# Robotic Multi-Articulated Endoscopic Surgical Tools for NOTES

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## Abstract

Natural Orifice Translumenal Endoscopic Surgery (NOTES) promises to be the next major advance in minimally invasive surgical innovation since laparoscopy a couple of decades ago. For this to occur, advanced technology for surgical devices and tools is needed. The present project aims to address the deficiencies of existing surgical tools through the development of a novel fluid powered endoscopic robotic platform for NOTES. Unlike robotic laparoscopic surgeries in which a robot manipulates a set of cable driven, otherwise passive, end-effectors (tools), our vision is that the surgical tools themselves be the robotic device. This will improve accuracy and the introduce the possibility of incorporating additional degrees of freedom. The robotic tool itself will be electronically controlled and teleoperated with haptic feedback. Our goals for this project include demonstrating the feasibility of a multi-articulated robotic endoscopic device in which the tools themselves comprise the robotic system rather than the more common passive end-effectors. The main challenges of the proposed device include multi-degree of freedom mechanism design, power delivery and actuation, micro-valve design and fabrication, and force-feedback control. These challenges will be met through the development of a prototype designed to demonstrate the necessary functionality.

## Current Technology

Due to the relatively recent progression towards NOTES as an option for minimally invasive surgery, the current technology around tools for NOTES is in a rapid state of development. As surgeons continue to advance the difficulty of surgical procedures that may be performed endoscopically, medical device designers must also continue to advance the difficulty and complexity of the tasks that endoscopic surgical tools are capable of performing (Figure 1). Current endoscopic instruments are ideally suited for diagnostic and simple therapeutic procedures and thus are not sufficient to meet the demands of more complex surgical interventions. The characteristics that are desired for advanced endoscopic instruments are often summarized as follows:

• Size of the working channels must be large enough to allow for the necessary tools yet small enough to incorporate enough ports to enable triangulation.

• Rigidity of the scope to provide a base from which precise control of the articulating surgical tools without the need for constant position monitoring.

• Suction is often necessary in order to clear liquids out of the way during a procedure and is a common feature among current endoscopes. It would be necessary to include this feature on advanced endoscopic instruments.

• Triangulation is also a critically important feature as it is one of the primary advantages of today's laparoscopic procedures over traditional endoscopic procedures.

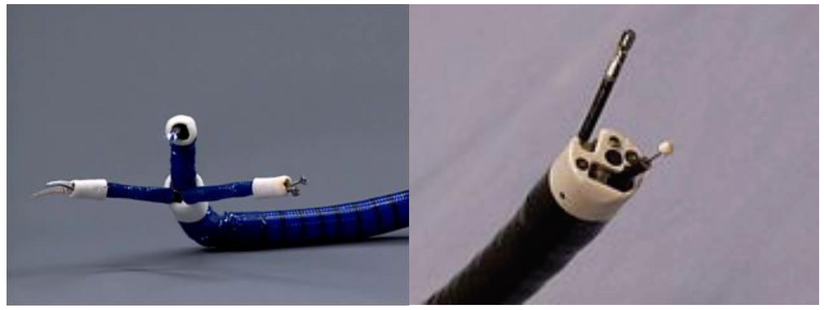

Figure 1: Two examples of emerging endoscopic surgical tools. Cobra by USGI Medical (left) and the R-Scope by Olympus (right).
[http://www.siech.org/Congresso%20Pisa/Articoli/Cuschieri.pdf]

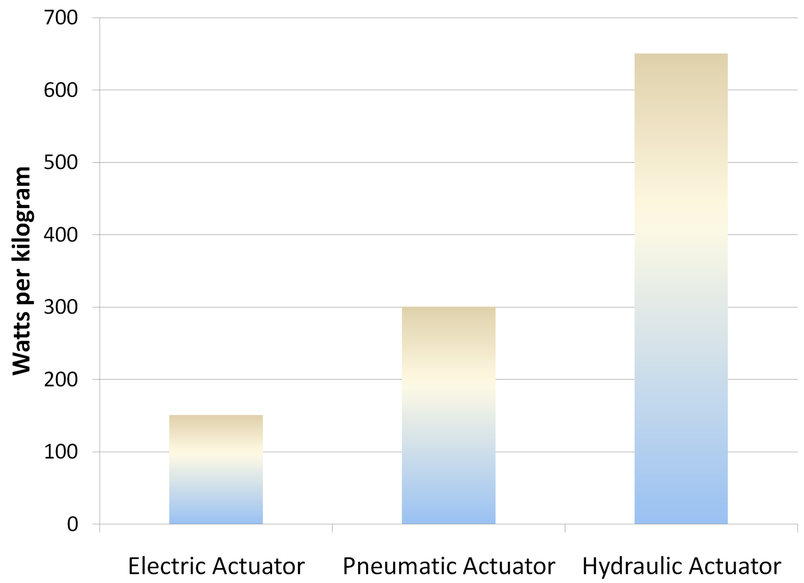


Figure 2: Column graph comparing the estimated power density of comparable electric, pneumatic, and hydraulic actuators.

Figure 3: The three areas of future work including manufacturing, device articulation, and controls.

## Why Fluid Power?

While there are several approaches that may be selected to achieve the desired characteristics of an endoscopic surgical instrument, fluid power technology is one choice which is well equipped for the task. Fluid power has several advantages when compared with alternatives such as eletromechanical power.

• Fluid power enables the power source to be located remotely. In robotics, this allows the mass of the system to be located in a base location while keeping the weight in robotic extensions minimal.

• Fluid power systems are capable of maintaining a constant force or torque with minimal energy input through the use of an accumulator. For an electromechanical system to achieve the same would require a high power input which would in turn generate heat.

• Fluid power has a higher power density when compared with an electric linear actuator with similar properties (Figure 2). This enables the use of a smaller actuators that maintain the same force output as their electronic counterparts.

## Summary

Natural Orifice Translumenal Endoscopic Surgery will likely continue to move towards the forefront of advanced minimally invasive surgical procedures. As this occurs, it will become increasingly necessary to develop advance surgical instruments capable of performing difficult procedures within limited available space. While medical device designers are working quickly to develop these tools, a new direction may be necessary to facilitate the scale of miniaturization that is necessary for these devices to be successful. Fluid power carries with it the characteristics necessary to achieve greater miniaturization while maintaining the level of sophistication required by surgeons.

This new approach to the design of a robotic multi-articulated endoscopic surgical tool will allow us to achieve greater maneuverability and higher force output at a scale which is appropriate for novel endoscopic surgical procedures. Future work on this project will focus on the areas of manufacturing, device articulation, and controls (Figure 3).

## Acknowledgements

This work is funded by a grant from the Medical Device Center as part of the Institute for Engineering in Medicine.

## References

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