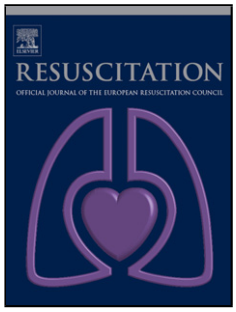


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Authors: Huda M. Ashoor, Erin Lillie, Wasifa Zarin, Ba' Pham, Paul A. Khan, Vera Nincic, Fatemeh Yazdi, Marco Ghassemi, John Ivory, Roberta Cardoso, Gavin D. Perkins, Allan R. de Caen, Andrea C. Tricco

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# Effectiveness of Different Compression-to-Ventilation Methods for Cardiopulmonary Resuscitation: A Systematic Review


Huda M. Ashoor[a], BSc Email: AshoorH@smh.ca

Erin Lillie[a], MSc Email: LillieE@smh.ca

Wasifa Zarin[a], MPH Email: ZarinW@smh.ca

Ba' Pham[a, b], MSc PhD Email: ba.pham@theta.utoronto.ca

Paul A. Khan[a], MSc PhD Email: KhanP@smh.ca

Vera Nincic[a], PhD Email: NincicV@smh.ca

Fatemeh Yazdi[a], MSc Email: SabaghYazdiF@smh.ca

Marco Ghassemi[a], MSc Email: GhassemiM@smh.ca

John Ivory[a], MSc Email: John.d.ivory@gmail.com

Roberta Cardoso[a], RN PhD Email: CardosoR@smh.ca

Gavin D. Perkins[c], MD Email: G.D.Perkins@warwick.ac.uk

Allan R. de Caen[d], MD Email: Allan.DeCaen@albertahealthservices.ca

Andrea C. Tricco[a, e, *], MSc PhD Email: TriccoA@smh.ca

[a] Li Ka Shing Knowledge Institute, St. Michael's Hospital, 209 Victoria Street, Toronto, Ontario, Canada, M5B 1W8

[b] Toronto Health Economics and Technology Assessment Collaborative, Faculty of Pharmacy and Institute of Health Policy Management Evaluation, University of Toronto, 144 College Street, Toronto, Ontario, Canada, M5S 3M2

[c] University of Warwick, Warwick Medical School and Heart of England NHS Foundation Trust, Coventry, CV4 7AL, United Kingdom

[d] Stollery Children's Hospital, University of Alberta, 8440 112 Street Northwest, Edmonton, Alberta, Canada, T6G 2B7

[e] Epidemiology Division, Dalla Lana School of Public Health, University of Toronto, Health Sciences Building, 155 College Street, 6th floor, Toronto, Ontario, Canada, M5T 3M7

***Corresponding Author**

Dr. Andrea Tricco

Scientist, Knowledge Translation

Li Ka Shing Knowledge Institute, St. Michael's Hospital,

209 Victoria Street, East Building, Toronto, Ontario, M5B 1W8, Canada

Phone: 416-864-6060, Fax: 416-864-5805, Email: TriccoA@smh.ca

**Collaborators (ILCOR Basic Life Support Task Force):**

*AHA - American Heart Association; ANZCOR - Australian & New Zealand Committee on Resuscitation; ERC - European Resuscitation Council; HSFC - Heart & Stroke Foundation of Canada; IAHF - Inter-American Heart Foundation; RCA - Resuscitation Council of Asia; RCSA - Resuscitation Council of Southern Africa*

Alfredo Sierra (IAHF)

Andrew Travers (HSFC)

Christian Vaillancourt (HSFC)

David Stanton (RCSA)

Julie Considine (ANZCOR)

Kevin Nation (ANZCOR)

Maaret Castren (ERC)

Michael Sayre (AHA)

Raffo Escalante (IAHF)

Raul Gazmuri (AHA)

Robert Berg (AHA)

Ruud Koster (ERC)

Swee Han Lim (RCA)

Tetsuya Sakamoto (RCA)

Theresa Mariero Olasveengen (ERC)

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**ABSTRACT**

**Aim:** To compare the effectiveness of different compression-to-ventilation methods during cardiopulmonary resuscitation (CPR) in patients with cardiac arrest.

**Methods:** We searched MEDLINE and Cochrane Central Register of Controlled Trials from inception until January 2016. We included experimental, quasi-experimental, and observational studies that compared different chest compression-to-ventilation ratios during CPR for all patients and assessed at least one of the following outcomes: favourable neurological outcomes, survival, return of spontaneous circulation (ROSC), and quality of life. Two reviewers independently screened literature search results, abstracted data, and appraised the risk of bias. Random-effects meta-analyses were conducted separately for randomised and non-randomised studies, as well as study characteristics, such as CPR provider.

**Results:** After screening 5,703 titles and abstracts and 229 full-text articles, we included 41 studies, of which 13 were companion reports. For adults receiving bystander or dispatcher-instructed CPR, no significant differences were observed across all comparisons and outcomes. Significantly less adults receiving bystander-initiated or plus dispatcher-instructed compression-only CPR experienced favourable neurological outcomes, survival, and ROSC compared to CPR 30:2 (compression-to-ventilation) in un-adjusted analyses in a large cohort study. Evidence from emergency medical service (EMS) CPR providers showed significantly more adults receiving CPR 30:2 experiencing improved favourable neurological outcomes and survival versus those receiving CPR 15:2. Significantly more children receiving CPR 15:2 or 30:2 experienced favourable neurological outcomes, survival, and greater ROSC compared to compression-only CPR. However, for children <1 years of age, no significant differences were observed between CPR 15:2 or 30:2 and compression-only CPR.

**Conclusions:** Our results demonstrated that for adults CPR 30:2 is associated with better survival and favourable neurological outcomes when compared to CPR 15:2. For children, more patients receiving CPR with either 15:2 or 30:2 compression-to ventilation ratio experienced

favourable neurological function, survival, and ROSC when compared to CO-CPR for children of all ages, but for children <1 years of age, no statistically significant differences were observed.

Keywords: Cardiac arrest; Cardiopulmonary resuscitation; Ventilation; Chest compression; Bystander CPR; Functional neurological outcome; Survival; Rate of Return to Spontaneous Circulation, ROSC, Quality of life

## INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality worldwide with millions of lives lost every year.[1] Less than 10% of people with OHCA who receive treatment survive to hospital discharge.[2] Cardiopulmonary resuscitation (CPR) is important for patient survival of sudden cardiac arrest; however, bystander CPR rates remain very low globally.[3]

CPR involves chest compressions and ventilations to maintain cardio-cerebral perfusion while attempting to restart the heart.[4] Although CPR is undoubtedly life-saving, it can be challenging to learn and difficult to perform. A barrier to attempting CPR is the administration of rescue breaths (i.e., mouth-to-mouth ventilation).[5] In addition, evidence suggests that prolonged interruptions in chest compressions to deliver ventilations may be harmful. Attempts to overcome these problems have led to the development of compression-only resuscitation and minimally-interrupted chest compression techniques. However, uncertainty exists about the effectiveness of these newer techniques, and whether effects differ depending on the CPR provider, setting, and characteristics of recipients.

We aimed to determine the effectiveness of different compression-to-ventilation methods during CPR regarding favourable neurological outcomes, survival, return of spontaneous circulation (ROSC), and quality of life among patients experiencing cardiac arrest, and whether this differed by CPR provider, setting, and characteristics of recipients.

## METHODS

### *Protocol*

The protocol was drafted using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-P)[6] in collaboration with clinical experts from the International Liaison Committee on Resuscitation (ILCOR) (Appendix A) and registered with PROSPERO (CRD42016047811).

### *Eligibility criteria*

The eligibility criteria based on PICOST (Population, Intervention, Control, Outcomes, Study design and Timeframe) were:[7]

***Population:*** Patients of all ages (i.e., neonates, children, adults) with cardiac arrest from any cause and across all settings (in-hospital and out-of-hospital). Studies that included animals were not eligible.

***Intervention:*** All manual CPR methods including Compression-only CPR (CO-CPR), Continuous Compression CPR (CC-CPR), and CPR with different compression-to-ventilation ratios. CO-CPR included compression with no ventilations, while CC-CPR included compression with asynchronous ventilations or minimally-interrupted cardiac resuscitation (MICR) (Appendix B). Studies that mentioned the use of a mechanical device during CPR were

only considered if the same device was used across all relevant intervention arms and would therefore not confound the observed effect.

***Comparators:*** Studies had to compare at least two different CPR methods from the eligible interventions; studies without a comparator were excluded.

***Outcomes:*** The primary outcome was favourable neurological outcomes, measured by cerebral performance or a modified Rankin Score. Secondary outcomes were survival, ROSC, and quality of life.

***Study designs:*** Randomised controlled trials (RCTs) and non-randomised studies (non-randomised controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Study designs without a comparator group (e.g., case series, cross-sectional studies), reviews, and pooled analyses were excluded.

***Other:*** We excluded unpublished studies (e.g., conference abstracts, trial protocols), and non-English papers.

***Information sources and literature search***

MEDLINE and the Cochrane Central Register of Controlled Trials were searched from inception until January 2016. An experienced librarian developed the original search strategy.

The final search strategy was conducted on January 15, 2016 (Appendix C). The unique results from the literature search were uploaded to proprietary online screening software, Synthesi.SR.[8] The literature search was supplemented by scanning the references of all studies included in the previous ILCOR reviews, and additional studies identified by the ILCOR content experts.

***Study selection***

A training exercise was conducted prior to commencing study selection using the predefined eligibility criteria (Appendix D) on a random sample of 25 titles and abstracts (i.e., level 1 screening). A similar training exercise was conducted for the screening of a random sample of 24 potentially relevant full-text articles (i.e., level 2 screening). The team established 75% agreement among all reviewers for level 1 screening and 83% for level 2 screening. Subsequently, pairs of reviewers screened citations independently for inclusion at level 1 (EL, FY, HMA, JI, MG, PAK, RC, TL, VN) and level 2 (FY, JI, MG, PAK, RC, VN) screening. All discrepancies were resolved by discussion or the involvement of a third reviewer (HMA, ACT) and/or clinical expert (GDP, ADC).

***Data items and data abstraction***

A standardized data abstraction form was developed and pilot-tested prior to beginning data abstraction. Data items were study characteristics (e.g., study design, year of conduct), patient characteristics (e.g., number of patients, mean age, and initial rhythm), CPR methods and outcomes (e.g., compressions-to-ventilations ratios, scale used, time point, results). Outcomes were abstracted according to the Utstein-style guidelines for resuscitation research.[9]

Companion reports (i.e., multiple publications reporting results from the same study participants) were identified by discerning overlap in study period, geographic location, setting, and type of CPR method. The publication with the longest follow-up period was considered the main publication and companion reports were only used to supplement the data abstracted from the main publication.

