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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, **MAP**: mean arterial pressure, **BLS**: Basic Life Support, **DACSE**: Device Assisted Controlled Sequential Elevation, **ROSC:** Return of spontaneous circulation

I. **Physiology and Potential Benefits of the Head and Thorax Elevation**

1. Moore J, Holley J, Scheppke K, Salverda B, Rojas-Salvador C, Jacobs M, et al. Faster time to elevation of the head and thorax during cardiopulmonary resuscitation increases the likelihood of return of spontaneous circulation after out of hospital cardiac arrest. Poster. NAEMSP - National Association of EMS Physicians; Virtual: NAEMSP; 2021.

   Poster/Abstract presented at NAESMP 2021. This analysis, with 227 patients treated in 6 US sites with a HUP CPR bundle of care including an EleGARD™ Patient Positioning System, an ITD-16 (ResQPOD-16), and manual ACD CPR (ResQPUMP) and/or automated CPR with a LUCAS device, showed that when time from 911 to EleGARD placement was ≤ 10 min ROSC rates were 58% for all rhythms and 92% for initial shockable rhythms. These ROSC rates were significantly higher than comparative historical data from ROC PRIMED study. Just like defibrillation, time is of the essence with Head Up CPR. For every minute delay in EleGARD placement after the 911 call, ROSC rates decreased by ~7% for all initial rhythms and those with a shockable rhythm.

2. Rojas-Salvador C, Salverda B, Lick M, Metzger A, Moore J, Lurie K. Evaluation of hemodynamic effects between a newly developed mechanical active compression decompression cardiopulmonary resuscitation device using an impedance threshold device during sequential elevation of the head and thorax and conventional CPR in a swine model of cardiac arrest. Poster. NAEMSP - National Association of EMS Physicians; Virtual: NAEMSP; 2021.

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Researchers examined the use of a mCPR device with 1cm lift from the chest as part of a HUP CPR bundle with ITD and DACSE. CerPP, $EtCO_2$, and rSO_2 were significantly higher in the group that used the mCPR with 1cm lift, ITD, and DACSE versus S-CPR. These findings support the use of mCPR with some active lift as part of a HUP CPR bundle of care.

3. Duhem H, Moore J, Rojas-Salvador C, Salverda B, Lick M, Pepe P, et al. Improving post-cardiac arrest cerebral perfusion pressure by elevating the head and thorax [Experimental Paper]. *Resuscitation*. 2021 February 2021;159:45-53.

   This study examined the effect of HUP on post-ROSC ICP and CerPP in a porcine model. Regardless of type of CPR provided (S-CPR vs HUP CPR with circulatory adjuncts) or length of resuscitation, elevation of the head and thorax post-ROSC improved ICP and CerPP and regional cerebral oximetry. No adverse effects were observed during or after the resuscitation related to the HUP. This study provides the first pre-clinical evidence that HUP post-ROSC provides signficant benefit, especially in terms of lowering ICP and increasing CerPP, as long as MAP was adequate. The authors emphasized the need for an adequate MAP into order to pump blood 'uphill' to the elevate head, drawing the clinical parallel to the care of the traumatic brain injured patient.

4. Moore J, Holley J, Scheppke K, Salverda B, Rojas-Salvador C, Jacobs M, et al. Faster Time to Elevation of the Head and Thorax During Cardiopulmonary Resuscitation Increases the Likelihood of Return of Spontaneous Circulation After Out of Hospital Cardiac Arrest [Abstract]. *Circulation*. 2020;142(24):e495.

   Late breaking science abstract presentation at American Heart Association 2020 Resuscitation Science Symposium. Dr. Moore and others analyzed 198 out of hospital cardiac arrest cases from 5 US sites where subjects received HUP CPR with a combination of ACD/ITD CPR, manual/ITD CPR, or mCPR/ITD with an EleGARD™ Patient Positioning System. When this HUP CPR bundle of care was deployed within 10 minutes of 911 activation, or within 5 minutes of EMS arrival, the overall ROSC rate was >50%. In light of this research, this group suggests considering methods for rapid EleGARD deployment as part of this bundle. (Video presentation available upon request by emailing clinical@elevatedcpr.com.)

