Circumferential Thoracoabdominal CPR vs. LUCAS 3.1: Superior Hemodynamics in a Porcine Cardiac Arrest Model

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Background

Survival after sudden cardiac arrest (SCA) remains below 10% in most medical systems, and the incidence of SCA is disproportionately higher in military settings. Sternal-piston compression is used in manual CPR and most mechanical devices. It is associated with vital organ blood flows below 20% of spontaneous circulation and skeletal fractures in more than 75% of patients. We have proposed that circumferential thoracoabdominal CPR (CTA-CPR) may be more effective and less injurious than sternal-piston based methods

CPR coronary perfusion pressure (CPP) — the aortic-to-right-atrial gradient during relaxation — and end-tidal CO2 (ETCO2) are associated with CPR hemodynamics and are predictive of ROSC.

The Stryker LUCAS is the most widely used mechanical sternal-piston CPR device and incorporates active decompression to enhance venous return. The CPP and ET-Co2 during CTA-CPR and LUCAS-CPR have not previously been compared.

Hypothesis

CTA-CPR generates superior perfusion pressures compared with LUCAS-CPR.

Methods

- Porcine VF model (female Yorkshire swine, N=5, 25–35 kg)
- CTA-CPR: custom thoracic + abdominal circumferential pneumatic constriction
- Comparator: LUCAS-CPR (active decompression)
- Measured: Ao, RA, CPP (Ao−RA), ETCO2
- Alternating 1-min epochs; Δ across epochs as key outcomes
- 28 matched pairs (pressures); 30 pairs (ETCO2); paired t-tests IACUC-approved

Animals were sedated with isoflurane and intubated. Fluid-filled pressure transducers connected to pigtail catheters were placed in the aorta and right atrium. VF was induced by 60 Hz transthoracic current. ETCO2 was measured by Capnostat (Respironics). Circumferential belts were inflated by a custom pneumatic system with counterphase abdominal constriction.

Military Relevance

Effective mechanical CPR is a priority in the treatment of sudden cardiac arrest in all military locations. CTA-CPR addresses key gaps in current devices: superior hemodynamics may result in a higher likelihood of ROSC. Additional benefits may include a large decrease in skeletal injury risk through force distribution, tolerance of patient position variation, and dual-use potential (abdominal tourniquet / traumatic arrest).

Figure 1. Hemodynamic Comparison: CTA-CPR vs LUCAS (matched pairs across 5 swine; mean +/- SD)

