

TITLE

“Critical Care Paramedics”: Where is the evidence? A Systematic Review

NAMES

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ABSTRACT

Objectives

Paramedic-delivered pre-hospital critical care is an established concept in a number of emergency medical services around the world and, more recently, has been introduced to the UK. This review identifies and describes the available evidence relating to paramedics who routinely provide pre-hospital critical care as primary scene response (“critical care paramedics”, or CCPs).

Methods

A systematic search of electronic databases was performed: CENTRAL, EMBASE, MEDLINE (through EMBASE and Web of Knowledge) and Web of Science (through Web of Knowledge).

Results

The search identified twelve relevant publications, one of which was a randomized-controlled trial. The remaining eleven were retrospective studies. Five studies compared CCPs with physician-led care. Three of these publications demonstrated improved outcomes with physician care, whilst two showed no difference. Four further publications examined CCPs versus non-physician-led care and found improved outcomes (two studies), mixed effects (one study) and no difference (one study) for CCPs. Finally, three publications addressed the addition of skills to CCP competencies. A randomized controlled trial of CCP rapid sequence induction (RSI) and tracheal intubation demonstrated improved neurologic outcomes. CCP tube thoracostomy was shown to have similar complication rates to the same procedure performed in the ED, while addition of a non-invasive ventilation protocol to CCP practice had no effect on long-term mortality.

Conclusion

There is limited evidence to support the concept of paramedic-delivered pre-hospital critical care. The best available evidence suggests a benefit from pre-hospital RSI carried out by CCPs in patients with severe traumatic brain injury, but the impact of

CCPs remains unclear for many conditions. Further high-quality research in this area would be welcome.

INTRODUCTION

The United Kingdom (UK) has seen a steady increase in emergency ambulance calls over the past decade, with the call volumes approaching 8 million in 2009-2010.[1] Only a small proportion of these incidents require pre-hospital critical care interventions such as advanced airway management, cardiopulmonary resuscitation or inotropic support.[2] The average pre-hospital provider is therefore only rarely able to carry out such interventions,[3] which are often complex and carry the risk of serious complications.[4] This leaves emergency medical services (EMS) and pre-hospital providers faced with the challenge of how to provide appropriate yet efficient care for the few severely ill or injured patients in urgent need of pre-hospital critical care.[5] The merit of advanced or critical care skills in pre-hospital care has been debated,[6] but there is evidence that extended procedural capacity and decision-making benefits many patient groups.[7, 8]

The question of who should be providing pre-hospital critical care is an ongoing controversy.[9, 10] Concerns regarding the risk of detrimental effects have led to the conclusion that only physicians should undertake certain interventions, such as rapid sequence induction of anaesthesia and tracheal intubation (RSI).[4, 11, 12] Others would argue that it is not the professional group of the pre-hospital provider that determines capability but clinical competency, and therefore well trained and experienced paramedics should be able to provide an equivalent level of pre-hospital critical care to physicians.[13, 14] Paramedics sub-specialising in the delivery of pre-hospital critical care have become established in North America, mainly as flight paramedics on helicopters, providing inter-hospital transfers and/or primary scene responses.[15] In parts of Australia, mobile intensive care ambulance (MICA) paramedics are dispatched to patients with suspected major trauma, either by car or helicopter.[14] Similar models exist in South Africa and New Zealand, and efforts to improve pre-hospital critical care in the UK have resulted in an increasing number of critical care paramedics (UK-CCPs) over recent years.[16] UK-CCPs work either with pre-hospital doctors, other UK-CCPs, paramedics or on their own (author's unpublished data, 2012). While there is no national training programme or

curriculum for UK-CCPs, most UK-CCPs have additional competencies beyond that of UK paramedics such as procedural sedation, joint or fracture reduction, invasive interventions such as thoracostomy (authors' unpublished data, 2012). In contrast to some of their colleagues in Australia[14] or North America,[15] UK-CCPs are currently not able to undertake RSI independently.[12] Within the authors' institution (South Western Ambulance Service), UK-CCPs are dispatched to severely ill or injured patients only, either by helicopter or car, and regular participation in clinical governance measures is mandatory.[17]

This review identifies and describes the available evidence relating to paramedics who routinely provide pre-hospital critical care as a primary scene response. For the purpose of clarity, we refer to paramedics acting in this capacity as 'critical care paramedics' (CCPs), since their titles and scope of practice vary widely across different emergency medical systems.

