Penetration of Tissues Using Micro Robots

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Microrobots hold potential in diverse biomedical applications owing to their relatively small size and manoeuvrability. These unique features allow them to move inside the human body to achieve tasks that cannot be attained through common remedial interventions. A potential minimally invasive biomedical application of microrobots is that they can target infected sites such as tumors and drill through them in a timely manner.

Literature Review

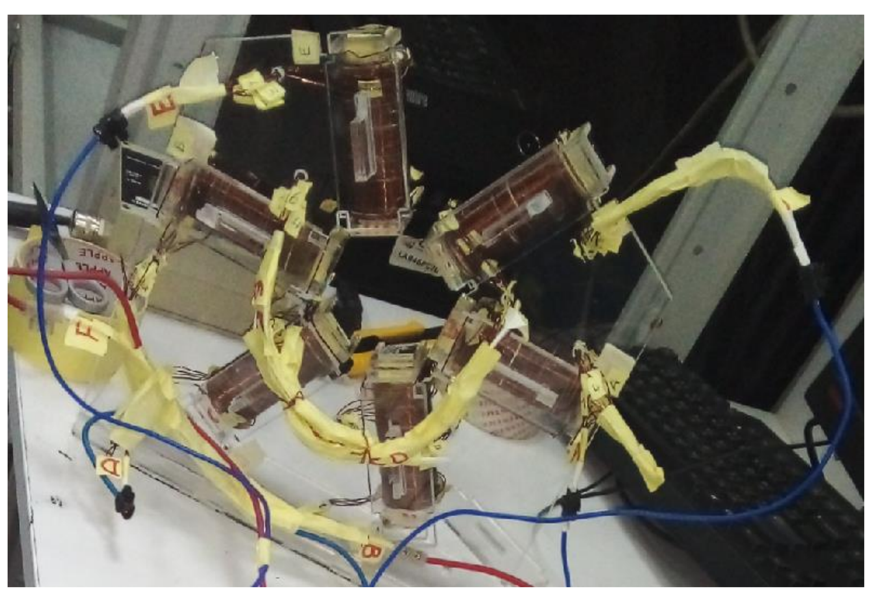
The research devoted to the control of micro and nano robots have significantly increased in the last years. Many propulsion mechanisms have been employed to provide movement in low Reynolds numbers.[1] The control and moving of microrobots using magnetic fields have been used for a long time enabling the actuation of various microrobot designs via different swimming mechanisms. Microrobots were mainly controlled via external magnetic fields. One microrobot was injected into the vascular system upstream from malignant tissue and were captured at the tumor using a local applied magnetic field [2].
Nelson *et al.* [3] used the non-uniformity of the rotating field in producing two independent rotating magnetic fields using a single magnet dipole. Alshafeei *et al.* introduced an open configuration of two synchronized rotating dipole fields to control the motion of helical microrobot inside a catheter segment [4] and in 3D space [5]. The open configuration of this magnetic-based robotic system enables scaling to the size of *in vivo* applications and its ability to remove blood clots has been demonstrated in *in vitro* applications [6].
Ishiyama *et al.* established a helical robot and examined its drilling capability for several design variables [7]. Alternatively, Jeong *et al.* improved its drilling ability by using both magnetic force and torque under a changing gradient magnetic field [8]. Even though the helical robot can unclog the blocked area, it takes a long amount of time to drill all the way through the clogged part. Drug-enhanced drilling motion has been investigated to enhance the drilling ability [9], [10].

