Mechanical catheter navigation with electromagnetic tracking to peripheral airway targets

F. Trauzettel[1,2], H. A. Jaeger[1,2], E.F. Hofstad[3], M.P. Kennedy[4], H. Leira[5], T. Lango[3], P. Cantillon-Murphy[1,2]

1) School of Engineering, University College Cork, Ireland, padraig@alum.mit.edu, 2) IHU Strasbourg, Strasbourg, France, 3) SINTEF, Trondheim, Norway, 4) Cork University Hospital, Cork, Ireland, 5) St.Olav's Hospital, Trondheim, Norway

1. Introduction

Lung cancer remains the single most deadly cancer in men and women due to low rates of early detection and treatment. Since non-small cell lung cancer usually starts in the outer airways, targeted minimally invasive biopsy which limits radiation exposure and avoids surgery is highly desirable. Current commercial solutions such as the superDimension (Medtronic Inc., Dublin, Ireland), and SpIN (Veran Medical, St. Louis, USA) systems rely on electromagnetic tracking for virtual navigation. However, clinical outcomes have been unconvincing due to poor accuracy, limitations in instrumentation and the lack of tracked catheters. This work proposes a novel mechanical catheter design with embedded electromagnetic tracking to facilitate tip-tracked navigation without the need for proprietary instruments or probe exchange. The catheter was used to reach peripheral airway targets by multiple users in pre-clinical studies.

2. Methods

The catheter used for this work (Figure 1) consisted in seven lumens within a 3mm diameter package; four lumens for stainless steel tendons used to deflect the distal tip, two lumens each containing one 5-degree-of-freedom EM tracking sensor (Northern Digital, Inc); and the final lumen is a 1.5mm working channel for instruments such as biopsy forceps or therapy probe.

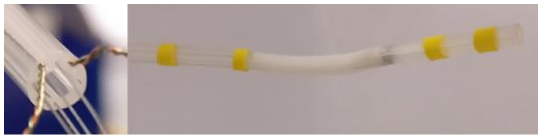

Figure 1: Proximal end (left) and distal articulating section (right) of the catheter

A testing apparatus was constructed with stepper motors and leadscrews for catheter characterisation. Pre-clinical testing was achieved in two live porcine model with independent expert users (MPK, HL) navigating to a total of 8 peripheral airway targets using virtual bronchoscopic navigation. Following virtual navigation to each tumour model, a Tornado® embolization coil (Cook Medical Inc., USA) was deployed at each for post procedure targeting verification using 3D CT.

3. Results

System characterisation of tendon deflection versus force and tendon extension identified significant non-linearities and hysteresis in the mechanical catheter characteristics. Rudimentary steering was achieved by rotation of the bronchoscopy with the catheter in the working channel. Notwithstanding catheter steering limitations, expert users successfully navigated to 8 peripheral targets (Figure 2) and deployed 8 marker coils using virtual navigation (see Table 1).

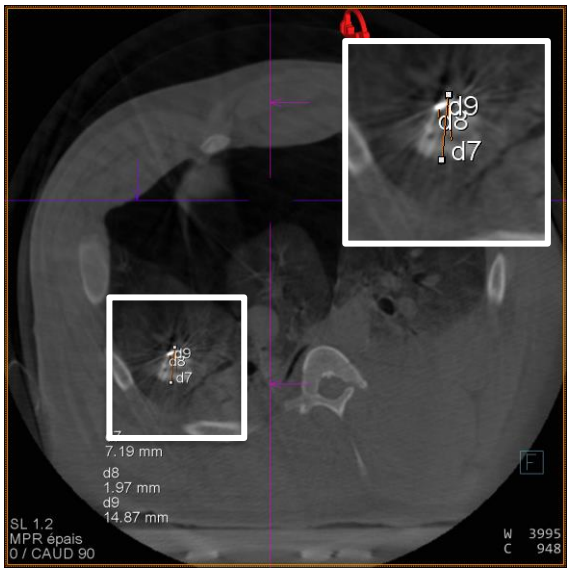

Figure 2: *Single-tendon tip angle vs tendon displacement.*

Table 1: *Closest distance from target to marker coil from CT*

Lung Position	Study 1	Study 2
Upper right	2.48 mm	5.54 mm
Centre left	6.95 mm	12.04 mm
Centre right	3.79 mm	1.97 mm
Lower right	8.07 mm	1.39 mm

4. Discussion & Conclusion

Tracked catheter navigation is feasible for targeting within 10mm of peripheral airway targets for endoscopic diagnosis and therapy. The results outlined here may serve as a platform for endoscopic catheter navigation in gastroenterology and urology.