[2] This burdens patients' families and healthcare systems.[3,4] The economic burden is most significant among lower-income countries due to inadequate infrastructure safety measures. Burn treatment is complex, necessitating high-level decision-making for early prevention and management. This could lead to quicker healing and avoid burn-related complications, particularly for mild, non-severe cases.[5]

Specialized burn centres are sometimes available near the site of burn injury. In such cases, first aid can significantly impact the outcomes of burns by evaluating the severity, associated injuries, and the patients' general health.[6] Based on this, the patients must be transferred to a specialized burn unit for definitive management after receiving the initial care. Pre-hospital care depends on the decisions of paramedical staff and emergency physicians at the burn site.[7] Immediate interventions can improve burn wounds' extent, depth, severity, and prognosis. Pre-hospital management aims to cease burning, cover the burnt area, relieve pain, and cool the burn wound. This keeps the patient vitally stable and decreases the progression of burn depth. Adequate pre-hospital management reduces the possibility of scar formation and directs care towards more specialized burn centres.[8,9] This could minimize the need for further surgical interventions, such as grafting, and reduce the length of hospital stays and overall costs.[10] While many published studies revealed the usefulness of pre-hospital EMS in improving burn outcomes, the available evidence deserved further assessment.[11,12] This is due to the lack of sufficient prospective studies that provide conclusive evidence for future practice. Therefore,

this meta-analysis was conducted to reveal the services provided by the EMS providers in managing patients with burn injuries and to assess the impact of these services on the short and long-term burn outcomes. The study also addressed the current limitations of EMS practice towards pre-hospital management of burn injuries.

Materials and Methods

This study was executed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[13] and the recommendations of the Cochrane collaboration.[14] The methods of this meta-analysis were registered at the International prospective register of systematic reviews (PROSPERO) database before study processing (Registration number; CRD42023401749) (*Supplementary Table 1*).

Literature search

A systematic review of the literature was conducted from the inception of databases to 1st July 2023 through twelve databases: PubMed, Web of Science, Scopus, Google Scholar, NYAM, SIGLE, Clinical trials, EMBASE, VHL, Controlled Trials (mRCT), ICTRP, and Cochrane Collaboration. The search strategy did not implement any limitations regarding age, type of burn injury, sex, language, ethnicity, race, or place. Each database was searched using specified keywords, customized based on the technicality of the searched database. The medical subject heading (MeSH) was used. The cross-referencing method, citation tracking, and screening of the references of the relevant studies were used to reveal all potentially relevant articles. These keywords were used: 'Pre-hospital', 'Out of Hospital', 'Pre-Hospital', 'Emergency medical services', 'EMS', 'Paramedical', 'Paramedic', 'Burn', 'Burns', 'Thermal', 'Burnt' (*Supplementary Table 2*).

Eligibility criteria

All original studies that included patients with burn injuries who received pre-hospital care by EMS staff were considered for inclusion. The studies must retrieve the services provided by EMS or the outcomes of burn management. Studies with unextractable data, review articles, letters, comments, non-human reports, guidelines, case reports, books, editorials, and posters were excluded. Two authors performed the screening steps to minimize the risk of bias. The discussion dissolved the inconsistency between the authors, and the authors made the final decision after the discussion. The PRISMA Flowchart documented the systematic search of the literature.

Data extraction

The characteristic data of the eligible articles were extracted. This included the study's title, the first author's second name, publication year, study methodology, study period, and study country. Patients' characteristics were retrieved, including sample size, age, and geographical distribution. The burn injury-related variables were revealed, comprehending the burn's depth, site, size, mechanisms, and total body surface area. The data associated with EMS were extracted, including the drug administered at the injury location, the interventions held by EMS providers, mission details, time to reach the place of call, and hospital transport time. The outcomes of burn management were revealed, including mortality, vital data at the transportation site, and severity of pain. Two authors extracted and reviewed the data using a Microsoft Excel spreadsheet to reduce the risk of information bias.

Quality assessment of the eligible studies

The quality of the analyzed articles was assessed and scored using the National Institute of Health (NIH) quality assessment tool.[15] The tool comprises 14 items evaluating the research question, study population, sampling methods, exposure, outcomes, follow-up, and confounders. The quality of the included observational studies was categorized into bad, good, and fair.

