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Review

# Impact of adult advanced cardiac life support course participation on patient outcomes—A systematic review and meta-analysis

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ABSTRACT

*Objectives:* The objective of this study was to evaluate the impact of the prior participation of one or more members of the adult resuscitation team in an accredited advanced life support course on patient outcomes (return of spontaneous circulation, survival to discharge, survival to 30 days, and survival to 1 year).

*Methods:* A systematic search of Medline, CINAHL, Embase, ERIC, and Cochrane databases was conducted through 6 March 2018. We included randomised and observational studies in any language. Reviewers independently extracted data on study design and outcomes. The GRADE approach was used to evaluate the overall quality of evidence for each outcome.

*Results:* Nine hundred and ninety-two articles were identified of which eight observational studies were included. No randomised controlled trials were identified. Meta-analysis showed an association between participation of healthcare personnel in an advanced life support course and return of spontaneous circulation [odds ratio (OR) 1.64; 95% CI 1.12–2.41, risk difference (RD) 0.10 (95% CI 0.03–0.17)]. Life support training showed a significant absolute effect on patient survival to discharge [RD 0.10, 95% CI 0.01–0.18], but non-significant relative effect [OR 2.12; 95% CI 0.98–4.57]. Data from one study showed an association with survival to 30 days [OR 7.15; 95% CI 1.61–31.69, RD 0.18 (95% CI 0.08–0.27)].

*Conclusion:* The inference of this review is that the advanced life support courses have a positive impact upon return of spontaneous circulation and survival to hospital discharge. The data also implies a positive impact upon survival to 30 days of adult cardiac arrest patients.

## Introduction

The Advanced Cardiac Life Support (ACLS) course was first developed by the American Heart Association (AHA) in 1979 following their third national conference on cardiopulmonary resuscitation (CPR). The aim at that time was to develop and disseminate a standardised approach to the management of adult patients in cardiac arrest. In the early 1980's, a series of experts from the United Kingdom visited various courses and conferences in the United States (USA). The imported anglicised versions of ACLS were unified by the Resuscitation Council (UK) and became the course known today in the UK as the Advanced Life Support (ALS) course. This course was subsequently used as the basis for the European Resuscitation Council (ERC) and Australian Resuscitation Council (ARC) ALS courses.

Both courses are targeted at healthcare professionals who play an active role in the management of adult patients suffering from cardiac arrest. Suitable candidates include doctors, nurses, nurse practitioners, paramedics, outreach clinicians, and resuscitation officers/trainees. They learn the knowledge and skills needed to recognise and treat the deteriorating patient, deliver high quality CPR to adults, manage a cardiac arrest by working with a multidisciplinary team in an emergency situation, and utilise non-technical skills to facilitate strong team leadership and effective team membership. Over the years since their inception, both courses have evolved in a similar fashion from a didactic lecture-based format to versions incorporating e-learning and a greater emphasis on video-based learning, repetitive practice, simulation-based training [1,2] and debriefing [3]. In parallel with developments in educational delivery, the courses have also been continually updated to reflect contemporary international resuscitation guidelines.

The courses are cumulatively accessed throughout the world by over 1.3 million candidates every year (1,270,000 ACLS and 41,500 ALS). Despite these courses being the gold-standard for resuscitation education, the key question for stakeholders is whether attendance of healthcare personnel on such courses has an impact on patient

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outcomes. This is particularly important since evidence suggests that skills of many providers tend to decay within months of taking resuscitation courses [1,4]. We aimed to conduct a systematic review and meta-analysis of the published literature to determine if participation of one or more members of the resuscitation team in an accredited advanced life support course improves patient outcomes.

## Methods

The review was planned, conducted and reported in adherence with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards of quality for reporting meta-analyses [5]. The study was registered with Prospero on 17 November 2017 (registration number CRD42017081667).

### *PICO question*

We structured our question according to the PICO format – Population/Patient, Intervention, Comparator, and Outcome [6]. We asked, "In adult patients who have a cardiac arrest (P), does prior participation of one or more members of the resuscitation team in an accredited advanced life support course (I) as opposed to no such participation (C) affect the following patient outcomes – return of spontaneous circulation (ROSC), survival to hospital discharge, survival to 30 days, or survival to one year (O)?"

