Primary aeromedical retrieval crew composition: Do different teams impact clinical outcomes? A descriptive systematic review

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CLINICIAN'S CAPSULE

What is known about the topic?
Aeromedical evacuation is risky, resource intensive, and is done by a variety of crew compositions.

What did this study ask?
What impact do advanced provider presence and crew composition have on outcomes for adult trauma patients evacuated by air?

What did this study find?
Findings showed a trend towards improved survival and other outcomes for adult trauma patients treated by aeromedical evacuation crews led by advanced providers.

Why does this study matter to clinicians?
Better outcomes could be achieved by determining how advanced providers contribute to reduced mortality and other metrics in aeromedical evacuation.

ABSTRACT

Objectives: Military Forward Aeromedical Evacuation and civilian Helicopter Emergency Medical Services are widely used to conduct Primary Aeromedical Retrieval. Crew composition in Primary Aeromedical Retrieval missions varies considerably. The ideal composition is unknown. Thus, we conducted a descriptive systematic review on mortality and other outcomes for different Primary Aeromedical Retrieval crew compositions.

Methods: Medline, Embase, and Cochrane Controlled Trials Register were searched up to January 2020. Results were reported per Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Studies of adult trauma air transported by different crews were included. Population, injury severity, crew composition, procedures, and outcomes, including mortality, were abstracted. Risk of bias was assessed using previously validated tools. A lack of reported effect measures precluded a quantitative analysis.

Results: Sixteen studies met inclusion criteria (3 prospective studies, 1 case-control, and 12 retrospective). Overall, studies reported a mortality benefit associated with advanced health care providers. This was most apparent in patients with severe but survivable injuries. In this population, early rapid sequence induction, endotracheal intubation, mechanical ventilation, thoracostomies, blood products transfusion, and treatment of hemorrhagic shock are better performed by advanced providers and may improve outcomes. The quality of evidence reported a moderate risk of bias in the included studies.

Conclusions: Overall, findings were divergent but showed a trend to decreased mortality in patients treated by advanced providers with interventions beyond the basic paramedic level. This trend was most significant in patients with severe but survivable injuries. These results should be cautiously interpreted because most studies were observational, had small sample sizes, and had a high potential for confounding factors.

RÉSUMÉ

Objectif: Les équipes d'évacuation sanitaire aérienne de l'avant dans le monde militaire et les services médicaux d'urgence par hélicoptère dans le monde civil sont souvent appelés à effectuer des évacuations sanitaires aériennes primaires. Toutefois, la composition des équipes de soins dans ce type d'évacuation varie considérablement, et on ne sait pas quelle est la meilleure composition. Aussi l'étude visait-elle à procéder à une revue systématique descriptive de la documentation médicale sur la mortalité et d'autres résultats cliniques associés à différentes compositions d'équipe d'évacuation sanitaire aérienne primaire.

Méthode: Des recherches ont été effectuées dans les bases de données Medline, Embase et Cochrane Controlled Trials Register jusqu'à janvier 2020, et les résultats ont été relevés conformément aux lignes directrices des Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Ont été sélectionnées des études portant sur le transport aérien

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d'adultes ayant subi un trauma et traités par des équipes de composition différente. Les données sur la population concernée, la gravité des blessures, la composition des équipes, les interventions effectuées et les résultats cliniques, dont la mortalité, ont fait l'objet d'analyse. Le risque de biais a été évalué à l'aide d'instruments déjà validés. Enfin, il n'a pas été possible de procéder à une analyse quantitative en raison du manque d'indicateurs communs d'effets.

Résultats: Seize études satisfaisaient aux critères de sélection (prospectives : 3; cas-témoins : 1; rétrospectives : 12). Dans l'ensemble, une association a été établie entre une diminution de la mortalité et le niveau avancé des fournisseurs de soins, diminution particulièrement marquée chez les patients ayant subi des blessures graves mais non mortelles. Le personnel en soins avancés réalise mieux la mise en route rapide et précoce de l'induction, de l'intubation endotrachéale, de la ventilation mécanique, des thoracotomies, des transfusions de produits sanguins et du traitement des chocs hémorragiques dans cette population, d'où l'amélioration possible des résultats cliniques. Enfin, l'analyse de la qualité des données indiquait un risque modéré de biais dans les études sélectionnées.

Conclusion: Dans l'ensemble, malgré des divergences, les données ont permis de relever une tendance vers une diminution de la mortalité chez les patients traités par des équipes en soins avancés effectuant des interventions qui dépassent la prestation des soins de base paramédicaux. Cette tendance était surtout manifeste chez les patients ayant subi des blessures graves mais non mortelles. Toutefois, l'interprétation des résultats appelle la prudence du fait que, dans la plupart des cas, il s'agissait d'études d'observation, réalisées sur des échantillons de petite taille et comportant un risque élevé de facteurs de confusion.