After approximately 75% agreement was achieved, pairs of reviewers (FY, JI, MG, PK, RC, VN) independently abstracted all relevant information from each article. All discrepancies were

resolved by discussion or involvement of a third reviewer (EL, WZ). We contacted authors for relevant missing information and to provide clarification; for example, to obtain a breakdown of patient population by age. Clinical experts assisted in coding the appropriate CPR provider type, intervention and aetiology categories across the studies.

***Risk of bias***

The Cochrane Risk-of-Bias Tool[10] was used for appraising RCTs and quasi-RCTs; Cochrane Effective Practice and Organization of Care (EPOC) Risk-of-Bias Tool[11] was used for cluster-crossover RCTs, non-randomised controlled trials, interrupted time series, and controlled before-and-after studies; and Newcastle-Ottawa Scale was used for cohort studies.[12] Experienced pairs of reviewers (FY, JI, MG, PAK, RC, VN) independently appraised the risk of bias of all included studies with discrepancies resolved by a third reviewer (EL, WZ).

***Synthesis of results***

Intervention effects (e.g., CO-CPR versus CPR 30:2 compression-to-ventilation ratio) were summarized using un-adjusted risk ratios (RR) and risk differences (RD) and pooled via random-effects meta-analysis. We assessed statistical heterogeneity using the $I^2$ statistic,[13] with an $I^2$ value above 75% indicative of substantial heterogeneity.[13] All statistical analyses were conducted using the *metafor* package in R (version 3.2.3).[14]

For the main analysis, the intervention effect estimates were derived separately for RCTs and non-randomised studies, as well as for adults and children. For survival, the main analysis was conducted using the longest duration of follow-up, yet we also conducted a sensitivity analysis using the survival data closest to the timing of CPR. As well, a series of subgroup analyses were conducted exploring the impact of factors potentially affecting the intervention effect estimates,

including aetiology of cardiac arrest, emergency medical service (EMS) response times, initial rhythm, and percentage of arrests that were witnessed.

Although not previously specified in the review protocol, we stratified overall results by CPR provider, (Appendix E) specifically: 1) Bystander plus dispatcher-instructed CPR, 2) dispatcher-instructed CPR (telephone CPR), 3) bystander delivered CPR, 4) CPR delivered by EMS staff, and 5) CPR delivered by hospital staff.

### ***GRADE appraisal***

Using the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) guidance,[15] we assessed the quality (or certainty) of the available evidence. This was conducted by three reviewers (HMA, EL, WZ) and verified by the study guarantor and content experts (ACT, GDP, ADC). Studies looking at before-and-after guideline changes were considered "indirect evidence" because multiple aspects of treatment were likely to have changed over time, in addition to the prescribed compression-to-ventilation ratios.

## RESULTS

### ***Literature search***

After screening 5,703 titles and abstracts and 229 potentially relevant full-text articles, 28 studies[2, 16-42] and 13 companion reports[39, 40, 43-54] fulfilled our eligibility criteria and were included (Figure 1).

### ***Study characteristics***

Included studies were published between 1993 and 2015 with a study period ranging from 1983 to 2015 (Table 1; Appendix F). We included one cluster-crossover RCT,[16] three RCTs,[20, 23, 24]

and 24 cohort studies.[2, 17-19, 21, 22, 25-42] Most studies were conducted in the USA and Japan (n=16), involving OHCAs (n=27), while one[31] was conducted in a hospital setting.

Nine studies[17, 18, 20, 29, 33, 35, 37, 39, 41] included cardiac arrests with cardiac causes, 13 papers[2, 19, 24-28, 30, 34, 36, 38, 40, 42] included both cardiac and non-cardiac causes, and one paper[21] included non-cardiac causes. CPR was provided by: EMS personnel,[16-18, 25, 27, 29, 30, 32, 33, 36, 41] bystanders,[19, 21, 22, 26, 34, 35, 37, 38] bystanders receiving dispatcher instructions,[20, 23, 24] bystander alone or with dispatcher instructions,[2, 28] and emergency department staff.[31] Most studies (n=16)[2, 16, 17, 19, 20, 22, 23, 25, 30-33, 35, 36, 38, 40] did not restrict the study population by initial rhythm, six[24, 26, 29, 34, 39, 41] included only patients with initial shockable rhythm, and one [27] included patients with initial non-shockable rhythm.

***Patient characteristics***

Twenty studies[16-21, 24-34, 36, 39, 40] included adults, two[28, 38] included children, and six[2, 23, 35, 37, 41, 42] included both adults and children (Table 1; Appendix G). The overall number of CPR recipients in each study ranged from 181 to 350,439 and the proportion of males ranged from 59 to79%. The mean age reported for adult-only studies ranged from 56.9 years (SD 18.6) to 74.1 years (SD 14.9), and was 4.9 years (SD 6.1) for paediatric-only studies.

***Risk of bias results***

Three RCTs were appraised with the Cochrane risk-of-bias tool (Appendix H). One trial[24] had an unclear random sequence generation, while another[20] had unclear allocation concealment, and the third trial[23] had a high risk of bias due to blinding of personnel, as well as incomplete outcome data bias. One cluster-crossover RCT[16] assessed using the EPOC risk-of-bias tool

(Appendix I) had an unclear risk of bias for random sequence generation, as well as for allocation concealment; all other items were scored as low risk of bias.

For the 23 cohort studies, the main methodological shortcoming was related to the comparability of cohorts on the basis of the design or analysis, as the majority did not adjust for potential confounding variables (Appendix J). In addition, the majority of the cohort studies did not report the duration of follow-up.[17, 22, 25-28, 30-34, 36, 37, 40-42]

***Reporting results***

Results of the main analysis stratified by patient age, CPR comparisons, provider, and outcome are presented below, as well as in Table 2. Only statistically significant findings are presented in the text, but all results are presented in Table 1, where it can be observed that statistically significant results were not found for the following comparisons: CO-CPR versus CPR 15:2 in mostly adult patients and CO-CPR versus CPR 30:2 or CPR 15:2 in mostly adult patients. Unless otherwise noted, sub-group analyses (Table 3) and sensitivity analyses (Table 4) demonstrated consistent results with the main analyses. For all studies not included in the meta-analyses adjusted and un-adjusted estimates can be found in Appendix K.

***CO-CPR vs. CPR 30:2 (adults)***

For bystanders plus dispatcher-instructed CPR, one cohort study[2] of 350,439 mostly adult patients found that significantly less patients receiving CO-CPR experienced favourable neurological outcomes (RD -0.74, 95% CI: -0.85, -0.63), survived (RD -1.42, 95% CI: -1.58, -1.25), and experienced ROSC (RD -1.62, 95% CI: -1.81, -1.42) compared to CPR 30:2.

***CPR 30:2 vs CPR 15:2 (adults)***

For EMS CPR, a meta-analysis of two cohort studies[25, 27] with 4,877 adults found that significantly more patients receiving CPR 30:2 experienced favourable neurological outcomes (RD 1.72, 95% CI: 0.52, 2.91) compared to CPR 15:2. A meta-analysis of six cohort studies[17, 25, 27, 30, 33, 36] with 13,962 adults revealed that significantly more patients receiving CPR 30:2 survived (RD 2.48, 95% CI: 1.57, 3.38) compared to CPR 15:2. The results for ROSC were not statistically significant.

***CPR 50:2 vs CPR 15:2 (adults)***

For EMS CPR, one cohort study[29] of 200 adults found that significantly more patients receiving CPR 50:2 survived (RD 21.48, 95% CI: 6.90, 36.06) and experienced ROSC (RD 21.89, 95% CI: 6.88, 36.90) compared to CPR 15:2.

***CC-CPR (with asynchronous ventilations at a rate of 10 per minute) vs. CPR 30:2 (adults)***

For EMS CPR, one cluster-crossover RCT[16] including 23,711 adults found significantly less patients receiving CC-CPR experienced ROSC (RD -1.15, 95% CI: -2.25, -0.05) compared to CPR 30:2 in un-adjusted analysis. However, results for favourable neurological outcomes and survival were not statistically significant. Results were also found not to be significant for ROSC (RD −1.1, 95% CI:-2.4, 0.1) when adjusted for confounding variables.

***CC-CPR (with minimally interrupted cardiac resuscitation) vs. CPR 15:2 (adults)***

For EMS CPR, one cohort study[18] of 181 adults found that significantly more patients receiving CC-CPR experienced favourable neurological outcomes (RD 24.11, 95% CI: 11.58, 36.63) compared to CPR 15:2.

***CC-CPR (with minimally interrupted cardiac resuscitation) vs. CPR 15:2 or 30:2 (adults)***

For EMS CPR, one cohort study[41] with 2,460 mostly adult patients found that significantly more patients receiving CC-CPR survived (RD 5.24, 95% CI: 2.88, 7.6) and experienced ROSC (RD 10.64, 95% CI: 6.80, 14.49) compared to CPR 15:2 or 30:2. The results for favourable neurological outcomes were not statistically significant.

***CC-CPR (with asynchronous positive-pressure ventilations delivered by a Thumper device) vs. CPR 5:1(adults)***

For in-hospital CPR, one cohort study[31] of 515 adults found that significantly more patients receiving CC-CPR survived (RD 5.86 95% CI: 1.19, 10.53), and experienced ROSC (RD 11.64, 95% CI: 3.61, 19.68) compared to CPR 5:1. The results for favourable neurological outcomes were not statistically significant.

***CO-CPR vs. CPR 30:2 (Paediatrics)***

For bystander plus dispatcher-instructed CPR, one cohort study[28] of 2,617 children (mean age: NR) found significantly less patients receiving CO-CPR experienced favourable neurological outcomes (RD -3.30, 95% CI: -4.88, -1.71), and survived (RD -7.04, 95% CI: -9.58, -4.50) compared to CPR 30:2.

***CO-CPR vs. CPR 15:2 or 30:2 (Paediatrics)***

For bystander CPR, one cohort study[38] of 2,439 paediatric (mean age: 4.9yrs) patients found significantly less patients receiving CO-CPR experienced favourable neurological outcomes (RD -3.02, 95% CI: -4.57, -1.47) or survived (RD -2.98, 95% CI: -5.51, -0.45) compared to CPR 15:2 or 30:2. The results for ROSC were not statistically significant.

***Quality of life***

None of the included studies reported data on quality of life.

***GRADE (Appendix L)***

The only results of high certainty in this systematic review were those for favourable neurological outcomes, survival, and ROSC, in one cluster-crossover RCT[16] which compared CO-CPR to CPR 30:2 provided by EMS. All other results were of low or very low certainty.

## DISCUSSION

For adults, our results suggest no statistically significant differences across all outcomes and comparisons for those receiving bystander-initiated CPR alone or dispatcher-instructed CPR with or without ventilations. Significantly less adults receiving bystander plus dispatcher-instructed CO-CPR experienced favourable neurological outcomes, survival, and ROSC compared to CPR 30:2. As well, significantly more patients receiving EMS CPR 30:2 experienced favourable neurological outcomes and survival compared to CPR 15:2.

