|  |
| --- |
| Question |
| **Should Head up CPR vs. standard CPR be used for cardiac arrest?** |
| **Population:** | Adults and children in any setting (in-hospital or out-of-hospital) with cardiac arrest  |
| **Intervention:** | Head-up CPR or Head-up CPR bundle (e.g., Head Up Position: HUP, Active Compression/Decompression: ACD, and the Impedance Threshold Device: ITD) |
| **Comparison:** | Standard or compression-only CPR in supine position  |
| **Main outcomes:** | Critical outcomes: Survival to hospital discharge with good neurological outcome, survival to hospital discharge, event survival, survival to 30 days, survival to 30 days with good neurological outcome Important outcome: Return of spontaneous circulation (ROSC) |
| **Setting:** | In-hospital and out-of-hospital setting |
| **Perspective:** |  |
| **Background:** |  |
| **Conflict of interests:** | The following Task Force members and other authors declared an intellectual conflict of interest, and this was acknowledged and managed by the Task Force Chairs and Conflict of Interest committees: Guillaume Debaty |

# Assessment

|  |
| --- |
| ProblemIs the problem a priority? |
| Judgement | Research evidence | Additional considerations |
| ○ No○ Probably no○ Probably yes● Yes○ Varies○ Don't know | Mortality after cardiac arrest remains high, and there is broad consensus that new treatments and strategies are needed.  |  |
| Desirable EffectsHow substantial are the desirable anticipated effects? |
| Judgement | Research evidence | Additional considerations |
| ○ Trivial○ Small○ Moderate○ Large○ Varies● Don't know | The systematic review search identified 375 studies, of which 15 studies were selected for full-text screening. There were three observational studies[[1]](#endnote-1),[[2]](#endnote-2),[[3]](#endnote-3) and no RCTs included. These three observational studies came from the same research initiative.The studies by Moore and Bachista obtained their Intervention patients from the same registry that included patients who received head-up CPR. This is referred to as the ACE (Automated Controlled Elevation)-CPR registry (2019-2020) in the Moore paper and as the AHUP (automated head/thorax-up positioning)-CPR registry (2019-2021) in the Bachista paper. To obtain their comparator patients, both studies utilized the large NIH-funded RCTs conducted approximately 10 years earlier: Moore drew from the ROC PRIMED study (conducted from 2007 to 2009) [[4]](#endnote-4), ROC ALPS study (conducted from 2012 to 2015)[[5]](#endnote-5), and ResQTrial (conducted from 2006 to 2009),[[6]](#endnote-6) while Bachista used the ROC PRIMED study and the ResQTrial. **Good Neurological Outcome and Survival to Hospital Discharge**For the critical outcomes of survival to hospital discharge with a good neurological outcome and survival to hospital discharge, we identified very-low-certainty evidence (downgraded for serious risk of bias) from three observational studies (Pepe, 2019; Moore, 2022; Bachista, 2024).1,2,3The observational study conducted by Pepe et al.1 included 2,322 adult out-of-hospital cardiac arrest patients. It compared outcomes before and after the introduction of the head-up / torso up chest compression technique. A bundle comprising the mechanical CPR device with an ITD was compared with a bundle comprising the former (mechanical CPR device with ITD) but with the addition of: 1. Applied oxygen with deferral of positive pressure ventilation for a few minutes (number of minutes not specified), 2. A pit crew approach for rapid placement of the mechanical CPR device and, 3. Placement of the patient in the reverse Trendelenburg position (20 degrees), with the specific time frame not clarified. Metrics such as average Emergency Medical Services (EMS) crew response intervals, relative frequency of ECG presentations, gender, and frequency of cases witnessed by bystanders were similar between groups. Details about survival with good neurological outcomes was limited to a mention that about 35–40% of those resuscitated ultimately achieved “intact neurologic status”, defined as “modified Rankin Score < 3” in both the pre- and post-intervention groups “wherever tracked”. Missing rates in both groups were unreported. The study by Moore et al. included 227 adult OHCA patients who received the head-up CPR bundle enrolled in the ACE-CPR registry from 2019 to 2020, and 5,196 adult OHCA patients who received conventional CPR with supine positioning enrolled in three RCTs conducted from 2005 to 2015 at high-performing pre-hospital systems in the United States.2 The study found no statistically significant difference for survival to hospital discharge between the head-up CPR group and the conventional CPR group (9.5% [21/222] vs. 6.7% [58/860], OR 1.44, 95% CI 0.86–2.44) or in survival to hospital discharge with favorable neurological status (5.9% [13/222] vs. 4.1% [35/860], OR 1.47, 95% CI 0.76–2.82). The odds ratio of cumulative survival to hospital discharge between conventional-CPR and head-up CPR groups, based on the time interval from the 9–1–1 emergency call to head-up CPR start after propensity-score matching, was 1.65 (95% CI 0.93-2.94) for < 20 mins and 0.82 (95% CI 0.23 – 2.97) for 20-38 mins, indicating no statistically significant difference. Similarly, the odds ratio of cumulative survival to hospital discharge with favourable neurological function between conventional-CPR and head-up