Keywords: Aeromedical Evacuation, air ambulance, crew composition, Forward Aeromedical Evacuation, Helicopter Emergency Medical Services, HEMS

INTRODUCTION

Mortality from trauma represents 10% of global deaths. Injuries kill over five million people annually and account for 12% of the global burden of disease.[1,2,3] In the military setting, severe injury mechanisms lead to distinctive early lethality patterns and more deaths occurring shortly after wounding.[4] Prehospital care improvements have led to increased survival, but the greatest potential for improved outcomes still lies in lowering preventable deaths.[5,6] It is thought that implementing a military rotary-wing Forward Aeromedical Evacuation during the Korean and Vietnam conflicts provided a 2% absolute mortality reduction in hospitalized soldiers, compared with World War II.[7] In subsequent years, civilian Helicopter Emergency Medical Services (HEMS) became widespread in the developed world.[8]

Together, military Rotary Wing and Vertical/Short Take Off and Landing Forward Aeromedical Evacuation and HEMS deliver Primary Aeromedical Retrieval. In this paper, *Primary Aeromedical Retrieval* is defined as retrieving patients from point of injury and transferring them to a medical treatment facility by Rotary Wing or Vertical/Short Take Off and Landing airframes with medical providers on board. *Forward Aeromedical Evacuation* refers to military Primary Aeromedical Retrieval, and *HEMS* refers to civilian Primary Aeromedical Retrieval.

In trauma, Primary Aeromedical Retrieval is thought to improve patient outcomes through rapid transfer to trauma centres and by providing advanced prehospital interventions.[9] Many studies show that Primary Aeromedical Retrieval is associated with improvements in morality and other outcomes. However, other studies showed no such benefit.[10]

HEMS is expensive to implement and maintain. One medium helicopter's annual operating costs can reach 1.3 M USD.[11] HEMS is inherently risky for crew members, particularly when responding at night or in marginal weather. Forward Aeromedical Evacuation missions are even costlier and riskier. Military rotary-wing aircraft are more expensive to acquire and operate than their related civilian airframes. Forward Aeromedical Evacuation crews are exposed to enemy action at the point of injury. It is therefore important to clearly determine the benefits of Primary Aeromedical Retrieval and to elucidate from where these benefits are derived.

The benefit of rapid retrieval is more pronounced the farther that the trauma centre is from the scene. Yet studies show that early advanced clinical interventions have a greater positive impact on mortality than retrieval time.[12] If clinical procedures during Primary Aeromedical Retrieval have an impact on mortality, does it matter what kind of medical professionals provide them? There are studies that compared physician HEMS to paramedic Ground EMS, with divergent conclusions. But the confounding factors when comparing HEMS and Ground EMS treatment groups are extensive and obviously included the mode of transportation.[13] In Europe, where

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physicians are common, a survival benefit due to physician-led crews was identified.[14] Other narrative reviews without a systematic approach reported conflicting results.[15] We therefore conducted a descriptive systematic review comparing different crew composition in Primary Aeromedical Retrieval, in military and civilian settings, addressing different clinical outcomes in the trauma population.

MATERIALS AND METHODS

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. [16]

Studies

The search included prospective and retrospective cohort studies (with or without a control group), case control studies, and randomized controlled trials that addressed clinical outcomes for different air ambulance crew configurations. Case reports and case series were excluded. Studies were included if they reported at least one outcome of interest.

Participants

We included studies with a population of adult trauma patients transported by air, directly from the scene of the accident to the receiving trauma centre. Providers studied included medical doctors, nurses, and/or paramedics of different backgrounds and levels of expertise.

Interventions and controls

The intervention was the Primary Aeromedical Retrieval crew composition, defined as any difference in provider type (medical doctors, nursing, and paramedics of different levels of training, subspecialties, or expertise). Controls were any comparison between crew configuration, that is, physician compared with paramedic, nurse, and so forth.

Outcome measures

The primary outcome of interest was mortality. Secondary outcomes included, but were not limited to, hemodynamic status, length of stay, disposition, mean response time, scene time, delivery time, clinical interventions, and procedures. We searched for any time-based data on response time, scene time, and time to the emergency department (ED) or operating room. We looked for information about on scene and flight clinical interventions performed, such as rapid sequence induction, endotracheal intubation, mechanical ventilation, oxygen treatment, fluid resuscitation with crystalloids or blood products, thoracic decompression by needle or tube thoracostomies, and analgesia. Finally, we documented patient disposition (discharge home, rehabilitation, direct discharge from ED, and patients transferred to another facility) and length of stay (Intensive Care Unit days, hospital days).

Search methods

We searched Medline (from 1946 to January 1, 2020), Embase (1947 to January 1, 2020), Cochrane Controlled Trials Register (from inception to January 1, 2020), ClinicalTrials.gov (http://www.clinicaltrials.gov), and Google Scholar (first 200 hits). The search was not restricted by date, language, or publication status. Search terms were defined a priori and by reviewing the MeSH terms of articles identified in preliminary literature searches. The search strategy was based on the Medline initial search strategy and was modified as necessary for the other databases. A search strategy combining MeSH headings and the keywords "air ambulance/aeromedical evacuation/air evacuation/aeromedical transport/air patient transport" AND "team or group/unit or squad/crew" was used after a decision with an experienced librarian.

Data abstraction

Two review authors (CL, JPRC) not blinded to authors, journal or institutions, examined all study abstracts and full texts independently, which were identified by the search. Titles and abstracts of every record retrieved were screened to determine which of the studies should undergo a full-text review. Full texts of the studies with questionable eligibility or considered eligible were retrieved in this phase for evaluation. The reference lists of the retrieved articles were also searched for additional citations. Any disagreements were resolved by consensus or with another review author (LTDL). Only published data were included. Study authors were not contacted for obtaining or clarifying further information. At the data extraction period, data were also collected independently by two review authors (CL and JPRC).