METHODS

Literature retrieval

We performed a systematic search of electronic databases: CENTRAL, EMBASE, MEDLINE (through EMBASE and Web of Knowledge) and Web of Science (through Web of Knowledge). No language limitation was applied. Due to significant developments in the practice of pre-hospital care such as RSI[18] and the use of pulse oximetry[19] in the early 1990s we decided to exclude papers published before 1990. This restriction was not applied to hand searches of citations in relevant reviews and manuscripts of potential interest. The searches aimed to include both the general concept of paramedic-delivered critical care as well as specific critical care competencies. The fact that many CCPs work on helicopters (Helicopter Emergency Medical Services: HEMS) or fixed wing aircrafts is also reflected in the search terms (see box 1).

Box 1. Search history (completed 22nd January 2013, years 1990 to 2013)

CENTRAL

Paramedic* 221 results

WEB OF KNOWLEDGE (1990 to 2012)

Topic=(prehospital OR pre-hospital)
AND Topic=(critical care) 583 results
Topic=(critical care paramedic*) 208 results
Topic=(mobile intensive care ambulance paramedic*) 14 results
Topic=(mobile intensive care ambulance service) 71 results
Topic=(“advanced paramedic*”) 9 results
Topic=(flight OR HEMS OR helicopter OR air ambulance)
AND Topic=(paramedic*) 201 results
Topic=(paramedic*)
AND Topic=('rapid sequence induction' OR 'rapid sequence intubation' OR RSI) 94 results
Topic=(paramedic*) AND
Topic=(cricothyroidotomy OR cricoidotomy OR cricothyrotomy OR 'surgical airway') 35 results
Topic=(paramedic*)
AND Topic=('non invasive ventilation' OR niv OR 'non-invasive ventilation') 12 results
Topic=(paramedic*)
AND Topic=('chest drain' OR thoracostomy) 16 results
Topic=(paramedic*)
AND Topic=(thoracotomy) 17 results
Topic=(paramedic*)
AND Topic=(inotrop* OR vasopressor) 8 results
Topic=(paramedic*)
AND Topic=('procedural sedation' OR 'sedation') 28 results

EMBASE (1990 to 2012)

critical AND care AND paramedics 288 results
advanced AND paramedics 371 results
mobile AND intensive AND care AND ('ambulance'/exp OR ambulance) 163 results
skills OR 'knowledge'/exp OR knowledge OR competencies
AND 'critical care'/exp OR 'critical care' AND 'pre hospital' OR prehospital 269 results
"rapid sequence intubation' OR 'rapid sequence induction"
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 85 results
"cricothyroidotomy' OR 'cricoidotomy"
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 80 results
' 'non invasive ventilation'/exp OR 'non invasive ventilation'
AND 'paramedic OR paramedical AND ('personnel'/exp OR personnel)' 93 results
"chest drain'/exp OR 'chest drain' OR "thoracostomy'/exp OR thoracostomy"
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 77 results
'thoracotomy'/exp OR thoracotomy
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 75 results
'inotrope OR 'inotropic support' OR 'vasopressor'/exp OR vasopressor'
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 93 results
"procedural sedation' OR 'conscious sedation'/exp OR 'conscious sedation"
AND "paramedic OR paramedical AND ('personnel'/exp OR personnel)" 300 results

Selection of eligible studies

Two independent reviewers (JVVF and JW) scanned all titles followed by all abstracts of potentially relevant manuscripts. Each reviewer applied inclusion criteria to the abstract, as outlined in box 2. Full manuscripts were retrieved if inclusion criteria were met, inclusion or exclusion could not be determined with certainty or if the reviewers disagreed. The same process was repeated for the full manuscripts, except reviewer disagreement at this stage was resolved by reference to a senior reviewer (JB). One reviewer (JVVF) then read all eligible publications in detail and discussed the findings with the senior reviewer (JB). The strength of evidence presented by each manuscript was assessed using the Oxford Centre of Evidence Based Medicine guidelines.[20] Data regarding quality of description of pre-hospital provider competencies, intervention studied, risks of bias and study outcomes were extracted.

