Active Decompression during Automated Head-up Cardiopulmonary Resuscitation

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Background

Active compression-decompression (ACD) CPR combined with an impedance threshold device (ITD) and controlled head-up positioning, collectively termed AHUP-CPR, is associated with improved outcomes compared with conventional CPR (C-CPR). ACD CPR lifts the chest wall after each compression, while the ITD impedes airflow into the lungs.

ACD CPR and ITD lower intrathoracic pressure during decompression, improving venous return, ventricular refilling, and cardiac output, while Head-up positioning lowers intracranial pressures and improves cardiac preload.

This study tested the hypothesis that full active decompression (AD), to at least 3 cm above the neutral chest position, is critical to maintaining and optimizing multiple hemodynamic parameters of physiological and clinical importance during AHUP-CPR.

Methods

10 female and male swine (~40 kg) were sedated, intubated, and anesthetized. Bilateral femoral accesses were obtained to place pressure transducers as well as left and right cardiac conductance catheters. Hemodynamics, including central aortic, venous and intracranial pressures, ETCO2, and cerebral oximetry were measured continuously.

Animals were placed in ventricular fibrillation and left untreated for 10 minutes before receiving 2 minutes of C-CPR and 2 minutes of ACD-CPR prior to head elevation. AHUP CPR was then continued for 11 minutes before abruptly stopping active decompression for one minute, then reintroducing it in 1 cm increments minute by minute up to 4 cm.

Data were analyzed with a linear mixed-effects model, using random intercepts for individual pigs.

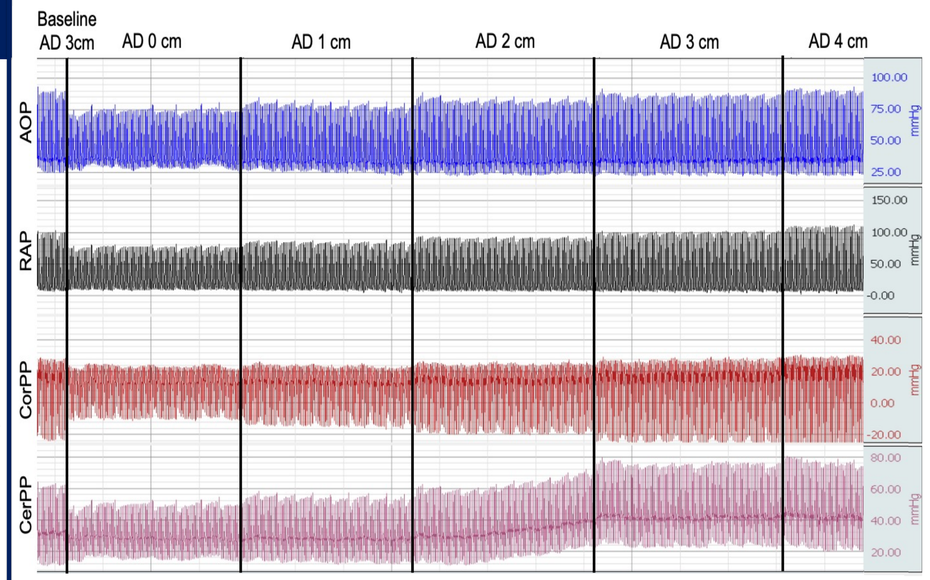

Figure 1: Representative tracing from a single pig showing changes in hemodynamics, aortic blood pressure (AOP), right atrial pressure (RAP), coronary perfusion pressure (CorPP) and cerebral perfusion pressure (CerPP), during automated head-up CPR over 15 minutes (Baseline AD 3 cm), followed by discontinuation of active decompression (AD 0 cm), and then an incremental increase every minute to up to 4 cm of active decompression.