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Risk of bias assessment

Risk of bias was assessed by two review authors (LTDL and CL) for each included study. Disagreements were resolved through discussion and consensus with a third author (HT). Each included study was classified as observational cohort or case-control, and the risk of bias was assessed according to each type of study design. The Newcastle–Ottawa Scale was used to assess risk of bias in cohort studies and case-control studies.[17] This tool defines patient groups as comparable in either the design or analysis when the effect of the exposure is adjusted for confounders. The Newcastle–Ottawa Scale assesses risk of bias in the domains of selection of exposed and non-exposed cohorts, comparability of cohorts, assessment of outcomes, and adequacy of follow-up. The Newcastle–Ottawa Scale scores 1 to 9. We considered studies with a score of ≤ 3 with high risk of bias, 4–6 moderate, and ≥ 7 low risk.

Analyses

Studies were analysed separately according to their design (retrospective or prospective cohorts and case-control studies). Clinical and methodological heterogeneity across the studies were assessed by examining the details of the subjects, the baseline data, the interventions, and the outcomes to determine whether or not the studies were sufficiently similar. Large heterogeneity and the absence of common outcome measures reported precluded meta-analyses. Therefore, all studies were analysed qualitatively with a descriptive systematic approach.

RESULTS

Included studies (Figure 1)

As indicated in Figure 1, the electronic search identified 3,778 potentially relevant citations. After removing duplicates, the abstracts for 1,668 potentially relevant studies were screened and 89 studies were selected for full-text review. From these, 16 studies met the inclusion criteria.[18–33] There was excellent agreement between the reviewers for study inclusion (Cohen`s Kappa, 0.87).[34]

Interventions performed across the studies (Table 1)

Most studies evaluated the performance of crews that included a physician versus a non-physician crew.[18–23,27–29,31–33] In two of these studies, the physician provider was a postgraduate resident physician.[19,22] In another study, four different HEMS configurations were compared, each with a different physician-led crew composition, helicopter, and base location.[29] Another study compared multiple crew configurations (dual flight nurse or flight nurse plus paramedic, or emergency medicine (EM) resident or EM physician) with ground crews.[24] Two observational studies did not address the presence of a physician as a crew member: Wirtz[22] examined the performance of a flight nurse + flight paramedic crew versus a dual flight nurse team. Mabry[30] compared the outcomes between a critical care flight paramedic + basic paramedic crew against a lone basic paramedic crew.

Clinical characteristics (see Table 1)

There were 3 prospective cohort studies[18, 23, 28] (n = 2,172), 12 retrospective cohort studies[19–22, 25–27, 29–33] (n = 8,491), and 1 case-control study[24] (n = 1,286). In all studies, patients were transported to a trauma centre. Four studies[21, 22, 25, 29] transported patients to more than one trauma centre. Four studies[28, 30-32] were conducted in a military setting (the Afghanistan conflict), and 12 studies[18-27, 29, 33] were conducted in civilian settings. Eight studies were conducted in the United States,[18-24, 26] two in Australia,[25, 27] one in Slovenia,[29] and one in South Korea.[33] One study compared two international settings: a trauma surgeon/paramedic crew in Hannover, Germany, with a flight nurse/paramedic crew in Knoxville, Tennessee.[21] The mean age ± SD of patients across all included studies was 35.6 ± 9.3, and their mean ± SD Injury Severity Score (ISS) was 18.0 ± 8.16. Most patients were male (73%).

Risk of bias (Table 2)

Observational cohort studies

Only one study[30] scored a 9 in the Newcastle–Ottawa Scale and demonstrated a low risk of bias. All other studies[18-23, 25–29, 31-33] scored a 6 to 8, demonstrating an overall moderate risk of bias. Most studies had no comparable controls, as they did not report adjustment for confounders in either the design or analysis.

Case-control study

The case-control study had a score of 8 in the Newcastle–Ottawa Scale.[24]

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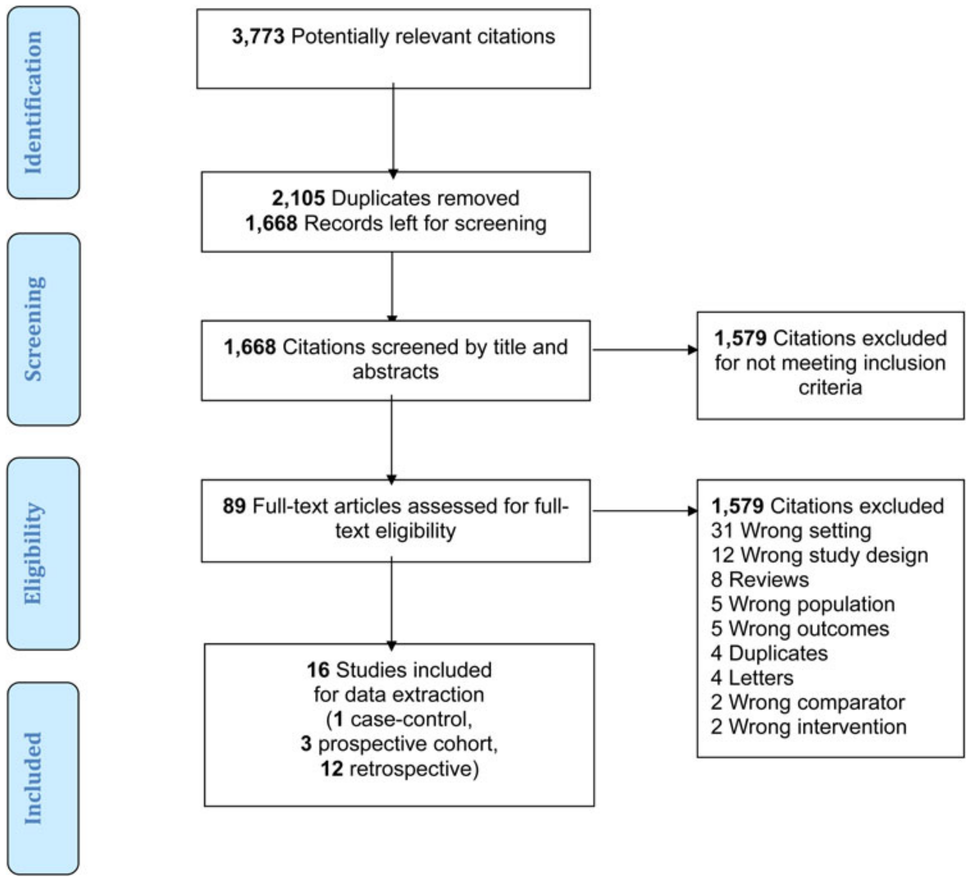

