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Review article

A systematic review of the effect of emergency medical service practitioners' experience and exposure to out-of-hospital cardiac arrest on patient survival and procedural performance☆

Kylie Dyson[a,b,*], Janet Bray[a], Karen Smith[a,c,d], Stephen Bernard[a,e,f], Judith Finn[a,d,g]

[a] Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia
[b] Operations Department, Ambulance Victoria, Victoria, Australia
[c] Research and Evaluation Department, Ambulance Victoria, Melbourne, Australia
[d] Discipline of Emergency Medicine, University of Western Australia, Perth, Australia
[e] Intensive Care Unit, Alfred Hospital, Melbourne, Australia
[f] Medical Advisor, Ambulance Victoria, Victoria, Australia
[g] Faculty of Health Sciences, Curtin University, Perth, Australia

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ABSTRACT

Background and objective: Emergency medical service (EMS) practitioners' experience and exposure to out-of-hospital cardiac arrest (OHCA) and advanced life support (ALS) procedures could be an important factor in procedural success and patient survival. We systematically reviewed the literature to examine these associations.
Methodology: We searched for publications using MEDLINE, EMBASE, CINAHL, CENTRAL and Web of Science. We included studies examining any type of EMS practitioner (e.g. paramedics, physicians) and OHCA patients of all ages and aetiologies. Two reviewers independently extracted data.
Results: The search identified 1658 citations, of which 11 observational studies of variable quality were included. The majority of studies did not adjust for important confounding factors and reported across different EMS personnel structures. OHCA survival was not consistently associated with various definitions of career experience in three studies, or with previous OHCA exposure in another study. Endotracheal intubation (ETI) was the only ALS procedure examined. Successful ETI placement was associated with the previous number of ETIs performed in four of five studies, but not career experience in three of four studies. Only one study examined OHCA outcome, and reported an increase in survival to hospital discharge when practitioners had high ETI exposure.
Conclusions: There is no clear evidence of an association with EMS practitioner career experience or exposure to OHCA cases and ALS procedures, with the exception of exposure to ETI and successful placement. However, most studies in this field had substantial risk of bias. Therefore, further studies are required before any definitive conclusions can be drawn.

1. Introduction

Globally, out-of-hospital cardiac arrest (OHCA) is a leading cause of death.[1] Survival from OHCA varies greatly across different locations, emergency medical services (EMS) and populations.[2] In general, survival is less than 10%, with little improvement seen over the last 30 years.[2] While many factors may contribute to the low survival in OHCA, outcomes may be improved if early and effective cardiopulmonary resuscitation (CPR) and defibrillation are provided.[3]

The efficacy of OHCA resuscitation can be maximised when EMS practitioners develop and maintain competency in the skills and knowledge of resuscitation.[4] Yet, resuscitation skills are known to deteriorate rapidly after training[5–7] and the quality of resuscitation care often differs considerably from that recommended in consensus guidelines.[8–12] Moreover, when the quality of CPR is poor, survival rates are decreased.[13–19]

Poor resuscitation performance may be the consequence of inadequate opportunities to practice and refine resuscitation skills. The association between the volume of cases and the outcome of

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* Corresponding author at: Department of Epidemiology and Preventative Medicine, Monash University, The Alfred Centre, Level 5, 99 Commercial Road, Melbourne, VIC 3004, Australia.
E-mail address: Kylie.dyson@monash.edu (K. Dyson).

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patients, known as the 'volume-outcome relationship', has been established in other medical fields such as some types of surgery.[20] However, the relationship between volume of EMS practitioner exposure and outcome of OHCA is uncertain. Our objective was to conduct a systematic review to examine the influence that EMS practitioner career experience, exposure to OHCA cases and exposure to advanced life support (ALS) procedures have on procedural performance and OHCA survival.

2. Methods

Protocol registration: PROSPERO registration number CRD42013005084.[21]

2.1. Search strategy

We searched the following databases for relevant publications from their earliest record until the 8 August 2013: Ovid MEDLINE (1950-), EMBASE (1966-), CINAHL (1937-), Cochrane Central Register of Controlled Trials, Web of Science with Conference Proceedings (1990) and the US National Library of Medicine Meeting abstracts. Keyword and MeSH terms included 'emergency medical services', 'resuscitation', 'heart arrest', 'experience' and 'exposure' (for full search strategy see http://www.crd.york.ac.uk/PROSPEROFILES/5084_STRATEGY_20130622.pdf).[21] All titles and abstracts were screened against the inclusion criteria by one reviewer (KD) to identify potentially eligible studies. Full text articles were then appraised in detail for the study selection criteria by two authors (KD and JB). The references of all included studies were visually scanned for additional studies not found with the above search strategy.