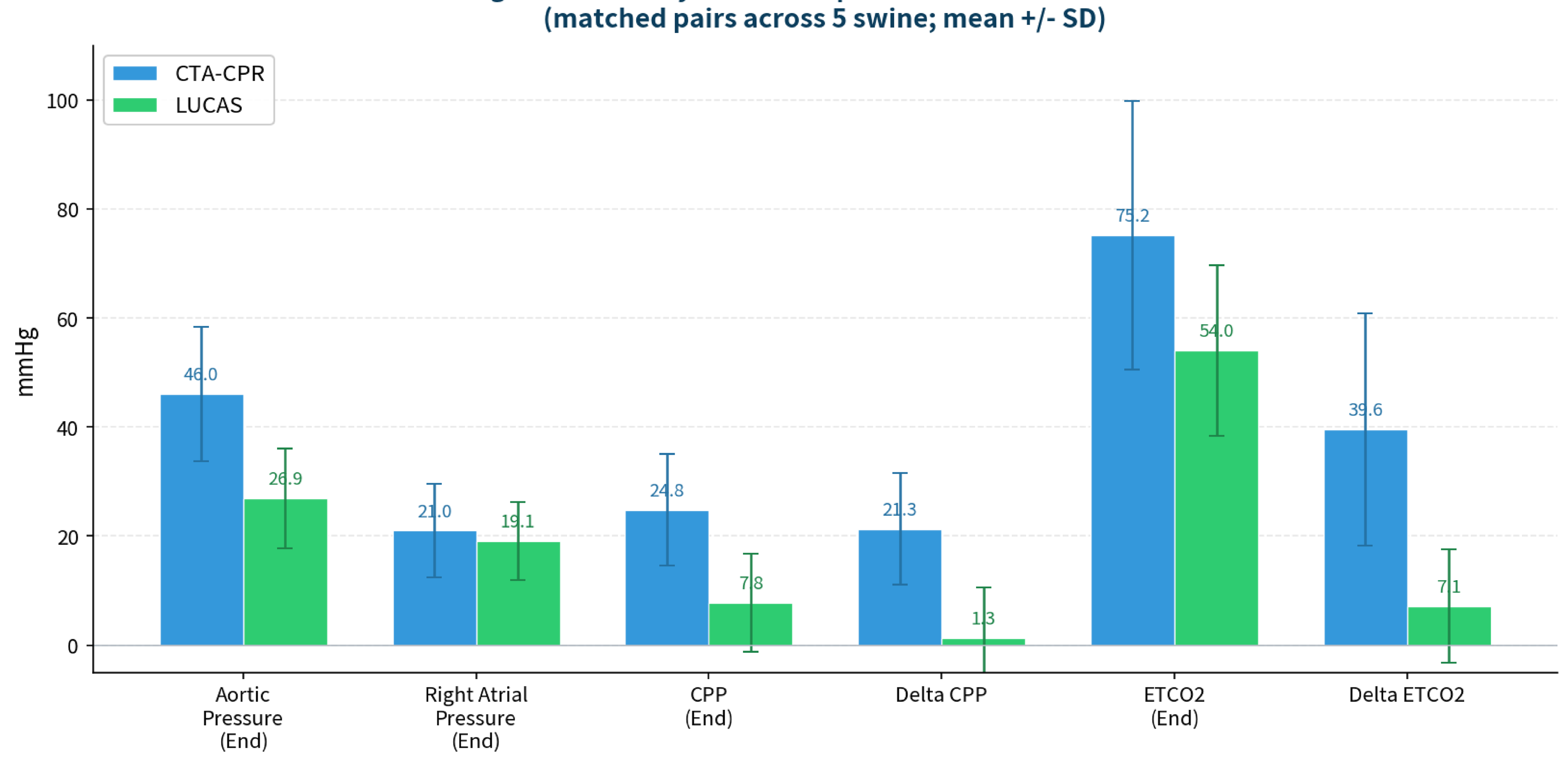


Table 1. Hemodynamic Comparison: CTA-CPR vs Lucas

Paired t-test n=28 matched pairs

	Ao*	RA	CPP*	ETCO2*	Delta Ao*	Delta RA	Delta CPP*	Delta ETCO2*
CTA-CPR	46.0 ± 12.3	21.0 ± 8.6	24.8 ± 10.3	75.2 ± 24.6	21.9 ± 11.7	0.3 ± 9.0	21.3 ± 10.2	39.6 ± 21.3
LUCAS-CPR	26.9 ± 9.1	19.1 ± 7.2	7.8 ± 9.0	54.0 ± 15.7	1.9 ± 7.7	0.6 ± 6.7	1.3 ± 9.3	7.1 ± 10.4