Figure 1. Flow chart of the screening process.

Outcomes measured across the studies (Table 3)

Primary outcome

Mortality was the most common outcome measured across the studies. In most studies, there was a mortality benefit associated with the presence of more advanced providers. In six studies, there was a significant mortality benefit in physician-led crews compared with non-physician-led crews.[18,21,24,25,31,32] Baxt[18] found that, in the physician-led group, 11 patients died, out of n = 316, where 16.9 were predicted to die (Z statistic = 2.284, $p < 0.05$). The study also identified a 35% reduction in mortality compared with the non-physician-led crews (Z statistic = 2.076, $p < 0.05$). Schmidt[21] found 9 unexpected survivors in the physician HEMS group (Z statistic = 2.459, W statistic = 1.35) compared with only 6 unexpected survivors in the United States, non-physician-led crews (Z statistic = 1.049). Abbott[24] found an 11% mortality reduction in the air transported group (OR = 1.75, $p < 0.01$, 95% CI 1.21-2.53), which persisted after adjustment for age (OR = 1.57, 95% CI: 1.06-2.27). Garner[25] found a significant mortality benefit in the physician-treated group (Z = 2.72, $p < 0.01$ and W = 0.48, 95% CI: 3.84-15.12) but not in the paramedic-treated group (Z = -1.16, $p = 0.25$). The adjusted W statistic in comparing the physician versus paramedic group was 13.44 (95% CI: 7.8-19.08), suggesting an additional 13 survivors per 100 patients treated by the physician group.

Three studies conducted in the military setting revealed that the survival benefit was most pronounced in patients with more severe, but survivable injuries.[30–32] Mabry[30] found a significant mortality reduction of 66% in patients with ISS > 15 treated by an advanced care paramedic-led crew compared with a basic paramedic crew. The mortality rate in U.S./North Atlantic Treaty Organization military, Afghan military settings, and Afghan civilian settings treated by Critical Care Flight Paramedic crews were 15%, 4%, and 5%, respectively, compared with respective mortality rates of 12%, 18%, and 16% for patients treated

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Table 1. Summary of included study findings	
Study (reference)	Summary of findings: intervention group outcomes compared to controls
Baxt 1987[18]	1. Patients expected to die in the flight nurse/flight MD-treated group survived injuries that were predicted to have been lethal. 2. Flight staffed by nurse and MD v. flight staffed by nurse and paramedic: mortality statistical difference in favour of the nurse/MD air ambulance configuration. 3. In nearly 50% of patients in the flight nurse/flight paramedic, procedures could have been performed in the field. These procedures could have possibly decreased mortality, while no such incident occurred in the flight nurse/flight physician-treated group.
Hamman 1991[19]	1. No demonstrable advantage to patient outcome when treated by a team that included a physician. 2. Patients had the same mortality difference in both groups with or without a physician (30% v. 47%, not statistically significant).
Burney 1992[20]	1. Small differences found in types of flights taken by P/N and N/N teams. However, no difference in objective measures of severity between the two teams. 2. No differences found with respect to parameters of severity or outcomes for P/N v. N/N crew composition. 3. No objective evidence to prefer one crew composition over another. 4. Mortality, ICU, and hospital LOS of P/N v. N/N patients were not different.
Schmidt 1992[21]	1. There was a significantly increased survival of patients expected to die in GE (Physician HEMS) compared with the United States (paramedic HEMS).
Ben Housel 1995[22]	1. Scene time was chosen as a surrogate measure of teamwork. There was no significant difference in scene time between an N/N crew and an N/R crew ($p = 0.87$). This suggests that an EM Resident Physician can be incorporated into a flight crew without adversely affecting scene time. 2. The proportion of patients who had IV or definitive airway procedures was not different between the N/N and N/R groups. 3. No firm conclusions about differences in the quality of care delivered by different crew configurations can be drawn.
Burney 1995[23]	1. Comparing P/N v. N/N flight crews: Composition of the flight team had no effect on flight time, patient care during transfer, or eventual hospital outcome. 2. There is no evidence to support that one type of flight crew is superior or preferable to another.
Abbott 1998[24]	1. There is an 11% decrease in mortality in the air medical group v. the ground ALS group. 2. Fewer patients required long-term care in the air medical group v. controls: 25% v. 15% patients were discharged to rehab facilities, and 5% v. 11% were discharged to extended care facilities.
Garner 1999[25]	1. MD + paramedic HEMS v. paramedic + paramedic HEMS: 8-19 additional survivors per 100 treated patients by the MD + paramedic HEMS configuration.
Wirtz 2002[26]	1. Using TRISS: no statistical significance in outcomes (mortality/survival, discharge to home or to rehabilitation) for patients transported by N/P air medical crews v. N/N crews.
Cameron 2005[27]	1. No significant difference in 30-day mortality, mean hospital LOS, number of patients transferred or discharged home from ED between patients treated by ICP v. an EP. 2. Tasking of a helicopter into the prehospital environment is more safely carried out by appropriately trained medical staff.

