Realistic Carotid Endarterectomy Simulation Using 3D Printing and Hydrogel Polymers

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INTRODUCTION:

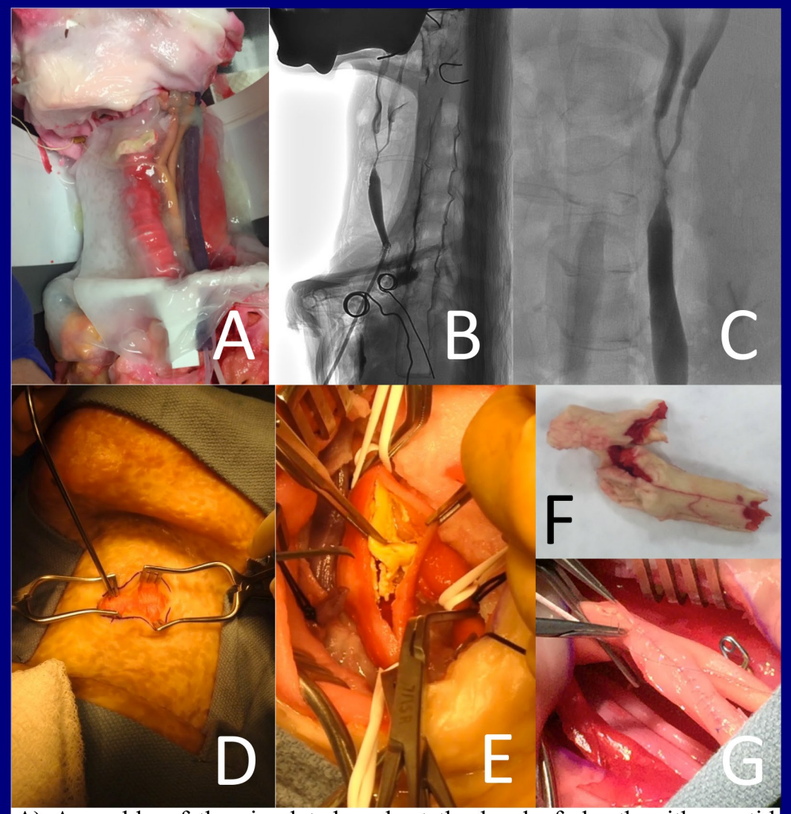
Training for a carotid endarterectomy has become difficult because of decreased volume secondary to advances in the medical management and regionalization of care. While live operative exposure is required, resident inexperience may compromise patient safety and lengthen case times. This needed training tool was designed to replicate all vital steps and measure operative performance.

METHODS:

- Anatomically accurate CAD model of the human neck was created.
- An Injection mold was 3D printed for each component (carotid artery, jugular vein, sternocleidomastoid muscle, etc.
- The printed molds were used to cast poly-vinyl alcohol hydrogels and an entrie neck was assembld in anatomical fashion .
- A ventricular assistive device was used to create pulsatile blood flow.
- 5 residents and attending physicians (n=10) completed the simualtion.
- Face validity surveys and operative performance were compared using T-test and Chi Squared statistics.

OBJECTIVE:

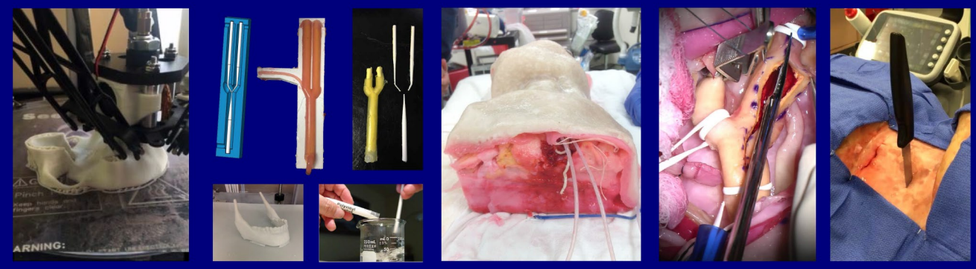
To develop and validate a sugical simulator for an open carotid endarterectomy.



A) Assembly of the simulated neck at the level of sheath with carotid artery, jugular vein and vagus nerve. **B)** Lateral radiograph demonstrating an unsubtracted view of the entire model with visible jaw, spine and clavicles. **C)** Anteroposterior radiograph showing severe stenosis extending from the common into both internal and external carotid arteries. **D)** Simulation of a carotid endarterectomy with a draped model at the platysma layer. **E)** Dissection of the plaque off the carotid artery wall in the correct subintimal plane. **F)** En-bloc removal of carotid plaque specimen. **G)** Primary closure of the carotid artery.

RESULTS:

The mean operative time for the expert group was 63.6 minutes versus 138.8 for the residents (p=0.002). Similarly, there was a difference in mean internal carotid artery clamp time of 43.4 minutes versus 83.2 (p=0.04). Only 2 hypoglossal nerve injuries occurred, both in the resident group. Attendings (n=5) reported an average of 4/5 on face validity questions.



Construct Validity	Attending Mean, n=5	Resident Mean, n=5	p Value
Total operative time (min)	63.6	138.8	0.002
Carotid clamp time (min)	43.4	83.2	0.04
Nerve injury	0/5	2/5	0.009
Face Vaility	4.0/5	4.2/5	0.44

CONCLUSIONS:

The hydrogel based simulator provides a realistic tool for practicing procedures in a safe and low cost environment. Surgical times on the models were similar to live cases suggesting appropriate difficulty of the task. Residents on average took twice as long as attendings and had more errors in technique.

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