2.2. Study selection

2.2.1. Studies types

All original research articles of all publication types and dates were included with no language restrictions. All types of study design were eligible for inclusion except case-studies.

2.2.2. Participants

OHCA patients of all ages and aetiologies and any type of EMS practitioner (e.g. paramedics, physicians) were included.

2.2.3. Exposure variables

There are no standardised definitions of EMS practitioners' career experience, exposure to OHCA cases or exposure to ALS procedures, therefore all definitions were considered for inclusion in the review.

2.2.4. Outcome measures

OHCA outcomes were evaluated using the Utstein consensus definitions[22] where possible. The primary outcomes were survival to hospital discharge and performance of procedures during resuscitation (i.e. successful placement of an endotracheal tube). Secondary outcomes were any return of spontaneous circulation (ROSC) and neurological outcome at discharge.

2.3. Data extraction

Data was extracted independently by two reviewers (KD and JB) using a pre-defined data extraction form based on minimum requirements recommended in the Cochrane Handbook for Systematic Reviews.[23] Authors of primary studies were contacted to provide missing or additional data and information.

2.4. Quality assessment

All included studies were independently assessed for quality (un-blinded) by two authors (KD and JB) using the Newcastle-Ottawa Scale for assessing the quality of non-randomised studies.[24] This is a nine question form which examines the selection of the study groups, the comparability of the groups and the ascertainment of the outcome of interest.[24] A third author (JF) arbitrated any disagreement regarding data extraction or quality assessment.

2.5. Data synthesis

For exposure and outcome measures where there was more than one study, we planned to undertake a meta-analysis if clinical and statistical heterogeneity was acceptable. Heterogeneity between studies was assessed by visual inspection of forest plots, χ^2 test (<0.05) and I^2 (>50%). If a meta-analysis was not possible we intended to report all relevant findings of included studies separately and provide a narrative synthesis.

3. Results

The search strategy initially identified 1658 citations (Fig. 1). After removing duplicates and screening titles and abstracts, eighteen potentially eligible studies were identified. Of these, eight studies were excluded because the exposure of interest was not compared with an outcome of interest ($n = 5$) or the outcome was not measured ($n = 3$). One additional article not identified by the database search was included after review of the reference lists of included studies.[25] The final result was eleven studies meeting the selection criteria and included in the review (Table 1).

3.1. Study characteristics

Of the eleven included studies, one was a conference abstract[26] and ten were full-text articles (Table 1). The majority of studies were conducted in the USA[25–32] and others were single studies conducted in England[33], Iceland[34] and Finland.[35] The majority of included studies were retrospective cohort studies.[26,28,29,31–33] There were also two before and after studies,[27,35] two prospective cohort studies, [25,34] and one education interventional study.[30] The year of publication ranged from 1984 to 2012. The EMS practitioners in the majority of studies were paramedics,[25–32] one study included emergency medical technicians (EMT) as well as paramedics[33] and two studies examined physicians only.[34,35]

Six of the studies reported that the patient populations or subgroups were composed of OHCA cases only;[28,29,31,33–35] some of these samples were further restricted to presumed cardiac aetiology OHCAs,[33,34] non-traumatic OHCAs,[28] witnessed ventricular fibrillation (VF) OHCAs[29] or cases where ALS resuscitation was initiated.[35] Five other studies included OHCA and other patient types (e.g. deeply comatose patients). Three of these studies did not report what percentage of their cohort were OHCAs,[26,27,30] whereas two others reported on cohorts composed of 30%[32] and 58%[25] OHCAs. Patient cohort sizes ranged from 150[26] to 21,753 cases.[31] Insufficient information about patient age was provided in the reports; only one study reported that paediatric patients were included.[31] The majority of patients in the four studies that reported on patient sex were male (62–78%).[25,29,31,34]

Only one study examined the specific influence of EMS practitioner exposure to OHCA[34] and seven studied the overall career experience of the EMS practitioner.[25,26,28–30,33,35] The only ALS procedure studied was endotracheal intubation (ETI).[25,27,28,30–32] Most papers only considered one exposure of interest, however three