For children, the results varied by the patients' age. CPR 15:2 or 30:2 compression-to-ventilation ratios showed more children with favourable neurological outcomes, survival, and ROSC when compared to CO-CPR for children of all ages. However, no statistically significant differences were observed across these outcomes for children less than one year old. In addition, only two studies with small sample sizes of children were identified for inclusion in our review. As such, our results might be affected by a lack of power to show a true effect in this population. Two additional studies have been published since our literature search was conducted and should be considered to inform guidelines for paediatric population. The studies by Fukuda and Naim examined CO-CPR compared to conventional CPR for paediatric population and both found

conventional CPR to be associated with improved outcomes for paediatrics, which was consistent with our results.[55, 56]

The findings from this review and meta-analysis require interpretation in the context of the settings where the interventions were applied. The 2015 consensus on science and treatment recommendations for dispatcher instructions noted that CPR instructions are associated with increased performance of CPR and better patient outcomes.[57] The finding of no statistically significant difference between CPR with a synchronous compression-to-ventilation ratio and dispatcher-instructed CO-CPR[58] supports ILCOR's recommendation for dispatcher-instructed CO-CPR. For bystander-initiated CPR, Iwami found that any CPR is better than no CPR,[2] in un-adjusted analyses CPR 30:2 compression-to-ventilation was associated with the best outcomes in adults. Iwami adjusted for measured confounding variables for no CPR versus CO-CPR or conventional CPR and found similar odds ratios across the two comparisons. Iwami eloquently notes "the most important result from this nationwide registry of OHCA is not the comparison of odds ratios (ORs) between CCCPR and conventional CPR but the increase in the total incidence of survival with favourable neurological outcomes attributed to either type of bystander CPR".[2] This review supports ILCOR's current recommendation that all victims of cardiac arrest should receive chest compressions. For those trained and willing to give rescue-breaths, our findings support that additional benefits can be achieved from CPR with a synchronous compression-to-ventilation ratio.

Of note, a meta-analysis by Hupfl[59] compared CO-CPR to conventional CPR and found the same three RCTs[20, 23, 24] as our systematic review with the same findings for survival at discharge. Also a recent Cochrane review[60] which included four studies demonstrated the same findings as our review.

There are some limitations of the included studies worth noting. All three RCTs had unclear risk of bias for at least one important criterion, and one of the RCTs had a high risk of bias for two components. In the discussion of one trial publication,[23] authors observed that some dispatchers seemed to have had a prejudice against CO-CPR and a preference for standard CPR, while some callers indicated a preference for a CPR technique irrespective of the randomised intervention. This issue may also have impacted the other studies. The included cohort studies were methodologically flawed because most did not adjust for confounding variables in their analysis. Consequently, those results might not be reliable and should be interpreted with caution. Additionally, a small number of studies where the focus was not to compare different compression-to-ventilation ratios (though these data were featured in sub-group analyses) were included, after having been identified by the content experts. It is possible that similar studies could have been missed during our screening process. Also we identified several studies examining minimally-interrupted cardiac resuscitation delivered by EMS from Arizona. In some of these cases, the evaluation appeared to run concurrently with a community campaign of bystander compression-only CPR.[21, 39] It was difficult to precisely determine the overlap in patient populations reported in these studies. For example, whilst it was clear that some studies examined specific sub-groups who received MICR (e.g. age),[61, 62] there appeared to be overlap in the patient populations evaluated between reports.[18, 41, 43] To minimize the risk of including individual patients more than once in our meta-analysis, we limited our analysis to the Bobrow, 2008[41] paper as we judged this to be the most comprehensive study that was aligned with our specific PICO question. Finally, the studies we evaluated included a variety of settings where EMS systems and response times may vary and for some studies it was not possible to separate paediatric from adult cases.

There are strengths that are worth noting in our review approach. Our team is multidisciplinary, including content experts, systematic review methodologists, a statistician, and trained systematic review staff. All levels of screening and data abstraction were conducted after a pilot-test and were done in duplicate, with discrepancies verified by a third reviewer. We also assessed the quality of the totality of the evidence using GRADE. However, there are some limitations to be noted, such as limiting to published studies only written in English. The majority of studies identified in this review were observational in nature and thereby at risk of bias from measured and unmeasured confounding factors. In our analyses we only included un-adjusted estimates because only four of the included papers[16, 28, 31, 41] undertook analyses which adjusted for potentially confounding variables (Appendix K). Also, since there were fewer than 10 studies in the meta-analyses[63], we were unable to statistically assess for publication bias.

In terms of areas identified for future research, we did not find any studies that measured quality of life. This is an important patient-related outcome that needs to be considered in future studies. In addition, none of the included studies provided data on neonates. Thus, for this population it might be necessary to use indirect evidence from paediatric studies or animal models to extrapolate results.

**CONCLUSIONS**

For adults, our results demonstrated that CPR 30:2 is associated with better survival and favourable neurological outcomes when compared to CPR 15:2. For children, more patients receiving CPR with either 15:2 or 30:2 compression-to ventilation ratio experienced favourable neurological function, survival, and ROSC when compared to CO-CPR for children of all ages, but for children <1 years of age, no statistically significant differences were observed.

## CONFLICTS OF INTEREST

Dr. Gavin Perkins and Dr. Allan deCaen are both affiliated with ILCOR, the commissioning committee of this review. All other authors have no known conflicts of interest to declare.

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## LIST OF ABBREVIATIONS

CA – cardiac arrest; CC-CPR – continuous compression CPR; CI – confidence interval; CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; EMS – emergency medical service; EPOC – Effective Practice and Organization of Care; GRADE – Grading of Recommendation, Assessment, Development, and Evaluation; ILCOR BLS – International Liaison Committee on Resuscitation Basic Life Support; MICR – minimally-interrupted cardiac resuscitation; OHCA – out-of-hospital cardiac arrest; OR – odds ratio; PICOST – Population,

Intervention, Control, Outcomes, Study design and Timeframe; PRESS – Peer Review of Electronic Search Strategies; PRISMA-P – Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols; RCTs – randomised controlled trials; RD – risk differences; ROSC – return of spontaneous circulation; RR – risk ratio; SD – standard deviation

## REFERENCES

1. Cabrini L, Biondi-Zoccai G, Landoni G, et al. Bystander-initiated chest compression-only CPR is better than standard CPR in out-of-hospital cardiac arrest. HSR proceedings in intensive care & cardiovascular anesthesia. 2010;2(4):279-85.
2. Iwami T, Kitamura T, Kiyohara K, Kawamura T. Dissemination of Chest Compression-Only Cardiopulmonary Resuscitation and Survival After Out-of-Hospital Cardiac Arrest. Circulation. 2015;132(5):415-22.
3. de Caen A, Tijssen JA. Is It Time to Stop Teaching Bystanders Ventilation as Part of Pediatric Cardiopulmonary Resuscitation? Circulation. 2016;134(25):2071-3.
4. Kouwenhoven WB, Jude JR, Knickerbocker GG. Closed-chest cardiac massage. JAMA. 1960;173:1064-7.
5. Becker LB, Berg RA, Pepe PE, et al. A reappraisal of mouth-to-mouth ventilation during bystander-initiated cardiopulmonary resuscitation. A statement for healthcare professionals from the Ventilation Working Group of the Basic Life Support and Pediatric Life Support Subcommittees, American Heart Association. Circulation. 1997;96(6):2102-12.
6. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015;349:g7647.
7. Stone PW. Popping the (PICO) question in research and evidence-based practice. Appl Nurs Res. 2002;15(3):197-8.
8. Synthesi.SR. Toronto: Knowledge Translation Program, St. Michael's Hospital; 2014.
9. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Resuscitation. 2015;96:328-40.
10. Higgins JP, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928.
11. Effective Practice and Organisation of Care (EPOC). EPOC Resources for review authors. Oslo: Norwegian Knowledge Centre for the Health Services; 2015. Available from: http://epoc.cochrane.org/epoc-specific-resources-review-authors.

12. Wells G, Shea B, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ontario, Canada: Ottawa Hospital Research Institute; 2011. Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
13. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539-58.
14. Viechtbauer W. Conducting Meta-Analyses in R with the metafor Package. Journal of Statistical Software. 2010;36(3):48.
15. Brozek JL, Akl EA, Alonso-Coello P, et al. Grading quality of evidence and strength of recommendations in clinical practice guidelines. Part 1 of 3. An overview of the GRADE approach and grading quality of evidence about interventions. Allergy. 2009;64(5):669-77.
16. Nichol G, Leroux B, Wang H, et al. Trial of Continuous or Interrupted Chest Compressions during CPR. N Engl J Med. 2015;373(23):2203-14.
17. Deasy C, Bray JE, Smith K, et al. Cardiac arrest outcomes before and after the 2005 resuscitation guidelines implementation: evidence of improvement? Resuscitation. 2011;82(8):984-8.
18. Kellum MJ, Kennedy KW, Barney R, et al. Cardiocerebral resuscitation improves neurologically intact survival of patients with out-of-hospital cardiac arrest. Ann Emerg Med. 2008;52(3):244-52.
19. SOS-KANTO study group. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study. Lancet. 2007;369(9565):920-6.
20. Hallstrom A, Cobb L, Johnson E, Copass M. Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. N Engl J Med. 2000;342(21):1546-53.
21. Panchal AR, Bobrow BJ, Spaite DW, et al. Chest compression-only cardiopulmonary resuscitation performed by lay rescuers for adult out-of-hospital cardiac arrest due to non-cardiac aetiologies. Resuscitation. 2013;84(4):435-9.
22. Ong ME, Ng FS, Anushia P, et al. Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. Resuscitation. 2008;78(2):119-26.
23. Svensson L, Bohm K, Castren M, et al. Compression-only CPR or standard CPR in out-of-hospital cardiac arrest. N Engl J Med. 2010;363(5):434-42.
24. Rea TD, Fahrenbruch C, Culley L, et al. CPR with chest compression alone or with rescue breathing. N Engl J Med. 2010;363(5):423-33.
25. Olasveengen TM, Vik E, Kuzovlev A, Sunde K. Effect of implementation of new resuscitation guidelines on quality of cardiopulmonary resuscitation and survival. Resuscitation. 2009;80(4):407-11.
26. Iwami T, Kawamura T, Hiraide A, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007;116(25):2900-7.
27. Kudenchuk PJ, Redshaw JD, Stubbs BA, et al. Impact of changes in resuscitation practice on survival and neurological outcome after out-of-hospital cardiac arrest resulting from nonshockable arrhythmias. Circulation. 2012;125(14):1787-94.
28. Goto Y, Maeda T, Goto Y. Impact of dispatcher-assisted bystander cardiopulmonary resuscitation on neurological outcomes in children with out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. J Am Heart Assoc. 2014;3(3):e000499.
29. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation. 2009;119(19):2597-605.
30. Steinmetz J, Barnung S, Nielsen SL, Risom M, Rasmussen LS. Improved survival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand. 2008;52(7):908-13.