Statistical analysis

Standardized Mean Difference (SMD) or Weighted Mean Difference (WMD) was used to compute the continuous variables. The mean and Standard Deviation (SD) were calculated from the median and range or mean and range.[16] The mortality risk was assessed by calculating the event rate and 95% CIs for each study, followed by pooling the effect sizes of all analyzed articles to evaluate the summary risk with 95% Confidence Interval (CI). The random-effects model was used when statistical heterogeneity was revealed; alternatively, the fixed-effect model was used. Statistical heterogeneity was evaluated using Higgins I^2 statistic and the Cochrane Q (Chi^2 test). Meta-analysis was carried out using Review Manager (Revman) v5.4 and Comprehensive Meta-Analysis (CMA) v3 software.[17,18] The significant difference was established at the value of *probability (P) value* < 0.05.

Results

A systematic search of the literature resulted in 538 reports. Of these, 186 reports were duplicated, leaving 351 articles for screening. The title and abstract screening process excluded 332 reports, yielding 19 articles eligible for full-text screening. This step resulted in nine articles being selected for data extraction, of which one was excluded due to overlapping data. An additional study was recognized using citation tracking, resulting in nine articles being finally included for meta-analysis. The PRISMA Flowchart for searching the literature and screening is shown in Figure 1.

Demographics of the included studies

Nine studies were analysed, comprising 6149 patients with burn injuries.[19-27] Eight articles of retrospective design and one of prospective design were included. The average age of the burn patients ranged from 5.4 to 42.7 years. Moreover, there were 2304 (67.8) males and 1094 (32.2%) females. There were 113 (33.53%) patients with scald injuries, 70 (31.53%) with contact injuries, and 36 (36%) with explosion injuries. Furthermore, 203 (3.93%) patients had burn injuries on their limbs, while 404 (7.7%) patients sustained burn injuries on the face or head. Multiple burn injuries were documented among 1695 (32.84%) patients. The quality of the eligible articles was good, with scores ranging from 66.66% to 83.33% (Table 1).

Interventions performed by EMS

Emergency medical services were performed using a helicopter for 2,657 patients with burn injuries. Subsequently, 62 patients were transferred using ambulance services offered by the EMS. They provided urgent support to the ground-based medical rescue teams. However, transport from rural areas was significantly longer than from urban areas. Furthermore, EMS providers administered analgesics to 1818 patients. Cooling the burn wound at the site of burn injury was carried out for 131 patients, while

peripheral intravenous lines were established for 366 patients. Oxygen was supplied to 450 patients, while wound washing was performed on 80. Fluid replacement was administered to 1,784 patients, and primary wound dressings were applied to 209 patients. Prophylactic intubation was performed on 742 patients. The average response time for calls ranged from 19 to 19.9 minutes, whereas the transport time to the hospital ranged from 11 to 32.71 minutes (Table 2).

Level of training of EMS for managing patients with burn injuries

Fein *et al*., (2014) reported inadequate training among EMS regarding caring for burn patients. They highlighted a significant need for improved data documentation. Ghaffarzad *et al*. (2017) reported a low level of training among EMS providers for the pre-hospital management of burn patients, with only 30% having received the necessary training. They reported a significant association between the level of EMS training and burn-related deaths. This association was also significant with the quality of pre-hospital services provided by the EMS, particularly adequate fluid therapy. They highlighted that the lack of necessary knowledge necessitates well-structured guidelines and educational programs for EMS providers. These programs should focus on evaluating and managing patients with burn injuries on the scene of accidents.[19,20,26,27]

The impact of EMS on the outcomes of burn

Vital data

Temperature

Two articles[22,24] that included 124 burn patients reported the difference in mean temperature levels before and after EMS management. There was no statistical heterogeneity between the included studies ($I^2 = 0\%$, $P = 0.80$), and the mean temperature did not differ significantly after EMS management (MD -0.56; 95% CI -1.19 to 0.08; $P = 0.09$) (Figure 2A).

