

ANNOTATED BIBLIOGRAPHY

This annotated bibliography provides an overview of current publications related to Elevated CPR™, often reported in the literature as ‘Head Up CPR’ or ‘gravity assisted CPR.’ It includes current research, commentary, and publications important to understanding the direct benefit and physiology of Elevated CPR, other key topics surrounding Elevated CPR, as well as publications reporting no benefit from Elevated CPR.

The following abbreviations are used throughout this document:

HUP: Head Up Position, **SUP:** Supine Position, **CPR:** Cardiopulmonary Resuscitation, **VF:** Ventricular Fibrillation, **S-CPR:** Standard CPR, **ACD:** Active Compression Decompression, **ITD:** Impedance Threshold Device, **CerPP:** Cerebral Perfusion Pressure, **CorPP:** Coronary Perfusion Pressure, **ICP:** Intracranial Pressure, **BLS:** Basic Life Support

I. Physiology and Benefits of Elevated CPR

1. Debaty G, Shin S, Metzger A, Kim T, Ryu HH, Rees J, et al. Tilting for perfusion: head-up position during cardiopulmonary resuscitation improves brain flow in a porcine model of cardiac arrest. Resuscitation. 2015;87(2015):38-43.

First research article published (first published online in 2014) comparing results of supine, whole body 30° head down or whole body 30° HUP CPR. Found that CPR performed with the LUCAS device, ITD, and HUP provides better CerPP, oxygenation, and cerebral blood flow compared to supine or whole body 30° head down.

2. Erich J. Heads-Up CPR: Can Elevating the Patient’s Head Improve Outcomes? EMSWorld. 2015 (August):22-28.

EMS article introducing concept to prehospital providers including highlighting early success of Palm Beach County with bundled care of HUP, ITD, ACD-CPR. PBC uses a Pelican case to create a whole body tilt. Authors and researchers caution this full body tilt method because of possible dependent pooling in the lower extremities with prolonged resuscitation.

3. Pepe P, Scheppke K, Antevy P, Coyle C, Millstone D, Moore J. Impact of head/ torso-up chest compressions and flow-oriented CPR adjuncts on survival [Abstract]. Critical Care Medicine. 2016;44(12 Supp):284.

Research abstract that highlights Palm Beach County Fire Rescue's improved survival after implementing new protocols that include HUP CPR. This agency took early research on HUP CPR and applied it with other tested methods resulting in a doubling of survival to hospital.

4. Ryu H, Moore J, Yannopoulos D, Lick M, McKnite S, Shin SD, et al. The Effect of Head Up Cardiopulmonary Resuscitation on Cerebral and Systemic Hemodynamics. Resuscitation. 2016;102:29-34.

Research showed that elevating head and shoulders during prolonged HUP ACD+ITD CPR but not during prolonged conventional standard CPR improves cerebral and coronary perfusion.

5. Kim T, Shin SD, Song KJ, Park YJ, Ryu HH, Debaty G, et al. The effect of resuscitation position on cerebral and coronary perfusion pressure during mechanical cardiopulmonary resuscitation in porcine cardiac arrest model. Resuscitation. 2017; 113:101-107. doi: <https://doi.org/10.1016/j.resuscitation.2017.02.008>.

Examines both cerebral and coronary blood flow for supine, head up, and head down positions at various angles initially to optimize resuscitation. Found that HUP 30 degrees optimizes cerebral and coronary perfusion in this porcine model using LUCAS 2 and ITD.

6. Moore J, Segal N, Lick M, Dodd K, et al. Head and thorax elevation during active compression decompression cardiopulmonary resuscitation with an impedance threshold device improves cerebral perfusion in a swine model of prolonged cardiac arrest. Resuscitation. 2017;2017(121):195-200. doi: <http://dx.doi.org/10.1016/j.resuscitation.2017.07.033>.