### *Study eligibility*

Studies of any language were included that specifically looked at the impact upon adult patient outcomes of attendance at an accredited advanced cardiac life support course, including the AHA ACLS, RC(UK), ERC or ARC ALS course, by one or more of the healthcare personnel attending a patient in cardiac arrest. Studies looking at other types of life support courses (e.g. trauma, paediatric, neonatal, basic life support) were excluded. Studies that only looked at the impact of individual components of the course (e.g. defibrillation, airway management, drug therapy) were also excluded. We included both randomized trials and observational studies in the systematic review.

### *Data sources*

We searched Medline, CINAHL, Embase, ERIC, and Cochrane with the last search date of 6 March 2018. The search strategy included terms "advanced cardiac life support", "cardiopulmonary resuscitation", "health personnel", "medical staff" and "nursing staff". The complete search strategy is described in Appendix 1 in Supplementary material. We also searched OpenGrey, EThOS and MedNar for reports presented at symposia, conferences, workshop and meetings.

### *Study selection*

The titles of all potentially eligible studies were screened for inclusion with 100% agreement by two reviewers (AL, AC). Any articles that were included were also scrutinised for additional citations that may be relevant to the PICO. Any disagreements between the reviewers were resolved by discussion.

### *Data collection*

Data from each paper was independently extracted by each reviewer and any conflicts were resolved by discussion to reach consensus. Data was collated separately for each outcome, namely return of spontaneous circulation (ROSC), survival to hospital discharge, survival to 30 days, and survival to 1 year. These outcomes were prioritised separately by two authors (A.L. and A.C.) as 'critical' with a consensus agreement on this in view of the impact upon patient as opposed to educational outcomes.

### *Analysis and GRADE approach*

We used both quantitative and qualitative syntheses of evidence. Considering the clinical and content heterogeneity of included studies, we used a random effects model for meta-analysis. Data was entered into Review Manager (RevMan5, The Cochrane Collaboration, Oxford, UK) to calculate the odds ratio (OR) and risk difference (RD), 95% confidence intervals and statistical heterogeneity. Heterogeneity between studies was assessed by reviewing the methodology in each study, as well as visually inspecting the forest plots, which were statistically assessed using the chi-squared test. The extent of heterogeneity among studies was expressed with $I^2$, with $I^2$ values > 50% indicating large inconsistency or heterogeneity [7]. We conducted sensitivity analyses for ROSC and survival to hospital discharge by pooling results of studies with the same study designs.

The GRADE (Grades of Recommendation, Assessment, Development and Evaluation) approach was used to evaluate the overall quality of evidence with respect to five different domains of quality [8]: (1) limitation of study design and execution; (2) inconsistency; (3) indirectness; (4) imprecision; and (5) publication bias across all included trials. An evidence profile was created with one row dedicated to each outcome. Rating was conducted independently by two raters (A.L. and A.C.). Where there was disagreement, consensus was reached by discussion.

## Results

### *Study selection*

The search identified 992 articles. Of these, 974 articles were excluded leaving 18 full text articles to be screened for eligibility (see Appendix 2 in Supplementary material). Ten papers were excluded as they were either: literature reviews that contained no additional data, studies of the wrong population (not a formal advanced life support course as an intervention), editorials, simulation-based research (i.e. with no clinical outcomes), or examining only individual advanced life support interventions. In total, eight observational studies were identified for inclusion from the initial search. No additional studies of relevance were found by searching the grey literature.

### *Study characteristics*

The study design and participant characteristics of included studies detailing any population differences are summarised in Table 1. All of the studies related to in-hospital cardiac arrest, with no studies referring to out-of-hospital cardiac arrest. The studies were conducted between 1986 and 2011. One study [9] related to the RC(UK) ALS course, whilst the remainder related to the AHA ACLS course delivered in a range of locations (USA, Brazil and India). Five studies were retrospective pre- and post-intervention cohort analyses [9–13]. One study was a retrospective cohort study [14] and two were prospective cohort studies [15,16]. In total, there were 1732 participants. Six studies (n = 1461) analysed the return of spontaneous circulation. Seven studies (n = 1507) analysed survival to hospital discharge. One study (n = 156) analysed survival to 30 days. Two studies (n = 455) analysed survival to 1 year. We were unable to formally evaluate the publication bias due to limited number of studies for each meta-analysis. It should be noted however that published outcomes were variable.