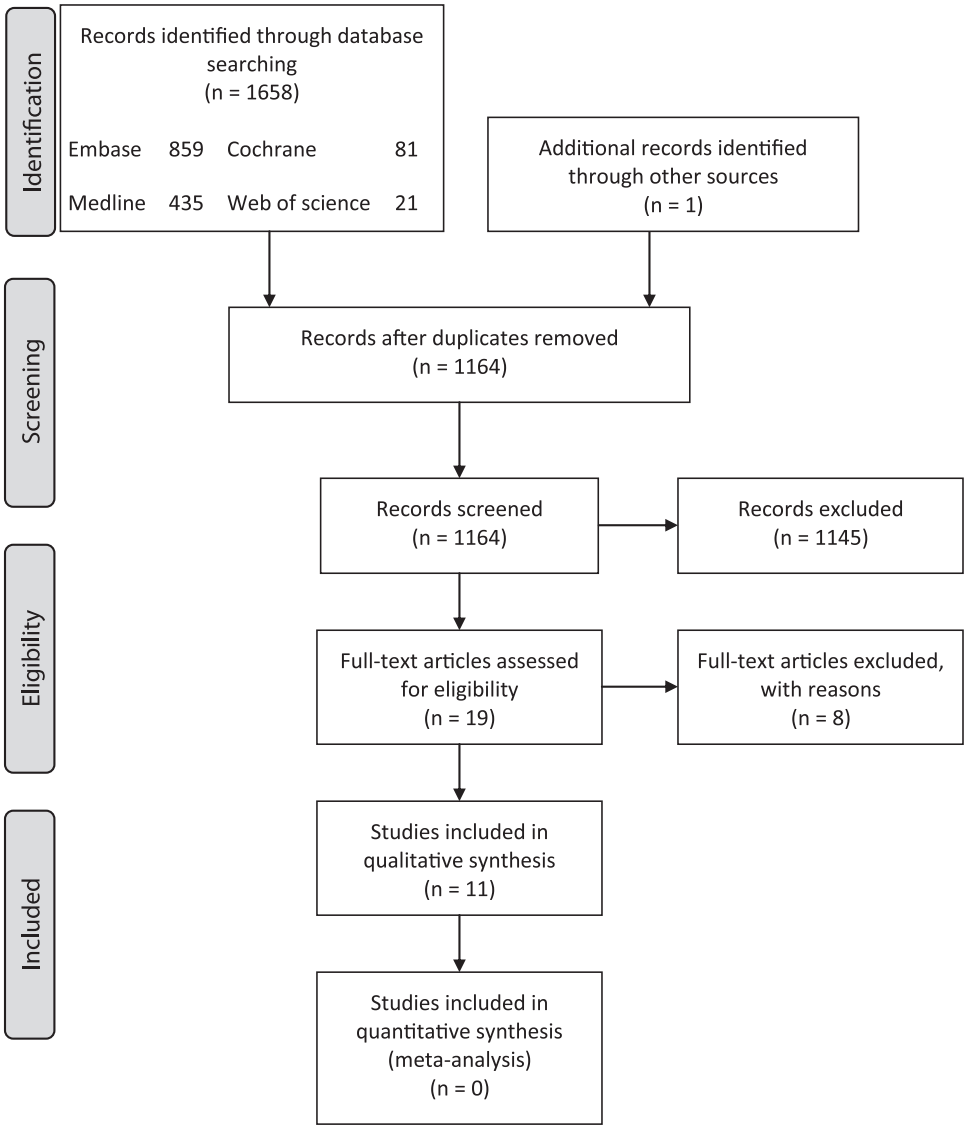

Fig. 1. PRISMA flow chart.

studies examined both practitioner experience and the number of ETIs performed.[25,28,30] No studies examined either of the secondary outcomes measures (i.e. ROSC or neurological outcome at discharge).

For exposure and outcome measures where there was more than one study, data synthesis was not possible due to clinical and methodological heterogeneity, therefore meta-analysis was not performed.

3.2. Study quality

The overall quality of studies was low; only five studies achieved a high quality score of six or more stars out of nine using the Newcastle-Ottawa Scale (Fig. 2). Most studies scored low across four areas.