Problem Statement

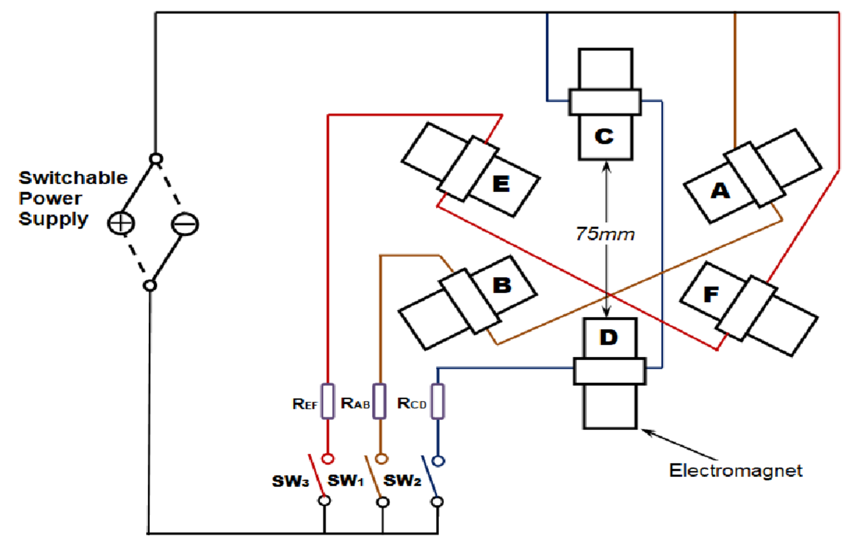
In this study, we are trying to work on penetrating five different tissues using a helical microrobot (micro-driller). All the tissues were taken from rabbit organs. The organ tissues used were brain, liver, kidney, lung and heart tissues. The aim of the study is to be able to penetrate stiff tumor tissues. Accordingly, a helical microrobot was tested against tissues of varying stiffness values

Methodology

a. Devices used



Stepwise Rotating Magnetic Field Actuator



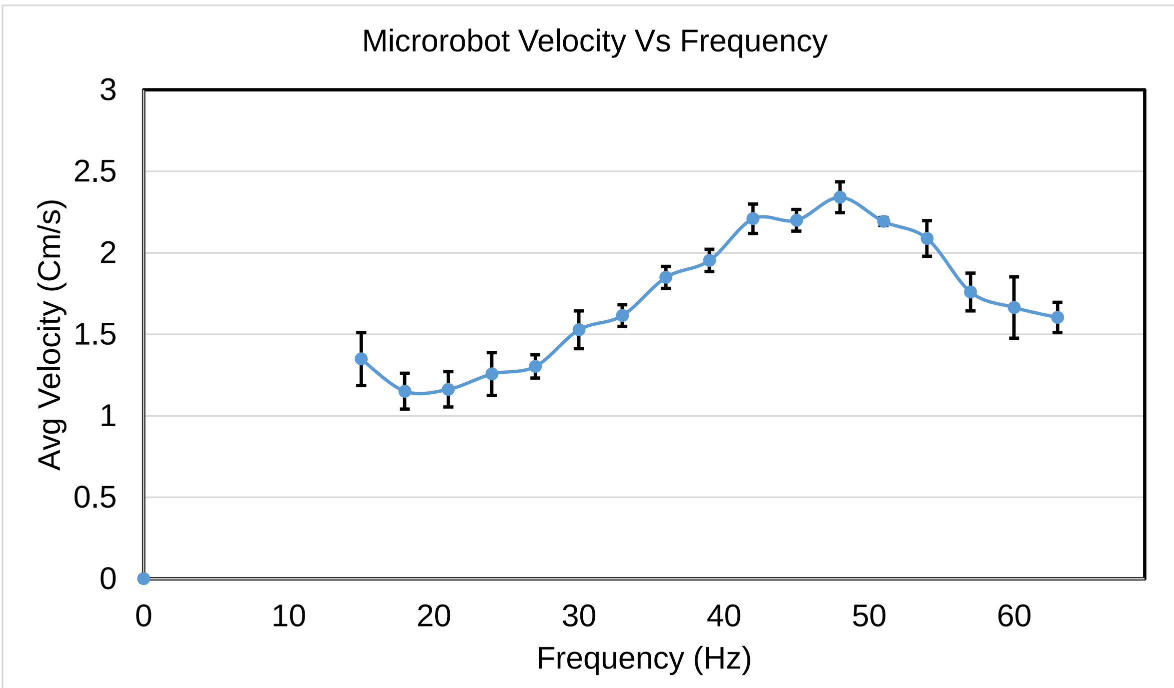
Schematic Representation of the Stepwise Rotating Magnetic Field Actuator

b. Tissues

Kidney, Liver, Brain, Lung and Heart

c. Steps

Five drilling experiments were conducted for each tissue with a constant time of 15 minutes each. Each tissue is sliced and inserted into a tube and the remaining area is filled with a saline solution. The microrobot is inserted in the tube and allowed to rotate via external magnetic fields. Once the helical tail gets in contact with the tissue, the drilling action commences. Only when the helical tail of the robot drills through the tissue, penetration is considered successful.
We used a magnetic field frequency at 48 Hz. This value was chosen because it is the frequency when the microrobot had a maximum velocity of 2.3 cm/s in a saline solution.