### *Risk of bias within studies*

The risk of bias assessment is summarised in Table 2. There were two main issues identified relating to eligibility criteria and presence of confounding issues. Only four studies [10,13,14,16] contained

**Table 1**
Summary of included studies.

| Study | Design | Setting | Number of patients | Outcome measures | Results |
|---|---|---|---|---|---|
| Lowenstein (1986) [10] | Retrospective cohort study, pre- and post-AHA ACLS | 379 bed urban teaching hospital, Boston USA | 90–37 pre ACLS (68% male; Age 68yr +/−1.8);<br>53 post ACLS (48% male; Age 65yr +/−2.1) | ROSC; Survival to hospital discharge | - 1st rhythm: Pre ACLS (VF 39%, Asystole 48%); Post ACLS (VF 25%, Asystole 56%)<br>- ROSC increased from 32% to 60% (p = 0.009)<br>- Survival to hospital discharge increased from 13% to 23% (p = NS) |
| Sanders (1994) [11] | Retrospective cohort study, pre- and post-AHA ACLS | Emergency Department in 42 bed rural community hospital, Arizona USA | 64–29 pre ACLS (66% male; Age 60.7 yr +/−23.6); 35 post ACLS (51% male; Age 69.6yr+/−17.3) | ROSC; Survival to hospital discharge | - 1 st rhythm: Pre ACLS (VF 36%, Asystole 40%); Post ACLS (VF 44%, Asystole 29%)<br>- No significant difference in ROSC (2/29 vs 7/35) and survival to discharge (1 vs 2) |
| Makker (1995) [15] | Parallel, prospective, consecutive sample of patients resuscitated by AHA ACLS certified medical residents, ACLS certified Emergency Physicians, and non-certified physicians | 437 bed community teaching hospital, New Jersey USA | 225–180 ACLS: 76 medical residents and 104 ED residents; 45 non—ACLS; 60.9% male; Age 63.4yr+/−17.6 | ROSC | - 1 st rhythm: VF/VT 26.2%, Asystole 15%<br>- ROSC ACLS certified medical 48.7% vs certified ED 29.8% (p = 0.010); All ACLS certified 37.8% vs non-ACLS certified 46.7% (p = NS) |
| Camp (1997) [12] | Retrospective cohort study, pre- and post-AHA ACLS | 119 bed rural community hospital, Georgia USA | 236–42 pre; 179 post ACLS; no data on age range or sex | Survival to hospital discharge | - No data on 1st rhythm<br>- Pre-intervention 35.7% survivors vs<br>- Post-intervention 29.1% survivors<br>- (p > 0.3) |
| Pottle (2000) [9] | Retrospective cohort study, pre- and post-RC(UK) ALS | 181 bed specialist cardiothoracic hospital, Harefield UK | 299–139 pre; 160 post ALS; 68.1% male; Age 72 yr (range 21–88) | ROSC; Survival to hospital discharge; Survival to 1 year | - 1 st rhythm: VF/VT 58.3%, Asystole 21.7%<br>- Increase in ROSC (71.94% to 80%) and Survival to discharge (32.8% to 41.9%)<br>- Similar numbers surviving to 1 year (22.3% vs 20.6%)<br>- No p values available (authors contacted) |
| Dane (2000) [14] | Parallel, cohort case comparison (nurse trained vs untrained in AHA ACLS) | 550 bed tertiary centre, Georgia USA | 117–29 non-ACLS; 88 ACLS | Survival to hospital discharge | - Survival rate 37.5% in ACLS trained group vs 10.3% in in-ACLS trained group (p < 0.02) |
| Moretti (2007) [16] | Parallel, multi-centre prospective cohort study (at least one member of team trained in AHA ACLS vs no trained member of team) | 7 hospitals in Brazil | 156–54 not trained; 102 trained; no data on age range or sex | ROSC; Survival to hospital discharge; Survival to 30 days; Survival to 1 year | - 1 st rhythm: VF 21.6%, Asystole 15.8%<br>- Significant increase in ROSC (p = 0.04), survival to 30 days (p < 0.02) and survival to 1 year (p < 0.002) for ACLS group<br>- Increased survival to discharge for ACLS group (p = 0.23) |
| Sodhi (2011) [13] | Retrospective cohort study, pre- and post-AHA ACLS | 250 bed tertiary care hospital, India | 627–284 pre ACLS (57% male; Age 58.8yr+/−8.2); 343 post ACLS (54.8% male; Age 55.1yr+/−6.9) | ROSC; Survival to hospital discharge | - No data on 1st rhythm<br>- Increase in ROSC from 18.3% to 28.3% (p < 0.005)<br>- Increase in survival to discharge 23.1% to 69.1% (p < 0.001) |