Box 2. Inclusion criteria following PICOS acronym

- P - Patient: All patients, including trauma, medical, paediatric or unselected groups.
- I - Intervention: Pre-hospital care or interventions delivered by one or more paramedics working at critical care level. This was defined as targeted dispatch to critically unwell patients (as in many HEMS) and the ability to deliver any of the following interventions: RSI, surgical airway, non-invasive ventilation, thoracostomy, thoracotomy, inotropic support, or procedural sedation.
- C - Comparator: Any other pre-hospital provider or specific intervention not delivered by CCPs.
- O - Outcome: Any clinical outcome, including but not limited to early or late mortality and morbidity, length of stay or complications.
- S - Study design: Any study with a comparative element, such as randomised controlled trial, before-after or case-control designs.

Presentation of results

All eligible studies are presented in a comprehensive results table. Due to the anticipated paucity of high-level evidence from randomized trials we planned a narrative analysis.

RESULTS

The search identified 3871 titles of which 609 were potentially relevant. A review of the abstracts identified 122 manuscripts for possible inclusion. This was reduced to 49 after duplications were removed. All 49 manuscripts were retrieved for further assessment.

After review of the full text publications, twelve eligible papers remained (see table 1). Reasons for exclusion of the other 37 publications were investigation of non-paramedic pre-hospital providers (16/37) or paramedics not working in a critical care capacity (7/37), study designs such as editorials, reviews, case series or descriptive studies without a comparative element (9/37), no reporting of clinical outcomes (4/37) and investigation of inter-hospital transfers only (1/37). One article did not provide information on the helicopter service studied.[21] As we were unsuccessful in contacting the author for clarification, this article was excluded. No previous review article that addresses this review question was found.

Included publications

There was one randomized, controlled trial (level II evidence).[22] The remaining eleven studies were of level III evidence, ten of which were retrospective cohort studies[23-32] and one a quasi-randomized cohort study which did not specify whether it was prospective or retrospective.[33] Five studies compared CCP-staffed HEMS with physician-staffed HEMS[23, 28, 30, 32, 33]. Outcomes for HEMS CCPs compared to HEMS paramedics with basic competencies were reported in one publication,[31] while one study compared CCP/nurse HEMS with nurse/nurse HEMS.[27] Two further publications compared HEMS paramedics with ground paramedics.[25, 29] Finally, three studies examined the effects of CCPs delivering specific interventions, such as tube thoracostomy,[24] non-invasive ventilation[26] and RSI[22]. The most commonly represented countries (5/12) were the USA[23-25, 27, 33] and Australia (3/12)[22, 28, 30]. One study each originated from Sweden,[26] Canada[29] and Afghanistan[31]. One paper compared data from the USA and Germany.[32]