CPR groups was 1.85 (95% CI 0.91-3.74) for < 20 mins and 0.42 (95% CI 0.05 – 3.39) for 20-38 mins, indicating no statistically significant difference.The study by Bachista et al. focused on patients with nonshockable rhythms and included 380 adult out-of-hospital nonshockable cardiac arrests who received the head-up CPR bundle in the AHUP-CPR registry, which is the same head-up CPR registry mentioned earlier.3 As a comparison group, the study included 1,852 adult out-of-hospital nonshockable cardiac arrests who received conventional CPR with supine positioning enrolled in two different RCTs in the United States. The study showed that the unadjusted likelihood of survival to hospital discharge in the head-up CPR group was 7.4% (28/380) versus 3.1% (58/1,852) in the conventional CPR group (OR 2.46, 95% CI 1.55–3.92), which remained higher after propensity score matching, 7.6% (27/353) in the head-up CPR group versus 2.8% (10/353) in the conventional CPR group (OR 2.84, 95% CI 1.35–5.96). The head-up CPR bundle was also associated with higher probabilities of survival with favorable neurological function (4.2% [15/353] vs. 1.1% [4/353]; OR 3.87, 95% CI 1.27–11.78).**ROSC**For the important outcome of ROSC, the observational study by Pepe et al. demonstrated an increased rate of successful resuscitation (defined as hospital arrival with sustained spontaneous circulation) from a mean of 17.87% (n = 806) to a mean of 34.22% (n = 1,356).The Moore study showed no statistically significant difference in the rate of ROSC between the head-up CPR group and the conventional CPR group (33% [74/222] vs. 33% [282/860], OR 1.02, 95% CI 0.75–1.49).The Bachista study indicated that ROSC rates were not statistically different between the head-UP CPR group and the conventional CPR group in unadjusted analyses (33% [125/380] vs. 29% [535/1,852], OR 1.21, 95% CI 0.95–1.53), nor in adjusted analyses with propensity score matching (33% [118/353] vs. 29% [101/353], OR 1.25, 95% CI 0.91–1.72). |  |
| Undesirable EffectsHow substantial are the undesirable anticipated effects? |
| Judgement | Research evidence | Additional considerations |
| ○ Large○ Moderate○ Small○ Trivial○ Varies● Don't know | In an observational study (December 31, 2021), there was no observed safety/complication issues reported in 965 OHCA patients who received head-up CPR from 11 EMS systems in the United States.3  |  |
| Certainty of evidenceWhat is the overall certainty of the evidence of effects? |
| Judgement | Research evidence | Additional considerations |
| ● Very low○ Low○ Moderate○ High○ No included studies | This topic was prioritized by the BLS Task Force based on new observational studies since our previous systematic review in 2021.[[7]](#endnote-7) In this systematic review, we identified very low certainty evidence that the head-up CPR bundle is associated with better survival and neurological outcomes.Head-up CPR is a newer resuscitation strategy, first described in 2014, that involves gradual elevation of the head after CPR has been initiated, to improve cerebral perfusion, coronary perfusion, and possibly ventilation during CPR.[[8]](#endnote-8),[[9]](#endnote-9) Although the intervention may sound simple, previous studies have suggested that it is more complex than initially thought.[[10]](#endnote-10) Animal studies have indicated that head-up CPR is most effective when used with ACD and ITD, as there is inadequate arterial pressure to create upward flow and achieve cerebral perfusion pressure in the absence of these devices.[[11]](#endnote-11),[[12]](#endnote-12),[[13]](#endnote-13) Based on these findings, head-up CPR is often performed as part of a bundled approach, including the use of ACD and ITD devices.1,2,3,[[14]](#endnote-14)The BLS Task Force recognized that the currently available evidence is still limited, highlighted by the absence of RCTs or observational studies with adequate comparisons. The implementation of the studied head-up CPR bundle requires the purchase of expensive equipment, which includes an automated head/thorax-up positioning device, a mechanical CPR device, and an ITD, as well as significant training. The task force concluded that there is not sufficient clinical evidence to support the use of head-up CPR or head-up CPR bundle during CPR except in the setting of clinical trials or research initiatives. The task force identified several distinct methods in the studies reviewed. Although the bundle approach that includes head-up position with automated head/thorax-up positioning device, ACD, and ITD has been adopted by certain EMS agencies in the United States, the systematic review did not find clinical evidence supporting a particular bundle approach or indicating that the sole use of head-up elevation is superior to other bundles. For example, a pilot study conducted by Kim et al. in Korea in 2022, which lacked a comparison group, described a method that used a 15 cm high wedge on the bed to raise the head approximately 15 cm without elevating the chest while using a mechanical CPR device but no other devices.