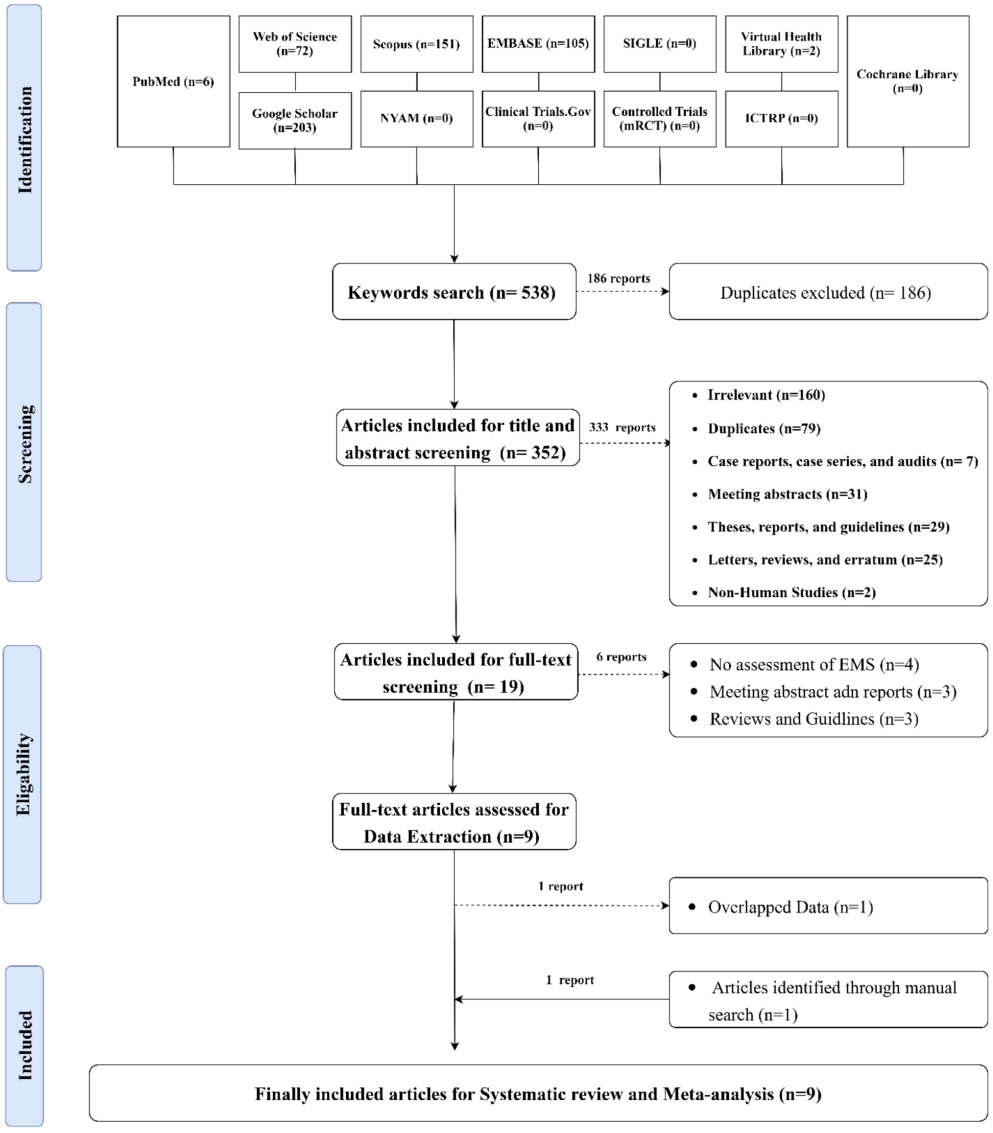

Figure 1. PRISMA Flow chart showing the process of the literature search, title, abstract, and full-text screening, systematic review, and meta-analysis.

Table 1. Demographics of the analysed studies and burn-related data.