(*Continued*)

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Table 1. Continued.

Study (reference)	Summary of findings: intervention group outcomes compared to controls
Calderbank 2011[28]	1. Crew opinion: doctor's presence was not clinically beneficial in 77% of missions. 2. Most common medical intervention: RSI (45%). Others were: analgesia, sedation, blood products (34%), chest drain or thoracostomy (5%), and pronouncing life extinct (6%). 3. Only a small proportion of the interventions performed appeared to be beyond the capability of well-trained military paramedics.
Klemenc- Ketis 2012[29]	1. Significant trend towards improved quality indicators in HEMS crew with the most skilled and experienced physicians and an emergency paramedic on board.
Mabry 2012[30]	1. U.S. Army National Guard air ambulance unit using CCFP and current EMS practices with a combat adaptation reduced 48-hour mortality in combat casualties with ISS $\geq$ 16 by 66% compared with standard Army air ambulance units. 2. Forty-seven percent (47%) relative reduction in mortality associated with advanced provider presence.
Apodaca 2013[31]	1. Paramedic-led PEDRO platform (for patients with mild, moderate, and critical/catastrophic injury): achieved predicted survival. 2. Physician-led MERT (severely injured casualties: polytrauma, multiple amputations): achieved greater than predicted survival. 3. MERT group – lowest ISS group: achieved predicted mortality. 4. MERT group – three (3) highest ISS groups: observed mortality statistically lower than the predicted (positive Z scores greater than 1.96). 5. PEDRO group: achieved expected mortality in all ISS groups, except ISS 20-29 (observed rate higher than predicted [16.2% v. 8.1%]; Z = 2.736).
Morrison 2013[32]	1. Two-thirds (2/3) of casualties were well served with the conventional medical retrieval platforms of DUSTOFF and PEDRO. 2. No difference in mortality between capabilities in the low category of injury severity (2/3 of the cohort). 3. Patients with severe but survivable injuries had a lower mortality when transported with an advanced physician-led retrieval capability. 4. There was a significant trend towards improved quality indicators in HEMS crews with the most skilled and experienced physicians and an emergency paramedic on board.
Jung 2016[33]	1. ATLS interventions by MDs: insufficient data to achieve significant survival outcomes 2. For MD-staffed HEMS transporting patients within 3 hours: TRISS analysis reported that an additional 9/100 patients would have survived (W statistic 9.0; $p = 0.035$). 3. MD-staffed v. non-MD staffed HEMS: patients treated by the former group achieved shorter times to OR but experienced longer transportation times.

Notes: CCFP = Critical Care Flight Paramedic; DUSTOFF = U.S. Forward Aeromedical Evacuation helicopter platform with two basic paramedics; ED = emergency department; EM = emergency medicine; EMS = emergency medical services; EP = emergency physician; GE = German; HEMS = Helicopter Emergency Medical Services; HTT = helicopter trauma team; ICP = intensive care paramedic; ISS = Injury Severity Score; LOS = length of stay; MD = medical doctor; MERT = Medical Emergency Response Team – Physician-led UK Forward Aeromedical Evacuation helicopter platform; N/N = Nurse/Nurse; N/P = Nurse/Physician; N/R = Nurse/Resident; PEDRO = U.S. Forward Aeromedical Evacuation helicopter platform with two advanced care paramedics; RSI = rapid sequence induction; TRISS = Trauma Injury Severity Score.

by basic paramedic crews. The 48-hour mortality of patients treated by advanced providers was 8% versus 15% in the group treated by basic paramedics (OR 0.24, 95% CI: 0.14-0.88). Apodaca[31] found a significant reduction of in-hospital mortality in patients with ISS of 20–29 treated by the physician-led UK Medical Emergency

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Table 2. Included studies – risk of bias (The Ottawa-Newcastle tool[17])