[[15]](#endnote-15) The study indicated that 4 (14.3%) patients who received head-up CPR survived to hospital admission, 1 (3.6%) survived to discharge, and 1 (3.6%) had neurologically intact survival at discharge. The aforementioned study by Pepe et al.1 described a head-up CPR method in which a scoop stretcher was used to elevate the head and torso by placing a hard case toward the top of the stretcher with a mechanical CPR device attached to the scoop stretcher. This approach differs from the newer head-up CPR bundle, which uses an automated head/thorax-up positioning device rather than a stretcher. The best approach (e.g., angle, use of other devices) needs to be determined in future research.Timing of the head elevation might be an important factor. Animal studies suggest that the greatest cerebral perfusion pressure is achieved with a 2-minute priming period in a flat position, followed by gradual elevation of the head and thorax over an additional 2 minutes when combined with the use of ACD and ITD.[[16]](#endnote-16),[[17]](#endnote-17) An observational study conducted by Moore et al. focusing on the impact of time to deployment of the head-up CPR bundle, showed that faster deployment was associated with a higher incidence of ROSC.[[18]](#endnote-18) This study, along with previous animal studies, suggests that faster deployment is associated with better neurological outcomes. However, clinical studies on this topic are limited, and the BLS Task Force does not find the current evidence sufficient to make a specific recommendation on this matter. |  |
| ValuesIs there important uncertainty about or variability in how much people value the main outcomes? |
| Judgement | Research evidence | Additional considerations |
| ○ Important uncertainty or variability○ Possibly important uncertainty or variability○ Probably no important uncertainty or variability● No important uncertainty or variability | There is no important uncertainty about how much people value improving survival after cardiac arrest.  |  |
| Balance of effectsDoes the balance between desirable and undesirable effects favor the intervention or the comparison? |
| Judgement | Research evidence | Additional considerations |
| ○ Favors the comparison○ Probably favors the comparison○ Does not favor either the intervention or the comparison○ Probably favors the intervention○ Favors the intervention○ Varies● Don't know | As both desirable and undesirable effects are very uncertain, balancing them is not really possible.  |  |
| Resources requiredHow large are the resource requirements (costs)? |
| Judgement | Research evidence | Additional considerations |
| ● Large costs○ Moderate costs○ Negligible costs and savings○ Moderate savings○ Large savings○ Varies○ Don't know | Implementation of the most studied head-up CPR bundle (HUP, ACD, and ITD) requires the purchase of expensive equipment, including an automated head/thorax-up positioning device, a mechanical CPR device, and an impedance threshold device. It also necessitates a substantial amount of education and training both in the use of this equipment and in the deployment of head-up CPR itself. |  |
| Certainty of evidence of required resourcesWhat is the certainty of the evidence of resource requirements (costs)? |
| Judgement | Research evidence | Additional considerations |
| ○ Very low○ Low○ Moderate○ High● No included studies | The cost of an automated head/thorax-up positioning device, a mechanical CPR device, and an impedance threshold device are significant when implemented in resuscitation systems, as is the cost of training and education. There are no important uncertainties regarding the required cost/resources.  |  |
| Cost effectivenessDoes the cost-effectiveness of the intervention favor the intervention or the comparison? |
| Judgement | Research evidence | Additional considerations |
| ○ Favors the comparison○ Probably favors the comparison○ Does not favor either the intervention or the comparison○ Probably favors the intervention○ Favors the intervention○ Varies● No included studies | The reported better short- and long-term outcomes at certain EMS agencies in the United States are encouraging. If the outcomes are generalizable to other resuscitation systems, the intervention might be cost-effective. However, there is not enough evidence to determine the effectiveness of head-up CPR, and no evidence assessing its cost-effectiveness. |  |
| EquityWhat would be the impact on health equity? |
| Judgement | Research evidence | Additional considerations |
| ○ Reduced●Probably reduced○ Probably no impact○ Probably increased○ Increased○ Varies○ Don't know | As the strategy requires expensive equipment, health equity would likely be negatively impacted.  |  |
| AcceptabilityIs the intervention acceptable to key stakeholders? |
| Judgement | Research evidence | Additional considerations |
| ○ No● Probably no○ Probably yes○ Yes○ Varies○ Don't know | Due to the significant cost of implementation and absence of RCTs or observational studies with adequate comparisons, it is unlikely to be an acceptable strategy for key stakeholders. The Basic Life Support Task Force does not find the current evidence sufficient to recommend routine use of this strategy and encourages further research before its clinical deployment.  |  |
| FeasibilityIs the intervention feasible to implement? |
| Judgement | Research evidence | Additional considerations |
| ○ No○ Probably no○ Probably yes○ Yes○ Varies● Don't know | The bundle approach that includes head-up position with automated head/thorax-up positioning device, ACD, and ITD has been adopted by certain EMS agencies in the United States, however, the feasibility of broader implementation is not known.  |  |