31. Lee IH, How CK, Lu WH, et al. Improved survival outcome with continuous chest compressions with ventilation compared to 5:1 compressions-to-ventilations mechanical cardiopulmonary resuscitation in out-of-hospital cardiac arrest. J Chin Med Assoc. 2013;76(3):158-63.
32. Hostler D, Rittenberger JC, Roth R, Callaway CW. Increased chest compression to ventilation ratio improves delivery of CPR. Resuscitation. 2007;74(3):446-52.
33. Robinson S, Swain AH, Hoyle SR, Larsen PD. Survival from out-of-hospital cardiac arrest in New Zealand following the 2005 resuscitation guideline changes. Resuscitation. 2010;81(12):1648-51.
34. Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation. Circulation. 2007;116(25):2908-12.
35. Van Hoeyweghen RJ, Bossaert LL, Mullie A, et al. Quality and efficiency of bystander CPR. Belgian Cerebral Resuscitation Study Group. Resuscitation. 1993;26(1):47-52.
36. Sayre MR, Cantrell SA, White LJ, Hiestand BC, Keseg DP, Koser S. Impact of the 2005 American Heart Association cardiopulmonary resuscitation and emergency cardiovascular care guidelines on out-of-hospital cardiac arrest survival. Prehosp Emerg Care. 2009;13(4):469-77.
37. Waalewijn RA, Tijssen JG, Koster RW. Bystander initiated actions in out-of-hospital cardiopulmonary resuscitation: results from the Amsterdam Resuscitation Study (ARRESUST). Resuscitation. 2001;50(3):273-9.
38. Kitamura T, Iwami T, Kawamura T, et al. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet. 2010;375(9723):1347-54.
39. Bobrow BJ, Spaite DW, Berg RA, et al. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA. 2010;304(13):1447-54.
40. Olasveengen TM, Wik L, Steen PA. Standard basic life support vs. continuous chest compressions only in out-of-hospital cardiac arrest. Acta Anaesthesiol Scand. 2008;52(7):914-9.
41. Bobrow BJ, Clark LL, Ewy GA, et al. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA. 2008;299(10):1158-65.
42. Holmberg M, Holmberg S, Herlitz J. Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden. Eur Heart J. 2001;22(6):511-9.
43. Kellum MJ, Kennedy KW, Ewy GA. Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest. Am J Med. 2006;119(4):335-40.
44. Bray JE, Deasy C, Walsh J, Bacon A, Currell A, Smith K. Changing EMS dispatcher CPR instructions to 400 compressions before mouth-to-mouth improved bystander CPR rates. Resuscitation. 2011;82(11):1393-8.
45. Iwami T, Kitamura T, Kawamura T, et al. Chest compression-only cardiopulmonary resuscitation for out-of-hospital cardiac arrest with public-access defibrillation: a nationwide cohort study. Circulation. 2012;126(24):2844-51.
46. Japanese Circulation Society Resuscitation Science Study Group. Chest-compression-only bystander cardiopulmonary resuscitation in the 30:2 compression-to-ventilation ratio era. Nationwide observational study. Circ J. 2013;77(11):2742-50.
47. Hallstrom AP. Dispatcher-assisted "phone" cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. Crit Care Med. 2000;28(11 Suppl):N190-2.
48. Olasveengen TM, Wik L, Kramer-Johansen J, Sunde K, Pytte M, Steen PA. Is CPR quality improving? A retrospective study of out-of-hospital cardiac arrest. Resuscitation. 2007;75(2):260-6.
49. Ogawa T, Akahane M, Koike S, Tanabe S, Mizoguchi T, Imamura T. Outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital

cardiopulmonary arrest witnessed by bystanders: nationwide population based observational study. BMJ. 2011;342:c7106.
50. Kitamura T, Iwami T, Kawamura T, et al. Time-dependent effectiveness of chest compression-only and conventional cardiopulmonary resuscitation for out-of-hospital cardiac arrest of cardiac origin. Resuscitation. 2011;82(1):3-9.
51. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A. Bystander-initiated rescue breathing for out-of-hospital cardiac arrests of noncardiac origin. Circulation. 2010;122(3):293-9.
52. Fukuda T, Fukuda-Ohashi N, Doi K, Matsubara T, Yahagi N. Effective pre-hospital care for out-of-hospital cardiac arrest caused by respiratory disease. Heart Lung Circ. 2015;24(3):241-9.
53. Kitamura T, Iwami T, Kawamura T, et al. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. Circulation. 2012;126(24):2834-43.
54. Maeda T, Kamikura T, Tanaka Y, et al. Impact of bystander-performed ventilation on functional outcomes after cardiac arrest and factors associated with ventilation-only cardiopulmonary resuscitation: A large observational study. Resuscitation. 2015;91:122-30.
55. Fukuda T, Ohashi-Fukuda N, Kobayashi H, et al. Conventional Versus Compression-Only Versus No-Bystander Cardiopulmonary Resuscitation for Pediatric Out-of-Hospital Cardiac ArrestClinical Perspective. Circulation. 2016;134(25):2060-70.
56. Naim MY, Burke RV, McNally BF, et al. Association of bystander cardiopulmonary resuscitation with overall and neurologically favorable survival after pediatric out-of-hospital cardiac arrest in the United States: a report from the Cardiac Arrest Registry to Enhance Survival Surveillance Registry. JAMA pediatrics. 2016.
57. Perkins GD, Travers AH, Berg RA, et al. Part 3: Adult basic life support and automated external defibrillation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2015;95:e43-69.
58. Deakin CD, Cheung S, Petley GW, Clewlow F. Assessment of the quality of cardiopulmonary resuscitation following modification of a standard telephone-directed protocol. Resuscitation. 2007;72(3):436-43.
59. Hupfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet. 2010;376(9752):1552-7.
60. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. Cochrane Database Syst Rev. 2017;3:Cd010134.
61. Mohler MJ, Wendel CS, Mosier J, et al. Cardiocerebral resuscitation improves out-of-hospital survival in older adults. J Am Geriatr Soc. 2011;59(5):822-6.
62. Mosier J, Itty A, Sanders A, et al. Cardiocerebral resuscitation is associated with improved survival and neurologic outcome from out-of-hospital cardiac arrest in elders. Acad Emerg Med. 2010;17(3):269-75.
63. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629-34.

## LEGENDS TO FIGURES

Table 1: Summary characteristics

Table 2: Main analysis stratified by patient age, CPR comparisons, provider, and outcome

Table 3. Subgroup Analysis - Favourable Neurological Outcomes

Table 4. Sensitivity Analysis

## Table 1. Summary Characteristics

| **Study and patient characteristics** | **Number of studies (%)** |
|---|---|
| Population | |
| Adults | 20 (71 %) |
| Paediatrics | 2 (7 %) |
| All (adults and paediatrics) | 6 (21 %) |
| Study region | |
| Australia and New Zealand | 2 (7 %) |
| Europe | 8 (29 %) |
| Asia | 7 (25 %) |
| North America | 11 (39 %) |
| Aetiology | |
| Cardiac | 9 (32 %) |
| Non-cardiac | 1 (4 %) |
| Cardiac and Non-cardiac | 13 (46 %) |
| Not specified | 5 (18 %) |
| Study design | |
| Cohorts | 24 (86 %) |
| RCTs | 3 (11 %) |
| NRCTs | 1 (4 %) |
| Sample size | 181 to 350,439 |
| Male (range of %) | 59 to 79 |
| Patient age | |
| Range of mean (SD) | 4.9 (6.1) to 74.1 (14.9) |
| Range of median (IQR) | 1.1 (0 to 9) to 79.0 (66 to 86) |
| **Intervention characteristics** | **Number of studies (%)** |
| Type of CPR method | |
| CPR 5:1 | 1 (4 %) |
| CPR 15:2 | 19 (68 %) |
| CPR 30:2 | 11 (39 %) |
| CPR15:2 or 30:2 | 4 (14 %) |
| CPR 50:2 | 1 (4 %) |
| CO-CPR | 16 (57 %) |
| CC-CPR[a] | 4 (14%) |
| Initial rhythm | |
| Shockable | 6 (21 %) |
| Non-shockable | 1 (4 %) |
| Shockable and Non-shockable | 16 (57 %) |
| Not specified | 5 (18 %) |
| Setting | |
| Out-of hospital CA | 27 (96 %) |
| In-of hospital CA | 1 (4 %) |
| Provider | |
| Bystander CPR only | 11 (39 %) |
| Bystander CPR + Dispatcher-instructed CPR | 2 (7 %) |
| Dispatcher-instructed CPR only | 3 (11 %) |
| EMS CPR only | 11 (39 %) |
| In-hospital CPR | 1 (4 %) |
| Arrest witnessed (range of %) | 7 to 50 |
| EMS Response time | |
| Range of mean (SD) | 3.7 (2) to 12.2 (5) |
| Range of median (IQR) | 5.0 (4 to 7) to 12.2 (6 to 11) |
| **Outcomes characteristics** | **Number of studies (%)** |
| Favourable neurological outcomes | 17 (61 %) |
| Survival | 26 (93 %) |

| | |
|---|---|
| Return of spontaneous circulation | 18 (64 %) |

**Abbreviations:** CA – cardiac arrest; CC-CPR - continuous compression CPR; CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; EMS – emergency medical service; IQR – interquartile range; NRCT – non-randomised controlled trials; RCT – randomised controlled trial; SD – standard deviation

[a]Includes cardiocerebral resuscitation and minimally interrupted cardiac resuscitation