Cohort studies	Representativeness of the exposed cohort	Selection of non-exposed cohort	Ascertainment of exposure	Outcome not present at start	Comparability of controls	Assessment of outcome	Adequate follow-up	Loss to follow-up	Total score
Baxt 1987[18]	*	*	*	*	*	-	*	*	7/9
Hamman 1991[19]	*	*	*	*	*	-	*	*	7/9
Burney 1992[20]	*	*	*	*	-	-	*	*	6/9
Schmidt 1992[21]	*	*	*	*	*	-	*	*	7/9
Ben Housel 1995[22]	*	*	*	*	-	-	*	*	6/9
Burney 1995[23]	*	*	*	*	*	-	*	*	6/9
Garner 1999[25]	*	*	*	*	*	-	*	*	7/9
Wirtz 2002[26]	*	*	*	*	*	*	*	*	8/9
Cameron 2005[27]	*	*	*	*	*	-	*	*	7/9
Calderbank 2011[28]	*	*	*	*	-	-	*	*	6/9
Klemenc-Ketis 2012[29]	*	*	*	*	-	-	*	*	6/9
Mabry 2012[30]	*	*	*	*	**	*	*	*	9/9
Apodaca 2013[31]	*	*	*	*	-	*	*	*	7/9
Morrison 2013[32]	*	*	*	*	*	*	*	*	8/9
Jung 2016[33]	*	*	*	*	*	*	*	*	8/9
Case control study	**Case definition**	**Representativeness of the cases**	**Selection of controls**	**Definition of controls**	**Comparability of cases and controls**	**Ascertainment of exposure**	**Ascertainment for cases and controls**	**Non-response rate**	**Total score**
Abbott 1998[24]	*	*	*	*	*	*	*	*	8/9

*High quality choices are indicated by a star. Comparability has a maximum of two stars. All other categories have a maximum of one.

Table 3. Included study characteristics

Study (reference)	1. Design 2. Enrolment years	1. Sample (n) 2. Population	1. ISS (mean/median) 2. Age (mean/median) 3. Male (%)	Intervention	Intervention group effect measure	Control group	Control group effect measure
Baxt 1987[18]	1. Prospective 2. Two years (not reported)	1. 574 2. Adult civilian blunt trauma	FN/MD: n = 316 1. 13.9* 2. 27.8* 3. Not reported FN/FP: n = 258 1. 13.6* 2. 27.6* 3. Not reported	FN + Flight MD	Predicted to die: 16.9 Died: 11 Mortality reduction: 35%	Flight Nurse + Flight Paramedic	Predicted to die: 19.5 Died: 19
Hamman 1991[19]	1. Retrospective 2. 1985	1. 259 2. Adult civilian trauma	MD n = 145 1. 15 ± 12 [a] 2. 34 ± 16 [a] 3. Not reported No MD n = 114 1. 15 ± 12 [a] 2. 30 ± 16 [a] 3. Not reported	PGY 2/3 MD + RN .	Predicted mortality: 17 (12%) Actual mortality: 12 (8%) Reduction in mortality in MD group: 30%	RN + RN or RN + Paramedic	Predicted mortality: 15 (13%) Actual mortality: 8 (7%) Reduction in mortality in the non-MD group: 47%
Burney 1992[20]	1. Retrospective 2. 1987–1988	1. 659 2. Adult civilian trauma	1. Not reported P/N 1. 45.7 ± 18.1 [a] 2. 66% N/N 1. Not reported 2. 50.9 ± 19.0 [a] 3. 61%	MD + FN	Discharged alive: 341 (83%)	Flight Nurse + Flight Nurse	Discharged alive: 190 (79%)
Schmidt 1992[21]	1. Retrospective 2. 1988–1989	1. 407 2. Adult civilian trauma	GER n = 221 1. 18* 2. 36* 3. Not reported U.S. n = 186 1. 19.8*	GE p-HEMS	Mortality: ISS < 25: 4.2% ISS 25-40: 20% ISS 41-49: 0% ISS 50-66: 63.6% ISS 67-75: 83.3%	U.S. Flight Nurse + Flight Paramedic	Mortality ISS < 25: 0 ISS 25-40: 15.4% ISS 41-49: 45.4% ISS 50-66: 80% ISS 67-75: 100%

(*Continued*)

Table 3. Continued.

Study (reference)	1. Design 2. Enrolment years	1. Sample (n) 2. Population	1. ISS (mean/median) 2. Age (mean/median) 3. Male (%)	Intervention	Intervention group effect measure	Control group	Control group effect measure
			2. 29.5* 3. Not reported				
Housel 1995[22]	1. Retrospective 2. 1991–1992	1. 86 2. Civilian adult trauma	N/N 1. Not reported 2. 36* 3. Not reported N/R 1. Not reported 2. 30* 3. Not reported	Flight Nurse + Resident MD	Mean scene time: 10.3 ± 5.3 SD[a]	Flight Nurse + Flight Nurse	Mean scene time: 10.3 ± 5.3[a]
Burney 1995[23]	1. Prospective 2. 1990–1992	1. 1,169 2. Adult civilian trauma	1. Not reported 2. 47.6 ± 19[a] 3. 63%	Physician + Flight Nurse	Survival at DC: 190/255 (75%)	Flight Nurse + Flight Nurse	Survival at hospital discharge: 723/914 (79%)
Abbott 1998[24]	1. Case-control 2. 1991–1995	1. 1,286 2. Closed head injury patients	1. ISS – <16: 27 patients; > 16: 169 patients 1. Not reported 2. Not reported	FN + FN, Paramedic, or EM resident or MD	Overall mortality: 20% ISS >16 mortality: 24% 11% decreased mortality 10% increased DC to rehab	Ground ALS Paramedics	Mortality 31% ISS > 16 mortality: 42%
Garner 1999[25]	1. Retrospective 2. 1996–1998	1. 207 2. Adult civilian blunt trauma ISS > 9	MD team n = 67 1. 25 (10-59)[b] 2. 31 (13-70)[b] 3. Not reported Paramedic team n = 140 1. 18 (10-66)[b] 2. 33 (2-89)[b] 3. Not reported	MD + Paramedic HEMS	Predicted deaths: 16 Observed deaths: 10 Adjusted analysis: 13.44 (95% CI: 7.80 to 19.08): 13/100 extra survivors in the physician group	Paramedic + Paramedic HEMS	Predicted deaths: 23 Observed deaths: 27
Wirtz 2002[26]	1. Retrospective 2. 1992–1999	1. 1,193 2. Adult civilian trauma	Nurse/Nurse 1. 23.17* 2. 39.61*	Nurse + Paramedic	Observed mortality: 18.43%	Nurse + Nurse	Observed mortality: 16.15%

(*Continued*)

Table 3. Continued.