Firstly, in most studies important information required for quality assessment was not reported. For example, in five of the studies the patient cohorts were not adequately described,[26,27,30,32,33] thus we were unable to determine the representativeness of the cohort in comparison to other OHCA studies.

Secondly, although ascertainment of the exposure variable (i.e. number of OHCA treated) was well described in the majority of studies, some studies did not use objective verifiable records (e.g. patient care records). One study did not report how the exposure (career experience) was ascertained[26] and in three studies

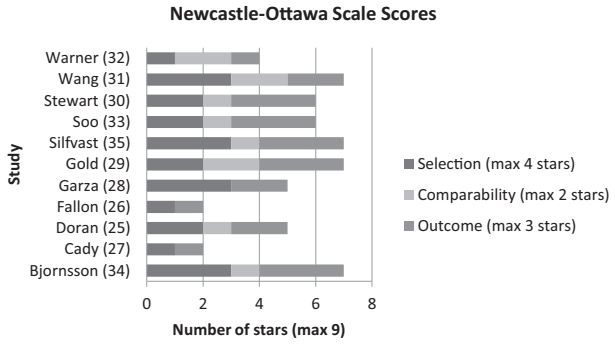

Fig. 2. Newcastle-Ottawa Scale scores.

Table 1
Summary of characteristics of included studies (ordered by exposure and outcome).

Study	Study design	Patients *n* (%OHCA)	Patient age (mean ± SD)	Practitioner (*n*)	Estimate of effect (95%CI, significance)	Adjusted for
Practitioner exposure to OHCA and survival						
Bjornsson[34] Iceland 2011	Prospective cohort	Presumed cardiac aetiology OHCA, *n* = 232 (100%)	68.1 ± 13.4	Physicians (*n* = 39)	≤5 OHCA exposures 19% survival versus >5 OHCA 20% survival ($p = 0.87$)	Unadjusted, stratified by rhythm
Practitioner career experience and OHCA survival						
Gold[29] USA 2009	Retrospective cohort	Witnessed VF presumed cardiac aetiology, *n* = 699 (100%)	Survivors: 59.9 ± 15.5, Non-survivors: 64.5 ± 14.9	Paramedics (*n* = 185)	Years of experience AOR: 1.01 (1.00–1.03, p = NR)	Age, bystander CPR, sex and location
Silfvast[35] Finland 1996	Before and after	Physician initiated ALS OHCA, before *n* = 297, after *n* = 323 (100%)	Before: 64 After: 68	Physicians (before *n* = 5, after *n* = 6)	Mean 6 years of experience 18% survival versus no experience 11% survival ($p < 0.05$)	Unadjusted
Soo[33] England 1999	Retrospective cohort	Presumed cardiac aetiology OHCA, *n* = 1071 (100%)	NR	Paramedics (*n* = 100) and EMTs (*n* = 275)	>4 years EMT experience OR: 2.71 (1.17–6.32, $p = 0.02$), >1 year paramedic experience OR: 1.78 (0.81–3.9, $p = 0.15$)	Unadjusted
Practitioner exposure to ETI and OHCA survival						
Wang[31] USA 2010	Retrospective cohort	OHCA subgroup, *n* = 21753 (100%)	96% adult	Paramedics (>94%), nurses and physicians (*n* = 4846)	Survival to hospital discharge ≤10 versus >50 ETI (over 6 years) AOR: 1.48 (1.15–1.89)	Rhythm, witnessed, age, bystander CPR, year, trauma, response time, sex, location and rescuer
Practitioner career experience and successful ETI placement						
Fallon[a, 26] USA 2012	Retrospective cohort	NR, *n* = 150 (NR%)	NR	Paramedics (*n* = NR)	≤5 years of experience versus >5, success rates 'similar', estimate of effect NR (p = NR)	Unadjusted
Practitioner exposure to ETI and successful placement						
Cady[27] USA 2004	Before and after	Adult advanced airway attempted, before *n* = 3160, after *n* = 2913 (NR%)	NR	Paramedics (before *n* = 459, after *n* = 531)	6.9 mean annual ETI before versus 3.7 after, difference in success 1.9% (0.5–3.3, $p = 0.007$)	Unadjusted
Warner[32] USA 2010	Retrospective cohort	Attempted ETI, *n* = 576 (30%)	NR	Paramedic students (*n* = 56)	Successful placement for each successive ETI AOR: 1.10 (1.03–1.17, $p = 0.006$)	Cervical spine precautions, OHCA, CPR and RSI
Practitioner career experience/exposure to ETI and successful placement						
Doran[25] USA 1995	Prospective cohort	Attempted ETI, *n* = 236 (58%)	51.4 ± 22.1	Paramedics (*n* = NR)	Ranked seniority and successful placement, estimate of effect NR ($p = 0.13$) Number of ETI and successful placement, estimate of effect NR ($p > 0.05$)	Unadjusted
Garza[28] USA 2003	Retrospective cohort	Adult non-traumatic OHCA, *n* = 1066 (100%)	NR	Paramedics (*n* = 98)	Months experience correlation with ETI success $r = 0.120$ ($p = 0.24$) Number of patients intubated correlation with ETI success $r = 0.324$ ($p < 0.001$)	Unadjusted
Stewart[30] USA 1984	Educational intervention	OHCA or deeply comatose, *n* = 763 (NR%)	NR	Intensive care paramedics (*n* = 122)	Months experience and ETI success, estimate of effect NR ($p < 0.05$) Number of ETI and successful placement, estimate of effect not reported ($p < 0.05$)	Training method, career experience and ETI exposure