## Table 2. Main analysis stratified by patient age, CPR comparisons, provider, and outcome

| Study ID | # of studies (# of patients) | CPR Provider | Outcome | Treatment %: (# events/n) | Control %: (# events/n) | Risk Ratio (95% CI) | Risk Difference % (95% CI) | $I^2$ |
|---|---|---|---|---|---|---|---|---|
| **Adults + All (both adult and paediatric) Patients** | | | | | | | | |
| ***CO-CPR vs. CPR 30:2*** | | | | | | | | |
| Iwami T, 2015[2a] | 1 Cohort (350,439) | Bystander + Dispatcher-instructed CPR | Favourable neurological outcomes | 1.94 (4846/249970) | 2.68 (2690/100469) | 0.72 (0.69, 0.76)† | -0.74 (-0.85, -0.63) | NA |
| | | | Survival* | 4.27 (10685/249970) | 5.69 (5717/100469) | 0.75 (0.73, 0.78)† | -1.42 (-1.58, -1.25) | NA |
| | | | ROSC | 6.33 (15818/249970) | 7.94 (7982/100469) | 0.80 (0.78, 0.82)† | -1.62 (-1.81, -1.42) | NA |
| ***CO-CPR vs. CPR 15:2*** | | | | | | | | |
| Rea TD, 2010[24] | 1 RCT (1,941) | Dispatcher-instructed CPR | Favourable neurological outcomes | 14.40 (94/653) | 11.53 (73/633) | 1.25 (0.94, 1.66) | 2.86 (-0.80, 6.53) | NA |
| Hallstrom A, 2000[20]; Rea TD, 2010[24]; Svensson L, 2010[23a] | 3 RCTs (3,737) | Dispatcher-instructed CPR | Survival* | 11.48 (211/1838) | 9.52 (180/1890) | 1.20 (1.00, 1.45) | 1.88 (-0.05, 3.82) | 0% |
| SOS-KANTO Study group, 2007[19]; Ong MEH, 2008[22] | 2 Cohorts (1,592) | Bystander CPR | Favourable neurological outcomes | 4.89 (29/593) | 3.60 (36/999) | 1.34 (0.82, 2.20) | 0.51 (-2.16, 3.18) | 1% |
| Van Hoeyweghen 1993[35]; Ong MEH, 2008[22]; Iwami T, 2007[26] | 3 Cohorts (2,185) | Bystander CPR | ROSC | 30.95 (251/811) | 32.67 (411/1258) | 0.89 (0.68, 1.16) | -4.19 (-13.68, 5.31) | 64% |
| SOS-KANTO Study group, 2007[19]; Ong, MEH, 2008[22]; Iwami, T, 2007[26]; Bohm, K, 2007[34]; Waalewijn, RA, 2001[37a]; Holmberg, 2001[42a] | 6 Cohorts (15,476) | Bystander CPR | Survival* | 6.00 (156/2601) | 7.55 (924/12240) | 0.88 (0.74, 1.04) | -0.83 (-1.85, 0.19) | 0% |
| ***CO-CPR vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Panchal, 2013[21]; Bobrow, 2010[39]; Olasveengen 2008[40] | 3 Cohorts (2,193) | Bystander CPR | Favourable neurological outcomes | 6.65 (76/1142) | 6.36 (67/1053) | 1.12 (0.71, 1.77) | 0.28 (-2.33, 2.89) | 29% |
| | | | Survival* | 11.58 (132/1140) | 8.64 (91/1053) | 1.16 (0.64, 2.09) | 1.27 (-3.70, 6.23) | 63% |
| Olasveengen, 2008[40] | 1 Cohort (426) | Bystander CPR | ROSC | 36.55 ( 53/145 ) | 37.37 (105/281) | 0.98 (0.75, 1.27) | -0.81 (-10.48, 8.85) | NA |
| ***CPR 30:2 vs. CPR 15:2*** | | | | | | | | |
| Olasveengen TM, 2009[25]; Kudenchuk P, 2012[27] | 2 Cohorts (4,877) | EMS CPR | Favourable neurological outcomes | 6.33 (169/2668) | 4.75 (105/2209) | 1.34 (1.02, 1.76)† | 1.72 (0.52, 2.91) | 24% |
| Olasveengen TM, 2009[25]; Kudenchuk | 6 Cohorts (14,044) | EMS CPR | Survival* | 10.01 (746/7449) | 7.66 (499/6513) | 1.37 (1.19, 1.59)† | 2.48 (1.57, 3.38) | 25% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| P, 2012[27]; Steinmetz J, 2008[30]; Robinson S, 2010[33]; Sayre M, 2009[36]; Deasy C, 2011[17] | | | | | | | | |
| Olasveengen TM, 2009[25]; Kudenchuk P, 2012[27]; Steinmetz J, 2008[30]; Sayre M, 2009[36]; Robinson S, 2010[33]; Deasy C, 2011[17]; Hostler D, 2007[32] | 7 Cohorts (15,287) | EMS CPR | ROSC | 34.99 (2404/6870) | 32.40 (2151/6639) | 1.11 (1.00, 1.23) | 3.45 (0.10, 6.80) | 64% |
| ***CPR 50:2 vs. CPR 15:2*** | | | | | | | | |
| Garza A, 2009[29] | 1 Cohort (200) | EMS CPR | Survival* | 43.86 (25/57) | 22.38 (32/143) | 1.96 (1.28, 2.99)† | 21.48 (6.90, 36.06) | NA |
| | | | ROSC | 59.65 (34/57) | 37.76 (54/143) | 1.58 (1.17, 2.13)† | 21.89 (6.88, 36.90) | NA |
| ***CC-CPR[b] vs. CPR 30:2*** | | | | | | | | |
| Nichol G, 2015[16] | 1 Cluster-crossover RCT (23,711) | EMS CPR | Favourable neurological outcomes | 7.03 (883/12560) | 7.68 (844/10995) | 0.92 (0.84, 1.00) | -0.65 (-1.31, 0.02) | NA |
| | | | Survival* | 8.95 (1129/12613) | 9.71 (1072/11035) | 0.92 (0.85, 1.00) | -0.76 (-1.51, -0.02) | NA |
| | | | ROSC | 24.18 (3058/12646) | 25.33 (2799 /11051) | 0.955 (0.913, 0.998)† | -1.15 (-2.25, -0.05) | NA |
| ***CC-CPR[c] vs. CPR 15:2*** | | | | | | | | |
| Kellum MJ, 2008[18] | 1 Cohort (181) | EMS CPR | Favourable neurological outcomes | 39.33 (35/89) | 15.22 (14/92) | 2.58 (1.50, 4.47)† | 24.11 (11.58, 36.63) | NA |
| ***CC-CPR[c] vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Bobrow, 2008[41a] | 1 Cohort (2,460) | EMS CPR | Favourable neurological outcomes | 46.67 (28/60) ‡ | 57.97 (40/69) ‡ | 0.81 (0.57, 1.13) | -11.30 (-28.48, 5.87) | NA |
| | | | Survival* | 9.08 (60/661) | 3.84 (69/1799) | 2.37 (1.69, 3.31)† | 5.24 (2.88, 7.60) | NA |
| | | | ROSC | 27.99 (185/661) | 17.34 (312/1799) | 1.61 (1.38, 1.89)† | 10.64 (6.80, 14.49) | NA |
| ***CC-CPR[d] vs. CPR 5:1*** | | | | | | | | |
| Lee IH, 2013[31 a] | 1 Cohort (515) | In-hospital CPR | Favourable neurological outcomes | 1.92 (4/208) | 1.63 (5/307) | 1.18 (0.32, 4.35) | 0.29 (-2.05, 2.64) | NA |
| | | | Survival* | 10.10 (21/208) | 4.23 (13/307) | 2.38 (1.22, 4.65)† | 5.86 (1.19, 10.53) | NA |
| | | | ROSC | 35.10 (73/208) | 23.45 (72/307) | 1.50 (1.14, 1.97)† | 11.64 (3.61, 19.68) | NA |
| **Paediatric Patients** | | | | | | | | |
| ***CO-CPR vs. CPR 30 :2*** | | | | | | | | |
| Goto Y, 2014[28] | 1 Cohort (2,617) | Bystander + Dispatcher-instructed CPR | Favourable neurological outcomes | 2.71 (38/1402) | 6.01 (73/1215) | 0.45 (0.31, 0.66)† | -3.30 (-4.88, -1.71) | NA |
| | | | Survival* | 8.84 (124/1402) | 15.88 (193/1215) | 0.56 (0.45, 0.69)† | -7.04 (-9.58, -4.50) | NA |
| ***CO-CPR vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Kitamura T, 2010[38] | 1 Cohort (2,439) | Bystander CPR | Favourable neurological outcomes | 2.59 (23/888) | 5.61 (87/1551) | 0.46 (0.29, 0.73)† | -3.02 (-4.57, -1.47) | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Survival* | 9.46 (84/888) | 12.44 (193/1551) | 0.76 (0.60, 0.97)† | -2.98 (-5.51, -0.45) | NA |
| | | | ROSC | 5.52 (49/888) | 7.48 (116/1551) | 0.74 (0.53, 1.02) | -1.96 (-3.95, 0.03) | NA |
| Kitamura T, 2010[38e] | 1 Cohort (1,444) | Bystander CPR | Favourable neurological outcomes | 3.72 (20/538) | 8.06 (73/906) | 0.46 (0.28, 0.75)† | -4.34 (-6.73, -1.95) | NA |
| | | | Survival* | 11.15 (60/538) | 15.89 (144/906) | 0.70 (0.53, 0.93)† | -4.74 (-8.31, -1.17) | NA |
| | | | ROSC | 7.06 (38/538) | 10.60 (96/906) | 0.67 (0.47, 0.96)† | -3.53 (-6.48, -0.58) | NA |
| Kitamura T, 2010[38f] | 1 Cohort (995) | Bystander CPR | Favourable neurological outcomes | 0.86 (3/350) | 2.17 (14/645) | 0.39 (0.11, 1.36) | -1.31 (-2.80, 0.17) | NA |
| | | | Survival* | 6.86 (24/350) | 7.60 (49/645) | 0.90 (0.56, 1.45) | -0.74 (-4.09, 2.61) | NA |
| | | | ROSC | 3.14 (11/350) | 3.10 (20/645) | 1.01 (0.49, 2.09) | 0.04 (-2.22, 2.31) | NA |

**Abbreviations:** CC-CPR - continuous compression CPR; CI - confidence interval; CO-CPR - compression-only CPR; CPR - cardiopulmonary resuscitation; EMS – emergency medical service; NA – not applicable; RCT – randomized controlled trial; ROSC – Return of spontaneous circulation

* Survival data reported at the longest follow-up time. For example, if a study reported survival data at admission, at discharge or at 30 days, the survival data at 30 days was used.
† Results were found to be statistically significant
‡ Number of patients reported for favourable neurological outcomes and not the number of patients enrolled.[a] Combined population (includes both adults and paediatrics)
[b] All patients received positive-pressure ventilation
[c] Minimally interrupted cardiac resuscitation
[d] Mechanical Thumper device (model 1008) continuous CPR versus Thumper device (model 1007)
[e] Age 1 to 17years
[f] Age < 1 year