Study (reference)	1. Design 2. Enrolment years	1. Sample (n) 2. Population	1. ISS (mean/median) 2. Age (mean/median) 3. Male (%)	Intervention	Intervention group effect measure	Control group	Control group effect measure
			3. 72.1% Nurse/Paramedic 1. 22.40* 2. 43.52* 3. 64.5%		Predicted mortality: 16.1%		Predicted mortality: 16.9%
Cameron 2005[27]	1. Retrospective 2. 1999–2003	1. 374 (203 traumas) 2. Adult civilian trauma	MD trauma: n = 113 1. RTS 7.72* 2. 34* 3. 64% ICP trauma: n = 90 1. RTS 7.73* 2. 33* 3. 65.6%	Flight Nurse + Emergency MD	30-day mortality: 6 (2.8%)	Intensive Care Paramedics	30-day mortality: 4 (2.5%)
Calderbank 2011[28]	1. Prospective 2. 2008	1. 429 2. Adult military trauma	1. Not reported 2. Not reported 3. Not reported	Physician HEMS	Frequency of mission crew's opinion that a doctor's presence was NOT clinically beneficial 219/283 missions (77%)	No control	Not reported
Klemenc- Ketis 2012[29]	1. Retrospective cross-sectional 1. 2003–2008	1. 833 2. Adult civilian trauma	1. Not reported 2. Not reported 3. Not reported	Physician HEMS	Various quality indicators: 1. Intubation/ resuscitation ratios 2. Analgesia	No control	Not reported
Mabry 2012[30]	1. Retrospective 2. 2007–2010	1. 671 2. Adult military/ civilian trauma	CCFP n = 469 1. 25.4 ± 8.9[a] 2. 25.2 ± 13.1[a] 3. Not reported MEDEVAC n = 202 1. 24.8 ± 9.7[a] 2. 29.4 ± 20.4[a] 3. Not reported	CCFP + EMT-B/ EMT-I	48h mortality: 8%	Single EMT-B	48h mortality: 15%

(*Continued*)

Table 3. Continued.

Study (reference)	1. Design 2. Enrolment years	1. Sample (n) 2. Population	1. ISS (mean/median) 2. Age (mean/median) 3. Male (%)	Intervention	Intervention group effect measure	Control group	Control group effect measure
Apodaca 2013[31]	1. Retrospective 2. 2009–2011	1. 975 2. Adult military trauma	MERT (n = 543) 1. 16 ± 13[a] 2. 24.1 ± 4.8[a] 3. Not reported PEDRO (n = 326) 1. 11 ± 10[a] 2. 23.6 ± 4.1[a] 3. Not reported DUSTOFF (n = 106) 1. 10 ± 10[a] 2. 24.4 ± 5.8[a] 3. Not reported	One of three studied MEDEVAC platforms UK MERT: Physician, RN, two paramedics in CH-47 Chinook	In-hospital mortality MERT: 23 (4.2%)	USAF PEDRO: two PJs in HH-60 Pave Hawk U.S. Army DUSTOFF: two EMT-Bs in UH-60 Blackhawk	In-hospital mortality: PEDRO: 15 (4.6%) DUSTOFF: excluded because of low number of fatalities
Morrison 2013[32]	1. Retrospective 2. 2008–2012	1. 2,818 2. Adult military/ civilian trauma	AMR 1. 16 ± 17[a] 2. 24 ± 7.7[a] 3. 96.9% CMR 1. 15 ± 16 2. 24.3 ± 9.5 3. 95.2%	AMR UK MERT: Physician-led RN, two paramedics in CH-47 Chinook	Overall mortality: 9.1% Mortality in: ISS < 16: 2.8% ISS 16-50: 12.2% ISS 51-75: 60% Mortality in patients with ISS 16-50 after excluding severe TBI: 12.7%	CMR medic-led USAF PEDRO: two PJs in HH-60 Pave Hawk U.S. Army DUSTOFF: two EMT-Bs in UH-60 Blackhawk	Overall mortality: 9.2% ISS < 16: 1.5% ISS 16-50: 18.2%% ISS 51-75: 60% Mortality in patients with ISS 16-50 after excluding severe TBI: 20.8%
Jung 2016[33]	1. Retrospective 2. 2011–2015	1. 180 2. Adult civilian blunt trauma	1. 20 (10-29)[b] 2. 51 (37-58)[b] 3. 81.7%	Physician HEMS	Survivors: 42 (84%)	Non-physician HEMS	Survivors: 66 (89.2%)

Notes: [a] Mean, [b] Median, *Standard deviation not reported.

