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ANNOTATED BIBLIOGRAPHY

This annotated bibliography provides an overview of current publications related to the ElevatedCPR® Method, often reported in the literature as 'Elevated CPR,' 'Head Up CPR' or 'gravity assisted CPR.' It includes current research, commentary, and publications important to understanding the potential benefit and physiology of the ElevatedCPR Method, other key topics surrounding the ElevatedCPR Method, as well as publications reporting no potential benefit from Head Up Position 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 Potential Benefits**

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.

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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. Gasping 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 from 20° to 30° to 40° during resuscitation is superior to elevating ASAP to 40° during ACD CPR + ITD. Cerebral perfusion pressures with this optimal approach were nearly normal, even after 20 minutes of ACD CPR + ITD.

10. Rojas-Salvador C, MooreJ, Salverda 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 Physcians; Austin, TX 2019.

Poster presenting evidence for improved CerPP and CorPP to >80% 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 CPR + ITD and sequential elevation of the head and thorax. Rapid elevation of the head and thorax over 24 seconds resulted in inferior outcomes.

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11. Pepe P, S. K., Antevy P, Crowe R, Millstone D, Coyle C, et al. (2019). Confirming the clinical safety and feasibility of a bundled methodology to improve cardiopulmonary resuscitation involving a head-up/torso-up chest compression technique. *Critical Care Medicine, 47*(3), 449-455. doi:DOI: 10.1097/CCM.0000000000003608

    Research examining human related factors of implementing a head/torso elevation for high quality CPR. The body was on a stretcher that was tilted upwards about 20 degrees. Study examined >2000 out of hospital cardiac arrest cases over three and half years for the safety and practical application of elevating the head and torso. They found a bundled care approach that included high quality manual CPR followed by CPR with the LUCAS 2.0, use of ITD, along with head and torso elevation to around 20° using a whole body head up tilt on a stretcher, had a synergistic effect. Survival to hospital alive rates nearly doubled from 18% to 34% for all patients. These results were maintained well beyond initial study effect period. Impact on survival to hospital discharge was not reported.

12. Lurie K, Lick C, Pepe P, Lamhaut L., Levy M, Price R, et al. (2019). State of the Future of the Science of Resuscitation. *Journal of Emergency Medical Services, March*(Supplement).

    Supplement to JEMS recapping the Take Heart America Conference in Oakland September 2018. Focus on current, cutting-edge science and implementation of such including HUP for CPR, supraglottic airways for resuscitation, ECMO, and high-performing Systems of Care.

13. Moore J Salverda B, Lick M, Rojas-Salvador C, Debaty G, Lurie K. Controlled sequential elevation of the head and thorax combined with active compression decompression cardiopulmonary resuscitation and an impedance threshold device improves neurological survival in a swine model of cardiac arrest. Presented at: American Heart Association Resuscitation Science Symposium; Nov 11, 2019; Philidelphia, PA. Circulation: American Heart Association; 2019.

    Abstract/Poster presented at American Heart Association 2019 Resuscitation Science Symposium. Bundled resuscitation using ACD+ITD CPR with a controlled sequence increased neurologically-intact survival 6-fold versus standard CPR in a swine model of cardiac arrest. In addition, CerPP, CorPP, ETCO2, and cerebral oximetry were all significantly higher throughout the 19 minutes of CPR with device-assisted controlled sequential elevation of the head and thorax versus conventional standard CPR.

14. Rojas-Salvador C SB, Moore J, Lick M, , Debaty G, Lurie K. . Controlled sequential elevation of the head and thorax rapidly achieves 50% of baseline cerebral perfusion pressure during active compression-decompression cardiopulmonary resuscitation with an impedance threshold device in a swine model of cardiac arrest. Presented at: American Heart Assoication Resuscitation Science Symposium; Nov 11, 2019; Philidelphia, PA. Circulation: American Heart Association; 2019.*

    Abstract/Poster presented at American Heart Association 2019 Resuscitation Science Symposium. Using ACD CPR + ITD with a 2-min device-assisted controlled sequential elevation time after a 2-minute period of priming achieved 50% baseline CerPP within <3 minutes. Achieving 50% of CerPP this rapidly and consistently has never been described before. The 2-minute rise-time rate outcomes were significantly better compared to the more rapid (24 second) or slower (10 minute) rise times. The device used elevates the head and heart to a maximum height of 22 cm and 9 cm, respectively.

    **Note: Accepted as a full manuscript to be published by Resuscitation, 2020.*

II. **Key Topics Related to CPR Advances**

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 pharmocology that individually offer limited gains, but together have an expontential effect on outcomes.

III. **Editorials, Commentaries and Special Reports, Including Those Showing No Potential Benefit of Head Up Position 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 18341: 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.

   Commentaries on 2018 Putzer et al article in Resuscitation. Moore describes what is required for successful HUP 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.

Iv. Video Resources/Lectures Related To Progressive Resuscitation Technology

1. AMC Amsterdam Department of Anesthesiology. Innovations in CPR [Vimeo]. Academic Medical Center (AMC) Amsterdam; 2018 [cited 2019 Dec 19]; Dr. Keith Lurie gives a lecture on innovation in CPR. Available from: https://vimeo.com/266253707

Dr. Keith Lurie presents grand rounds to anesthesia fellows in the Netherlands on the physiology of standard CPR. He discusses innovations, including elevating the head, that, when bundled together with ACD+ITD, have the potential to improve the physiological environment for the resuscitation patient.

2. Society of Critical Care Medicine. A 2020 Vision of CPR: Evolution, Revolution, and Novel Solution 2019 [cited 2019 Dec 19]; Dr. Paul Pepe, plenary speaker, gives a talk at the 48th Critical Care Congress]. Available from: https://www.youtube.com/watch?v=mgixu2iMckM&list=PLsb8sp1zaJWoZAWHK0FIAUPkFE6STk7wx&index=10&t=0s&fbclid=IwAR218HSAnKGrFF6pVCiFi4KWOzRw2tPzxUZn1XEMfVA9tCRpmicUqEzkcrc

Plenary presentation at Society of Critical Care Medicine 2019 annual conference discusses where CPR has come from, innovations, and new direction for resuscitation. At minute 34:17, there is a discussion of gravity-assisted CPR and the bundle of care needed to deploy this CPR effectively.

3. EMedHome.com. EMedHome's Video with Johanna Moore, MD: Cutting-edge resuscitation: Head-up CPR, eCPR, and more: Emergency Medicine News; [cited 2019 Dec 19]; Dr. Moore explores cutting-edge resuscitation, including head-up CPR, eCPR, and more]. Available from: https://journals.lww.com/em-news/pages/videogallery.aspx?videoId=374&autoPlay=true

Dr. Johanna Moore presents innovations that are currently in use at Hennepin County Medical Center and the greater Minneapolis area. At minute 5:05, she discusses the findings from her NIH-funded studies for head-up position CPR, where near-normal CerPP was achieved with a bundle of care including use of ACD+ITD+HUP.