# Summary of judgements

|  | **Judgement** |
| --- | --- |
| **Problem** | No | Probably no | Probably yes | **Yes** |  | Varies | Don't know |
| **Desirable Effects** | Trivial | Small | Moderate | Large |  | Varies | **Don't know** |
| **Undesirable Effects** | Large | Moderate | Small | Trivial |  | Varies | **Don't know** |
| **Certainty of evidence** | **Very low** | Low | Moderate | High |  |  | **No included studies** |
| **Values** | Important uncertainty or variability | Possibly important uncertainty or variability | Probably no important uncertainty or variability | **No important uncertainty or variability** |  |  |  |
| **Balance of effects** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **Don't know** |
| **Resources required** | **Large costs** | Moderate costs | Negligible costs and savings | Moderate savings | Large savings | Varies | Don't know |
| **Certainty of evidence of required resources** | Very low | Low | Moderate | High |  |  | **No included studies** |
| **Cost effectiveness** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **No included studies** |
| **Equity** | Reduced | **Probably reduced** | Probably no impact | Probably increased | Increased | Varies | Don't know |
| **Acceptability** | No | **Probably no** | Probably yes | Yes |  | Varies | Don't know |
| **Feasibility** | No | Probably no | Probably yes | Yes |  | Varies | **Don't know** |

# Type of recommendation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Strong recommendation against the intervention | **Conditional recommendation against the intervention** | Conditional recommendation for either the intervention or the comparison | Conditional recommendation for the intervention | Strong recommendation for the intervention |
| ○  | **●**  | ○  | ○  | ○  |

# Conclusions

|  |
| --- |
| Recommendation |
| The treatment recommendation remains unchanged from 2021:We suggest against the routine use of head-up CPR during CPR (weak recommendation, very-low-certainty evidence).We suggest that the usefulness of head-up CPR during CPR be assessed in clinical trials or research initiatives (weak recommendation, very-low-certainty evidence). |
|  |