Study ID		Study region	Study method	Study period	Sample Size	Age	Gender		Burn mechanisms					Location of burn Injury				Quality assessment	
							Males	Females	Scald	Contact	Explosion	Fire	Chemical	Limb	Face/head	Trunk	Multiple		
					N	Mean±SD	N	N	N	%	%	N	N	N	N	N	N	%	Decision
1	Fein *et al*., 2014[19]	Australia	Retrospective Study	2008 and 2010	117	21±12	74	43	73	34	NR	NR	NR	49	4	23	41	81.81%	Good
2	Ghaffarzad *et al*., 2017[20]	Iran	Retrospective Study	2014-2015	100	NR	NR	NR	10	NR	36	50	NR	NR	NR	NR	NR	66.66%	Good
3	Hall *et al*., 2017[21]	Australia	Retrospective Study	January 2010 to August 2015	105	37 (23–50)**	79	26	NR	36	NR	174	48	NR	NR	NR	NR	83.33%	Good
4	Maudet *et al*., 2020[22]	Switzerland	Retrospective Study	January 2008 and December 2017	86	26 (12–51)*	63	21	NR	NR	NR	NR	NR	NR	52	NR	NR	83.33%	Good
5	McCulloh *et al*., 2017[23]	USA	Retrospective Study	2007-2015	139	5.4±0.41	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	66.66%	Good
6	Newberry *et al*., 2018[24]	USA	Prospective observational study	May to August 2015	439	30 (22–40) **	151	288	NR	NR	NR	NR	NR	NR	NR	NR	NR	83.33%	Good
7	Rzońca *et al*., 2019[25]	Poland	Retrospective Study	January 2011 to December 2018	2534	32.80 (27.03)	1842	691	NR	NR	NR	NR	248	142	344	337	1613	81.81%	Good
8	Schiefer *et al*., 2020[26]	Germany	Retrospective Study	January 1989 to December 2018	2509	42.7±19.4	NR	NR	NR	NR	NR	NR	NR	12	4	23	41	66.66%	Good
9	Tran *et al*., 2022[27]	USA	Retrospective Study	NR	120	35 (27) **	95	25	30	NR	NR	NR	NR	NR	NR	NR	NR	66.66%	Good

*Data reported using median and range, ** Data reported using median and interquartile range, NR, Non-reported

Table 2. Interventions performed by emergency medical services.

Study ID		Mission details		%TBSA	Interventions performed								Time to the place of call	To hospital transport time
		Helicopter	Ambulance		Analgesics	Cooling	Peripheral Venous Line	Fluid Therapy	Oxygen Supply	Wound washing	Basic dressing	Prophylactic intubation		
		Number	Number	Median/Range	Number	Number	Number	Number	Number	Number	Number	Number	Mean±SD	Mean±SD
1	Fein *et al*., 2014[19]	NR	NR	5 (0.2–25)	20	86	NR	NR	7	NR	32	NR	NR	NR
2	Ghaffarzad *et al*., 2017[20]	NR	NR	NR	NR	NR	96	NR	NR	10	70	0	NR	NR
3	Hall *et al*., 2017[21]	76	27	15% (8.5–20)**	NR	NR	12	NR	NR	NR	NR	19	NR	NR
4	Maudet *et al*., 2020[22]	47	35	NR	61	NR	64	NR	51	NR	NR	21	19 (13–30)*	11 (7–17)*
5	McCulloh *et al*., 2017[23]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
6	Newberry *et al*., 2018[24]	NR	NR	NR	NR	NR	194	143	392	70	107	NR	NR	NR
7	Rzońca *et al*., 2019[25]	2534	NR	NR	1737	NR	NR	1641	NR	NR	NR	702	19.90±9.49	32.71±24.94
8	Schiefer *et al*., 2020[26]	NR	NR	NR	NR	45	NR	NR	NR	NR	70	NR	NR	NR
9	Tran et al., 2022[27]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

*Data reported using median and range, ** Data reported using median and interquartile range, NR, Non-reported.

Respiratory rate

Two studies that included 182 patients with burn injuries evaluated the difference in mean respiratory rate before and after EMS intervention.[21,22] There was a statistically significant reduction in the mean respiratory rate after EMS intervention, with an MD of -5.18 (95% -6.64, -3.72; P<0.001), and significant homogeneity between the included studies (I^2= 28%, P= 0.24). (Figure 2B).

