Optical Fibre Sensor for Measuring Endotracheal Tube Cuff Contact Pressure on Tracheal Wall

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1. Introduction

Endotracheal Tube (ETT) provides ventilation and oxygenation for unconscious and COVID patients.

The ETT cuff has 2 main functions [1]:

- Prevent air to lungs from escaping through the mouth
- Prevent liquid/bacteria entering lungs

Complications

1) Over-inflation- risk of tracheal damage (like stenosis)[2]
2) Under-inflation- risk of Ventilator Associated Pneumonia (VAP) [2]

4500 patients of every 100,000 die from VAP every year [3]

Solution

A fibre optic pressure sensor on the ETT cuff to measure contact pressure on the tracheal wall. Once the sensor senses contact from the cuff, inflation stops, creating an adequate seal without over-inflation

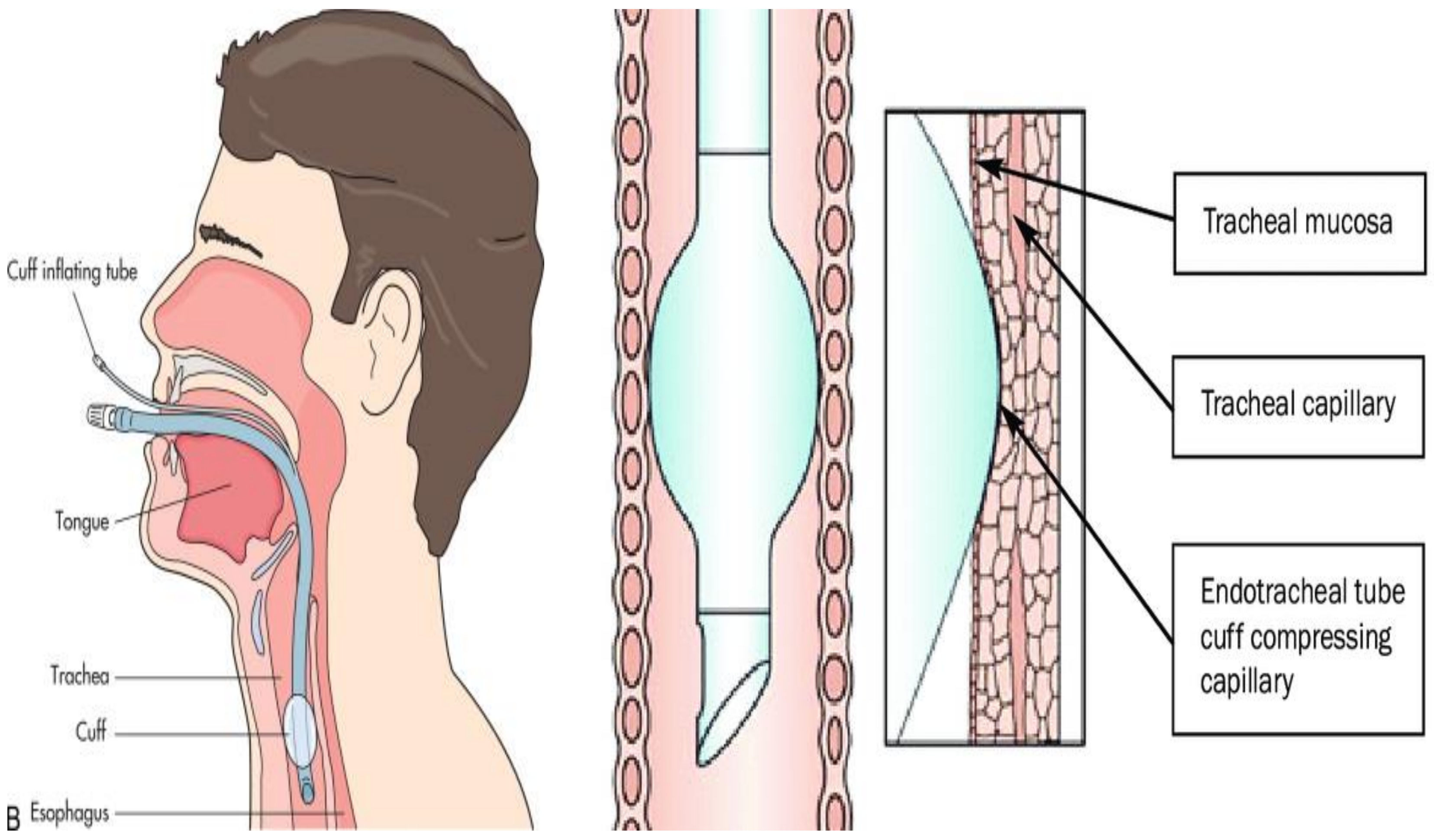

Figure 1: Right: The cuff, when over-inflated, blocks blood flow to the tracheal mucosa. This causes many complications in the trachea [4], Left: The ETT placed into the trachea via the mouth. The cuff is located at the bottom the tube and is inflated to create a seal [1]