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5. Moore JC, Salverda B, Rojas-Salvador C, Lick M, Debaty G, Lurie K. Controlled sequential elevation of the head and thorax combined with active compression decompression cardiopumonary resuscitation and an impedance threshold device improves neurological survival in a porcine model of cardiac arrest. *Resuscitation*. 2020a. DOI:https://doi.org/10.1016/j.resuscitation.2020.09.030

ACD-CPR with ITD and HUP have been shown to improve both CorPP and CerPP in several previous studies but little is known about the neurological outcomes with this "triple therapy" of ACD-CPR, ITD and HUP. Moore et al. applied the previously studied method of elevating the head and thorax in a timed sequence with the use of ACD-CPR and ITD compared to S-CPR in a porcine model, monitoring hemodynamic factors during the resuscitation and testing neurological outcomes at 24 hours. This first pre-clinical look at neurological outcomes resulted in 6/8 animals in the interventions group with an intact neurological survival (CPC of 1 or 2) versus 1 animal in the S-CPR group surviving neurologically intact (CPC of 2). The additional 7 animals in the control group had no ROSC or died before 24 hours (CPC of 5).

Importantly, HUP was initiated within 2 minutes of the start of CPR with full elevation achieved by 4 minutes. Additional findings from this study replicate improved hemodynamic factors including $EtCO_2$, CorPP, and MAP improvements with the triple therapy versus S-CPR. ICP and CerPP were not reported in this study to avoid possibly altering neurological outcomes with invasive monitoring. Instead, regional cerebral oxygenation (rSO_2) was monitored and was also better in the intervention group. The researchers highlight that the triple therapy was applied with intent, as a bundle, reporting that no one single intervention was responsible for the good outcome.

6. Lurie K, Lamhaut L, Lick C, Heightman AJ. Proceedings from the 2nd Annual International State of the Future of Resuscitation Conference. *Journal of Emergency Medical Services*. 2020; September(Supplement).

Supplement to JEMS recapping the Take Heart America Conference in Paris, France in October 2019. Presentations specific to HUP include:

Dr. Joe Holley: *Lessons from the Dead*. Use of human cadaver model to show the effects of various interventions used during resuscitation including the positive effects of ACD-CPR with ITD and controlled sequential elevation on ICP, CerPP, and CorPP.

Dr. Johanna Moore: *Device-guided Head-Up/Torso-Up CPR*. Report on consistent laboratory findings where normal CerPP was obtained with use of ACD-CPR, ITD and controlled sequential elevation. Dr. Moore emphasizes the need to perform this sequence deliberately and with care, identifying several key 'do's and don'ts'.

The supplement concludes with two remarkable case reports using a bundle of care that includes HUP and resulting in neurologically intact survival. The first relates the story of a 15-year-old warm-water drowning victim who was able to return to school on time in the Fall after his mid-summer event. The second reports on a 60-year-old refractory ventricular fibrillation patient whose entire cardiac arrest was captured on airport surveillance video. His recovery has been chronicled on his YouTube channel.

7. Pepe P, Aufderheide T, Lamhaut L, Davis D, Lick C, Polderman K, et al. Rationale and Strategies for Development of an Optimal Bundle of Management for Cardiac Arrest. *Critical Care Explorations*. 2020. 2:e0214.

Several dozen international resuscitation experts and practitioners joined together to form the International Resuscitation Collaborative (IRC). They examined best practice techniques and technologies across 10 agencies in the United States who have a 30% higher neurologically intact discharge rate over the national average reported by CARES.

Recognizing the limitations of traditional, single-intervention studies, the IRC looked at groups of interventions to assess the commonalities among these high performing Systems. Their primary endpoint was neurologically intact hospital discharge. They also used ROSC as a measure of success.

The IRC found that these agencies blend conventional and novel approaches to resuscitation across the entire continuum of care. Highest performing agencies focused on training and technology that improves community response, provides professional rescuers with the tools to enhance flow and monitor quality, uses invasive technology in the hospital and focuses on brain recovery. Common interventions include: dispatch assisted CPR, immediate chest compressions, AED use, ITD use with SGA and ACD-CPR, m-CPR, HUP-CPR as well as ECMO and immediate cardiac catheterization at designated resuscitation centers.

The IRC concluded that it is not a single intervention that is poised to improve outcomes from sudden cardiac arrest, but rather bundled care that uses both conventional and innovative techniques.

8. Moore J, Salverda B, Lick M, Rojas-Salvador C, Segal N, Debaty G, Lurie K. Controlled progressive elevation rather than an optimal angle maximizes cerebral perfusion pressure during head up CPR in a swine model of cardiac arrest [Experimental Paper]. Resuscitation. 2020b; 150:23-28.