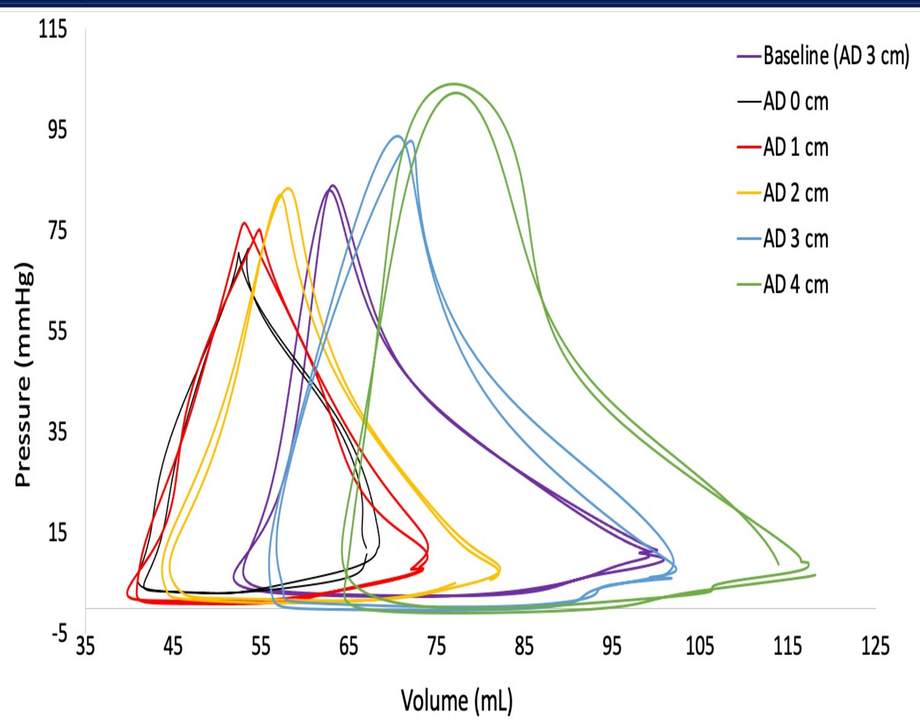

Figure 2: Representative data showing changes in right-sides pressure-volume loops during automated head-up CPR over 15 minutes (Baseline AD 3cm), discontinuation of active decompression above the anterior plane of chest (AD 0), and an increase to 4 cm (AD 1-4cm)

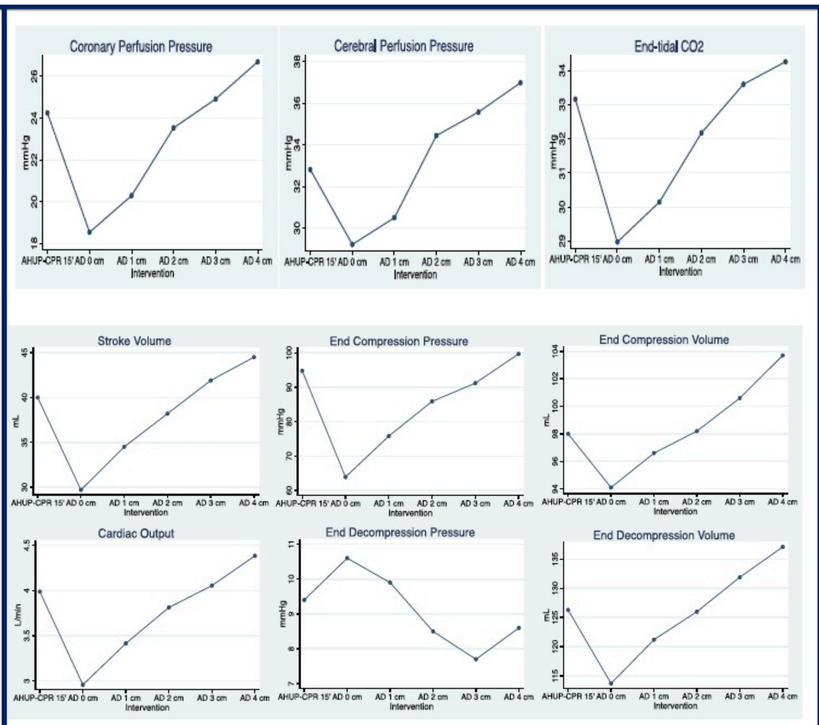

Figure 3: Effect of discontinuing and reinitiating active decompression (AD) during automated head-up CPR on key hemodynamic parameters after 15 min of AHUP-CPR. Changes in these parameters were similar between the right and left heart.

Results

Coronary and cerebral perfusion pressures, compression and decompression aortic pressures, compression right atrial pressure, ETCO2, right and left ventricular preload, compliance, stroke volume, and cardiac output all decreased immediately with discontinuation of ACD ($p<0.01$). Cessation of AD caused increases in decompression phase right atrial and biventricular pressures. Restoration of AD caused physiological parameters to return to ≥ 90% of pre-discontinuation values.

Conclusions

Full chest wall lift with >3 cm of active decompression (AD) was needed to maintain and optimize hemodynamics during head-up CPR. After pausing AD, incremental restoration of AD resulted in nearly complete restoration of peripheral and central hemodynamic measures.

These observations support the benefit of and need for ≥3 cm of AD to optimize AHUP-CPR.