Systolic blood pressure (mmHg)

The impact of EMS management on the mean systolic blood pressure (SBP) was reported in two articles that included 182 patients with burn injuries.[21,22] There was a statistically significant reduction in SBP after EMS intervention (MD -29.16; 95% -54.30, -4.01; P= 0.02), with substantial heterogeneity between the analyzed studies (I^2=93%, P<0.001) (Figure 2C).

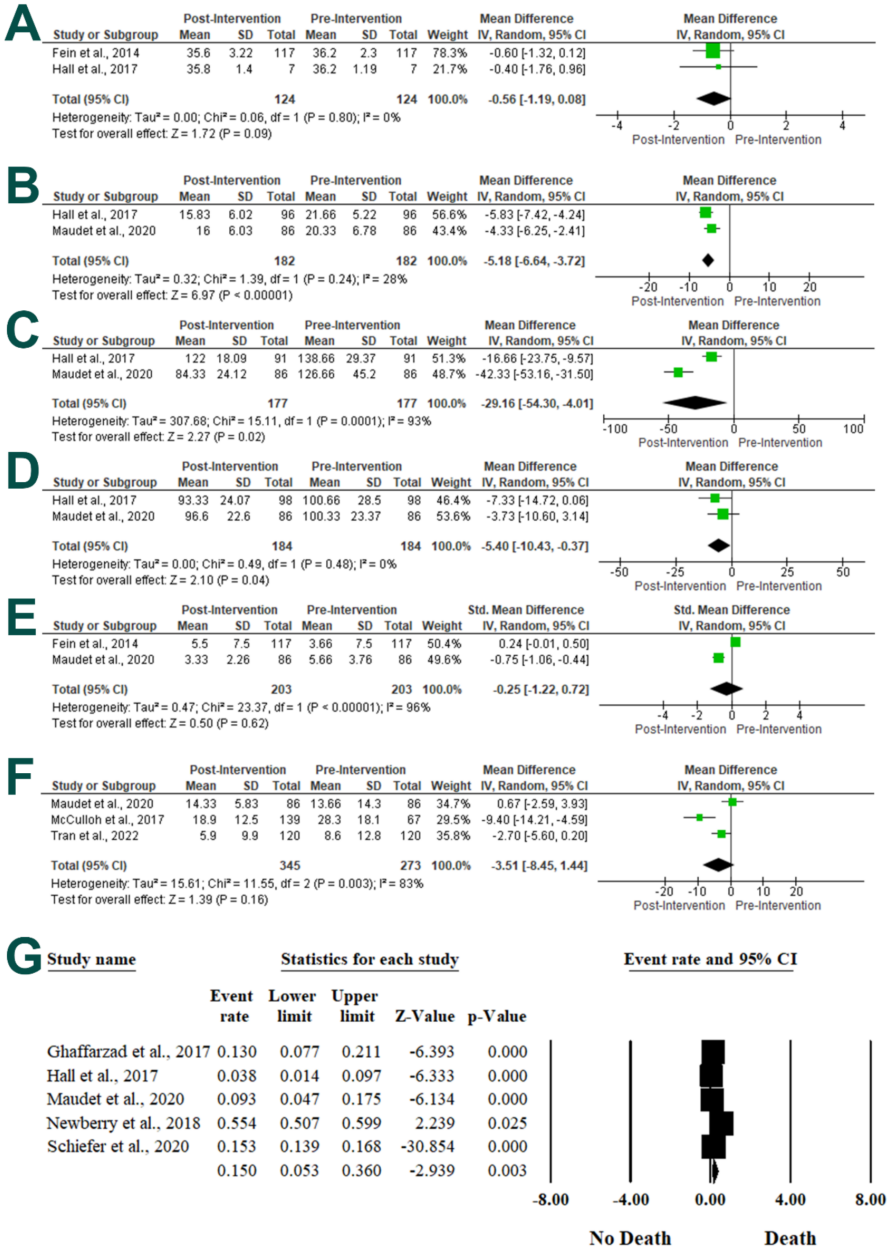

Figure 2. Forest plot of summary analysis of the (**A**) Mean Difference (MD) and 95% CI of mean temperature (°C) level pre and after EMS management (**B**) Mean Difference (MD) and 95% CI of mean respiratory rate (breath per minute) before and after EMS intervention (**C**) Mean Difference (MD) and 95% CI of mean systolic blood pressure (mmHg) pre and after EMS management (**D**) Mean Difference (MD) and 95% CI of mean heart rate (beats per minute) pre and after EMS management (**E**) Standardized Mean Difference (SMD) and 95% CI of mean severity of pain pre and after EMS management (**F**) Mean Difference (MD) and 95% CI of the mean total body surface area (%) pre and after EMS management. (**G**) The mortality risk among patients with burn injuries received EMS management. Size of the green or black squares is proportional to the statistical weight of each trial. The black diamond represents the pooled point estimate. The positioning of both diamonds and squares (along with 95% CIs) beyond the vertical line (unit value) suggests a significant outcome (IV = inverse variance).

Heart rate (/min)

Two studies that included 182 patients with burn injuries evaluated the difference in mean heart rate before and after EMS intervention.[21,22] There was a statistically significant reduction in the mean heart rate after EMS intervention, with an MD of -5.40 (95% CI -10.43, -0.37; P = 0.04), and homogeneity among the analyzed articles (I^2=0%, P=0.48) (Figure 2D).

Severity of pain

The severity of pain after analgesic administration by EMS among patients with burn injuries was assessed among 203 patients across two articles [19, 22]. Post-EMS management, the mean levels of pain did not show a statistically significant difference (MD -0.25; 95% -1.22, 0.72; P= 0.09) despite significant statistical heterogeneity (I^2=96%, P<0.001) (Figure 2E).

Estimating total body surface area of burn (%)

Three studies that included 345 patients with burn injuries evaluated the accuracy of total body surface area (TBSA%) estimation by EMS providers.[22,23,27] In the random-effects model (I^2=83%, P=0.003), there was an overestimation of TBSA by EMS providers when compared to the final TBSA assessment, although this difference was not statistically significant (MD -3.51; 95% -8.45, 1.44; P=0.16) (Figure 2F).