HUP CPR has been shown to double brain blood flow with increased CerPP during ACD CPR with ITD. However, the optimal angle for HUP CPR is unknown. This study in pigs was designed to compare 3 different HUP CPR angles (20°, 30°, 40°) using an automated device to deliver ACD CPR together with an ITD attached to the endotracheal tube. CerPP, previously shown to correlate with brain blood flow, was the primary study endpoint. Each pig was treated with HUP CPR using each of the 3 different angles, with CPR at each angle for 5 minutes, delivered in a total of 6 different randomization sequences. No HUP CPR angle was found to be superior.

However, a follow up study demonstrated that elevating the head and the heart starting at 20°, then progressing to 30° and then to 40° resulted in nearly normal CerPP values and showed that controlled progressive elevation of the head and thorax during CPR is more beneficial than an absolute angle or height to maximize CerPP. This study therefore described the discovery of the importance of controlled sequential elevation of the head and thorax during ACD+ITD CPR to optimize CerPP values during ACD+ITD CPR. A follow up study by Rojas et al. (*Rojas, Resuscitation, 2020,* full annotated reference above) furthered this research by identifying the optimal rate of rise during HUP ACD + ITD CPR to achieve nearly normal CerPP during prolonged CPR.

9. Rojas-Salvador C, Moore J, Salverda B, Lick M, Debaty G, Lurie K. (2020). 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*, EPub ahead of print. doi:10.1016/j.resuscitation.2019.12.011

This porcine study sought to verify the optimal sequence, speed and final height for head and thorax elevation during CPR using a comprehensive bundle of care that includes continuous CPR with ACD+ITD-16.

They assessed an immediate rise (24 seconds) without 'priming' the cardio-cerebral circuit and 2, 4, and 10-minute elevations with a period of priming in the down position. The immediate rise protocol simulated using a transport stretcher to raise the upper body at the waist and the controlled protocols simulated the use of a device for controlled sequential elevation. The primary endpoint was CerPP after 7 minutes of CPR.

The 2-minute rise to a head height of 22cm and heart height of 10 cm after a 2-minute period of priming was found to be the optimal rise time and height. A 2-minute rise time reduced the potential harm of raising the head too quickly, as the arterial pressure can fall, while reaching CerPP that was 50% baseline by 2.5 minutes and 80% by 7 minutes. CorPP was also found to increase over time in the two-minute rise group versus the immediate rise group.

An additional finding of this study was that placement on the automated head and thorax elevation device, which raises the head to 10cm and thorax to 7 cm in the lowest position, immediately reduced ICP by decreasing venous congestion of the brain after receiving CPR in the supine position. The study also documented time to first gasp, a strongly positive neuroprognosticator, with first gasp occurring 1-2 minutes sooner in the slow rise group versus the quick rise group.

These findings support the immediate placement of an elevation device under a patient receiving CPR, a period of priming the cardio-cerebral circuit with the use of ITD, followed by a slow progressive 2 min rise to optimize CerPP, CorPP and create an environment that markedly improves survival with good brain function in pigs and could lead to improved neurological outcomes.

10. Scheppke K, Pepe P, Antevy P, Lick C, Coyle C, Garay S, et al. (2020). Safety and feasibility of an automated patient positioning system for controlled sequential elevation of the head and thorax during cardiopulmonary resuscitation [Research Poster Presentation]. National Association of EMS Physicians Annual Conference, San Diego, CA.

    Poster presented at NAEMSP 2020. This quality improvement project reviewed historical and post intervention data in Palm Beach County Florida where the intervention was a patient positioning device (EleGARD). The vast majority of patients presented with asystole or PEA. The new device was used to provide device-assisted controlled sequential elevation of the head and thorax (DACSE) during ACD CPR with an ITD-16, as part of an expanded cardiac arrest bundle of care. The authors reported that use of DACSE was safe and not difficult to use. ETCO2 levels increased post DACSE intervention to normal values in >70% of patients and the ROSC rates in patients presenting with asystole or PEA were 44%.

11. Rojas-Salvador N, Salverda. B, Moore J, Lick M, Debaty G, Lurie K. (2020). Regional cerebral tissue oxygenation correlates with aortic pressure, end tidal CO2, coronary perfusion pressure and neurological outcome in a swine model of cardiac arrest [Research Poster Presentation]. National Association of EMS Physicians Annual Conference, San Diego, CA.