Retrieval Team (MERT–UK Forward Aeromedical Evacuation with advanced medical providers) compared with patients treated by two other non-physician-led forward Aeromedical Evacuation capabilities (4.8% v. 16.2%, $p < 0.021$). Furthermore, the Medical Emergency Retrieval Team–treated groups achieved lower mortality than predicted by the Trauma Injury Severity Score in all ISS > 9 patient groups, whereas the paramedic-led U.S. Army group was found to have a higher than predicted mortality in the ISS 20–29 group.[31] Morrison[32] found a mortality reduction in patients with ISS 16–50 (after excluding severe traumatic brain injury [TBI]) in patients treated by the physician-led UK Medical Emergency Retrieval Team compared with patients treated by two other Forward Aeromedical Evacuation platforms with no physicians (12.2% v. 18.2%, $p = 0.035$).

In four studies,[19,20,23,27] there was no significant mortality difference associated with the presence of more advanced health care providers. Hamman[19] found similar mortality and similar causes of death when directly comparing flight teams with and without a physician (Z statistic 2.03 v. 3.11 for physician and non-physician groups). Burney[20] found no difference in mortality between patients treated by physician plus nurse and nurse plus nurse teams (year one: 76% v. 78%, $p = 0.06$, year two: 70% v. 80%, $p = 0.06$). In addition, Wirtz[21] found no significant difference in mortality outcomes between patients transported by a flight nurse plus paramedic crew versus a dual flight nurse crew ($p = 0.14$).

For secondary outcomes, see Supplemental Material.

DISCUSSION

Main findings

This review summarizes the evidence for how crew composition in Primary Aeromedical Retrieval impacts clinical outcomes in adult trauma patients. Overall, there was a trend to improved mortality with crews comprising, or led by, providers with advanced training and/or more experience. Where population segments were broken down by ISS, this mortality benefit was most pronounced in patients with severe but survivable injuries, and in patients with severe TBI. With respect to secondary outcomes, most studies reported no significant differences in quality of patient care indicators, such as on-scene time, ratios of appropriate clinical interventions, hypotension, length of hospital and Intensive Care Unit stay, and discharge disposition.

In a review of mortality during recent military settings, 87.3% of battlefield deaths occurred prehospital, of which 35.2% died instantaneously due to physical dismemberment, catastrophic brain injury, and destructive cardiothoracic great vessel injuries.[6] The remainder died within minutes to hours before reaching a trauma centre. Most patients (75.7%) had non-survivable injuries (severe TBI, great vessel injury, high spinal cord injury, and abdomino-pelvic destructive injuries). The remaining 24.3% had potentially survivable injuries, of which 8.0% were airway compromise and 90.9% were hemorrhagic (67.3% truncal, 19.2% junctional, and 13.5% extremity). It is hard to extrapolate from military to civilian settings. However, we can say that this analysis points to a set of "most potentially survivable injuries." Bearing in mind this (military) injury and mortality pattern, and examining studies showing a pronounced survival trend in severely injured patients treated by (military) Forward Aeromedical Evacuation crews containing advanced providers, one can posit that 1) there is a subset of key prehospital interventions that have the greatest influence on overall mortality,[5] and 2) there is a subset of providers prepared to a) assess the requirement for, and b) implement the aforementioned interventions better than the remainder.

The evidence suggests that advanced providers in Primary Aeromedical Retrieval may be more decisive and/or competent in performing these interventions. However, our inquiry suffers from a lack of detailed content and high-quality evidence, which precludes robust conclusions about which prehospital interventions are responsible for improving clinical outcomes and which providers are best prepared to administer them. In fact, the current data registries may simply not have sufficiently granular, high-quality data. We also noted that the current evidence does not report on other aspects that advanced providers may offer: leadership, clinical judgement and decision-making, reassurance, leading after action reviews, and coordinating quality improvement.[28]

Strengths and weaknesses of this review and future research

To our knowledge, this is the first systematic review to examine the influence of crew composition on clinical outcomes in adult trauma. This study is limited by the observational nature of the data, so confounding is

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highly probable. Also, most observational data are represented by small retrospective studies with high clinical and methodological heterogeneity. The interventions and controls varied substantially across all studies. Moreover, the various different endpoints were addressed inconsistently and without adjusted analyses for covariates. Finally, no common effect measures could be pooled for quantitative analysis due to the data's heterogeneity.

Primary Aeromedical Retrieval's high costs, high risks, combined with high military trauma prehospital mortality with its great proportion of survivable injuries underscore a need for well-designed studies. Randomized controlled studies that are planned in detail from the design and research question phase should be conducted. Interventions and controls should be better standardized. Meaningful clinical endpoints should be addressed, such as mortality and other important outcome measures in patients with brain injury, compromised airway and ventilator status, and hemorrhagic injuries. Data points should detail the type of intervention performed, by which provider, and to what effect. Some examples of important interventions are intravenous and intraosseous access, chest decompression, time between injury and transfusion of blood products and tranexamic acid administration, junctional and extremity tourniquet application, use of vasoactive drugs, and hypothermia prevention.

CONCLUSION

In trauma, the data on the outcomes of different crew composition in Primary Aeromedical Retrieval demonstrated that a trend towards decreased mortality was associated with the presence of advanced providers. However, these results should be interpreted with caution because the evidence is constrained by small sample sizes, observational studies, non-random treatment group allocation, and a high likelihood of confounding factors. Ultimately, an appropriately powered randomized trial that captures sufficient details on injury patterns, crew configurations, interventions and procedures performed, and meaningful clinical outcomes will be required to determine the most appropriate Primary Aeromedical Retrieval crew composition.

Supplemental material: The supplemental material for this article can be found at https://doi.org/10.1017/cem.2020.404.

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