Mortality risk

Five articles included 3239 patients with burn injuries and assessed the mortality risk among burn patients [20-22, 24, 26]. Of the included patients, 652 burn-related deaths were reported with a risk of 15%, ranging from 5.3% to 36% (P=0.003) with significant heterogeneity (I^2=98.7%, P<0.001) (Figure 2E).

Discussion

Providing immediate and effective care for burn-injury patients impacts their outcomes.[38] The present study highlighted the leading role of EMS providers in managing patients with burn injuries before transporting them to a more specialized health facility. These interventions include adequate fluid resuscitation, adequate analgesics, and proper cooling of the burn wound. These interventions controlled vital parameters, mainly respiratory, blood, and heart rates. Furthermore, there was a relative improvement in the severity of pain with adequate fluid resuscitation.The improvement in vital parameters and adequate resuscitation considerably improve the outcomes of burn patients. However, there was a relative overestimation of the extent of burn injury. In this respect, Loguidice *et al*. (2016) reported a significant association between early post-burn heart rate variability and mortality, particularly when incorporated with %TBSA.[29] Adequate early fluid resuscitation in patients with burns reduces the further need for resuscitation and minimzes the risk of mortality.[30] EMS providers need more knowledge regarding documenting and managing burn patients in pre-hospital settings. Of note, a substantial amount of data was not reported, and the summarized data displays only a portion of the patients included in the original studies.

The lack of knowledge among EMS providers was mainly attributed to the need for a more precise assessment of the extent of the burn at the scene of injuries. Judgment in estimating TBSA and fluid resuscitation requires revision to prevent fluid overload. Froutan *et al*. (2014) identified factors impacting the quality of pre-hospital services for burn patients. These factors included the stress at the burn scene, insufficient information, the nature of burn care and progressive burnout.[31] This highlights the need for informative guidelines and decisive approaches to standardize pre-hospital care of burn-injury patients.[19,20,23,26] These findings indicated the need for further paramedic educational programs regarding the initial first aid for patients with burn injuries at the scene of the accidents.