|  |
| --- |
| Justification |
| This topic was prioritized by the BLS Task Force based on new observational studies since our previous systematic review in 2021.7 In this systematic review, we identified very low certainty evidence that the head-up CPR bundle is associated with better survival and neurological outcomes.Head-up CPR is a newer resuscitation strategy, first described in 2014, that involves gradual elevation of the head after CPR has been initiated, to improve cerebral perfusion, coronary perfusion, and possibly ventilation during CPR.8,9 Although the intervention may sound simple, previous studies have suggested that it is more complex than initially thought.10 Animal studies have indicated that head-up CPR is most effective when used with ACD and ITD, as there is inadequate arterial pressure to create upward flow and achieve cerebral perfusion pressure in the absence of these devices.11,12,13 Based on these findings, head-up CPR is often performed as part of a bundled approach, including the use of ACD and ITD devices.1,2,3,14The BLS Task Force recognized that the currently available evidence is still limited, highlighted by the absence of RCTs or observational studies with adequate comparisons. The implementation of the studied head-up CPR bundle requires the purchase of expensive equipment, which includes an automated head/thorax-up positioning device, a mechanical CPR device, and an ITD, as well as significant training. The task force concluded that there is not sufficient clinical evidence to support the use of head-up CPR or head-up CPR bundle during CPR except in the setting of clinical trials or research initiatives. The task force identified several distinct methods in the studies reviewed. Although the bundle approach that includes head-up position with automated head/thorax-up positioning device, ACD, and ITD has been adopted by certain EMS agencies in the United States, the systematic review did not find clinical evidence supporting a particular bundle approach or indicating that the sole use of head-up elevation is superior to other bundles. For example, a pilot study conducted by Kim et al. in Korea in 2022, which lacked a comparison group, described a method that used a 15 cm high wedge on the bed to raise the head approximately 15 cm without elevating the chest while using a mechanical CPR device but no other devices.14 The study indicated that 4 (14.3%) patients who received head-up CPR survived to hospital admission, 1 (3.6%) survived to discharge, and 1 (3.6%) had neurologically intact survival at discharge. The aforementioned study by Pepe et al.1 described a head-up CPR method in which a scoop stretcher was used to elevate the head and torso by placing a hard case toward the top of the stretcher with a mechanical CPR device attached to the scoop stretcher. This approach differs from the newer head-up CPR bundle, which uses an automated head/thorax-up positioning device rather than a stretcher. The best approach (e.g., angle, use of other devices) needs to be determined in future research.Timing of the head elevation might be an important factor. Animal studies suggest that the greatest cerebral perfusion pressure is achieved with a 2-minute priming period in a flat position, followed by gradual elevation of the head and thorax over an additional 2 minutes when combined with the use of ACD and ITD.15,16 An observational study conducted by Moore et al. focusing on the impact of time to deployment of the head-up CPR bundle, showed that faster deployment was associated with a higher incidence of ROSC.17 This study, along with previous animal studies, suggests that faster deployment is associated with better neurological outcomes. However, clinical studies on this topic are limited, and the BLS Task Force does not find the current evidence sufficient to make a specific recommendation on this matter. |

|  |
| --- |
| Subgroup considerations |
| We initially considered performing a subgroup analysis focused on initial cardiac rhythms (i.e., cardiac arrest with shockable versus non-shockable rhythms); however, the limited number of studies (three), two of which came from the same registry, did not allow for such an analysis. |

|  |
| --- |
| Implementation considerations |
| As above |

|  |
| --- |
| Monitoring and evaluation |
| As above |

|  |
| --- |
| Research priorities |
| 1. We found there was no RCT that evaluated the effect of head-up CPR or head-up CPR bundle.
2. Head-up CPR has mainly been evaluated as a bundle with mechanical CPR with ACD and the use of an ITD.
3. The optimal approach—such as the angle and timing of head elevation—if head-up CPR proves to be beneficial, still needs to be determined in the future.
 |

References:

1. Pepe PE, Scheppke KA, Antevy PM, Crowe RP, Millstone D, Coyle C, Prusansky C, Garay S, Ellis R, Fowler RL, Moore JC. Confirming the Clinical Safety and Feasibility of a Bundled Methodology to Improve Cardiopulmonary Resuscitation Involving a Head-Up/Torso-Up Chest Compression Technique. Crit Care Med. 2019 Mar;47(3):449-455. doi: 10.1097/CCM.0000000000003608. PMID: 30768501; PMCID: PMC6407820. [↑](#endnote-ref-1)
2. Moore JC, Pepe PE, Scheppke KA, Lick C, Duval S, Holley J, Salverda B, Jacobs M, Nystrom P, Quinn R, Adams PJ, Hutchison M, Mason C, Martinez E, Mason S, Clift A, Antevy PM, Coyle C, Grizzard E, Garay S, Crowe RP, Lurie KG, Debaty GP, Labarère J. Head and thorax elevation during cardiopulmonary resuscitation using circulatory adjuncts is associated with improved survival. Resuscitation. 2022 Oct;179:9-17. doi: 10.1016/j.resuscitation.2022.07.039. Epub 2022 Aug 4. PMID: 35933057. [↑](#endnote-ref-2)
3. Bachista KM, Moore JC, Labarère J, Crowe RP, Emanuelson LD, Lick CJ, Debaty GP, Holley JE, Quinn RP, Scheppke KA, Pepe PE. Survival for Nonshockable Cardiac Arrests Treated With Noninvasive Circulatory Adjuncts and Head/Thorax Elevation. Crit Care Med. 2024 Feb 1;52(2):170-181. doi: 10.1097/CCM.0000000000006055. Epub 2024 Jan 19. PMID: 38240504. [↑](#endnote-ref-3)
4. Aufderheide TP, Nichol G, Rea TD, Brown SP, Leroux BG, Pepe PE, Kudenchuk PJ, Christenson J, Daya MR, Dorian P, Callaway CW, Idris AH, Andrusiek D, Stephens SW, Hostler D, Davis DP, Dunford JV, Pirrallo RG, Stiell IG, Clement CM, Craig A, Van Ottingham L, Schmidt TA, Wang HE, Weisfeldt ML, Ornato JP, Sopko G; Resuscitation Outcomes Consortium (ROC) Investigators. A trial of an impedance threshold device in out-of-hospital cardiac arrest. N Engl J Med. 2011 Sep 1;365(9):798-806. doi: 10.1056/NEJMoa1010821. PMID: 21879897; PMCID: PMC3204381. [↑](#endnote-ref-4)
5. Kudenchuk PJ, Brown SP, Daya M, Rea T, Nichol G, Morrison LJ, Leroux B, Vaillancourt C, Wittwer L, Callaway CW, Christenson J, Egan D, Ornato JP, Weisfeldt ML, Stiell IG, Idris AH, Aufderheide TP, Dunford JV, Colella MR, Vilke GM, Brienza AM, Desvigne-Nickens P, Gray PC, Gray R, Seals N, Straight R, Dorian P; Resuscitation Outcomes Consortium Investigators. Amiodarone, Lidocaine, or Placebo in Out-of-Hospital Cardiac Arrest. N Engl J Med. 2016 May 5;374(18):1711-22. doi: 10.1056/NEJMoa1514204. Epub 2016 Apr 4. PMID: 27043165. [↑](#endnote-ref-5)
6. Aufderheide TP, Frascone RJ, Wayne MA, Mahoney BD, Swor RA, Domeier RM, Olinger ML, Holcomb RG, Tupper DE, Yannopoulos D, Lurie KG. Standard cardiopulmonary resuscitation versus active compression-decompression cardiopulmonary resuscitation with augmentation of negative intrathoracic pressure for out-of-hospital cardiac arrest: a randomised trial. Lancet. 2011 Jan 22;377(9762):301-11. doi: 10.1016/S0140-6736(10)62103-4. PMID: 21251705; PMCID: PMC3057398. [↑](#endnote-ref-6)
7. Wyckoff MH, Singletary EM, Soar J, Olasveengen TM, et al. 2021 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Neonatal Life Support; Education, Implementation, and Teams; First Aid Task Forces; and the COVID-19 Working Group. Resuscitation. 2021 Dec;169:229-311. doi: 10.1016/j.resuscitation.2021.10.040. Epub 2021 Nov 11. PMID: 34933747; PMCID: PMC8581280. [↑](#endnote-ref-7)
8. Debaty G, Shin SD, Metzger A, Ryu HH, Kim T, Rees J, McKnite S, Matsuura T, Lick M, Yannopoulos D, Lurie KG. Gravity-Assisted Head-up Cardiopulmonary Resuscitation Improves Cerebral Blood Flow and Perfusion Pressures in a Porcine Model of Cardiac Arrest. Circulation. 2014 Nov 25;130(suppl\_2):A88-. [↑](#endnote-ref-8)