**Table 2**
Risk of bias assessment.

| Study | Year | Design | Total Patients | Population | Industry Funding | Non-RCT bias assessment | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Eligibility Criteria | Exposure/Outcome | Confounding | Follow Up |
| **Lowenstein** | 1986 | Non-RCT | 90 | AHA ACLS | No | Low | Low | Low | Low |
| **Sanders** | 1994 | Non-RCT | 64 | AHA ACLS | No | High[b] | Low | Low | Low |
| **Makker** | 1995 | Non-RCT | 225 | AHA ACLS | No | Unclear[c] | Low | High[d] | Low |
| **Camp** | 1997 | Non-RCT | 236 | AHA ACLS | No | High[e] | Low | High[d] | Low |
| **Pottle** | 2000 | Non-RCT | 299 | RC(UK) ALS | No | High[f] | Low | High[d] | Low |
| **Dane** | 2000 | Non-RCT | 117 | AHA ACLS | Partial[a] | Low | Low | High[d] | Low |
| **Moretti** | 2007 | Non-RCT | 156 | AHA ACLS | No | Low | Low | Low | Low |
| **Sodhi** | 2011 | Non-RCT | 627 | AHA ACLS | No | Low | Low | High[d] | Low |

[a] Portions of the research were funded by a Teaching Methods Grant from AHA to the first author.
[b] Did not elaborate on exclusion criteria for cardiac arrest patients.
[c] All incidents analysed but not clear how identified.
[d] Prognostic factors not adjusted for in statistical analysis of most studies; considered low if they reported characteristics of patients in one group vs another and described p values.
[e] Differing and unclear eligibility criteria for three periods of study.
[f] Only those with completed audit form (86.5%) included.

sufficient detail about eligibility criteria for inclusion, including clear exclusion criteria. In one study [12], there were differing eligibility criteria for the three periods of study. In another [9], only those with a completed audit form were included. Only three studies [10,11,16] were assessed to be low risk for confounding issues. The remaining studies did not report characteristics in the different groups and therefore could not demonstrate that prognostic factors had been adjusted for in the statistical analysis. All of the studies were assessed to be low risk for exposure, outcome and follow up.

*Results*

The results are summarised in Table 3.

*Return of spontaneous circulation*

For the critical outcome of return of spontaneous circulation, we identified six studies [9–11,13,15,16] (n = 1461; very low quality evidence downgraded for risk of bias, inconsistency, indirectness and imprecision) with data ranging from 1979 to 2010. The data showed an association between course participation and return of spontaneous circulation, with a pooled odds ratio of 1.64 (95% CI 1.12–2.41; Fig. 1)