Poster presented at NAEMSP 2020. This research examined correlation between non-invasive regional cerebral tissue oxygenation (rSO_2) and neurologically intact survival from sudden cardiac arrest. Swine were treated with conventional CPR in the flat position versus device assisted controlled sequential elevation (DACSE) with an ITD-16 and automated ACD at 100 compression/decompressions per minute. rSO_2, along with traditional monitoring parameters were monitored in both groups. Swine with higher rSO_2 were found to be more likely to survive neurologically intact in both the conventional CPR group and the DACSE ACD ITD group. rSO_2 values correlated highly with $ETCO_2$, which was also predictive of a positive outcome. In addition, the group treated with DACSE ACD ITD had more favorable neurological outcomes with 6/7 neurologically intact at 24 hours compared to just 1/7 in the conventional group.

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, California in September 2018. Focused 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. Pepe P, Scheppke 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:10.1097/CCM.0000000000003608

    Research examined 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.

14. 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 showed 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.

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

Powell et al. described their experience with the Rialto, California resuscitation tool kit. They highlight a number of advances including HUP CPR. When uninterrupted chest compressions, early defibrillation, de-emphasis of epinephrine, use of an ITD, and elevating the head and thorax were combined, they found their overall ROSC rates increased from 23% to 60%. Their ROSC rates increased from 40% to 60% with the addition of HUP CPR. They did not report the total number of patients treated, the hospital discharge rates or neurologically intact survival rates. The article emphasizes the importance of a bundle of care approach to the treatment of cardiac arrest. Note that this article was published in the *Journal of Emergency Medicine* (JEMS), which is not a peer-reviewed journal.

16. 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 used 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.

17. 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.

Examined 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.

18. 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.

19. Erich J. Heads-Up CPR: Can Elevating the Patient's Head Improve Outcomes? *EMS World*. 2015 (August):22-28.

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

20. 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 online in 2014) compared 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.

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II. **Related Resuscitation Topics**

1. Holley J, Moore J, Jacobs M, Rojas-Salvador C, Lick C, Salverda B, Lick M, Frascone RJ, Youngquist S, Lurie K. (2020). Supraglottic airway devices variably develop negative intrathoracic pressures: A prospective cross-over study of cardiopulmonary resuscitation in human cadavers. *Resuscitation*(2020), 32-38. https://doi.org/https://doi.org/10.1016/j.resuscitation.2019.12.022

   This was a human cadaveric study assessing supraglottic airways (SGA) with different CPR methodologies and in different body positions, including flat and HUP. The ability to generate negative intrathoracic pressure was the primary study endpoint. Different SGAs were compared while CPR was performed using conventional/manual, conventional/mechanical (LUCAS 2.0), ACD and HUP ACD with and without ITD-16. The better the airway was sealed during the decompression phase of CPR, the lower the intrathoracic pressure. Multiple prior studies in animals and humans have demonstrated that increased *negative* intrathoracic pressure during the decompression phase of CPR improves blood flow to the heart and brain.

   In the current study human cadavers received CPR with and without an ITD-16. The study found that when an ITD-16 was used, negative intrathoracic pressures were significantly lower during the decompression phase of CPR, regardless of the method of CPR or the airway adjunct. Using an endotracheal tube as the gold standard, the study found that best airway seal was obtained by iGel, air-Q®sp, and LMA-S. These findings were similar if the body was flat or HUP, confirming it is possible to use a variety of airway adjuncts during both flat and HUP CPR and still maintain an airway seal during CPR.

2. 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, the study showed the cost benefit of improving OHCA care.

3. 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.

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 emphasized need for bundled care approach to a multimodal problem. Likened 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.

5. 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. Discussed components of S-CPR, identifying common errors and limitations. Introduced improvements to S-CPR with good technique and technology including use of the ITD, ACD, and HUP.

6. Sniffing Position and Intubation
   There is very little published data examining patients in cardiac arrest related to elevation of the head and the sniffing position. Historically these patients were often excluded, as CPR added an additional challenge to the intubation process due to the continuous motion of the patients. Moreover, there are no randomized studies using video-laryngoscopy in patients in cardiac arrest related to the position of the head and neck.

