Team B3: Single-Step Tracheostomy Device

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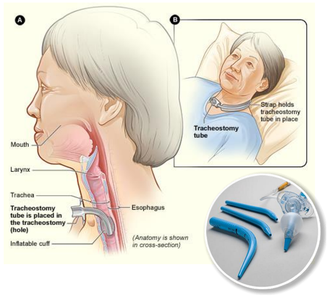
Motivation/background



Tracheostomy: insertion of tube into the trachea to bypass upper airway damage or obstruction and restore airflow

Standard-of-care procedure:

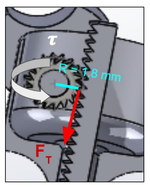
1. Create puncture in the trachea with a hollow needle
2. Pass guidewire through needle and into trachea
3. Insert and remove series of progressively larger dilators to expand the opening
4. Install tracheostomy tube

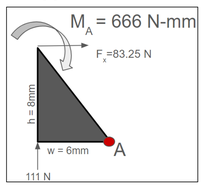
Objective: perform the dilation in a single step → shorten overall procedure time, increase efficiency of tube insertion, and reduce risk to the patient.

Methods

Design criteria	
Function	Enables single-step dilation of incision
Mechanism	Flanges remain attached until expansion and resist deformation
Size	Dilation to 12mm diameter, hollow central channel
Cost	≤ market standard

Applied force calculations





Comfortable wrist torque: 200 N-mm

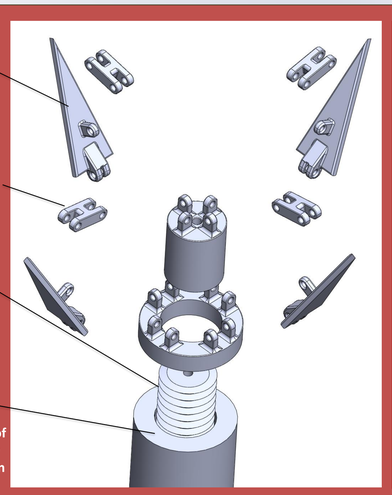
$$F_T = \frac{\tau}{r}$$

$$\frac{200\ N{-}mm}{1.8\ mm} = 111.1\ N$$

Ex vivo testing procedure

Puncture with hollow needle → Insert guidewire → Insert device → Perform dilation → Insert tube

Single-step tracheostomy device

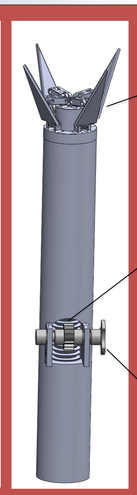


Flanges
x4, form pointed tip that is inserted into tracheal puncture

Inner struts
Join flanges to central plunger

Plunger
As knob is turned, plunger advances to expand flanges outward

Shaft
Tracheostomy tube fits around exterior of shaft, can be directly inserted after dilation

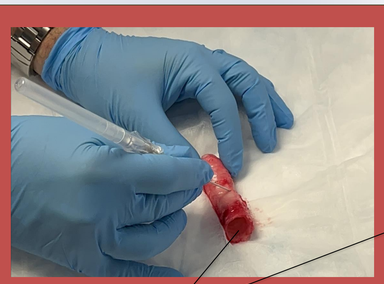


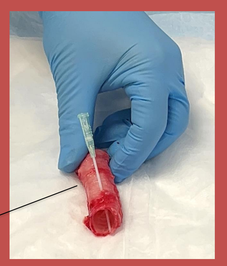
Dilated tip
Flanges expand puncture to 12mm diameter for insertion of tracheostomy tube

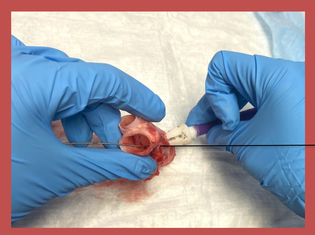
Gear
Meshes to plunger, allows rotation from knob to advance plunger

Knob
Physician turns knob to initiate dilation

Ex vivo testing





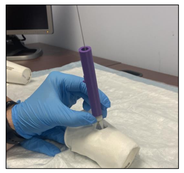


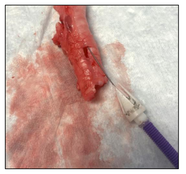
Puncture
Hollow needle punctures trachea and provides access for guide wire

Dilation
Single-step tracheostomy device expands puncture for tube insertion

Results

Dilation experiments		
Material	**Thickness (mm)**	**Diameter of dilation (mm)**
Proof-of-concept (paper)	0.20	13.88
Porcine trachea	29.0	6.00





Bioethical implications

Patients
- Reduced risk of infection, hypoxemia, tissue damage

Healthcare facilities
- Increased procedure success and efficiency

Family and caretakers
- Improved patient outcomes
- Easier tube replacement

Healthcare workers
- Improved ease of use
- More consistent results

Conclusions/future direction

- **Hinged dilator mechanism successfully dilates puncture in pig trachea**
- **More advanced fabrication is required for commercial production of finely-detailed hinges**
- **Future iterations should accommodate curved tracheostomy tube → enable direct insertion**

References

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