2. Working Principle and Fabrication of Optical Fibre Pressure Sensor

A fibre Bragg Grating (FBG) is inscribed into the fibre core using a UV laser. The FBG is sensitive to strain so if the fibre is embedded in a polymer and then a load is applied to that polymer, it will turn the load into axial strain along the fibre, which will result in a wavelength shift.

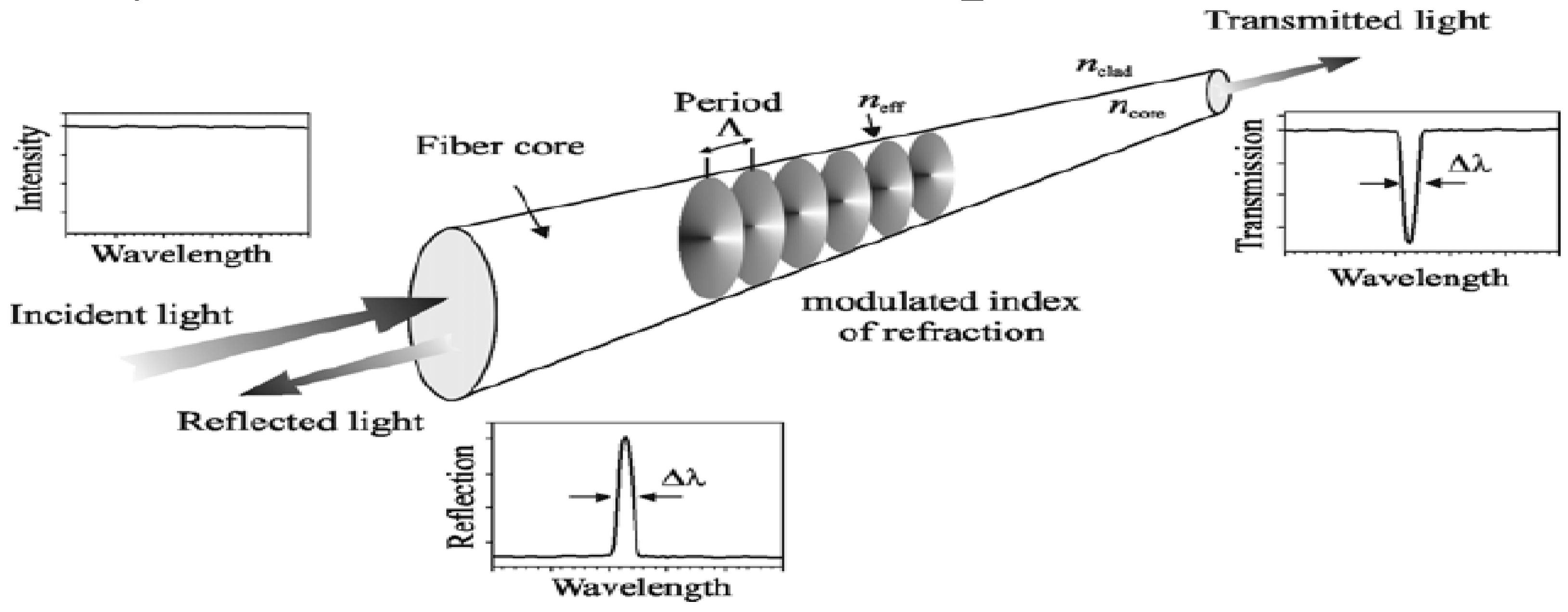

Figure 2: Diagram representing a Bragg grating inscribed into the core of an optical fibre and the transmitted and reflected wavelengths [5]