**Table 3**
Summary of findings. **Question**: ALS compared to no ALS for health problem or population.

| Certainty assessment | | | | | | | No of patients | | Effect | | Certainty | Importance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noof studies | Study design | Risk of bias | Inconsistency | Indirectness | Imprecision | Other considerations | ALS | no ALS | Odds Ratio (95% CI) | Risk Difference (95% CI) | | |
| ROSC | | | | | | | | | | | | |
| 6 | observational studies | serious[a] | serious[b] | serious[c] | serious[d] | none | 378/873 (43.3%) | 203/588 (34.5%) | **OR 1.64** (1.12 to 2.41) | **RD 0.10** (0.03 to 0.17) | ⊕○○○ VERY LOW | CRITICAL |
| Survival to Discharge | | | | | | | | | | | | |
| 7 | observational studies | serious[a] | serious[b] | serious[c] | serious[d] | none | 259/893 (29.0%) | 100/614 (16.3%) | **OR 2.12** (0.98 to 4.57) | **RD 0.10** (0.01 to 0.18) | ⊕○○○ VERY LOW | CRITICAL |
| 30 day survival | | | | | | | | | | | | |
| 1 | observational studies | not serious | not serious | not serious | serious[d] | none | 22/102 (21.6%) | 2/54 (3.7%) | **OR 7.15** (1.61 to 31.69) | **RD 0.18** (0.08 to 0.27) | ⊕○○○ VERY LOW | CRITICAL |
| 1 year survival | | | | | | | | | | | | |
| 2 | observational studies | serious[a] | serious[b] | not serious | serious[d] | none | 51/262 (19.5%) | 31/193 (16.1%) | **OR 3.61** (0.11 to 119.42) | **RD 0.08** (0.13 to 0.30) | ⊕○○○ VERY LOW | CRITICAL |

**CI:** Confidence interval; **OR:** Odds ratio; **RD**: Risk difference.
Explanations.
[a] Mixture of serious and low risk of bias studies.
[b] Some studies showed significant improvement, and some showed no improvement.
[c] Differences in patient type, hospital type, provider type and team composition, and nature of intervention.
[d] Absence of confidence intervals.

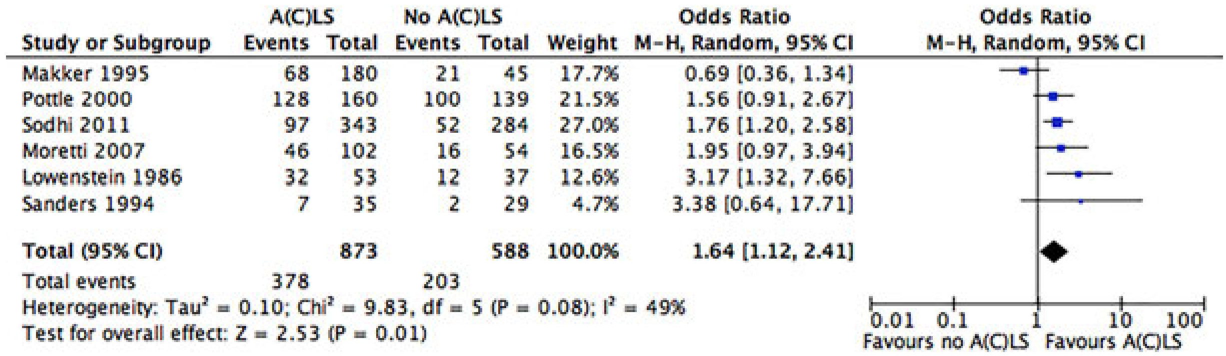


**Fig. 1.** Return of spontaneous circulation.

and a pooled risk difference of 0.10 (95% CI 0.03–0.17). Statistical heterogeneity was moderate ($I^2$ = 49%, p = 0.08).

Within studies evaluating ROSC, Moretti et al [16] showed that increased numbers of ACLS-certified staff in the resuscitation team was associated with a higher rate of ROSC (OR 2.07, p = 0.037) in the logistic regression model.

*Survival to hospital discharge*

For the critical outcome of survival to hospital discharge, we identified seven studies [9–14,16] (n = 1507; very low quality evidence downgraded for risk of bias, inconsistency, indirectness and imprecision) with data ranging from 1979 to 2010. The data showed a significant absolute effect on patient survival to hospital discharge, with a pooled risk difference of 0.10 (95% CI 0.01–0.18; Fig. 2B), but a non-significant relative effect with a pooled odds ratio of 2.12 (95% CI 0.98–4.57; Fig. 2A). Statistical heterogeneity was high ($I^2$ = 82%, $p < 0.001$).

Dane et al [14] reported the effect of ACLS training (adjusted OR 1.97, p = 0.04) on survival to hospital discharge, adjusting for initial rhythm. The effect size is much smaller compared to unadjusted OR, indicating that the initial rhythm is an important factor associated with survival.