Research uses microspheres to measure blood flow to brain and other organs during prolonged (greater than 15 minutes) SUP and HUP ACD+ITD CPR. Showed doubling of blood flow to brain with HUP ACD+ITD CPR (head and shoulders raised) versus SUP CPR. Time to first gasp was also found to be shorter in the HUP ACD+ITD group. Gaspings may be used as a clinical indicator of improved blood flow to the brain.

7. Powell J, Dearden, K, Grayson, S. Rialto's Resuscitation Toolkit. Journal of Emergency Medical Services. 2017 (December):28-34.

Prehospital journal article highlighting the bundle of care including HUP CPR and ITD used by Rialto California EMS to double survival rates in their community.

8. Moore J, Holley J, Segal N, Lick M. et al. Consistent head up cardiopulmonary resuscitation haemodynamics are observed across porcine and human cadaver translational models. Resuscitation. 2018; 132: 133-139. <https://doi.org/10.1016/j.resuscitation.2018.04.009>

This research developed and validated a human cadaver model to assess the physiology of HUP CPR. It shows consistent, reproducible and significant decreases in ICP and rise in CerPP with HUP CPR across the VF porcine model, cadaveric porcine model and human cadaveric model. Standard and ACD CPR plus an ITD were studied in all three models.

9. Moore J Salveda B, Lick M, Rojas-Salvador C, Debaty G, Segal N, Lurie K. Controlled progressive elevation maximizes cerebral perfusion pressure during head up CPR in swine model of cardiac arrest [Abstract]. Circulation. 2018;138(Supplement2):A17.

Abstract presented at American Heart Association 2018 Resuscitation Science Symposium. Scientific evidence showing that controlled, progressive elevation of head and thorax during resuscitation is key to this therapy.

10. Rojas-Salvador C, Moore J, Salveda B, Debaty G, Lick M, Lurie K. Controlled Head and Upper Thorax Elevation Improves Cerebral Perfusion Pressure during Active Compression-Decompression Cardiopulmonary Resuscitation with an Impedance Threshold Device in a Porcine Model of Cardiac Arrest. Poster presented at: National Association of EMS Physicians; Austin, TX 2019.

Poster presenting evidence for improved CerPP and CorPP to >70% of baseline during a prolonged resuscitation with controlled lifting sequence of head and thorax over 2 minutes. These gains were maintained over 19 minutes demonstrating the unique clinical advantage of the combination of ACD/ ITD and sequential elevation of the head and thorax.

II. Key Topics Related to Elevated CPR

1. Lurie K, Nemergut E, Yannopoulos D, Sweeney M. The Physiology of Cardiopulmonary Resuscitation [Review Article]. *Anesthesia & Analgesia*. 2016;122(3):767-783.

Comprehensive review of the physiology of resuscitation. Discusses components of S-CPR, identifying common errors and limitations. Introduces improvements to S-CPR with good technique and technology including use of the ITD, ACD, and HUP.

2. Debaty G, Labarere J, Frascone RJ, Wayne M, et al. Long-Term Prognostic Value of Gasping During Out-of-Hospital Cardiac Arrest. *Journal of the American College of Cardiology*, Sep2017. 2017:2017. doi: <http://dx.doi.org/10.1016/j.jacc.2017.07.782>

Multicenter, randomized, controlled study. Examined prognostic value of gasping during cardiac arrest. Found that gasping during cardiac arrest, regardless of presenting rhythm, was associated with positive 1-year survival with good neurological outcome.

3. Lurie K, Levy M, Swor R, Moore J. The economic impact of out-of-hospital cardiac arrest. *Journal of Emergency Medical Services*. 2017 (December):10-16.

Using a formula similar to that for the economic burden of motor vehicle deaths, the cost of OHCA was assessed. Examining both direct and indirect cost to society they show the cost benefit of improving OHCA care.

4. Segal N, Youngquist S, Lurie K. Ideal (i)CPR: Looking beyond the shadows in the cave. *Resuscitation*. 2017;121:81-82. doi: <https://doi.org/10.1016/j.resuscitation.2017.10.009>.