   There are multiple studies from patients not in cardiac arrest from inside and outside the hospital showing the benefits of the sniffing position and elevation of the head and neck. Those studies show that first pass intubation success is higher with the elevation of the head and neck in sniffing position.

   Examples of some publications:

   Murphy D I, Rea T, McCoy A M, Sayre M R, Fahrenbruch C E, Yin L, et al. Inclined position is associated with improved first pass success and laryngoscopic view in prehospital endotracheal intubations. *American Journal of Emergency Medicine*. 2019;37(2019):937-947.

This prehospital study showed inclined position during intubation was associated with higher first pass success versus the flat position in a large randomized prehospital study. However, cardiac arrest patients were excluded. These data suggest that elevation of the head facilitates more effective intubation.

El-Orbany M, Woehick H, Salem MR. Head and neck position for direct laryngoscopy [Review Article]. *Anesthesia & Analgesia*. 2011;113(1):103-109.

Review of the literature noted there were limited studies on the sniffing position and direct laryngoscopy. Those studies supported the benefit of use of the sniffing position to improve intubation success. However, the sniffing position did not guarantee adequate exposure of the larynx in all patients due to anatomical difference from one subject to the next.

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

1. Paxton J, O'Neil B. Is 'heads up' the way forward [Editorial]. *Resuscitation*. 2020;158:270-272.

   Editorial response to Moore et al. experimental paper in the same publication which examines post-ROSC neurological outcome with a HUP new bundle of care in an animal survival study comparing HUP CPR with C-CPR in the flat position. Paxton & O'Brien chronicle the progression of science that led to the HUP CPR bundle of care, lauding not only the science but the initiative to go beyond just a variation on the current AHA guidelines. These authors state "The theory behind HUP CPR appears sound" and that "only by questioning traditional practices, such as patient positioning during external cardiac massage, can we hope to improve upon currently employed methods to treat OHCA.

2. Gazmuri R and Dhliwayo N. From a toilet plunger to head-up CPR: Bundling systemic and regional venous return augmentation to improve the hemodynamic efficacy of chest compression [Editorial]. *Resuscitation*. 2020;2:Online ahead of print

   In this editorial, Drs. Gazmuri & Dhliwayo began by noting that "*prompt generation of blood flow at levels able to reverse or at least ameliorate myocardial and cerebral ischemia is critical for successful resuscitation from cardiac arrest. Yet, conventional cardiopulmonary resuscitation (CPR) fails to promote more than a small fraction of the normal cardiac output and to distribute such blood flow to the coronary and cerebral circuits.*"

They highlighted the use of ACD combined with an ITD as an adjunct to standard CPR to improve cardio-cerebral blood flow and resuscitation outcomes. They cited research and practice that shows "*bundling the ITD with ACD CPR was shown to generate superior hemodynamic effects in animal models translating into a favorable short-term survival in a small clinical study in Europe, and survival to hospital discharged with intact neurological function in a larger study conducted in the USA*".

Drs. Gazmuri & Dhliwayo continued by addressing the research presented by Rojas et al. in this same issue of *Resuscitation*. The Rojas study (Rojas, *Resuscitation*, 2020) showed that elevation of the head and thorax in a timed sequence including a period of ACD+ITD CPR in a low position followed by a 2-minute rise resulted in CerPP in excess of 80% baseline with similar CorPP findings. Gazmuri et al. suggested that, especially with no known adverse effects, it is reasonable to assume that a bundle of care that includes ACD with ITD and sequenced HUP would likely lead to improved outcomes in the clinical setting, especially if they can be implemented with ease and early in the resuscitation effort.

They concluded by stating: "*Dr. Keith Lurie along with his former and current colleagues are to be credited for their sustained effort over the years in recognizing the importance of augmenting systemic and regional venous return during CPR, with the promise that bundling of ACD-CPR, ITD, and Head-Up CPR may lead to a substantial improvement in cardiac resuscitation outcomes.*"

3. Elphinstone A, and Laws S. Does 'heads-up' cardiopulmonary resuscitation improve outcomes for patients in out-of-hospital cardiac arrest? A systematic review [Literature Review]. *British Paramedic Journal*. 2020;4(4):16-24

Elphinstone and Laws published their systematic review of the literature related to HUP CPR with the goal to try to identify the impact of this intervention in patients on survival to hospital discharge and neurologic outcome. At the time of publication of this review, there was one published article with human data that includes this kind of information. That publication by Pepe et al., referenced previously in this bibliography, was not included in their analysis. (Pepe, *Critical Care Medicine*, 2019). Other human data have since been published.