*Survival to 30 days*

For the critical outcome of survival to 30 days, we identified one study [16] (n = 156; very low quality evidence downgraded for imprecision) with data ranging from 1998 to 2001. The data showed an association between course participation and patient survival to 30 days with an odds ratio of 7.15 (95% CI 1.61–31.69) and risk difference of 0.18 (95% CI 0.08–0.27). As the 95% confidence limits are wide, these results should be interpreted with caution.

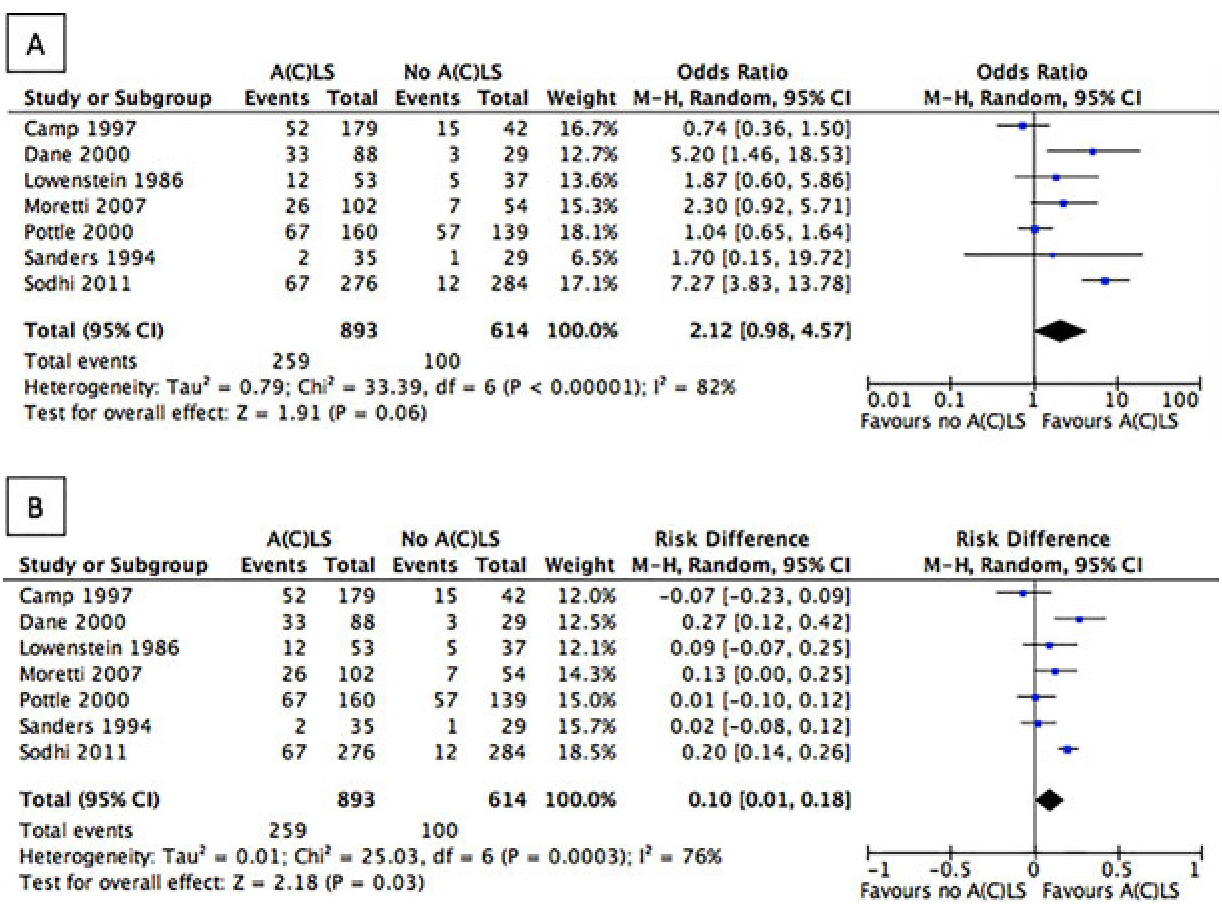


**Fig. 2.** Survival to hospital discharge.

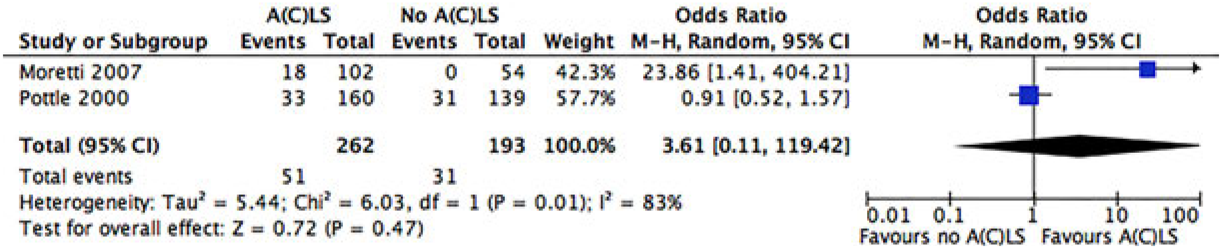


**Fig. 3.** Survival to 1 year.

*Survival to 1 year*

For the critical outcome of survival to one year, we identified two studies [9,16] (n = 455; very low quality evidence downgraded for risk of bias, inconsistency, and imprecision) with data ranging from 1993 to 2001. The data showed non-significant association between course participation and patient survival to 1 year with a pooled odds ratio of 3.61 (95% CI 0.11–119.42; Fig. 3) and risk difference of 0.08 (95% CI -0.13–0.30). Statistical heterogeneity was high ($I^2$ = 83%, p = 0.01).

*Sensitivity analysis*

We conducted sensitivity analyses by pooling results with the same study designs. We found an association between course participation and ROSC in pre- and post- cohort studies; however, the association is not significant in studies with parallel control. For long term survival outcome (i.e. survival to hospital discharge and survival to one year), studies with rigorous designs showed significant results (Table 4).

## Discussion

*Limitations and strengths*

Analysing the outcomes from non-randomised studies can be challenging as there is a high risk of selection bias, due to differences between populations in the various intervention groups. Only three of the studies [10,11,16] included a detailed description of the separate group characteristics. Only one study adjusted for the initial rhythm of the patient [14] and one study adjusted for the number of ACLS certified staff in the resuscitation team [16].