Table 1. Publications included in systematic review

Author Country Study period	Grade of evidence Study design	Rural or urban	Inclusion criteria	CCP characteristics	Intervention	Comparison	Analysis	Adjustments	Outcomes	Findings
Comparison of CCP and physician-lead care										
Baxt W California, USA Study period not specified	3 Cohort, not specified if prospective or retrospective	Not specified	All blunt trauma patients receiving interventions by one of two HEMS crews and transport to one trauma centre.	HEMS nurse / paramedic crew. Nurse able to perform same procedures as physicians; paramedics restricted to non-RSI intubation, limited medication and IV access.	Nurse / paramedic HEMS crew (n=258)	Physician HEMS crew (Faculty-level emergency physician) (n=316)	TRISS-based analysis	No further adjustment	Mortality (time not specified)	Mortality in nurse/paramedic group no different from predicted (Z +0.208) but better than predicted in physician group (Z +2.284). Difference in predicted and observed mortality significantly different between groups (P<0.05), favouring physician-led care.
Garner A New South Wales, Australia 1996-1998	3 Retrospective cohort	Mixed	All blunt trauma with ISS ≥ 10 transported by one of two HEMS to different receiving hospitals.	HEMS double paramedic crew. Competencies not specified, but do not include RSI or administration of blood products.	Paramedic HEMS crew (n=140)	Physician HEMS crew (Faculty-level emergency physician) (n=67)	TRISS-based analysis	Adjusted W used, as M statistic indicated poor matches with MTOS patient cohort	Mortality pre-discharge (time not specified) Interventions delivered	Mortality less in physician group (8 to 19 additional survivors per 100 patients). Physicians performed more procedures than paramedics (intubation 34/67 vs. 14/140, thoracostomy 8/67 vs. 2/140, median volume of IV fluid in hypotensive patients 5035ml vs. 1475ml).
Schmidt U Germany / USA 1988-1989	3 Retrospective cohort	Not specified	All trauma patients with multiple injuries in an American (USA) and a German (GER) HEMS, transporting to one respective trauma centre.	USA HEMS double paramedic / nurse crew. Competencies not specified.	USA paramedic HEMS crew (n=186)	GER physician HEMS crew (Senior resident or faculty-level trauma surgeon) (n=221)	Direct comparison TRISS-based analysis	No further adjustment	Frequency of interventions. Early mortality (<6 hours) Mortality (time not specified)	More interventions (intubation, IV fluid, thoracostomy) in GER. More early deaths in USA than GER (12 and 4, respectively). Overall mortality in GER significantly better than predicted (Z +2.459), USA not different from predicted (Z +1.049). 10.8% penetrating trauma in USA, 0% in Germany.
Hamman B Kentucky, USA 1985-1987	3 Retrospective cohort	Not specified	All trauma patients transported by one HEMS before and after removal of physicians from the service.	HEMS double crew of nurse/nurse or nurse/paramedic with at least 2 years critical care experience. Same procedures as physician except cricothyrotomy and tube thoracostomy.	Non-physician HEMS crew (n=114)	Physician HEMS crew (Senior resident or faculty-level emergency physician) (n=145)	TRISS-based analysis	No further adjustment	Mortality (time not specified) Interventions delivered Revised Trauma Score (RTS)	Significantly better survival than expected for both groups (Z score +3.11 and +2.03 for the non-physician and physician group, respectively). No significant differences between the groups in trauma severity (RTS) or number and types of interventions performed.
Cameron S Queensland, Australia 1999-2003	3 Retrospective cohort	Not specified	All patients transported by one HEMS before and after removal of physicians from the service.	HEMS double crew of intensive care paramedics. Not able to perform RSI or invasive monitoring.	Paramedic tasking and staffing of HEMS (n=163)	Physician tasking and staffing of HEMS (Emergency physician) (n=211)	Direct comparison	RTS calculated for trauma patients	Mortality at 30 days Length of hospital stay Discharge from ED Secondary transfer from receiving hospital to other facility	No difference in 30-day mortality (2.8% and 2.5%), hospital length of stay (mean of 2 and 1 days) or secondary transfers (9% and 8%) between physician and paramedic group, respectively. More discharges from ED for paramedic group than physician group (33.1% and 14.7%, p=0.0001) respectively. No difference in trauma severity (RTS) between groups.

Continued

Table 1. Continued

Author Country Study period	Grade of evidence Study design	Rural or urban	Inclusion criteria	CCP characteristics	Intervention	Comparison	Analysis	Adjustments	Outcomes	Findings
Comparison of CCP and non-physician-lead care										
Mabry R Afghanistan 2007-2010	3 Retrospective cohort	Mixed	All trauma with ISS > 16 (civilian and military) transported by helicopter during either US Army or US Army National Guard deployment.	HEMS double critical care-trained flight paramedic (CCFP) or CCFP/EMT crew	CCFP HEMS crew (n=202)	US Army MEDEVAC HEMS with single emergency technician (n=469). Flight surgeon on board for unspecified number of missions.	Multi-variate logistic regression model	Adjusted for ISS, incident location, season and patient category	Mortality at 48 hours	Mortality 8% and 15% in CCP and paramedic group, respectively. After adjusting for covariates, 48-hr mortality significantly lower with CCFP treatment (odds ratio 0.34). No difference in trauma severity (ISS) between the groups.
Mitchell A Nova Scotia, Canada 1998-2002	3 Retrospective cohort	Rural	All blunt trauma patients (aged > 15 yr) with ISS ≥ 12 transported to one tertiary trauma centre. Includes secondary transfer.	HEMS critical care paramedic and registered nurse crew	HEMS transport (n=237, 84% secondary transfers)	Paramedic ground transport (n=554, 44% secondary transfers)	TRISS-based analysis	Insertion of normal physiological values where data was missing.	Mortality (time not specified)	Significantly lower mortality than predicted with CCP HEMS transport (Z +2.77), significantly higher mortality than predicted with ground transport (Z -1.99). 6.4 more survivors than expected per 100 patients in HEMS group, 2.4 unexpected non-survivors per 100 patients in ground group.
Kerr W Maryland, USA 1988-1995	3 Retrospective cohort	Not specified	All trauma transported to one trauma centre. Includes 17% secondary transfer.	HEMS single paramedic crew with additional training including use of ventilators, EtCO2 monitoring, ETI, IO access, needle thoracostomy and cricothyrotomy.	HEMS transport (n=11623)	Paramedic ground transport (n=11379)	direct comparison of ISS-stratified groups	No further adjustment	Mortality pre-discharge (time not specified)	Mortality for ISS < 31 was 4.1% and 3.1% for HEMS and ground transport, respectively (p<0.001). Mortality for ISS ≥ 31 was 37.1% and 45.3% for HEMS and ground transport, respectively (p<0.001).
Wirtz M State of New York, USA 1992-1999	3 Retrospective cohort	Not specified	All trauma patients >15 years old with injury severity score (ISS) > 9, transported by two different HEMS to one trauma centre. Includes secondary transfers.	HEMS nurse / paramedic crew (both with critical care competencies)	Nurse / paramedic HEMS crew (n=220)	Nurse / nurse HEMS crew (n=841)	TRISS-based analysis	No further adjustment	Mortality (time not specified)	No difference in mortality between the groups. No difference in mortality compared to predicted (Z +1.27 and -0.94 for nurse/paramedic and nurse/nurse care, respectively).
Evaluation of added skills for CCPs										
Bernard S Victoria, Australia 2004-2008	2 Prospective, randomized controlled trial	Urban	All patients with head injury, GCS<9, intact airway reflexes and age >15 attended by an intensive care (MICA) paramedic.	MICA paramedics on ground vehicle	Rapid sequence induction (RSI) by MICA paramedic (n=160)	RSI in receiving emergency department (ED) (n=152)	Intention to treat	No further adjustment	Extended Glasgow Outcome Scale (GOSe) at 6 months	GOSe at 6 months not significantly different (median 5 and 3 for MICA RSI and ED RSI, respectively, p=0.28). Secondary outcome 'good neurologic outcome' (GOSe 5 - 8) significantly better for MICA RSI (51% and 39% respectively, p=0.046).