[a] Abstract only; OHCA, out-of-hospital cardiac arrest; SD, standard deviation; CI, confidence interval; VF, ventricular fibrillation; OR, odds ratio; CPR, cardiopulmonary resuscitation; ALS, advanced life support; NR, not reported EMT, emergency medical technician; ETI, endotracheal intubation; RSI, rapid sequence induction.

exposure measures (number of ETI/OHCA) were only self-reported by EMS practitioners.[28,32,34]

Thirdly, few studies adjusted for factors known to predict OHCA survival or procedural performance (e.g. initial rhythm[36] or the presence of trismus[37]). Only three studies adjusted for more than one confounder[29,31,32] and three ETI studies made no attempt to adjust for any significant confounders.[26–28] Two studies investigating survival from OHCA reported an unadjusted analysis of all patients in addition to results stratified by shockable rhythm[34] or a subgroup of patients with an initial shockable rhythm.[35]

Lastly, ascertainment of outcome varied. Five studies used record linkage and obtained follow up in an acceptable length of time.[29,30,33–35] The remaining studies scored lower on the Newcastle-Ottowa Scale as a consequence of using self-reports to obtain the outcome measures,[28,32] providing no statement about loss to follow up[25–27,32] or a poor follow-up rate.[31]

3.3. Practitioner exposure to OHCA and survival

The search revealed only one study that measured the association between EMS practitioner exposure to OHCA cases and patient survival.[34] Bjornsson et al.[34] found no difference in survival to discharge in patients resuscitated by physicians with previous OHCA exposure of either ≤5 or >5 OHCA cases over 4 years (19% versus 20%, respectively, $p = 0.87$, unadjusted). Their findings were unchanged when the patient cohort was stratified to shockable and non-shockable rhythms.

3.4. Practitioner career experience and OHCA survival

Three studies examined the association between practitioner career experience and OHCA survival to hospital discharge,[29,33,35] however, their definitions of 'experience' varied. Soo et al.[33] reported on the median months of experience of both EMTs and paramedics prior to each resuscitation attempt (28 and 16 months respectively), whilst Gold and Eisenberg[29] analysed paramedic years of experience (no overall median reported) and Silfvast and Ekstrand[35] examined two groups of physicians (one with no prehospital experience and another with a mean of six years).

Comparisons between these studies are difficult because they report on EMTs, paramedics and physicians and they originate from three countries with different EMS (USA[29], Finland[35], England[33]). The patient cohorts in the studies by Gold and Eisenberg[29] ($n = 699$) and Soo et al.[33] ($n = 1071$) were composed of presumed cardiac aetiology OHCA, although Gold and Eisenberg further restricted to witnessed VF only. The patient cohort in the study by Silfvast and Ekstrand[35] ($n = 839$) was selected by the physicians on their arrival at the scene when they decided to initiate ALS, or terminate resuscitation 'based on the clinical situation'. This method resulted in a 19% difference in attempted resuscitation rates between the experienced and inexperienced groups.