* statistical significance, $p<0.01$

Figure 2. Pressure measurement tracings during single porcine comparison study

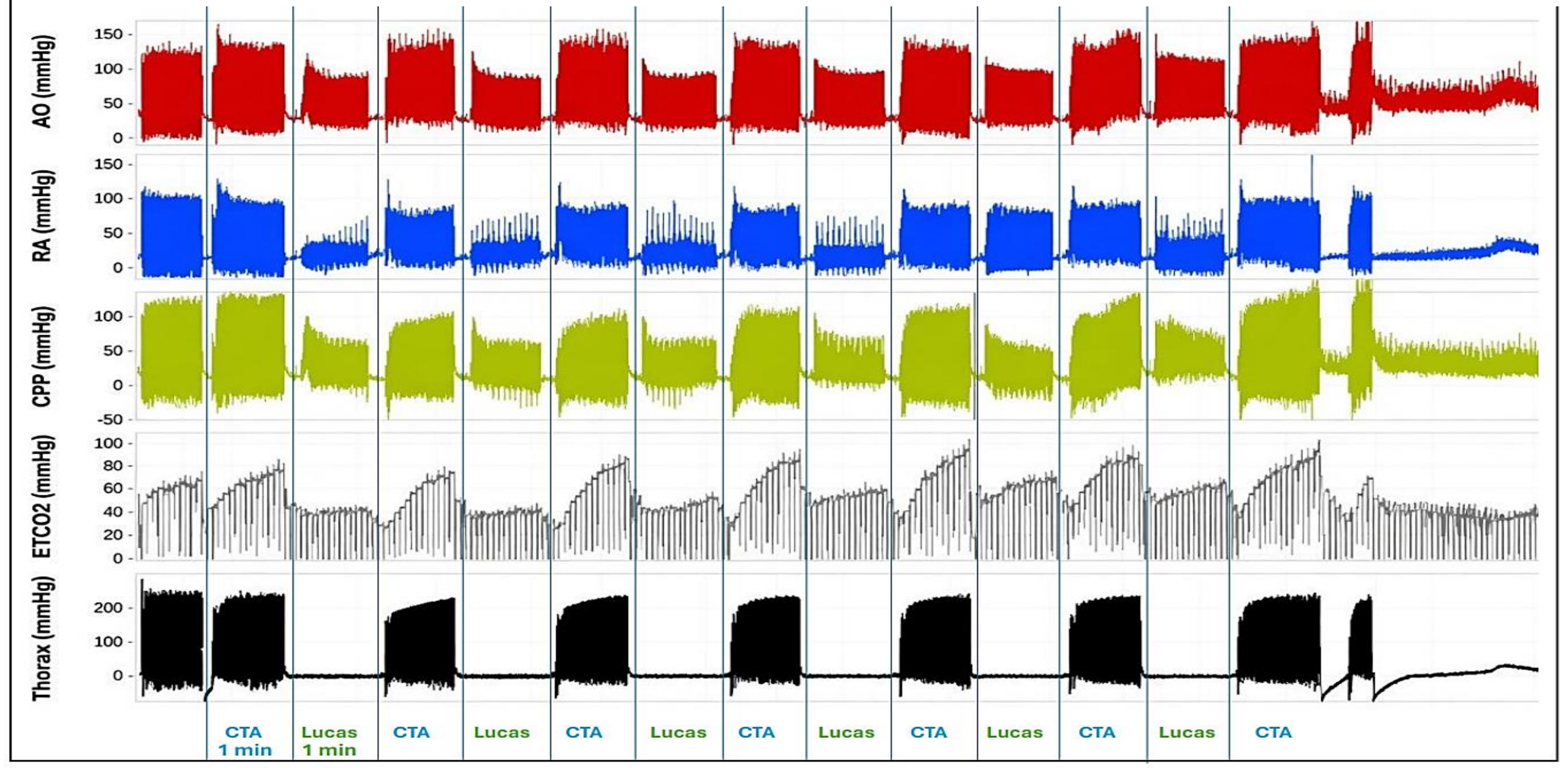
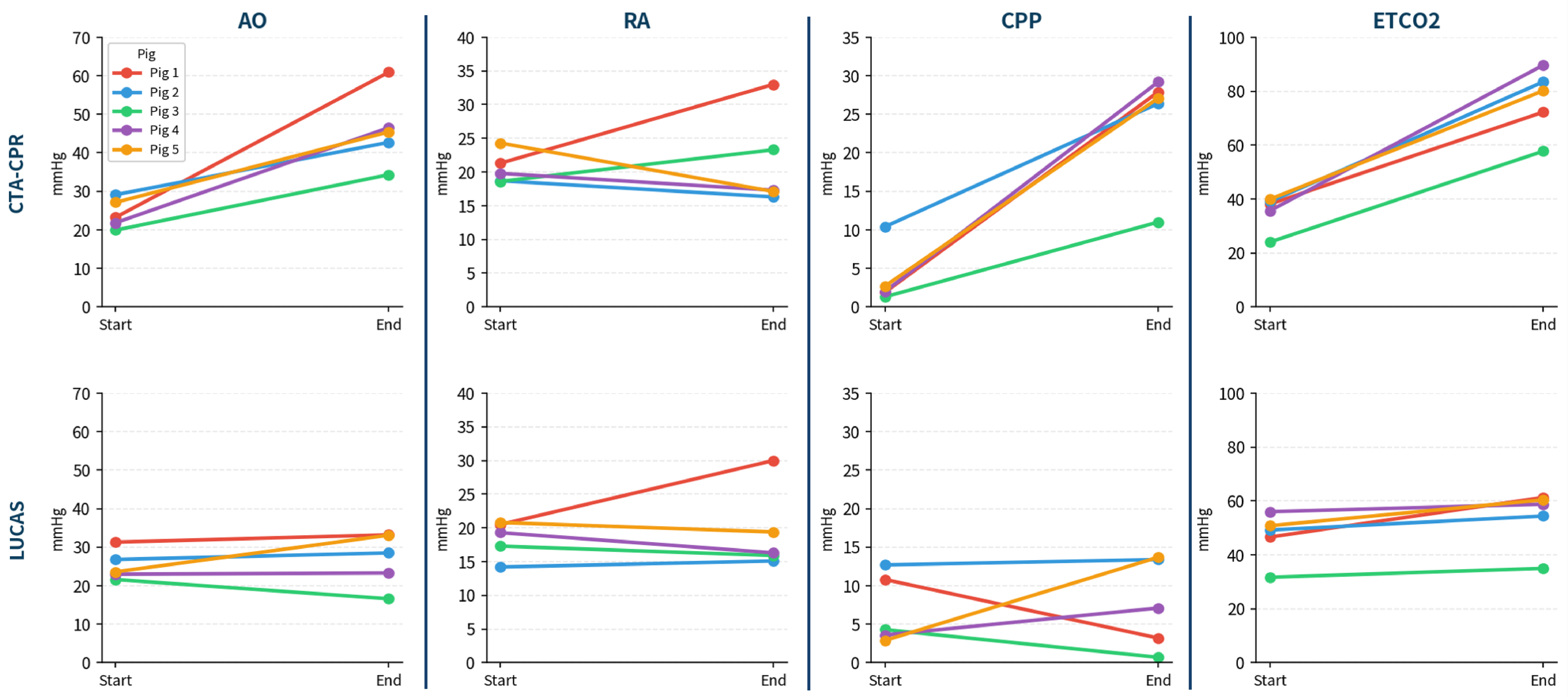