Continued

Table 1. Continued

Author Country Study period	Grade of evidence Study design	Rural or urban	Inclusion criteria	CCP characteristics	Intervention	Comparison	Analysis	Adjustments	Outcomes	Findings
York D Illinois, USA 1988-1990	3 Retrospective cohort	Not specified	All chest trauma transported to one level 1 trauma centre. Includes secondary transfer.	HEMS paramedic working with flight nurse. Paramedic training or competencies not further specified.	Tube thoracostomy by HEMS paramedic / flight nurse (n=72)	Tube thoracostomy in hospital after ground transport (n=100)	Direct comparison	No adjustments	Complications (bleeding, misplacement or infection) ISS and trauma score Mortality	No difference in complication rates. Un-adjusted mortality significantly higher in HEMS group than hospital group (29/72 and 14/100, respectively). ISS and trauma score worse in HEMS group (39 and 27; 7 and 10, respectively). No mortality comparison after adjustment for trauma severity.
Gardtman M Sweden 1990-1996	3 Retrospective cohort	Urban	All patient with clinical diagnosis of pulmonary oedema attended by a mobile coronary care unit (MCCU).	MCCU paramedic +/- nurse crew	Pre-hospital care with heart failure protocol including non-invasive ventilation (n=158)	Pre-hospital care before heart failure protocol (n=158)	Direct comparison Kaplain - Meier curve for survival	No further adjustment	Physiologic and clinical findings at hospital arrival Mortality pre-discharge and at 1 year 1-year cumulative morbidity	Physiologic parameters unchanged, but significant improvement in clinical picture of pulmonary oedema. No difference in pre-discharge or 1-year mortality (18% and 18%, 39.2% and 35.8% before and after implementation of heart failure protocol, respectively). No difference in morbidity over one year follow-up.

List of abbreviations for table 1. HEMS: Helicopter emergency service. TRISS: Trauma and Injury Severity Score (determines the probability of survival of a patient). Z-score: Statistically significant difference in mortality if higher than +1.96 or lower than -1.96 (TRISS analysis). ISS: Injury Severity Score. RSI: Rapid sequence induction of anaesthesia and tracheal intubation. W-score: Number of unexpected survivors or unexpected non-survivors (TRISS analysis). M-value: Indicates how well study population matches that of the Major Trauma Outcome Study (TRISS analysis). MTOS: Major Trauma Outcome Study, used as comparator in TRISS analysis. GCS: Glasgow Coma Scale. RTS: Revised Trauma Score.

EVIDENCE REVIEW

The articles identified by this systematic search can be arranged into three distinct questions. How does CCP-led care compare to physician-led care? How does CCP-led care compare to other non-physician-led care? What is the effect of adding specific skills to existing CCP competencies?