Commentary emphasizing need for bundled care approach to a multimodal problem. Likens cardiac arrest care to care of any other complex disease. Both require new approaches, advanced technology and pharmacology that individually offer limited gains, but together have an exponential effect on outcomes.

III. Editorials, Commentaries and Special Reports: Including Those Showing No Benefit of Elevated CPR

1. Wesley K, Wesley K. Tilt Angle Significantly Affects CPR [Editorial]. Journal of Emergency Medical Services. 2015;40(3).

EMS commentary on Debaty (2015) research as it applies to EMS. Presents HUP CPR as a simple, novel approach that should be considered for incorporation into EMS protocols.

2. Park Y, Shin S, Song K, Lee K, Hong K, Ro Y. Abstract 1834I: Worsened Survival With Head-up Positional Cardiopulmonary Resuscitation in a Porcine Cardiac Arrest Model. [Report]. Circulation. 2017 November 11, 2016.;134(Suppl_1).

Published only as an abstract to date. Used a model of HUP CPR with a whole body tilt with poor outcomes. Highlights potential safety issues when HUP CPR is performed incorrectly. Shows that HUP CPR is ineffective unless circulatory enhancers such as the ITD and/ or ACD CPR are used concurrently.

3. Putzer G, Braun P, Martini J, Niederstatter I. et al. Effects of head-up vs. supine CPR on cerebral oxygenation and cerebral metabolism – a prospective, randomized porcine study. Resuscitation. 2018;2018(128):51-55.

Researchers aimed to study the effect of head elevation in BLS CPR. The study definition of BLS does NOT include the use of an ITD for circulatory support. Study concluded that although HUP CPR decreased ICP and improved CerPP, it did not improve cerebral oxygenation. These findings are similar to work of Ryu et al (referenced above) showing that HUP CPR is *not* effective unless circulatory enhancers such as the ITD and/ or ACD CPR are used currently. Commentaries to this article are listed below.

4. Moore J, Segal N, Debaty G, Lurie K. "The Do's and Don'ts" of Head Up CPR: Lessons learned from the Animal Laboratory [Letter to the editor]. Resuscitation. 2018; 2018(129):e6-e7.
doi.org/10.1016/j.resuscitation.2018.05.023

Putzer G, Martini J, Helbok R, Mair P. Reply to "The Do's and Don'ts" of Head Up CPR: Lessons learned from the Animal Laboratory [Letter to the Editor]. Resuscitation. 2018; 2018(129):e8.
[doi:10.1016/j.resuscitation.2018.06.006](https://doi.org/10.1016/j.resuscitation.2018.06.006).

Commentaries on 2018 Putzer et al article in Resuscitation. Moore describes what is required for successful HeadUP CPR and what should and should not be done to get the benefit from this new approach. Moore suggests that lack of ITD therapy in the Putzer study could be a critical compounding factor for the neutral finding of improved CerPP without improved cerebral oxygenation. Putzer rebuts that CerPP should not be the only measure and does concede that a bundled care approach to cardiac arrest is necessary especially in light of emerging technologies.

5. Strobos, NC. Debunking another CPR myth: Lay the patient flat, or head up CPR? [Editorial]. Resuscitation. 2018;132:A1-A2.
<https://doi.org/10.1016/j.resuscitation.2018.07.010>

Editorial addressing study by Moore, et al. in the same issue of Resuscitation. Strobos recognized that the traditional approach of "lay the patient flat" may be wrong and credits Moore et al. for "Debunking another CPR myth." She discusses the challenges of translating CPR research to cadavers. Strobos further recognizes that HUP CPR is more than just raising the head during resuscitation. She notes this should not be done cavalierly. It is only beneficial when combined with ACD CPR and ITD in a complete device-assisted head up CPR manner.

6. Shaw G. Is a 'Golden Age' of resuscitation on the horizon [Special Report]. Emergency Medicine News. 2018; November:18-19.

Discusses recent advances that point toward the changing horizon of resuscitation including prognostic indicators, CPR training and techniques such as extracorporeal membrane oxygenation and head up positioning and resuscitation end-point decision making.