Innovative User-Centric Design and Engineering Process to Develop a Part Task Trainer for Military Medical Training

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Disclosure

This presentation contains graphic pictures of simulated and real trauma injuries

WARNING: GRAPHIC INJURIES

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Outline

- Background
- Training Gap
- Methodology
- Functional Testing
- Challenges and Risk
- Lessons Learned
- Future Work

Background

Ocular trauma is frequently encountered in combat and accounts for 8.5% of US battlefield injuries.

186,555 eye injuries were reported by military medical facilities worldwide between 2000 to 2010.

13 years of conflict in the Middle East caused a considerable number of treatable eye injuries that resulted in permanent visual impairment.

Background

Non-Penetrating Ocular Trauma

- Combat Environment
  - Blunt trauma to the face
- Non-Combat Environment
  - Construction work
  - Vehicle repairs
  - Playing sports
  - Altercations

Trauma patient with an untreated proptotic eye that is also displaying abnormal EOMs

Image adapted from (US CPHM/TCMC, 2018).

Blunt trauma patient with a treated proptotic eye.

Image adapted from (US CPHM/TCMC, 2018).

Background

Blunt trauma to the face can cause a retrobulbar hematoma (RBH) which can result in a compartment syndrome of the orbit.

The build-up of blood in the orbit can place pressure on the optic nerve thereby denying blood flow to both the nerve and the retina (ischemia).

Permanent damage to the optic nerve and retina can occur after as little as 90 minutes of ischemia; permanent damage results in irreversible vision loss.

Blindness rates from improperly treated RBH are as high as 52%.

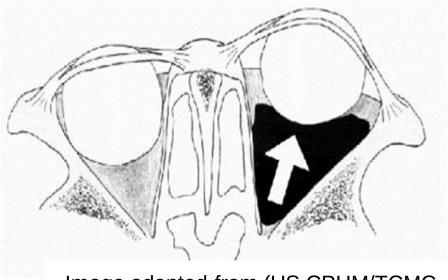


Image adapted from (US CPHM/TCMC, 2018).

Image adapted from (Rubin, & Tayani, 1999).

Background

Lateral Canthotomy & Cantholysis (LCC)

- LCC is a simple eyesight-saving procedure to treat compartment syndrome of the orbit.
- Can be performed in the field with very few surgical instruments.
- Transection of the lateral canthal tendon releases the built-up pressure within the orbit reducing the force that is exerted on the optic nerve.
- Blood flow is restored to the optic nerve and retina, saving vision on the afflicted eye.

Training Gap

- Currently, there is no LCC training model available, civilian or military, prior to animal or cadaveric phases of training.
- Training gap in the US Army; providers are not performing this relatively simple eyesight-saving procedure.
- LCC must be practiced and rehearsed for military providers’ competency development.

Methodology

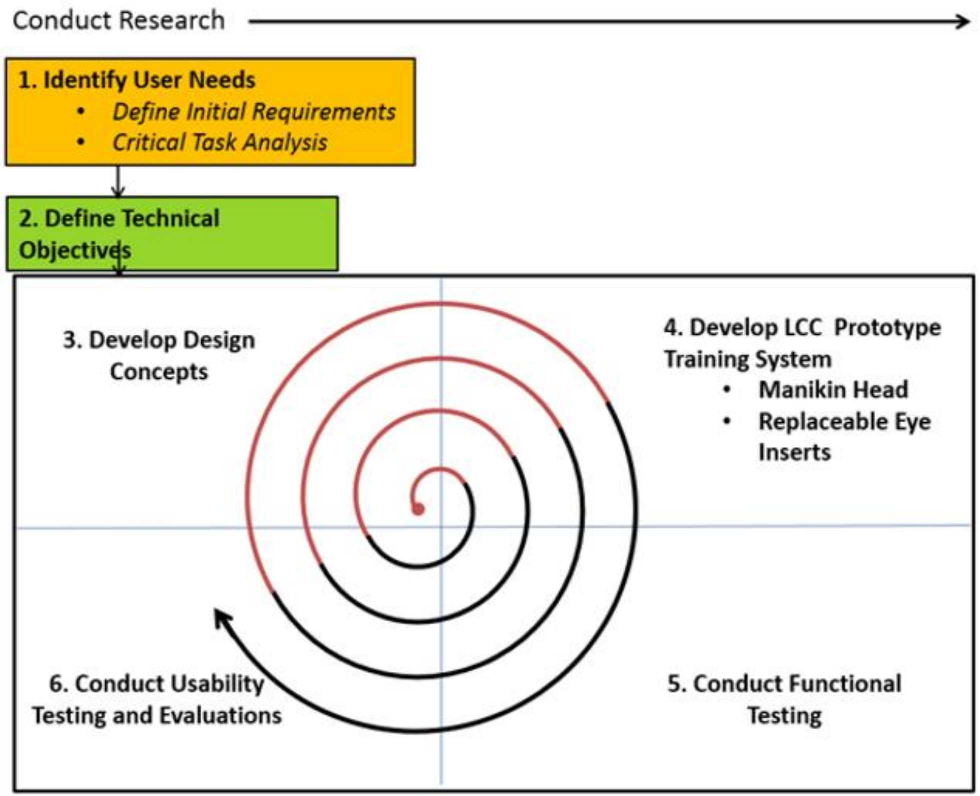
Technical Objectives and Requirements

Develop a part-task trainer that allows students to rehearse the LCC procedure until they are comfortable with, and proficiently able to perform, the procedure.