These three studies didn't reveal a consistent association between practitioner experience and OHCA survival.[29,33,35] Silfvast and Ekstand[35] found that survival was significantly higher before an experienced group of physicians were replaced with a team of physicians inexperienced in prehospital care (18% versus 11%, $p < 0.05$, unadjusted). However, these authors did not adjust for initial rhythm and there was no significant difference in survival found when the cohort was restricted to a subgroup of bystander witnessed VF cases.[35] Soo et al.[33] found patients treated by EMTs with >4 years of experience had increased odds of survival (OR = 2.71, 95%CI: 1.17–6.32, unadjusted). However, these authors did not find the same association for paramedics who had worked for over a year (1.78, 95%CI: 0.81–3.9, unadjusted). After adjusting for significant confounders, Gold and Eisenberg[29] found paramedic years of experience was not significantly associated with the odds of survival (OR = 1.01, 95%CI: 1.00–1.03, adjusted).

3.5. Practitioner exposure to ALS procedures and OHCA survival

Only Wang et al.[31] examined the association between the number of ETIs EMS practitioners perform and survival from OHCA. Their OHCA subgroup ($n = 21,753$) included all aetiologies of OHCA and is the only study to include both adults (96%) and children. The majority of ETIs (94%) in this study were performed by paramedics, with the remainder performed by EMS nurses and physicians. Exposure in this study was defined as the cumulative number of ETIs performed by EMS practitioners over a six year period and included exposure to non-OHCA ETI. Probabilistic record linkage was used to obtain outcome data (hospital and death records); successful linkage was made for 78% of the cohort.

Wang et al.[31] reported increased odds of survival to hospital discharge for patients intubated by practitioners with 'very high' ETI exposure (>50 in six years) compared to 'low' exposure (≤10 in six years) (OR: 1.48, 95%CI: 1.15–1.89, adjusted). Their analysis adjusted for many significant predictors of OHCA survival and the number of patient contacts the practitioner had been exposed to over the study period. However, practitioner type, ground or air ambulance and the use of induction agents were not adjusted for in the analysis. It is also noted that practitioners with 'very high' exposure to ETI only treated 2.9% of OHCA patients in this study.

3.6. Practitioner exposure to ALS procedures and procedural performance

The search for studies examining the association between practitioner exposure to ALS procedures and procedural performance only revealed studies exploring ETI exposure. Five studies[25,27,28,30,32] examining the number of ETIs performed by EMS practitioners and successful placement were found. Whilst these studies only examined paramedics, two reported on novices intubators[30,32] and others are assumed to have included paramedics with existing ETI experience.[25,27,28] The studies used different methods to measure paramedic 'exposure' to ETI, such as the mean or median number of ETIs performed by paramedics over differing time periods or the success for each additional ETI performed. Only one study reported on a cohort that was exclusively OHCA patients ($n = 1066$).[28] In other studies OHCA patients represented 30% ($n = 576$)[32] and 58% ($n = 236$)[32] of cases, or was not reported ($n = 150$[27], $n = 763$[30]). Successful ETI was self-reported in three studies[25,27,32] and confirmed by a physician in the other two.[28,30] The overall rate of successful ETI in the studies ranged from 83%[30] to 93%.[27]

Four out of five studies reported a positive association between the number of ETIs performed by EMS practitioners and successful placement.[27,28,30,32] Warner et al.[32] reported an increase in the odds of successful placement for each successive ETI performed by novice paramedic students (OR = 1.097, 95%CI 1.026–1.173, adjusted). Cady and Pirrallo[27] found a reduction in the ETI success rate (1.9%, 95%CI 0.5–3.3, $p = 0.007$, unadjusted) when the mean number of ETIs performed annually by paramedics reduced from 6.9 to 3.7 following the introduction of an alternative advanced airway. Garza et al.[28] found a significant correlation between the number of ETIs attempted by paramedics and successful placement ($r = 0.324$, $p < 0.001$, unadjusted). Stewart et al.[30] reported a positive association between the number of ETIs performed by novice intensive care paramedics and successful placement (estimate of effect not reported, $p < 0.05$, adjusted). In addition, these authors also reported a significantly higher rate of successful

placement in the last 50 ETIs performed by three small groups of paramedics (n = 28–32) when compared the first 50 performed (88.7% versus 75.3%, $p < 0.001$, unadjusted).[30] In contrast to the above studies, Doran et al.[25] found that successful ETI placement was not associated with the mean number of ETIs performed by paramedics over an 8 month period (estimate of effect and significance not reported, unadjusted). However, these authors did not take into account exposure to ETI which occurred before the study period.