CCPs versus physician-led care

Five studies addressed this question, of which three[28, 32, 33] showed a mortality benefit for physician-staffed HEMS and two showed no difference[23, 30]. Physicians were at least senior residents or faculty-level in four of the studies,[23, 28, 32, 33] the fifth study[30] did not specify the level of training of the emergency physicians. Baxt[33] found significantly improved mortality for a nurse/physician HEMS crew compared to a nurse/CCP HEMS crew. The paramedic crewmember in the CCP group had less procedural capacity compared to both the HEMS nurses and physicians and interventions were undertaken more often or more aggressively in the physician group. Garner[28] compared a dual CCP HEMS crew and a physician/paramedic HEMS crew in Australia and showed improved survival of the physician group over the CCP group. This study also found significantly more interventions delivered in the physician group, including the administration of blood products and neuromuscular-blocking drugs, both of which were outside the paramedic scope of practice. Schmidt[32] compared paramedic-staffed HEMS in USA with physician-staffed HEMS in Germany and found significantly more interventions delivered and less early deaths in the German group. Further differences were the absence of penetrating trauma and significantly shorter response times in the one-tier German EMS system. Hamman's before-and-after study[23] included CCPs with at least two years of critical care experience and also an unspecified number of nurse/nurse HEMS crew missions in the non-physician group. This study found significantly improved survival for both groups compared to the Major Trauma Outcome Study (MTOS) population. There was no difference between the physician and non-physician group. Finally, Cameron[30] compared both staffing and dispatch of an Australian HEMS by either physicians or intensive care paramedics. While there was a significantly higher rate

of discharges from the receiving ED during the time when CCPs were responsible for HEMS dispatch, revised trauma score (RTS), mortality, length of stay and rate of secondary transfers from the receiving hospital to another facility remained the same.

CCPs versus non-physician-led care

Of the four studies addressing this question, one compared CCP HEMS crews with paramedic HEMS crews and found a significantly better survival rate for CCP HEMS.[31] Two publications compared CCP HEMS crews with ground paramedics, with one showing improvement in mortality[29] in the CCP group and the other reporting mixed results.[25] The last study compared CCP/nurse HEMS crews and nurse/nurse HEMS crews and found no difference in outcome.[27] Mabry's publication[31] compared two different military HEMS crew configuration: a dual CCP crew and a single paramedic who was supported by a flight surgeon on an unspecified number of missions. Both groups attended to civilian and military trauma patients, with one crew relieving the other at the end of their rotation. After logistic regression analysis, mortality was significantly less in the CCP group. Mitchell [29] compared CCP HEMS and ground transport of trauma patients to a Canadian tertiary centre. This study reported significantly improved survival in the CCP HEMS group, which also included a higher number of secondary transfers compared to the ground paramedic group. Kerr[25] undertook a large database analysis, comparing CCP HEMS crews to paramedic ground transport. While the direct comparison for patients with $ISS < 31$ showed a small but statistically significant higher mortality in the HEMS group, this was reversed for patients with $ISS \geq 31$. Differences between the patient groups included a higher percentage of penetrating trauma in the ground group. Wirtz[27] compared a CCP/nurse HEMS crew with a nurse/nurse HEMS crew, with both nurses and paramedics having critical care competencies. A Trauma Injury and Severity Score (TRISS)-based analysis showed no difference in mortality between the groups.

Additional critical care skills for CCPs

We identified three studies which examined the effect of specific interventions delivered by CCPs, of which one showed a significant improvement[22] and two showed no difference in their respective outcomes.[24, 26] The first study by Bernard[22] was a randomized controlled trial of MICA paramedics undertaking pre-hospital RSI vs. basic airway manoeuvres pre-hospital followed by RSI in the receiving ED. There was no significant difference in the primary outcome with a median Extended Glasgow Outcome Scale (GOSe) score of 5 and 3 ($p=0.28$) for CCP RSI and ED RSI, respectively. The a priori defined secondary outcome of 'good neurologic recovery' (GOSe 5-8) was achieved significantly more often in the CCP RSI group (51% vs. 39%, respectively, $p=0.046$). York[24] compared the complication rates and mortality of trauma patients receiving a tube thoracostomy either by a CCP/nurse HEMS crew or by physicians in the receiving hospital after ground transport. Complication rates were equal between the groups, with ISS and unadjusted mortality higher in the HEMS group. Gardtman [26] examined the effect of adding a protocol for pre-hospital heart failure treatment, including non-invasive ventilation, to the competencies of a CCP/nurse team on a mobile coronary care unit (MCCU). While the intervention improved the clinical picture at hospital admission, mortality at discharge and at one year were unchanged.