## Table 3. Subgroup Analysis - Favourable Neurological Outcomes

| Study ID | # of studies (# of patients) | CPR Provider | Aetiology | Mean EMS response (mins) | Initial Rhythm | % Arrest Witnessed (Rx; Ctrl) | ROB | Treatment % (# events /n) | Control % (# events /n) | Risk Ratio (95% CI) | Risk Difference % (95% CI) | $I^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Adults + All (both adult and paediatric) Patients** | | | | | | | | | | | | |
| ***CO-CPR vs. CPR 30:2*** | | | | | | | | | | | | |
| Iwami T, 2015[2a] | 1 Cohort (350,439) | Bystander + Dispatcher-instructed | Cardiac + noncardiac | 8.00 | shockable + nonshockable | 35; 42 | Moderate risk | 1.94 (4846/249970) | 2.68 (2690/100469) | 0.72 (0.69, 0.76)* | -0.74 (-0.85, -0.63) | NA |
| ***CO-CPR vs. CPR 15:2*** | | | | | | | | | | | | |
| Rea TD, 2010[24] | 1 RCT (1,941) | Dispatcher-instructed CPR | Cardiac + noncardiac | 6.50 | shockable | 43; 46 | Low risk | 14.40 (94/653) | 11.53 (73/633) | 1.25 (0.94, 1.66) | 2.86 (-0.80, 6.53) | NA |
| SOS-KANTO Study group, 2007[19]; Ong MEH, 2008[22] [MAIN ANALYSIS] | 2 Cohorts (1,592) | Bystander CPR | Combined | Combined | Combined | Combined | Combined | 4.89 (29/593) | 3.60 (36/999) | 1.34 (0.82, 2.20) | 0.51 (-2.16, 3.18) | 1% |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ong MEH, 2008[22] [SENSITVITY ANALYSIS] | 1 Cohort (441) | Bystander CPR | NR | 11.50 | shockable + nonshockable | 77; 78 | Unclear risk | 1.30 (2/154) | 2.09 (6/287) | 0.62 (0.13, 3.04) | -0.79 (-3.23, 1.64) | NA |
| SOS-KANTO Study group, 2007[19] [SENSITVITY ANALYSIS] | 1 Cohort (1,151) | Bystander CPR | Cardiac + noncardiac | NR | shockable + nonshockable | 100; 100 | Low risk | 6.15 (27/439) | 4.21 (30/712) | 1.46 (0.88, 2.42) | 1.94 (-0.75, 4.63) | NA |
| ***CPR 30:2 vs. CPR 15:2*** | | | | | | | | | | | | |
| Olasveengen TM, 2009[25]; Kudenchuk P, 2012[27] [MAIN ANALYSIS] | 2 Cohort (4,877) | EMS CPR | Combined | Combined | Combined | Combined | Combined | 6.33 (169/2668) | 4.75 (105/2209) | 1.34 (1.02, 1.76)* | 1.72 (0.52, 2.91) | 24% |
| Olasveengen TM, 2009[25] [SENSITVITY ANALYSIS] | 1 Cohort (917) | EMS CPR | Cardiac + noncardiac | 9.00 | shockable + nonshockable | 59; 57 | Unclear risk | 11.83 (57/482) | 10.34 (45/435) | 1.14 (0.79, 1.65) | 1.48 (-2.58, 5.54) | NA |
| Kudenchuk P, 2012[27] [SENSITVITY ANALYSIS] | 1 Cohort (3,960) | EMS CPR | Cardiac + noncardiac | 5.50 | nonshockable | 39; 39 | Unclear risk | 5.12 (112/2186) | 3.38 (60/1774) | 1.51 (1.11, 2.06)* | 1.74 (0.49, 2.99) | NA |
| ***CC-CPR[b] vs. CPR 30:2*** | | | | | | | | | | | | |
| Nichol G, 2015[16] | 1 Cluster-crossover RCT (23,711) | EMS CPR | NR | 5.90 | shockable + nonshockable | 41; 43 | Low risk | 7.03 (883/12560) | 7.68 (844/10995) | 0.92 (0.84, 1.00) | -0.65 (-1.31, 0.02) | NA |
| ***CC-CPR[c] vs. CPR 15 :2*** | | | | | | | | | | | | |
| Kellum MJ, 2008[18] | 1 Cohort (181) | EMS CPR | Cardiac | 8.60 | shockable | 100; 100 | High risk | 39.33 (35/89) | 15.22 (14/92) | 2.58 (1.50, 4.47)* | 24.11 (11.58, 36.63) | NA |
| ***CC-CPR vs. CPR 5:1*** | | | | | | | | | | | | |
| Lee IH, 2013[31] | 1 Cohort (515) | In-hospital CPR | NR | 4.50 | shockable + nonshockable | 14; 15 | Unclear risk | 1.92 (4/208) | 1.63 (5/307) | 1.18 (0.32, 4.35) | 0.29 (-2.05, 2.64) | NA |
| **Paediatrics Patients** | | | | | | | | | | | | |
| ***CO-CPR vs. CPR 30 :2*** | | | | | | | | | | | | |
| Goto Y, 2014[28] | 1 Cohort (2,617) | Bystander + Dispatcher-instructed CPR | Cardiac + noncardiac | NR | NR | NA | Moderate risk | 2.71 (38/1402) | 6.01 (73/1215) | 0.45 (0.31, 0.66)* | -3.30 (-4.88, -1.71) | NA |
| ***CO-CPR vs. CPR 15:2 or 30:2*** | | | | | | | | | | | | |
| Kitamura T, 2010[38] | 1 Cohort (2,439) | Bystander CPR | Cardiac + noncardiac | 8.50 | shockable + nonshockable | 25; 24 | Moderate risk | 2.59 (23/888) | 5.61 (87/1551) | 0.46 (0.29, 0.73)* | -3.02 (-4.57, -1.47) | NA |
| Kitamura T, 2010[38d] | 1 Cohort (1,444) | Bystander CPR | Cardiac + noncardiac | 8.50 | shockable + nonshockable | 25; 24 | Moderate risk | 3.72 (20/538) | 8.06 (73/906) | 0.46 (0.28, | -4.34 (-6.73, - | NA |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 0.75)* | 1.95) | |
| Kitamura T, 2010[38e] | 1 Cohort (995) | Bystander CPR | Cardiac + noncardiac | 8.50 | shockable + nonshockable | 25; 24 | Moderate risk | 0.86 (3/350) | 2.17 (14/645) | 0.39 (0.11, 1.36) | -1.31 (-2.80, 0.17) | NA |

**Abbreviations:** CC-CPR - continuous compression CPR; CI – confidence interval; CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; EMS – emergency medical service; NA – not applicable; RCT – randomised controlled trial; ROB – risk of bias

* Results were found to be statistically significant
[a] Combined population (includes both adults and paediatrics)
[b] All patients received positive-pressure ventilation.
[c] Mechanical Thumper device (model 1008) continuous CPR versus Thumper device (model 1007)
[d] Age 1 to 17years
[e] Age < 1 year