3.7. Practitioner career experience and ALS procedural performance

The only ALS procedure identified by the search was ETI. Four studies (including one abstract) were found that examined the effect of EMS practitioner experience on the performance of ETI.[25,26,28,30] The studies were all conducted in the USA and only included paramedics.[25,26,28,30] It is not clear how comparable the patient cohorts were because they were not described in detail. Only Garza et al.[28] (n = 1066) focused exclusively on OHCA patients and Doran et al.[25] (n = 236) reported that OHCA patients composed 58% of the patient cohort; Stewart et al.[30] (n = 763), and Fallon et al.[26] (n = 150) do not report what proportion of patients, if any, were OHCAs. Three studies quantified 'experience' in either years[26] or months[28,30] and one study used sequential certification numbers to rank paramedics by seniority.[25] Successful ETI placement ranged between 83 and 88% overall.[25,28,30] ETI placement was confirmed by a physician in two studies[28,30] and by paramedic assessment of clinical signs such as the 'presence of bilateral breath sounds' in one study.[25]

Stewart et al.[30] found that the months of experience of intensive care paramedics was positively associated with ETI success in OHCA and in deeply comatose patients after adjusting for the method of training and paramedic exposure to the skill (estimate of effect not reported, $p < 0.05$, adjusted). In contrast, Fallon et al.[26] reported that ETI success rates of paramedics with ≤5 and >5 years of experience were 'similar' (estimate of effect and significance not reported, unadjusted).[26] Similarly, Doran et al.[25] found no association between experience and the rate of successful ETI (estimate of effect not reported, $p = 0.13$). Although Garza et al.[28] found a correlation with practitioner exposure to ETI, they did not find a significant correlation between months of paramedic experience and ETI success ($r = 0.120$, $p = 0.241$, unadjusted).

4. Discussion

This review has found that there may be an association between the number of ETIs performed by EMS practitioners and successful ETI placement, however, there is no clear evidence that EMS practitioner career experience or exposure to OHCA cases or ALS procedures is associated with survival or procedural performance. Few studies were found examining practitioner experience and exposure to OHCA and the search revealed no studies that examined practitioner exposure to procedures other than ETI or survival outcomes other than survival to discharge.

The association between higher EMS practitioner exposure to ETI and successful ETI placement is consistently reported in the literature.[25,27,28,30,32] There is also some evidence suggesting that 'very high' ETI exposure (50 over 6 years) is also associated with improved OHCA survival.[31] However, exposure to ETI in all these studies was less than ten per year.[25,27,28,30–32] These exposure rates are very low compared to other disciplines that are not required to contend with the uncontrolled prehospital environment. For example, anaesthesia trainees perform a yearly average of 364 ETIs.[38] Given the consequences of limited opportunities for EMS practitioners to perform this complex skill, it may be more appropriate for practitioners who do not have adequate exposure to ETI to use other advanced airways which may require less skills maintenance, such as supraglottic airways.[39] However, further research is required to establish the minimum ETI exposure to both achieve and maintain competence. Moreover, further evidence is required as to whether there is an association between ETI exposure and OHCA patient survival outcomes. Such work should also attempt to address the methodological limitations in this field of research, as summarised below.

The studies to date are limited in three areas. Firstly, the majority of ETI studies either did not describe the method used to confirm successful ETI placement[26] or relied on self-reporting[25,27,32] which may over-estimate success rates.[40] Those studies where placement was confirmed by an end tidal carbon dioxide detector[28] or a physician either on scene or in hospital[28,30] had the lowest success rates (83[30] and 85%[28]). Secondly, the diversity of the patient cohorts meant some studies included non-OHCA and paediatric patients, both of which are known to result in lower rates of successful ETI placement.[40] Lastly, only two ETI studies[30,32] adjusted for potential confounders, including cervical spine precautions and rapid sequence induction. Future studies exploring ETI exposure should provide a detailed description of the cohort, adjust for significant confounders and employ a reliable method of confirming ETI placement such as capnography.[41]

The lack of adjustment for known confounders and detailed description of the cohort is a weakness in the studies examining the association of EMS practitioner experience and OHCA exposure with survival. In addition, results reported by Silfvast and Ekstrand[35] showed that these studies may be subject to selection bias as their study showed a difference in the rate of attempted resuscitation for patients treated by experienced and inexperienced practitioners that is likely to bias survival rates. These limitations, and the low number of studies conducted, make it difficult to draw conclusions about the influence of exposure to OHCA cases on patient survival. However, of note, was that in most of the studies, EMS practitioner exposure to OHCA appeared to be low.