DISCUSSION

CCP versus physician-led care

Baxt's study[33] has been frequently cited as a justification for including physicians in HEMS crews.[34, 35] The quasi-randomisation (not achieved by other studies) and the fact that the nurse crewmember in both the CCP and the physician group were capable of the same procedures as the physicians makes this a compelling argument. However, Baxt relates the differences in outcome partially to the fact that the paramedic in the nurse/CCP HEMS crew had significantly less competencies, which excluded thoracostomy, cricothyrotomy or extended medications available only to the nurses and physicians. The other potential factor was the positive effect of

physician decision-making beyond rigid pre-hospital protocols.[33] Similarly, the CCPs scope of practice in Garner's study[28] did not include potentially life saving interventions such as RSI or blood transfusions, which were received by 42% of patients in the physician group. While recognizing these differences, Garner argues that even when both paramedics and physicians were able to achieve an intervention, such as IV fluid replacement in hypotensive trauma patients, this was done more aggressively by the physicians. However, this comparison is again influenced by the availability of blood products, and is an interesting finding in view of the current trend towards limiting intravenous fluids in trauma patients.[36] Both of these studies have been cited in support of physician staffing of helicopters.[35] However, one could argue that they point to better outcomes with increased procedural skills, training and experience rather than the inherent superiority of a particular professional group.

This view would be supported by the publications from Hamman[23] and Cameron,[30] which explicitly state that their HEMS CCPs have significant critical care experience. Despite some differences in procedural capacity between CCPs and physicians (including RSI and tube thoracostomy), both report no differences in mortality. Both studies investigate CCP HEMS crews after removal of a physician from the HEMS crew. This might influence the results in favour of CCPs, as general advances in trauma care, including in-hospital management, might have biased the outcomes. Another possibility is that these CCPs worked alongside pre-hospital physicians for a significant period before then being dispatched on their own. Physician review and feedback of paramedic practice has been shown to improve paramedic decision making.[37]

The third study to show superior outcomes for physicians compared to CCPs is Schmidt's[32] evaluation of an American and German HEMS. One major confounding factor is the absence of penetrating trauma in the German patient cohort, while the cause of unexpected deaths in the USA system was 'mostly the result of penetrating trauma to the head'. Together with differences in dispatch times and the lack of

description of USA HEMS paramedic competencies, it is very difficult to attribute effects on outcomes to the HEMS staffing alone.

CCP versus non-physician-led care

The applicability of Mabry's study[31] is limited by its setting within military conflict, however it is the only publication comparing CCP and paramedic care on the same transport platform. The better survival rate in the CCP group can be explained by a number of factors beyond advanced procedural capability of the CCPs. The most obvious of these is the difference in training and experience. The CCPs had an average of nine years experience and critical care training, whereas the paramedics might have had as little as one year of clinical practice prior to deployment. In addition, CCPs had an extensive clinical governance system with regular peer review and medical director feedback in place. In contrast, supervision of the paramedic group was the responsibility of flight surgeons, often primary care trained, with 'little or no experience in EMS medical direction, trauma or critical care'. These physicians also attended an unspecified proportion of missions in the paramedic group. It should be noted that the CCP group was always a dual crew whereas the paramedic group was single-crewed for a large proportion of missions. Mitchell's study[29] also shows that CCPs achieve better outcomes than paramedics, however several other factors might have influenced this. Firstly, 84% of HEMS missions (and 44% of ground transports) in this study were transfers from other facilities where patients would have received treatment not controlled for in this study. In addition, the impact of helicopter versus ground transport needs to be considered. The actual effect of speed of transport by helicopter remains debatable,[34] but is likely to be more significant in the rural setting of this study. The actual impact of CCP attendance is therefore difficult to measure.

Kerr's comparison[25] of CCP HEMS and paramedic ground transport found an absolute reduction in mortality of 8.2% in trauma patients with $ISS \geq 31$ in the HEMS CCP group. While this is encouraging, the statistically significant mortality increase of 1.0% for patients with $ISS < 31$ in the HEMS CCP group needs to be addressed. The authors do not offer an explanation, and while these dichotomous results could be a

statistical anomaly, the large sample size of the study makes this less likely. A possible explanation is that the risks of advanced interventions, when applied indiscriminately in non-critical situations, outweigh their benefit. Dispatch of critical care teams on helicopters has been shown to be of no benefit to non-critical patients,[38] and careful consideration to the appropriateness of all pre-hospital interventions is mandatory.