## Table 4. Sensitivity Analysis

| Study ID | # of studies (# of patients) | CPR Provider | Outcome | Treatment %: (# events/n) | Control %: (# events/n) | Risk Ratio (95% CI) | Risk Difference % (95% CI) | $I^2$ |
|---|---|---|---|---|---|---|---|---|
| **Sensitivity analysis for age group: Adults + All (both adult and paediatric) Patients** | | | | | | | | |
| ***CO-CPR vs. CPR 15:2*** | | | | | | | | |
| Hallstrom A, 2000[20]; Rea TD, 2010[24]; Svensson L, 2010[23a] [MAIN ANALYSIS] | Adults + All 3 RCTs (3,737) | Dispatcher-instructed CPR | Survival* | 11.48 (211/1838) | 9.52 (180/1890) | 1.20 (1.00, 1.45) | 1.88 (-0.05, 3.82) | 0% |
| Hallstrom A, 2000[20]; Rea TD, 2010[24] [SENSITVITY ANALYSIS] | Adults 2 RCTs (2,461) | Dispatcher-instructed CPR | Survival* | 12.89 (157/1218) | 10.86 (134/1234) | 1.19 (0.96, 1.48) | 2.02 (-0.54, 4.59) | 0% |
| Svensson L, 2010[23] [SENSITVITY ANALYSIS] | All (both adult and paediatric) 1 RCT (1,276) | Dispatcher-instructed CPR | Survival* | 8.71 (54/620) | 7.01 (46/656) | 1.24 (0.85, 1.81) | 1.70 (-1.26, 4.65) | NA |
| SOS-KANTO Study group, 2007[19]; Ong, MEH, 2008[22]; Iwami, T, 2007[26]; Bohm, K, 2007[34]; Waalewijn, RA, 2001[37a]; Holmberg, 2001[42a] [MAIN ANALYSIS] | Adults + All 6 Cohorts (15,476) | Bystander CPR | Survival* | 6.00 (156/2601) | 7.55 (924/12240) | 0.88 (0.74, 1.04) | -0.83 (-1.85, 0.19) | 0% |
| SOS-KANTO Study, 2007[19]; Ong MEH, | Adults 4 Cohorts (12,273) | Bystander CPR | Survival* | 5.74 (131/2282) | 6.88 (687/9991) | 0.91 (0.75, 1.09) | -0.62 (-1.70, 0.45) | 0% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2008[22]; Iwami T, 2007[26]; Bohm K, 2007[34] [SENSITVITY ANALYSIS] | | | | | | | | |
| Waalewijn RA, 2001[37]; Holmberg, 2001[42] [SENSITVITY ANALYSIS] | All (both adult and paediatric) 2 Cohort (3,203) | Bystander CPR | Survival* | 7.84 (25/319) | 10.54 (237/2249) | 0.78 (0.53, 1.16) | -2.60 (-5.74, 0.53) | 0% |
| **Sensitivity analysis for age group: Paediatrics Patients** | | | | | | | | |
| ***CO-CPR vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Kitamura T, 2010[38] [MAIN ANALYSIS] | 1 Cohort (2,439) | Bystander CPR | Favourable neurological outcomes | 2.59 (23/888) | 5.61 (87/1551) | 0.46 (0.29, 0.73)† | -3.02 (-4.57, -1.47) | NA |
| | | | Survival* | 9.46 (84/888) | 12.44 (193/1551) | 0.76 (0.6, 0.97)† | -2.98 (-5.51, -0.45) | NA |
| | | | ROSC | 5.52 (49/888) | 7.48 (116/1551) | 0.74 (0.53, 1.02) | -1.96 (-3.95, 0.03) | NA |
| Kitamura T, 2010[38] [SENSITVITY ANALYSIS] | Age 1-17 years 1 Cohort (1,444) | Bystander CPR | Favourable neurological outcomes | 3.72 (20/538) | 8.06 (73/906) | 0.46 (0.28, 0.75)† | -4.34 (-6.73, -1.95) | NA |
| | | | Survival* | 11.15 (60/538) | 15.89 (144/906) | 0.70 (0.53, 0.93)† | -4.74 (-8.31, -1.17) | NA |
| | | | ROSC | 7.06 (38/538) | 10.60 (96/906) | 0.67 (0.47, 0.96)† | -3.53 (-6.48, -0.58) | NA |
| Kitamura T, 2010[38] [SENSITVITY ANALYSIS] | Age < 1 year 1 Cohort (995) | Bystander CPR | Favourable neurological outcomes | 0.86 (3/350) | 2.17 (14/645) | 0.39 (0.11, 1.36) | -1.31 (-2.80, 0.17) | NA |
| | | | Survival* | 6.86 (24/350) | 7.60 (49/645) | 0.90 (0.56, 1.45) | -0.74 (-4.09, 2.61) | NA |
| | | | ROSC | 3.14 (11/350) | 3.10 (20/645) | 1.01 (0.49, 2.09) | 0.04 (-2.22, 2.31) | NA |
| **Sensitivity analysis for survival data closest to CPR** | | | | | | | | |
| ***CO-CPR vs. CPR 15:2*** | | | | | | | | |
| SOS-KANTO Study group, 2007[19]; Ong, MEH, 2008[22]; Iwami, T, 2007[26]; Bohm, K, 2007[34]; Waalewijn, RA, 2001[37a]; Holmberg, 2001[42a] [MAIN ANALYSIS] | Longest follow-up time 6 Cohorts (15,476) | Bystander CPR | Survival | 6.00 (156/2601) | 7.55 (924/12240) | 0.88 (0.74, 1.04) | -0.83 (-1.85, 0.19) | 0% |
| SOS-KANTO Study group, 2007[19]; Ong, MEH, 2008[22]; Iwami, T, 2007[26]; Bohm, K, 2007[34]; Waalewijn, RA, 2001[37]; Holmberg, 2001[42] [SENSITVITY ANALYSIS] | Closest follow-up time 6 Cohorts (15,476) | Bystander CPR | Survival | 12.42 (323/2601) | 16.72 (2047/12240) | 0.93 (0.80, 1.08) | -0.97 (-2.22, 0.28) | 16% |
| Hallstrom A, 2000[20]; Rea | Longest | Dispatcher- | Survival | 11.48 (211/1838) | 9.52 (180/1890) | 1.20 (1.00, 1.45) | 1.88 (-0.05, 3.82) | 0% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TD, 2010[24]; Svensson L, 2010[23a] [MAIN ANALYSIS] | follow-up time 3 RCTs (3,737) | instructed CPR | | | | | | |
| Hallstrom A, 2000[20]; Rea TD, 2010[24]; Svensson L, 2010[23] [SENSITVITY ANALYSIS] | Closest follow-up time 3 RCTs (3,737) | Dispatcher-instructed CPR | Survival | 14.07 (211/1500) | 11.63 (178/1531) | 1.22 (1.01, 1.46)† | 2.37 (0.00, 4.73) | 0% |
| ***CO-CPR vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Panchal, 2013[21]; Bobrow, 2010[39]; Olasveengen 2008[40] [MAIN ANALYSIS] | Longest follow-up time 3 Cohorts (2,193) | Bystander CPR | Survival | 11.58 (132/1140) | 8.64 (91/1053) | 1.16 (0.64, 2.09) | 1.27 (-3.70, 6.23) | 63% |
| Panchal, 2013[21]; Bobrow, 2010[39]; Olasveengen, 2008[40] [SENSITVITY ANALYSIS] | Closest follow-up time 3 Cohorts (2,193) | Bystander CPR | Survival | 15.26 (174/1140) | 15.95 (168/1053) | 1.21 (0.76, 1.95) | 2.00 (-2.95, 6.94) | 74% |
| ***CPR 30:2 vs. CPR 15:2*** | | | | | | | | |
| Olasveengen TM, 2009[25]; Kudenchuk P, 2012[27]; Steinmetz J, 2008[30]; Robinson S, 2010[33]; Sayre M, 2009[36]; Deasy C, 2011[17] [MAIN ANALYSIS] | Longest follow-up time 6 Cohorts (14,044) | EMS CPR | Survival | 10.01 (746/7449) | 7.66 (499/6513) | 1.37 (1.19, 1.59)† | 2.48 (1.57, 3.38) | 25% |
| Olasveengen TM, 2009[25]; Kudenchuk P, 2012[27]; Steinmetz J, 2008[30]; Robinson S, 2010[33]; Sayre M, 2009[36]; Deasy C, 2011[17] [SENSITVITY ANALYSIS] | Closest follow-up time 6 Cohorts (14,044) | EMS CPR | Survival | 24.42 (1819/7449) | 19.53 (1272/6513) | 1.38 (1.21, 1.56)† | 5.81 (2.99, 8.62) | 50% |
| ***CC-CPR[a] vs. CPR 15:2 or 30:2*** | | | | | | | | |
| Bobrow, 2008[41] [MAIN ANALYSIS] | Longest follow-up | EMS CPR | Survival | 9.08 (60/661) | 3.84 (69/1799) | 2.37 (1.69, 3.31)† | 5.24 (2.88, 7.60) | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | time<br>1 Cohort (2,460) | | | | | | | |
| Bobrow, 2008[41] [SENSITVITY ANALYSIS] | Closest follow-up time<br>1 Cohort (2,460) | EMS CPR | Survival | 21.94 (145/661) | 15.06 (271/1799) | 1.46 (1.22, 1.74)† | 6.87 (3.31, 10.43) | NA |
| ***CC-CPR[b] vs. CPR 5:1*** | | | | | | | | |
| Lee IH, 2013[31] [MAIN ANALYSIS] | Longest follow-up time<br>1 Cohort (515) | In-hospital CPR | Survival | 10.10 (21/208) | 4.23 (13/307) | 2.38 (1.22, 4.65)† | 5.86 (1.19, 10.53) | NA |
| Lee IH, 2013[31] [SENSITVITY ANALYSIS] | Closest follow-up time<br>1 Cohort (515) | In-hospital CPR | Survival | 32.21 (67/208) | 23.13 (71/307) | 1.39 (1.05, 1.85)† | 9.08 (1.17, 16.99) | NA |

**Abbreviations:** CC-CPR – continuous compression CPR; CI – confidence interval; CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; EMS – emergency medical service; NA – not applicable; RCT – randomised controlled trial; ROSC – return of spontaneous circulation

* Survival data reported closest to CPR. For example, if a study reported survival data at admission, at discharge or at 30 days, the survival data at admission was used.

† Results were found to be statistically significant

[a] Minimally interrupted cardiac resuscitation

[b] Mechanical Thumper device (model 1008) continuous CPR versus Thumper device (model 1007)

Figure 1. Flow chart

**Figure 1. Flow chart**

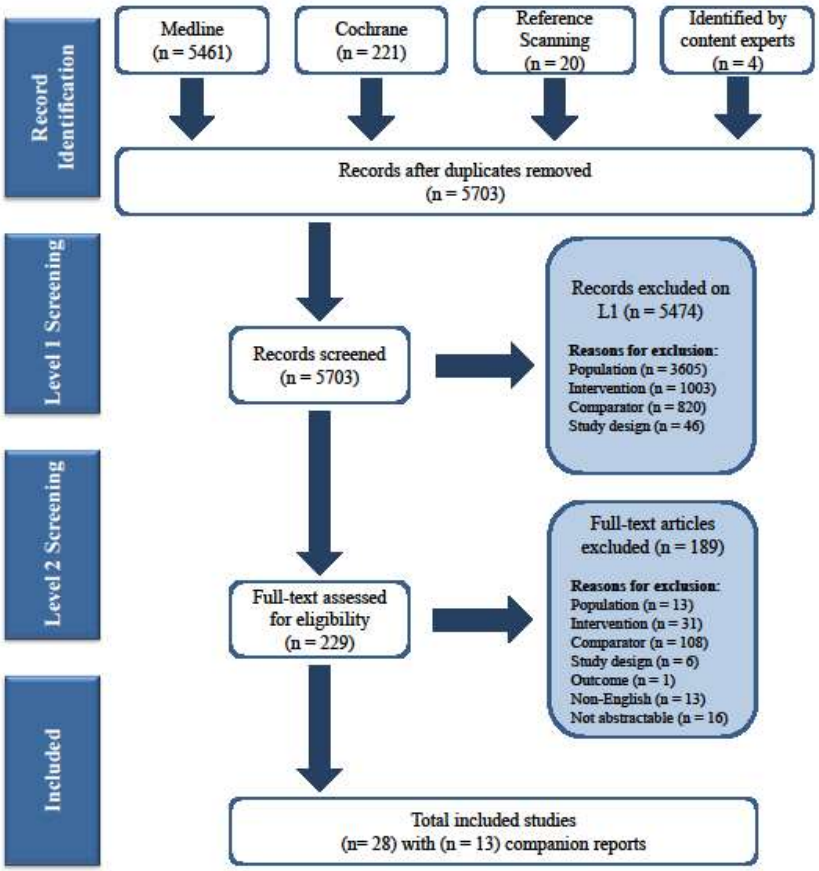

Figure 2. Forest plots of risk ratio for favourable neurological outcomes, ROSC and survival with CO-CPR vs. CPR 15:2. Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.

**Figure 2. Forest plots of risk ratio for favourable neurological outcome, ROSC and survival with CO-CPR vs. CPR 15:2. Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.**

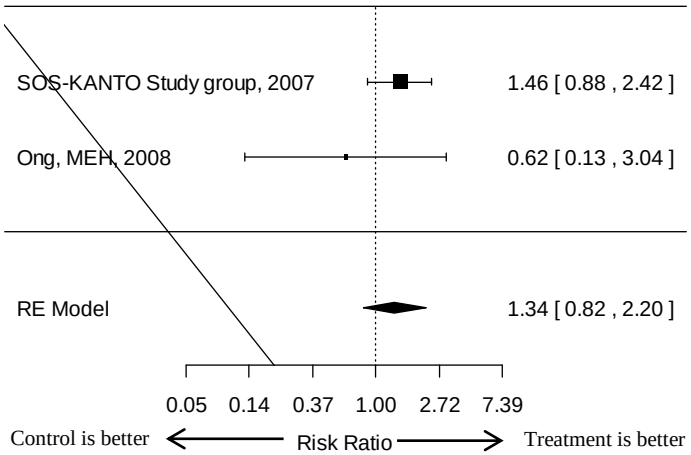


**Figure 2a.** Favourable neurological outcome estimates from cohort studies of bystander administered CPR in adult patients