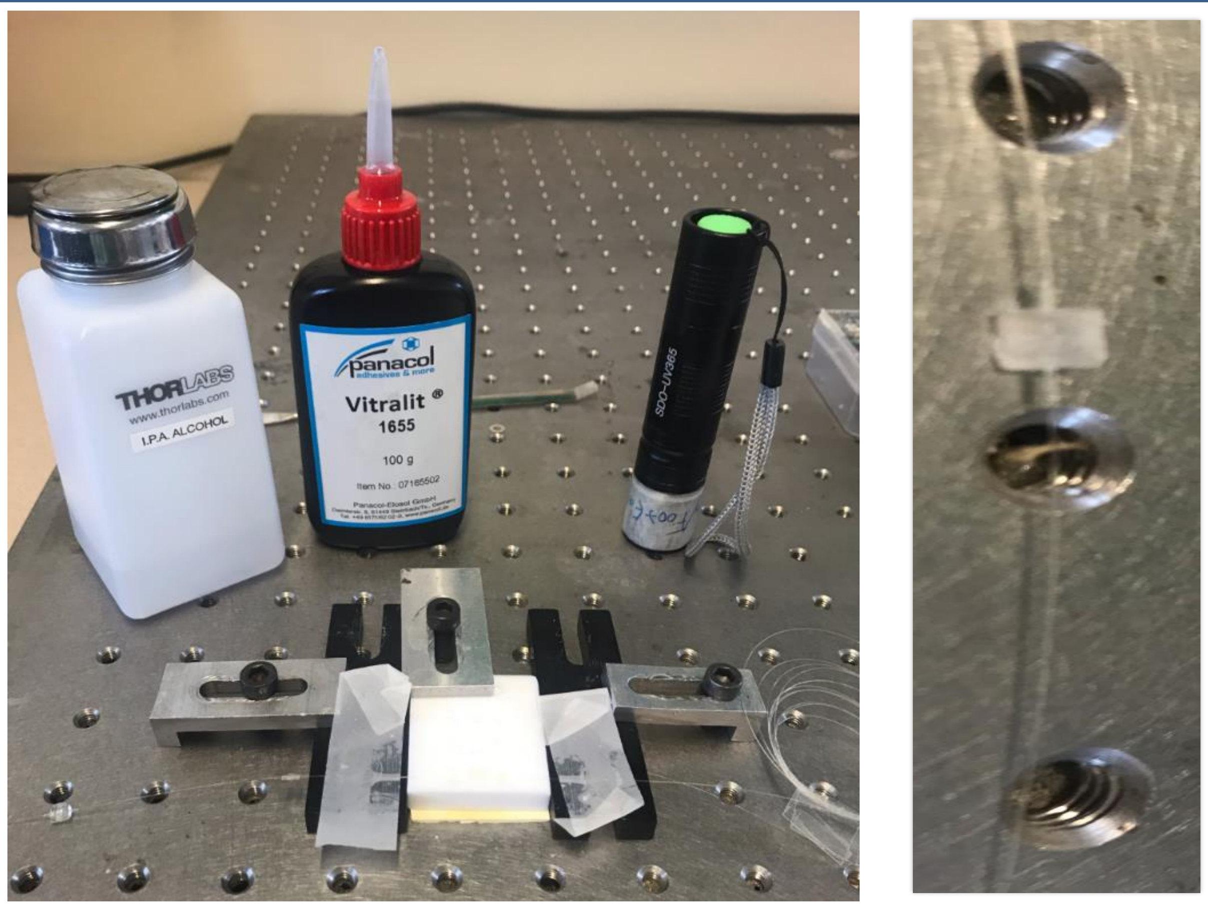

Figure 3: Polymer SYLGARD is poured into a white 4mmx4mm mould (left) with the fibre (with the FBG inscribed) placed in the centre. After the polymer has cured the sensor (right) is ready to be calibrated.