- The part-task trainer must simulate:
  - the pressure of a proptotic eye
  - relevant anatomical landmarks of the eye and orbit
  - tendon strumming
  - tendon cutting

- The part-task training must allow for:
  - quick reset
  - low cost per use

Methodology



Methodology

Prioritize Requirements and Design Goals

- A survey of pairwise comparisons of design goals was used to reconcile SME inputs and quantify the relative importance of each.
- Enabled the research and development team to prioritize requirements and focus on the top design features identified by the user community to be incorporated in the system.

1. Tendon Cut/Pop
2. Orbit Decompression
3. Retrobulbar Pressure
4. Tendon Strumming

Methodology

Design and Develop the Prototype

- Initial concepts incorporated the technical objectives.
- Using spiral development the training system evolved from a partial head to a complete skull frame with a partial neck and removable eye socket inserts.

Figure adapted from Sotomayor, T. M., Bailey, M. P., & Dykens, I. T. (2018, October). *A Lateral Canthotomy and Cantholysis (LCC) Part-Task Training System.* Poster session presented at the International Conference on Human Systems Engineering and Design: Future Trends and Applications, Reims Champagne-Ardenne, France.

Functional Testing

- Objective Measure: Simulated Intraocular Pressure

- Subjective Measure: Subject Matter Experts (SMEs) perform the LCC procedure and provide subjective feedback (Simulated Intraocular Pressure is accurate, too firm or too soft)

SME provides subjective feedback (left). The LCC Training System with replaceable eye inserts (middle) and the intraocular pressure measurement apparatus (right).

Figure adapted from Sotomayor, T. M., Bailey, M. P., Dykens, I. T., & Dorton, S. (2018). Saving eyesight using simulation. Proceedings of the 2018 Interservice/Industry Training, Simulation, and Education Conference Orlando, FL. Paper retrieved from http://www.iitsec.org/about-iitsec/publications-and-proceedings

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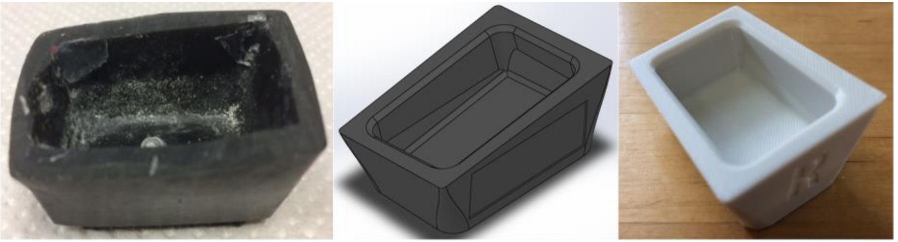
Rapid Prototyping

3D Printing

- Facilitated rapid design changes to address feedback.
- Increased consistency of the manufactured insert components over hand-carved inserts.
- 12 mannequin heads and 400 replaceable eye socket inserts developed to date to support hands-on testing and evaluation.



Hand-carved insert frame — *CAD model of insert* — *3D printed insert frame*

Figure adapted from Sotomayor, T. M., Bailey, M. P., & Dykens, I. T. (2018, October). *A Lateral Canthotomy and Cantholysis (LCC) Part-Task Training System.* Poster session presented at the International Conference on Human Systems Engineering and Design: Future Trends and Applications, Reims Champagne-Ardenne, France.

Challenges

Functional challenges of the simulated eye insert include:

- Achieving a consistent release of the retrobulbar pressure when the LCC procedure is performed.
- Providing realistic haptic feedback (the pop) when the cantholysis is performed.
- Achieving realistic eyelid laxity post-LCC procedure.

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Risks

Enhancing the fidelity while cost effectively manufacturing the replaceable eye inserts.

Mitigations:

- Optimizing mechanical designs and manufacturing process.
- Developing a manufacturing plan which takes into account cost metrics, manufacturing options, and cost savings (refurbishing/reset).

Lessons Learned

A survey of pairwise comparisons of requirements and design goals enabled the team to:

- Reconcile SME inputs and quantify the relative importance of each design goal of the LCC training system.
- Focus on the top design features identified by the user community to be incorporated in the system.

Lessons Learned

3D printing and small batch development of the eye inserts enabled the team to rapidly:

- Address SME feedback regarding usability and accuracy with design changes.
- Produce updated eye inserts for further evaluation and testing.

Lessons Learned

Functional testing of the eye inserts enabled the design team to:

- Translate subjective feedback into quantitative design and production metrics.
- Achieve smaller variances in the pressures of all proptotic eye inserts (pre- and post-LCC).
- Achieve a more consistent release of retrobular pressure (post-LCC).

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Questions

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