A Cardiac Suspension Unit for Mitigating Thoracic Pressure in Postoperative Open-Sternal Newborns
A Heat Bed and X-Ray Compatible Design
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2018

Abstract

Background
Children born with congenital heart defects require corrective surgery where the breastbone is split. Immediate closure may not always be possible due to compression on the heart. Cardiac suspension is technique whereby traction is applied anterior to the chest to prevent these complications. However, this technique is limited by its unquantified tension, lack of compatibility with X-ray, and its crude aesthetic. Therefore, it was proposed that a mechanical tensioner unit could be designed to perform cardiac suspension while resolving these challenges.

Methods
An engineering design methodology will be undertaken to develop the tensioner. First, the design requirements will be established through a chart-review and survey interviews. Next, commercial and conceptual options will be evaluated in a Pugh matrix. The device will be considered as a series of sub-systems evaluated through mechanical analytics, FEA, and bench-top testing. Most notably, the device will be tested for its rigidity, tensile transmission, heat transfer and radiolucency.

Results
Initial data on suspension patients is presented and list of design requirements is established. Next, a cantilever structure is chosen for the overall design. The framing shows good fixation to the bed, but with a slight deflection that is within the design threshold. A compensator system and non-backdrivable input are developed and assessed for the wire-guide system. However, transmission losses are noted due to friction which should be addressed in future work. Finally, Euler-Bernoulli beam modelling identifies Ultem for the design of the cantilever. Initial analytical and experimental testing validated this material selection.

Significance
This research presents the first formal investigation into the cardiac suspension technique. A complete prototype was designed, built and tested from this project. Despite some outstanding challenges, this new medical device is a strong step towards resolving the current limitations of cardiac suspension and consequently improving patient care.

Keywords: Cardiac Suspension, Delayed Sternal Closure, Multivariate Design, Tensioner, Neonates, Critical-Care, Non-Backdrivable, Open Chest Management, X-ray compatibility, Radiant Heating