3. Calibration of Optical Fibre Pressure Sensor

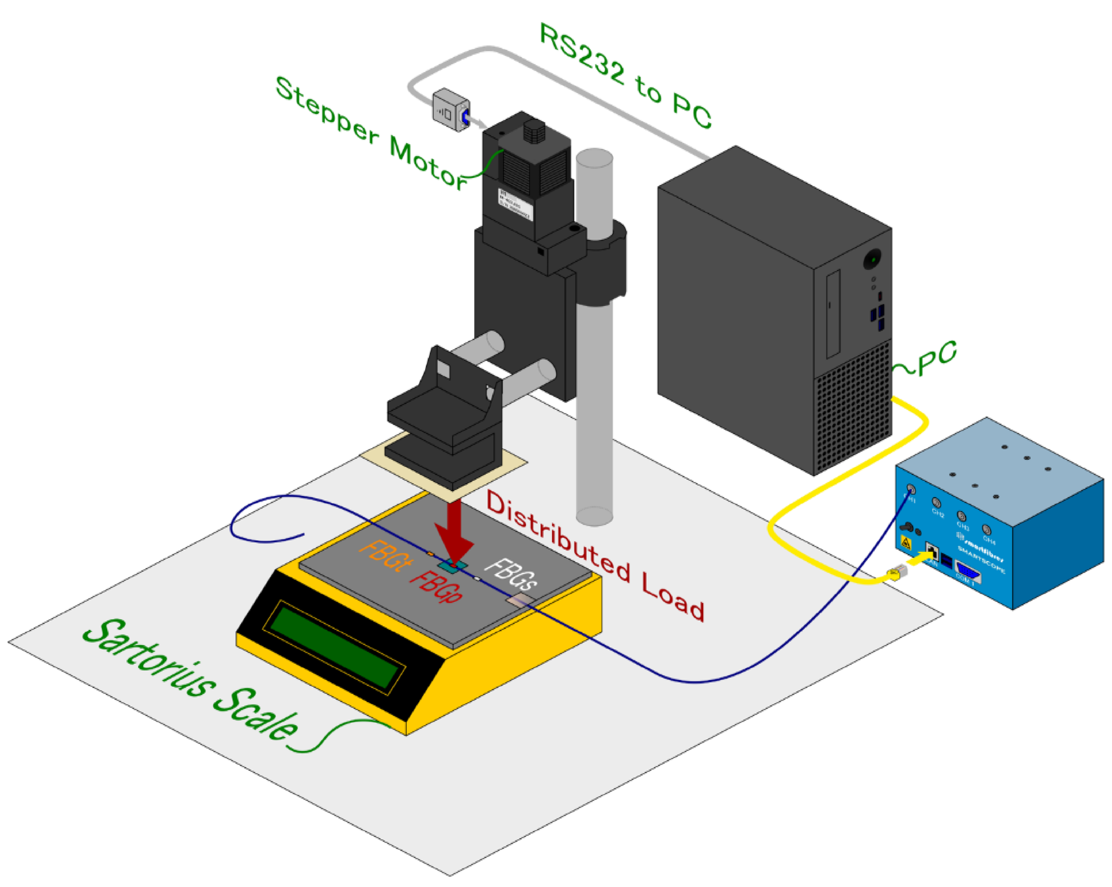

Figure 4: The Calibration Setup consists of highly accurate scales with the fibre pressure sensor on it, above it is a loading arm which presses onto the sensor in 0.1mm increments. The scales records the load on the sensor and the wavelength shift of the fibre is recorded