Advanced life support training is not the only factor that can influence patient outcomes. Despite this, we feel that it is reasonable to combine the studies in the analysis as the intervention (ALS training) and the outcome measures are objective and standardised. To strengthen the analysis, we performed a sensitivity analysis by pooling results with the same study designs.

International Guidelines are reviewed and updated every five years, meaning that papers studying the effects of the course prior to 2015 are no longer as applicable. The algorithms for managing patients in cardiac arrest have changed significantly over the years, and the instructional design of how the courses are taught have also been updated in line with educational research [1].

A limitation is that there was no standardisation between studies with regard to the number of advanced life support trained members of the resuscitation team. It could be argued that the collective knowledge, clinical skills and non-technical skill performance of a team where many or all members are advanced life support trained may produce better outcomes than a team with only one trained member.

Whilst the target audience remains similar, some of the interventions taught on the course have varied over the years. One of the largest studies to study the importance of advanced airway management and drug therapy was the OPALS study from Ontario [17] which included 5638 patients enrolled from 17 cities in a system already optimised to deliver rapid defibrillation. There were significant differences to return of spontaneous circulation and survival to hospital, but no significant difference however for longer term outcomes (i.e. survival to discharge, survival with cerebral performance category level 1 to one year). These findings support the argument that advanced airway management and drug therapy are of lesser importance in the management of patients in cardiac arrest. On both the AHA ACLS and RC(UK) ALS courses, advanced airway management has been de-emphasised.