Finally, Wirtz[27] compared nurse/CCP and nurse/nurse HEMS crews: both nurses and CCPs had equal competencies and freedom of decision making. Not surprisingly, no difference in outcome was found between the groups, supporting the argument that comprehensive protocols, training and experience are more important determinants of effective pre-hospital care than an individual's professional background.

Additional critical care skills for CCPs

The best available evidence identified by this review is a well-designed prospective, randomized controlled trial by Bernard,[22] demonstrating improved neurologic outcome for patients with traumatic brain injury undergoing pre-hospital RSI by CCPs in Australia. This is remarkable also for the fact that very few studies have ever been able to show a clear benefit from pre-hospital RSI by any provider.[39] The results are also in stark contrast to the only other prospective study of paramedic RSI, completed in San Diego.[4] The San Diego study matched patients with traumatic brain injury undergoing RSI with historic controls and found an increased mortality in the paramedic RSI group. The reasons for these contradictory results are likely to be found in training and skill maintenance. In the San Diego study, a large number of paramedics received a one-day training programme and would, on average, undertake RSI once every two years.[4] On the other hand, Australian MICA paramedics receive extensive training in critical care and, due to targeted dispatch, regularly attend severely injured patients.[22] Similarly, York[24] showed that a nurse/CCP HEMS crew can carry out pre-hospital chest tube thoracostomy with complication rates that are not different to those occurring in hospital. Like MICA paramedics, this HEMS team was only dispatched to high acuity trauma and placed

76 chest tubes over a period of two years. Another intervention studied was a pre-hospital protocol for heart failure, including non-invasive ventilation, carried out by a nurse/paramedic team on a MCCU in Sweden.[26] The team successfully applied non-invasive ventilation to 91% of patients, but the authors could not demonstrate any benefits in long-term outcomes; a finding which is consistent with other studies.[40] This likely reflects the underlying disease process, which will be difficult to affect within the short time frame of pre-hospital care.

Strengths and Weaknesses

This is the first review to look at the evidence supporting the development of critical care paramedics. Whilst the quality of the evidence identified is variable, it allows an assessment to be made of the anticipated effectiveness of this new professional group, alongside likely conditions for success. However, we may have overlooked some relevant evidence, particularly that published in non-English language and less accessible sources. There may also be an element of publication bias, with a reluctance to publicise unexpected or adverse outcomes. The nature of the source data make it impossible to pool individual studies or undertake detailed numerical analysis, so the findings of this review are necessarily narrative in form.

Furthermore, CCP and pre-hospital physician training, practice and skill maintenance varies between EMS and this needs to be considered when applying the results of this review.

CONCLUSION

CCPs are a group of paramedics with critical care skills who are dispatched to severely ill and injured patients. As is the case for many aspects of pre-hospital care, there is currently only limited evidence to support this model. The best available evidence suggests a benefit from pre-hospital RSI carried out by CCPs in patients with severe traumatic brain injury,[22] but the impact of CCPs on long term outcomes remains unclear for many conditions, and further high-quality research in this area would be welcome.

The evidence reviewed indicates that CCPs are able to deliver care to critically ill and injured patients that is superior to care delivered by paramedics and nurses without additional training and competencies. Whether CCPs can achieve the same standards as doctors trained in pre-hospital medicine remains unclear, but seems possible under certain conditions. High-quality training in procedures, up-to-date protocols and access to the relevant critical care equipment and medications are essential for optimal procedural capability. Regular exposure to critically ill and injured patients is vital to maintain skills and decision-making after initial training. Finally, a robust clinical governance system with feedback, clinical review and medical oversight will identify and address problems and strengthen clinical and decision-making skills. EMS in which these conditions are provided have demonstrated encouraging results for CCPs.[17, 22, 31] Any EMS considering the introduction of critical care skills, be it through paramedics, physicians or nurses, should consider whether it can deliver this level of support to its pre-hospital providers.[13]

CONFLICT OF INTEREST

JW works as critical care paramedic within South Western Ambulance Service. Both JB and JVF work closely with critical care paramedics in their clinical and academic practice.

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