Augmentation of Intraventricular Stroke Volume during Head Up Position CPR: Implications for Clinical Outcomes

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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, increases cerebral perfusion pressure, cerebral blood flow, end-tidal CO2, cerebral oximetry, and coronary perfusion pressure in animal studies versus conventional CPR (C-CPR).*
- AHUP-CPR is associated with increased neurologically favorable survival compared to C-CPR in pigs and humans.

Hypothesis

AHUP-CPR will increase cardiac stroke volume and other key hemodynamics compared with C-CPR in a porcine model of cardiac arrest.

Methods

- 15 female and male swine (~40 kg) were sedated, intubated, and anesthetized.
- Bilateral femoral access was obtained to place pressure transducers as well as cardiac conductance catheters.
- Cardiac conductance catheters were placed in the left and right ventricles and confirmed via fluoroscopy.
- Ventricular fibrillation was induced and left untreated for 10 minutes.
- C-CPR was performed for 2 minutes in the supine position before transitioning to ACD CPR with the ITD. After 2 minutes of ACD+ITD CPR with the head and thorax elevation 12 and 8 cm, respectively, the head and thorax were raised gradually over 2 minutes to a height of 24 and 9 cm, respectively. AHUP-CPR was continued thereafter with the head and thorax at those levels. Data were analyzed with a linear mixed-effects model, using random intercepts for individual pigs. Cardiac stroke volume was the primary endpoint.

Abbreviations: AO-aortic pressure; BiV = biventricular; CO = cardiac output; CerPP = cerebral perfusion pressure; Com = compression phase; CorPP = coronary perfusion pressure; Dec = decompression phase; ECP = end compression phase pressure; EDP = end decompression phase pressure; ECV = end compression phase volume; EDV = end decompression phase volume; ETCO2 = end tidal CO2; ICP = intracranial pressure; RA = right atrial; rSO2=regional cerebral oximetry; SV = stroke volume.

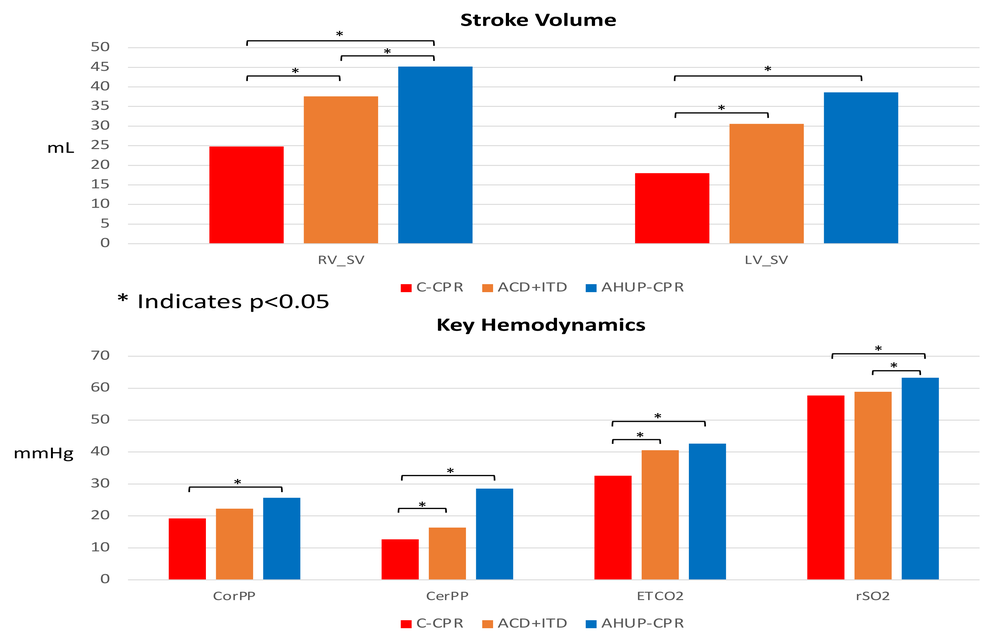

Figure: Right and left ventricular stroke volume and peripheral hemodynamics during conventional CPR, active compression-decompression CPR with an impedance threshold device, and automated head-up CPR.