The authors did highlight key findings that were consistent from multiple animal studies. Specifically, they reported that ACD CPR with an ITD (referred to as augmented CPR), and elevation of the head and thorax consistently lowered intracranial pressure and increased cerebral and coronary perfusion pressures.

4. Park Y, Hong K, Shin S, Kim T, Ro Y, Song K, Ryu H. (2019). Worsened survival in the head-up tilt position cardiopulmonary resuscitation in a porcine cardiac arrest model. *Clnical and Experimental Emergency Medicine, 6*(3), 250-256. https://doi.org/https://doi.org/10.15441/ceem.18.060

The study examined whether placement of pigs in cardiac arrest in a whole body head up tilt at 30° angle would improve neurologically intact survival rates compared with CPR in the flat position. Both groups were treated with a LUCAS 2.0 device and an impedance threshold device (ITD-10) after 15 minutes of untreated VF. In the whole body head up tilt group, the body was tilted upward rapidly after 15 minutes of VF and then CPR was initiated. None of the head up pigs survived whereas 6/8 in the flat group survived.

This study, after it was published in abstract form, resulted in Dr. Moore et al. writing a letter to *Resuscitation* entitled "Do's and Don'ts of Head Up CPR" which is noted in this bibliography. With the current understanding of the physiology of head up CPR, the findings by Park et al. are predictable and not surprising.

There are several important reasons for their negative study results which should be understood before a HUP CPR protocol is considered and implemented.

First, as previously noted in this bibliography, Kim et al. *Resuscitation,* 2017 and Rojas, et al. *Resuscitation*, 2020, reported *rapid elevation of the head and thorax without first starting CPR in the flat position to 'prime the system' and start circulation* will lower the arterial pressure and reduce blood flow to the brain immediately. This is why the arterial pressure values reported by Park et al. in their report were so low in the whole-body head up tilt group, just 20% of those in the flat position. Rapid elevation of the head and thorax even with CPR ongoing, has been shown to result in poorer outcomes, as was recently reported by Rojas et al. *Resuscitation*, 2020. This same research also showed a slow controlled elevation timing sequence after 'priming the system' with LUCAS CPR and the ITD-16 optimizes brain blood flow and survival.

Second, prolonged elevation of the head and thorax with a whole-body tilt will result in blood pooling in the abdomen and lower extremities over time. This physiology is similar to what happens to alive patients with a whole-body tilt who are prone to syncope: the blood pressure falls as blood pools in the lower extremities.

Third, an ITD-10 was used instead of an ITD-16 by Park et al. The ITD with a 16 cm of H2O resistance prior to opening helps generate greater negative intrathoracic pressures (to -16 cm of H2O versus -10 cm H2O) during the decompression phase of CPR, thereby ultimately providing more blood flow to the brain. This is why the ITD-16 is used in the studies by Moore et al. and Rojas et al.

The 100% mortality after 24-hours with the Park et al. experimental model confirms the necessity to 'prime the pump', elevate the head and thorax slowly, and refrain from the whole body head up tilt position. As such, the findings by Park et al. are completely consistent with the other studies on head up CPR, especially those by Dr. Moore et al. described herein.

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

Discussed 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.

6. 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 discussed the challenges of translating CPR research to cadavers. Strobos further recognized that HUP CPR is more than just raising the head during resuscitation. She noted 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.

7. 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 described what is required for successful HUP CPR and what should and should not be done to get the benefit from this new approach. Moore suggested 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 rebutted that CerPP should not be the only measure and conceded that a bundled care approach to cardiac arrest is necessary especially in light of emerging technologies.

8. 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 in this bibliography.

9. 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. Presented HUP CPR as a simple, novel approach that should be considered for incorporation into EMS protocols.

IV. Video Resources/Lectures Related to Progressive Resuscitation Technology

1. EMedHome.com. EMedHome's Video with Johanna Moore, MD: Cutting-edge resuscitation: Head-up CPR, eCPR, and more: Emergency Medicine News; [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.

2. Society of Critical Care Medicine. A 2020 Vision of CPR: Evolution, Revolution, and Novel Solution 2019. 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. AMC Amsterdam Department of Anesthesiology. Innovations in CPR [Vimeo]. Academic Medical Center (AMC) Amsterdam; 2018. 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.