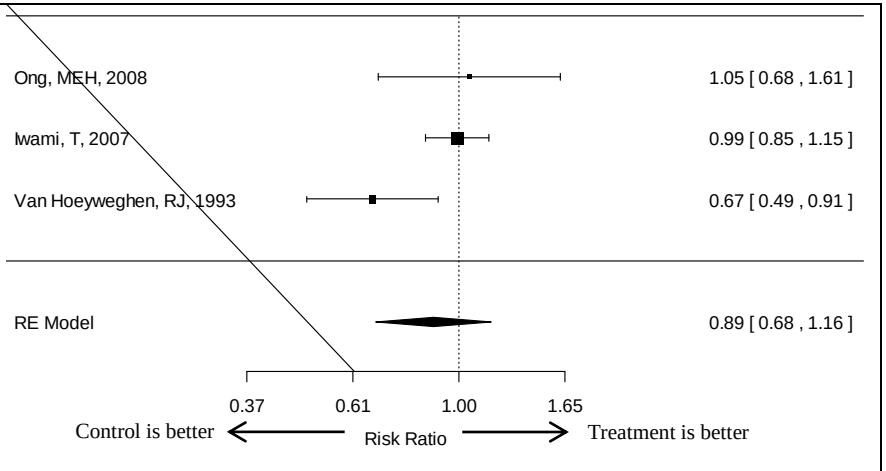


**Figure 2b.** ROSC outcome estimates from cohort studies of bystander administered CPR in adult patients

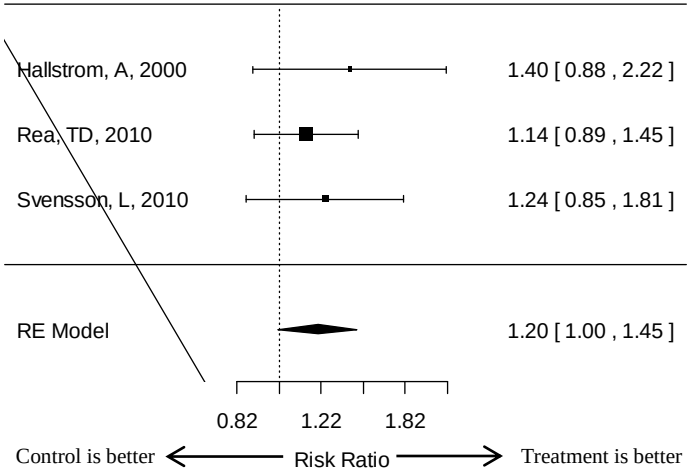


**Figure 2c.** Survival outcome estimates from RCT studies of dispatcher-instructed CPR in adult and mixed population patients

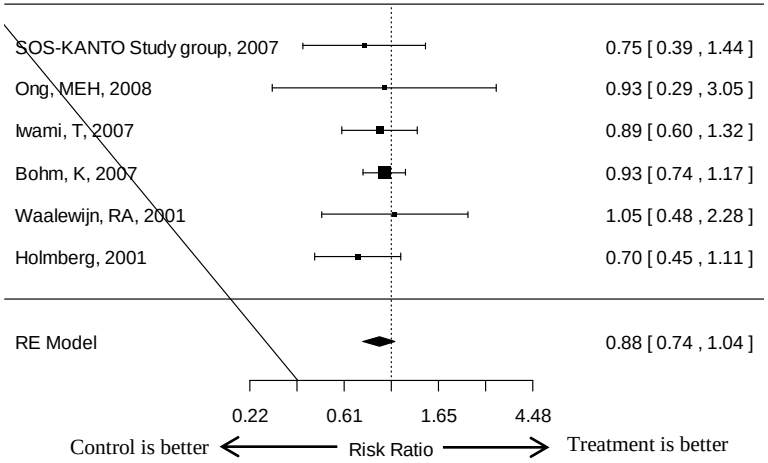


**Figure 2d**. Survival outcome estimates from cohort studies of bystander administered CPR in adult and mixed population patients

**Abbreviations:** CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; RCT – randomised controlled trial; RE – random effects; ROSC – return of spontaneous circulation

Figure 3. Forest plots of risk ratio for favourable neurological outcomes and survival with CO-CPR vs. CPR 15:2 or 30:2 Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.)

**Figure 3. Forest plots of risk ratio for favourable neurological outcome and survival with CO-CPR vs. CPR 15:2 or 30:2 Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.**

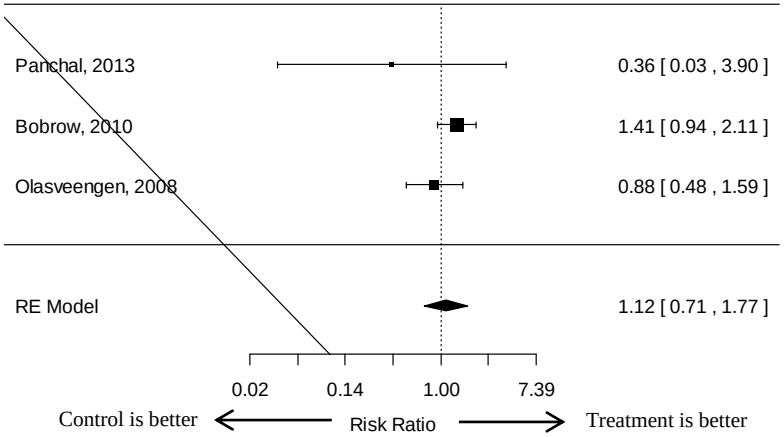


**Figure 3a.** Favourable neurological outcome estimates from cohort studies of bystander administered CPR in adult patients

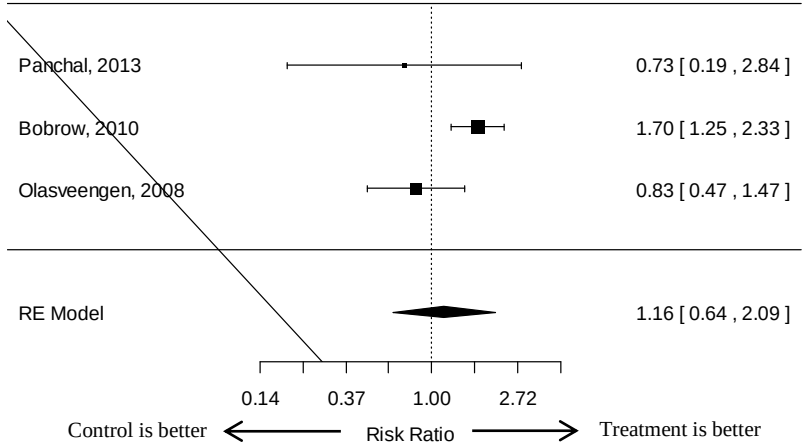


**Figure 3b.** Survival outcome estimates from cohort studies of bystander administered CPR in adult patients

**Abbreviations:** CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; RCT – randomised controlled trial; RE – random effects

Figure 4. Forest plots of risk ratio for favourable neurological outcomes, ROSC and survival with CPR 30:2 vs. CPR 15:2. Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.

**Figure 4. Forest plots of risk ratio for favourable neurological outcome, ROSC and survival with CPR 30:2 vs. CPR 15:2. Treatment effect is measured using risk ratio estimate (95% confidence interval), with values ≥1 indicating that treatment is more effective than control.**

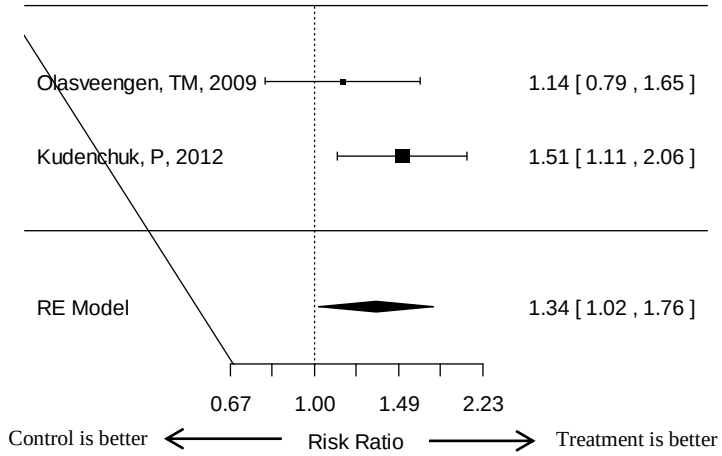


**Figure 4a.** Favourable neurological outcome estimates from cohort studies of EMS administered CPR in adult patients

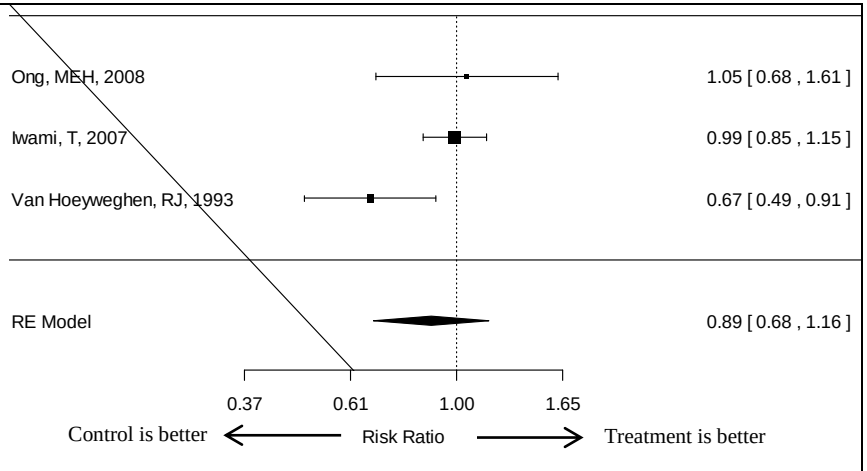


**Figure 4b**. ROSC outcome estimates from cohort studies of EMS administered CPR in adult patients

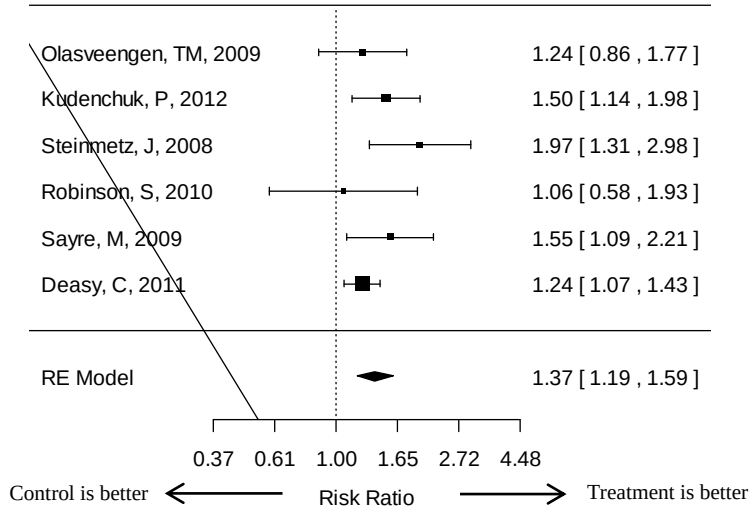


**Figure 4c.** Survival outcome estimates from cohort studies of EMS administered CPR in adult patients.

**Abbreviations:** CO-CPR – compression-only CPR; CPR – cardiopulmonary resuscitation; EMS – emergency medical service; RE – random; ROSC – return of spontaneous circulation