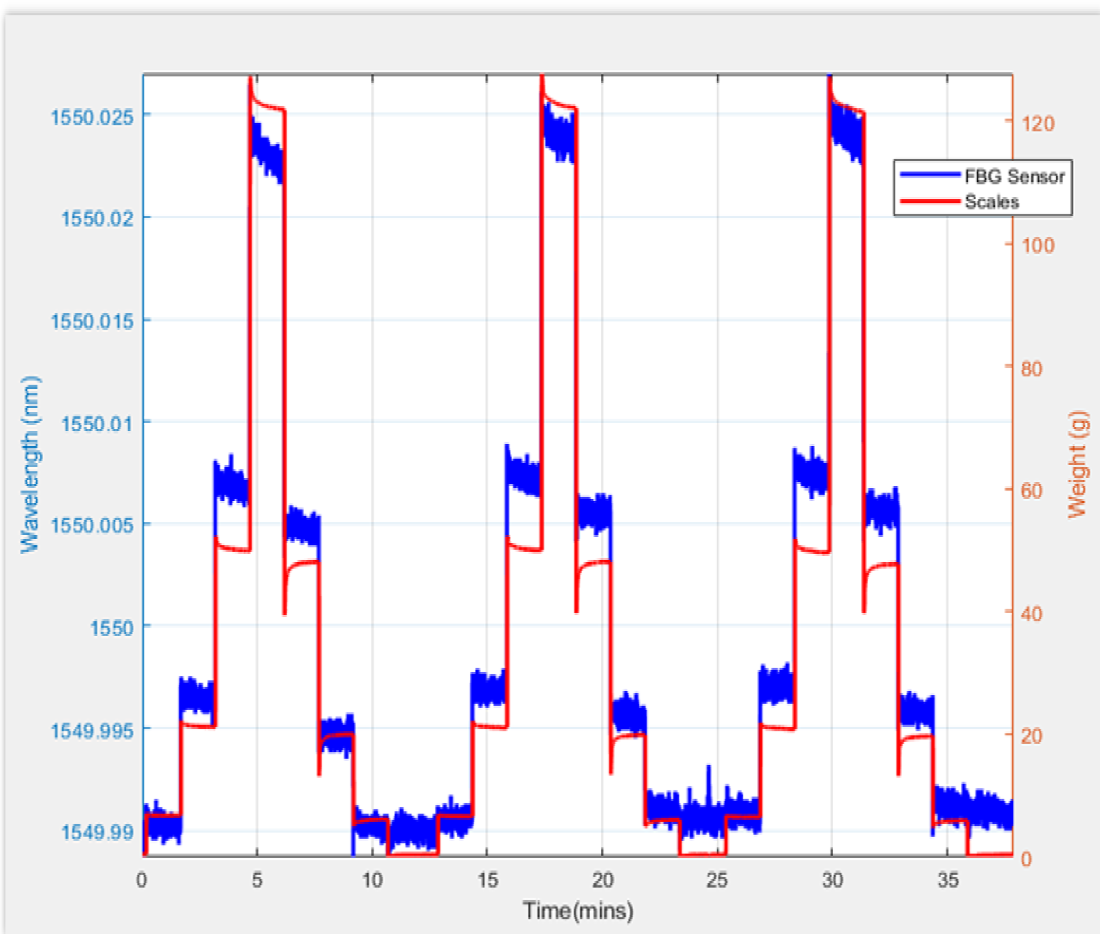

Figure 5: Fibre sensor response (blue) to weight applied versus scales response (red) to three loading and unloading cycles.

The fibre sensor shows good repeatability as it always returns to its original baseline.

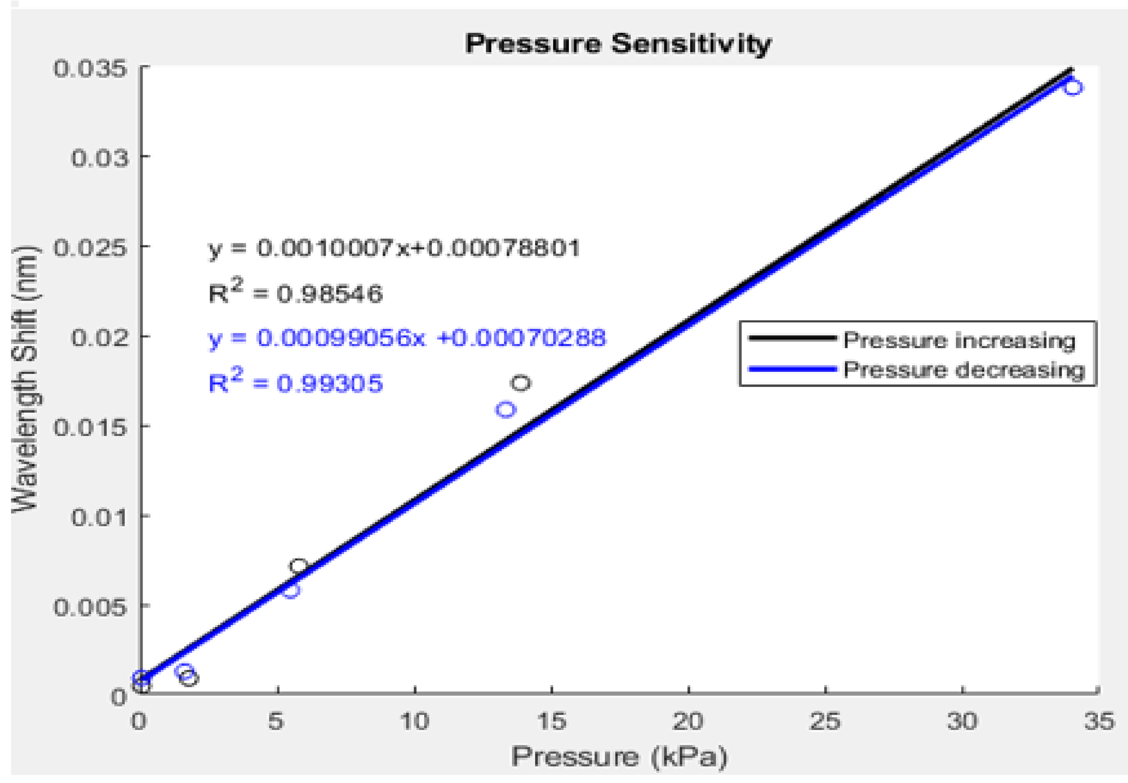

Figure 6: Pressure sensitivity was calculated from using the polymer patch area. The sensitivity was recorded as 0.996pm wavelength shift per kPa of pressure.

4. Conclusion

- A fibre optic pressure sensor has been created and calibrated
- The sensor has a sensitivity of 0.996pm per kPa

5. Future Work

- Fibre sensor to be tested in calibration tube for ETT pressure calibration
- Fibre sensor to be tested in tracheal phantom

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References

[1] Malamed *et al.*, 2015, [2] Tsaousi *et al.*, 2018, [3] NHS England, 2016, [4] Pervez *et al.*, 2011, [5] Othonos *et al.*, 2006

Pictures: [1], [3].

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