The average annual exposure to OHCA by EMS practitioners was reported at between 4 and 9 cases per year.[29,33,34] It is possible that such low exposure might contribute to a deterioration in resuscitation skills that occurs over time after training[5–7] and also the delivery of sub-optimal resuscitation in some cases.[8–12] Simulation and exposure in other settings, such as the operating theatre, provide possible alternatives to actual prehospital exposure for the development and maintenance of EMS practitioner skills and knowledge. Although EMS practitioner skills are often developed by these methods,[39] differences in patient characteristics and the controlled nature of these environments[32,39] mean that they are unlikely to exactly replicate prehospital exposure to skills. Further research is therefore required to investigate the effectiveness of simulation and exposure in other settings as a substitute for actual EMS practitioner exposure – especially for those services where OHCA and prehospital ETI exposure is low.

The majority of authors did not report how EMS practitioners were initially trained in ETI and OHCA resuscitation or whether any refresher training took place during the course of their study period.[25–29,31,35] Training methods and intervals are likely to vary between different EMS and influence how ALS competency is developed and maintained. Details of training methods need to be described in future work in this field.

Further studies are needed to explore the possible link between volume and outcome in OHCA resuscitation. The volume-outcome relationship between hospitals has been examined for the post-resuscitation care of OHCA patients, but this literature has

conflicting findings. Several studies have reported increased survival at hospitals that receive higher volumes of OHCA cases[42–44] but other studies have found no association.[45,46]

The volume-outcome relationship can be applied at the individual, team or institutional level. Specific skills in resuscitation, such as ETI, are performed by individuals; however, the overall resuscitation is usually a team effort. The effects of exposure at different levels may vary and it is possible that one individual in a team, with high exposure for example, may have more of an influence on outcomes than the rest of the team. These different definitions of exposure need to be explored further along with their correlation with experience.

The effect of exposure to other skills such as supraglottic airway insertion and manual defibrillation (including rhythm recognition) may vary from practitioner exposure to OHCA cases alone because not all ALS procedures are performed at every OHCA. Therefore, studies that examine EMS practitioner exposure to ALS procedures other than ETI are required to determine the influence that they have on OHCA survival and procedural performance.

4.1. Limitations and strengths

This study included a rigorous search of the literature and used standardised criteria to evaluate the quality of included studies, but did not include grey literature. In addition, complete information was not available for all studies, such as the percentage of the cohort that were OHCA, despite efforts made to contact authors.

This review included studies published across four decades, four countries and different EMS which employ a variety of EMS professionals. In addition the reporting of data and definitions of 'exposure' and 'experience' were not standardised. Due to the heterogeneity of studies we were not able to perform a meta-analysis when there was more than one study. Although, through this review, we were able highlight areas where there is a lack of evidence.

4.2. Implications

Most of the included studies were observational and it is unlikely that any experimental studies will be conducted in the future. EMS typically dispatch ambulances and practitioners who are closest to OHCAs due to the importance of shorter response times for survival. Consequently, randomising practitioners according to experience or exposure would not be feasible. Therefore, the best available future evidence should be based on observational studies that are of high quality to minimise the risk of bias. It is also important that future studies examining the association between EMS practitioner experience/exposure and patient outcomes adjust for significant predictors of outcome, such as patient characteristics, to minimise risk of bias on effect measures.

5. Conclusion

There is an association between the number of ETIs performed by EMS practitioners and successful ETI placement however there is no clear evidence that EMS practitioner career experience or exposure to OHCA cases or numbers of ALS procedures is associated with survival or procedural performance. However, there were few studies, most of which had substantial risk of bias. Therefore, further high quality observational studies are required before any conclusion can be drawn. Although, current evidence suggests that for EMS where exposure to ETI is low, there should be consideration of the use of alternative advanced airways, such as supraglottic airways, where skill maintenance may be easier to achieve.

Conflict of interest statement

All authors have no financial or personal conflicts of interest that could inappropriately influence (bias) their work to disclose.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2014.05.020.

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