9. Debaty G, Shin SD, Metzger A, Kim T, Ryu HH, Rees J, McKnite S, Matsuura T, Lick M, Yannopoulos D, Lurie K. Tilting for perfusion: head-up position during cardiopulmonary resuscitation improves brain flow in a porcine model of cardiac arrest. Resuscitation. 2015 Feb;87:38-43. doi: 10.1016/j.resuscitation.2014.11.019. Epub 2014 Nov 28. PMID: 25447353. [↑](#endnote-ref-9)
10. Segal N. Dissecting CPR. Resuscitation. 2024 Jan;194:110100. doi: 10.1016/j.resuscitation.2023.110100. Epub 2023 Dec 23. PMID: 38145717. [↑](#endnote-ref-10)
11. Putzer G, Braun P, Martini J, Niederstätter I, Abram J, Lindner AK, Neururer S, Mulino M, Glodny B, Helbok R, Mair P. Effects of head-up vs. supine CPR on cerebral oxygenation and cerebral metabolism - a prospective, randomized porcine study. Resuscitation. 2018 Jul;128:51-55. doi: 10.1016/j.resuscitation.2018.04.038. Epub 2018 May 1. PMID: 29727706. [↑](#endnote-ref-11)
12. Ryu HH, Moore JC, Yannopoulos D, Lick M, McKnite S, Shin SD, Kim TY, Metzger A, Rees J, Tsangaris A, Debaty G, Lurie KG. The Effect of Head Up Cardiopulmonary Resuscitation on Cerebral and Systemic Hemodynamics. Resuscitation. 2016 May;102:29-34. doi: 10.1016/j.resuscitation.2016.01.033. Epub 2016 Feb 22. PMID: 26905388. [↑](#endnote-ref-12)
13. Moore JC, Holley J, Segal N, Lick MC, Labarère J, Frascone RJ, Dodd KW, Robinson AE, Lick C, Klein L, Ashton A, McArthur A, Tsangaris A, Makaretz A, Makaretz M, Debaty G, Pepe PE, Lurie KG. Consistent head up cardiopulmonary resuscitation haemodynamics are observed across porcine and human cadaver translational models. Resuscitation. 2018 Nov;132:133-139. doi: 10.1016/j.resuscitation.2018.04.009. Epub 2018 Apr 24. PMID: 29702188. [↑](#endnote-ref-13)
14. Moore JC. Head-up cardiopulmonary resuscitation. Curr Opin Crit Care. 2023 Jun 1;29(3):155-161. doi: 10.1097/MCC.0000000000001037. Epub 2023 Mar 20. PMID: 37078637. [↑](#endnote-ref-14)
15. Kim DW, Choi JK, Won SH, Yun YJ, Jo YH, Park SM, Lee DK, Jang DH. A new variant position of head-up CPR may be associated with improvement in the measurements of cranial near-infrared spectroscopy suggestive of an increase in cerebral blood flow in non-traumatic out-of-hospital cardiac arrest patients: A prospective interventional pilot study. Resuscitation. 2022 Jun;175:159-166. doi: 10.1016/j.resuscitation.2022.03.032. Epub 2022 Apr 5. PMID: 35395338. [↑](#endnote-ref-15)
16. Moore JC, Salverda B, Lick M, Rojas-Salvador C, Segal N, Debaty G, Lurie KG. Controlled progressive elevation rather than an optimal angle maximizes cerebral perfusion pressure during head up CPR in a swine model of cardiac arrest. Resuscitation. 2020 May;150:23-28. doi: 10.1016/j.resuscitation.2020.02.023. Epub 2020 Feb 27. PMID: 32114071; PMCID: PMC7709734. [↑](#endnote-ref-16)
17. Rojas-Salvador C, Moore JC, Salverda B, Lick M, Debaty G, Lurie KG. Effect of controlled sequential elevation timing of the head and thorax during cardiopulmonary resuscitation on cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2020 Apr;149:162-169. doi: 10.1016/j.resuscitation.2019.12.011. Epub 2020 Jan 21. PMID: 31972229; PMCID: PMC9358682. [↑](#endnote-ref-17)
18. Moore JC, Duval S, Lick C, Holley J, Scheppke KA, Salverda B, Rojas-Salvador C, Jacobs M, Nystrom P, Quinn R, Adams PJ, Debaty GP, Hutchison M, Mason C, Martinez E, Mason S, Clift A, Antevy P, Coyle C, Grizzard E, Garay S, Lurie KG, Pepe PE. Faster time to automated elevation of the head and thorax during cardiopulmonary resuscitation increases the probability of return of spontaneous circulation. Resuscitation. 2022 Jan;170:63-69. doi: 10.1016/j.resuscitation.2021.11.008. Epub 2021 Nov 15. PMID: 34793874. [↑](#endnote-ref-18)