A Mechatronic Bio-Mimicking Simulator to Study Various Combinations of Mechanical Compressions During CPR.

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BACKGROUND

Current automated CPR devices are based upon the theories of Cardiac pump (e.g., Manual CPR, Thumper TM, LUCAS TM, Life-Stat TM), Thoracic pump (AutoPulse TM, Reax-Resuscitation device TM) & the Abdominal pump (LifeStick TM).

Results of all these devices are largely at par with each other, and not superior to the manual CPR1-5

KNOWLEDGE GAPS / QUESTIONS

Efficacy of these three sets of devices have only been tested in isolation. Their combinations have not been systematically studied, except in mathematical and electric circuit models 6,7.

Testing various combinations of only Cardiac, Thoracic and abdominal pumping, with option of varying the time intervals between these, would lead to >430 possible iterations8. Addition of extra variables like duration, force and depth of individual compression would yield an impossibly huge number to test in-vivo.

INTRODUCTION

To overcome this impasse, we present a mechatronic bio-mimicking simulator which can study, on a physical model of circulatory system, almost all possible, existing and novel, combinations of mechanical intervention during CPR.

Our initial findings support a novel combination of Thoraco-Abdominal compressions producing significantly higher COP. This is explained by a "venous-backflow theory".

METHODS

A fluid-filled, multi-chamber, passive, closed circulatory platform was created, comprising valved-conduits and chambers representing heart, lungs, splanchnic and lower limbs reservoirs.

Physico-elastic properties of the chambers were optimized to bio-mimic the required organ-compliances.

An exit conduit from its cardiac chamber, carried fluidic sensors recording Cardiac-out-put (COP) in real-time.

This circulatory platform was encased within a programmable electro-pneumatic, multi-effector, actuation system which could run with various combinations of the in-vogue & novel thoracic and abdominal compressional sequences, with varied force, speed and timings.

SCHEMATICS

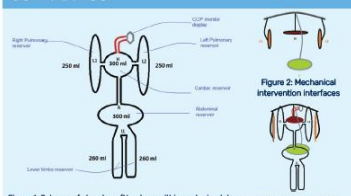
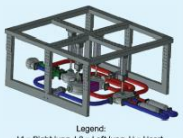


Figure 1: Scheme of chambers (Numbers within each circulatory chamber denote the average blood volume therein).

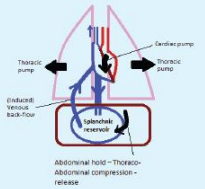
Figure 2: Mechanical intervention interfaces

Figure 3: Superimposed chambers and actuators.

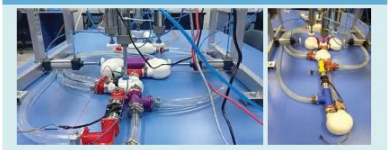


Legend:
L1 = Right lung, L2 = Left lung, H = Heart, A= Abdomen, LL= Lower limbs

VENOUS BACK-FLOW THEORY



SIMULATOR



FUNDING

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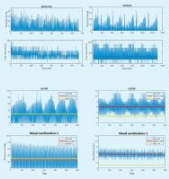
RESULTS



Three actuator configurations mimicking the actions of LUCAS™, Autopulse™ and Lifestick™ produced mean "aortic" pressure of 27.64±28.23, 18.32±19.38 & 15.96±21.24 mmHg, respectively, with corresponding flow rates of 6.02±2.65, 5.16±1.69 and 4.20±2.22 liters/minute.

A novel configuration of sustained abdominal compression followed by Thoracic compression and subsequent collective release, produced distinctly higher mean pressures of 44.46±40.81 mmHg (>60% higher than that with LUCAS™ configuration) with flowrates of 5.09±1.72 L/min.

CONCLUSION

The presented simulator provides a platform to test countless combinations/variations of existing and novel methods of CPR, to short-list the best-COP-producing methods, which could further be studied into animal and human studies.

A "venous-backflow" theory of CPR-hemodynamics is proposed with its possible interventional implications. We are in the process of conducting animal model studies to substantiate these results.