Figure 3. Average per pig measurement trajectories from start to end of 1min epochs



Results

In this n=5 swine crossover study (28 paired time-epochs), CTA-CPR generated markedly superior indicators of hemodynamics compared with the most widely used mechanical CPR device. ($p < 0.01$; Table 1, Figure 1).

Representative multi-channel recordings (Figure 2) illustrate the rapid rise in aortic pressure, CPP, and ETCO2 when switching from LUCAS to CTA-CPR and the corresponding decline when switching back.

The LUCAS provides active decompression, which would be expected to lower RA pressure and improve the AO−RA gradient. However, RA pressure did not differ significantly between devices ($p = 0.3$ for End RA; $p = 0.9$ for Delta RA).

Per-pig end-point trajectory analysis (Figure 3) confirmed that the CTA-CPR advantage was consistent across animals: nearly every animal showed a steep rise in AO, CPP, and ETCO2 during CTA-CPR epochs, while LUCAS epochs remained flat or declined.

Discussion

In this swine crossover study, CTA-CPR generated markedly superior indicators or hemodynamics compared with the most widely used mechanical CPR device.

Key findings include a greater than threefold higher end-epoch CPP, a large positive ΔCPP versus essentially no improvement with LUCAS, and substantially higher ETCO2 generation. All results are consistent with greater forward flow.

The lack of significant difference in right atrial pressure is notable given that the LUCAS performs active decompression. One might have expected lower RA pressures and a consequent CPP advantage for that device.

CTA-CPR applies greater total force while distributing it circumferentially, eliminating the high localized forces that cause skeletal injury with sternal-piston devices. This combination of superior hemodynamics and improved safety profile is particularly relevant for prolonged resuscitation and resource-limited medical systems.

These data indicate that CTA-CPR may be a hemodynamically superior alternative to current mechanical CPR devices, and warrant further evaluation with ROSC and neurologic outcome as primary endpoints.

Limitations

Although expanded to five animals and 28 matched pairs, the sample remains modest. Porcine thoracic anatomy differs from humans and may significantly favor circumferential versus sternal-piston mechanisms. Endpoints are hemodynamic surrogates rather than direct organ blood flow or survival.

Disclosure

CPR Therapeutics, Inc. funded aspects of this work and is developing circumferential CPR technologies. Norman Paradis and team members are affiliated with CPR-T. LUCAS is a registered trademark of Stryker; no endorsement is implied. Supported in part by NIH SBIR 1R44HL164199-01A1 and NSF SBIR 2437512. The views expressed herein are those of the authors and do not reflect the official policy or position of the Department of Defense or its components.