Over the years, there has been increasing emphasis on the team approach to resuscitation, with inclusion of new content in the form of videos, lectures and inclusion in the debriefing component of simulation-based education. Multiple reviews of the team training literature support the use of simulation-based team training for improving the process of resuscitative care, both in the simulated and clinical environments [18–22]. While this potentially adds benefit for patient outcomes, it does introduce a potential confounder as these elements were not emphasized in most advanced life support courses until 2010 [23,24]. Emphasis is now given to key crisis resource management principles, including teamwork, leadership, resource allocation, communication and situational awareness [1,25,26]. The RC(UK) ALS course includes the use of an adapted version of the TEAM tool [27] to guide an informal assessment of use of these skills during the teaching scenarios.

It would seem therefore that the benefits of the course outweigh the individual components taught. It is well documented that individual skills decay rapidly after tuition [1,4], but many other factors contribute to determining the outcome of the patient. This is alluded to by Pepe, Abramson and Brown [28] who challenge the efficacy of the components of ACLS yet state that "it would appear that something about the 'ACLS' worked".

*Integration with prior work*

Williams et al [29] concluded that some evidence is available that advanced life support interventions can improve outcome for patients suffering cardiac arrest in hospital. Their review included studies analysing the outcome from simulation assessments as well as actual patient outcomes. Only one study relating to our review [16] was identified as their review was limited to studies published between 2005

**Table 4**
sensitivity analyses.

| Outcome | Design | Number of studies | Effect size (95% CI) | P -value | $I^2$ |
|---|---|---|---|---|---|
| ROSC | Historical control | 4 | 1.85 (1.38, 2.46) | < 0.001 | 0% |
| | Parallel control | 2 | 1.15 (0.42, 3.18) | 0.78 | 77% |
| Survival to hospital discharge | Historical control | 5 | 1.78 (0.66, 4.81) | 0.26 | 87% |
| | Parallel control | 2 | 3.05 (1.42, 6.57) | 0.004 | 0.6% |
| Survival to one year | Historical control | 1 | 0.91 (0.52, 1.57) | 0.72 | N/A |
| | Parallel control | 1 | 23.86 (1.41, 404.21) | 0.03 | N/A |

and 2010. We believe that our review is the first to identify all studies relating exclusively to actual patient outcomes.

*Implications and recommendations*

The studies included in this review contain data ranging from 1979 to 2010. During this time, the content and delivery of the course has changed significantly. In the earlier papers, the authors have truly been able to look at outcomes before and after introduction of the course. The course from those early days, however, bears no resemblance to contemporary versions and the clinical science behind cardiac resuscitation has advanced significantly since then. The latter studies therefore benefit from representing an era more closely aligned with current practice. The drawback however is that it is more difficult to guarantee that those in the control cohorts have not had some sort of previous advanced life support instruction. The difference between the early and latter studies partly explains the large heterogeneity of the meta-analyses.

One theme that has emerged from some of the papers is that the introduction of advanced life support courses to hospitals may impact upon clinical practice and actually increase the number of resuscitation attempts made [10,12]. This has an effect in particular on the comparison of outcomes in pre- and post-intervention studies as the population studied is then different. Conversely, the number of patients who previously had an inappropriate resuscitation attempt may decrease as well. Clearly both these factors may be a positive consequence of the course and may contribute to an increased survival rate from the implementation of the course.

The advanced life support courses have a cost and resource implication for candidates, faculties, and organisations. They have evolved over the years in terms of course length and availability of e-learning in recognition of the increasing time pressures on healthcare professionals. It is appropriate to analyse if attendance at such a course produces any tangible benefit to patient outcomes given the resource that is invested in these courses. Within the limit of available studies, we feel that there is a desirable effect in terms of patient outcome albeit from very low quality evidence. The organisations that administer and govern these courses should continue to explore opportunities to deliver the training in the most educationally efficient way possible whilst being mindful of the resource implications. This approach is feasible and should continue to be acceptable to all stakeholders.

## Conclusions

When looking at the analysis of pooled data, the inference is that the advanced life support courses have a positive impact upon return of spontaneous circulation and survival to hospital discharge. The data also implies a positive impact upon survival to 30 days. Future research should explore the impact of the courses on patient outcomes in the context of fully trained resuscitation teams.

## Conflict of interest statement

Andrew Lockey is a Trustee of the Resuscitation Council (UK), which administers the Advanced Life Support course in the UK. None of the other authors have any conflicts of interest.

## Acknowledgement

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2018.05.034.

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