In the present study, EMS offered a wide range of interventions for managing patients with burn injuries. This included administration of analgesics, cooling the wound, wound care, oxygen therapy, and intubation. Of note, the mortality rate among burn patients who received EMS management was 15% in the present study. This figure was relatively low compared to a risk of 18% among patients who received EMS care in Brusselaers *et al*. (2010).[32] The role of the paramedics in stabilizing the patients' vital data before transferring to a specialized centre had a prognostic value. Kallinen *et al*. (2016) showed that the first SBP measured on the scene of burn injuries was associated with survival at 30 days and six months intervals.[33] Cooling the wound burn at the scene of injury decreases the need for further skin grafting in pediatric patients, decreasing the depth and size of the wound and enhancing the potential for re-epithelialization.[34,35] This revealed the ultimate role of EMS providers in caring for burn victims and their contribution to minimizing the burn injuries' negative repercussions on the short and long-term outcomes. However, the current knowledge of EMS providers needs further improvement. Consistent with this finding, Eaton *et al*. (2020) highlighted the need for paramedics to be highly skilful in managing patients with life-threatening conditions.[36] Lam *et al*. (2018) reported inadequate knowledge regarding the emergency management of burn victims, particularly with primary healthcare providers. They highlighted the need for continuous medical education programs for all healthcare providers regarding the optimal management of burn injuries.[37] These findings are localized to the British and Vietnamese experience, and further studies are necessary to globalize their expertise. Training should empower EMS providers with confidence in decision-making and professionalism in performing necessary procedures before hospitalization. This could improve the outcomes of burn injuries and reduce the economic burden of burns on the healthcare systems.[38] Phillips *et al*. (2022) recommended regular follow-up and case review protocols to ensure better burn care in the pre-hospital settings. This will ensure a better understanding of the patients' urgent needs at the scene of burn injuries and provide safe transfer to specialized burn centres.[39] Holbert *et al*. (2023) recommended approach of effective fast pain relief, rapid wound cooling, and patient support. This support aims to find vascular access, maintain the normothermic environment, and precise assessment of the burn extent. Furthermore, the patients should be transferred to appropriate facilities for definitive burn management.[40] The training of EMS providers should consider confidence when treating burn patients and clear guidelines with a simple approach to estimate the burnt area. The Queensland Ambulance Service Burns and Trauma Guidelines should be followed.[41]

There was a tendency to overestimate the extent of burn injury in the pre-hospital settings. Parallel with this finding, Brekke *et al*. (2023) highlighted an overestimation of the burn size based on %TBSA with more than 50% of the actual extent. This was associated with an underestimation of the burn depth by approximately 50%.[42] Misreporting the actual status of burn injuries may lead to improper management of burn cases and may be associated with poor outcomes. Miscalculating the fluid replacement may increase the risk of pulmonary oedema, compartment syndrome, and the

need for escharotomies. Underestimation of the extent of burn wounds increases the risk of renal dysfunction and circulatory collapse.[43] However, accurately determining burn size is more important for further care of burn patients. This is critically needed for adequate calculation of fluid therapy, planning surgical interventions, and continuous nutritional support.

The present study gathered data that presents a nuanced view of the role of EMS providers in pre-hospital burn care. On the contrary, this meta-analysis had some limitations. Substantial statistical heterogeneity among the analyzed studies affected the evidence yielded. The heterogeneity may be due to differences in study methodologies, settings, demographics of the included patients, and management protocols. The majority of the analyzed articles were retrospective, with a higher risk of information selection bias. The factors influencing the quality of care for burn patients should be evaluated. This included burn-related factors, associated injuries, and patient demographic characteristics. These factors may correlate with the quality of EMS care and the outcomes of burns. Further studies are needed to address the limitations of the studies analyzed in this meta-analysis for future clinical practice.

Conclusions

This meta-analysis revealed the considerable role of EMS in providing the necessary care for burn victims. This included transferring patients to specialized burn centres to receive urgent care. EMS providers delivered the required care to stabilize burn patients and reduce pain at the injury scene. Improving the knowledge of EMS providers towards burn care can considerably reduce the risk of burn-related poor outcomes and improve the prognosis. Healthcare providers should implement more training programs for EMS providers to enhance emergency decision-making practices.

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Online Supplementary Materials
Table S1. PRISMA 2009 Checklist.
Table S2. The search strategy for each database