	AO (Com/Dec/ Mean) (mmHg)	RA (Com/Dec/ Mean) (mmHg)	ICP (Com/Dec/ Mean) (mmHg)	ETCO2 (Mean±SE) (mmHg)	CorPP (Mean±SE) (mmHg)	CerPP (Mean±SE) (mmHg)	rSO2% (Mean±SE)
Baseline	113/77/94	14/5/9	25/20/22	42.2 ± 0.7	79 ± 3	71 ± 4	76.3 ± 1.5
C-CPR	70/31/51	85/12/49	42/20/32	32.5 ± 2.2	19.2 ± 2.6	12.7 ± 1.9	57.7 ± 1.6
ACD+ITD	82/31/57	96/8/55	44/17/31	40.6 ± 2.6*	22.3 ± 1.6	16.4 ± 3.7	58.6 ± 1.5
AHUP-CPR	92/34/63	126/8/71	39/9/24	42.6 ± 3.0*	25.7 ± 3.2*	28.6 ± 5.8*	63.3 ± 1.8*

	ECP (mmHg)	EDP (mmHg)	EDV (mL)	ECV (mL)	SV (mL)	CO (mL/min)
RV|Baseline	21.8 ± 3.0	1.7 ± 0.9	120.4 ± 9.6	67.6 ± 11.2	51.7 ± 4.4	5.8 ± 0.4
RV|C-CPR	67.0 ± 3.9	9.8 ± 1.2	122.7 ± 8.6	104.3 ± 8.7	24.8 ± 2.8	2.5 ± 0.3
RV|ACD+ITD	83.3 ± 6.9	9.9 ± 1.2	114.0 ± 10.2	94.8 ± 8.5	36.7 ± 3.8*	3.7 ± 0.4*
RV|AHUP-CPR	106.8 ± 9.8*	7.8 ± 0.7	118.5 ± 8.4	87.3 ± 8.4*	45.2 ± 4.1*	4.4 ± 0.4*
LV|Baseline	85.3 ± 8.5	4.7 ± 1.4	149.4 ± 20.7	105.6 ± 20.9	50.4 ± 5.9	5.9 ± 0.5
LV|C-CPR	58.6 ± 3.9	9.7 ± 0.7	107.7 ± 18.0	97.0 ± 17.6	18.0 ± 1.9	1.8 ± 0.2
LV|ACD+ITD	79.9 ± 8.9	12.7 ± 1.9	109.7 ± 13.6	88.3 ± 16.2	30.6 ± 4.0*	3.0 ± 0.4*
LV|AHUP-CPR	89.6 ± 9.8*	9.6 ± 1.4	119.7 ± 11.8	96.3 ± 11.8	38.6 ± 6.6*	3.8 ± 0.7*

Data presented as means ± standard error. * Indicates p<0.05

Results

- **CerPP, CorPP, ETCO2, and rSO2, as well as biventricular SV and cardiac output, increased progressively with AHUP-CPR ($p<0.05$).**
- **C-CPR generated a RV SV of 24.8 mL (48% of BL) and LV SV of 18.0 mL (36% of BL).**
- **ACD+ITD increased RV and LV SV by an average of 59% versus C-CPR.**
- **AHUP-CPR further increased biventricular SV by an average of 113%, reaching 88% and 76% of RV and LV pre-VF values, respectively.**

Conclusions

- **This study demonstrated biventricular stroke volume is significantly augmented with AHUP-CPR versus C-CPR or ACD+ITD in the flat position.**
- **Treatment with AHUP-CPR also resulted in significantly higher ETCO2, rSO2, and CerPP values versus C-CPR or ACD-CPR in the flat position which helps explain the improved clinical outcomes associated with early use of AHUP-CPR by first responders.****

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