Microrobot Velocity vs Frequency graph of the micro-driller moving in a Saline Solution.

d. Microrobot

Micro-driller under the microscope

Diameter of the micro-driller = 0.6 mm
The material of the micro-driller is carbide.
Length of the tail = about 5 mm
Pitch = 1.06 mm

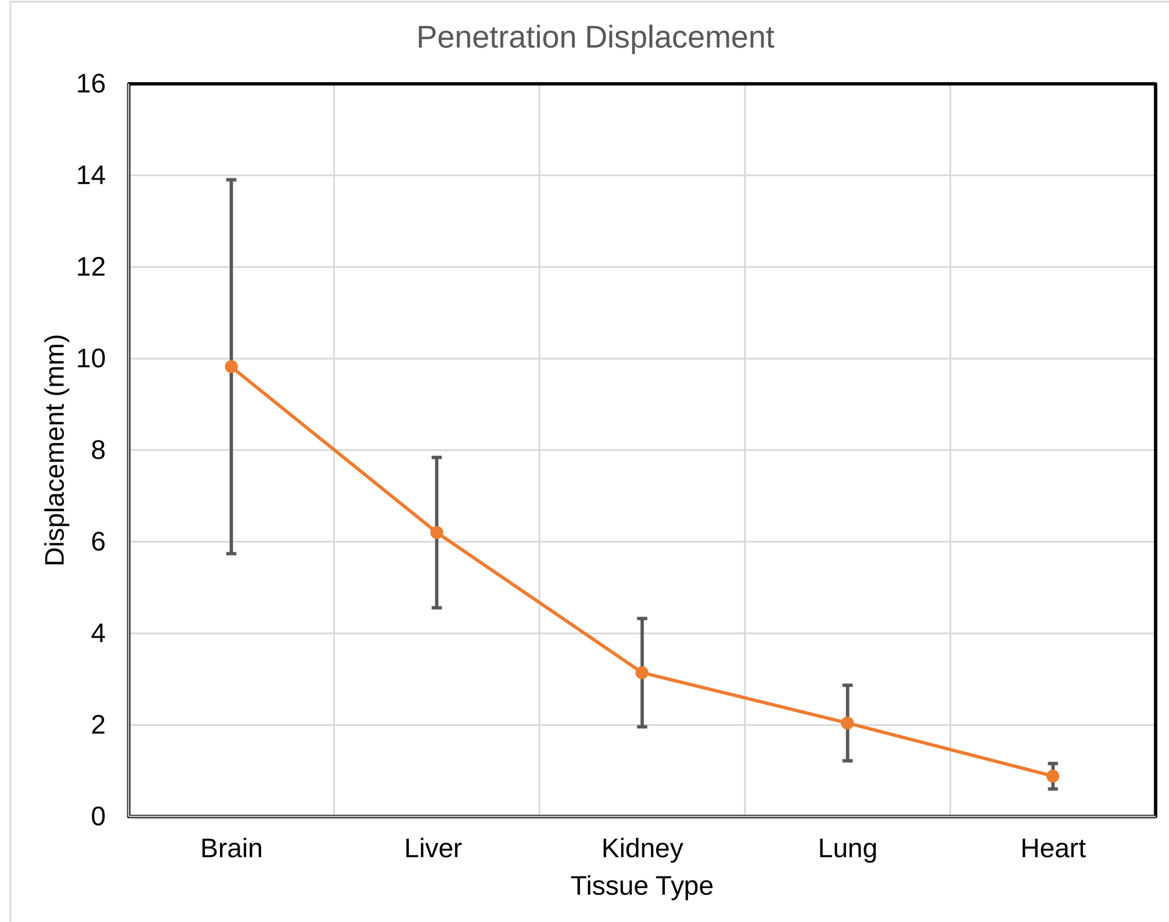
Results

The results were as follows:

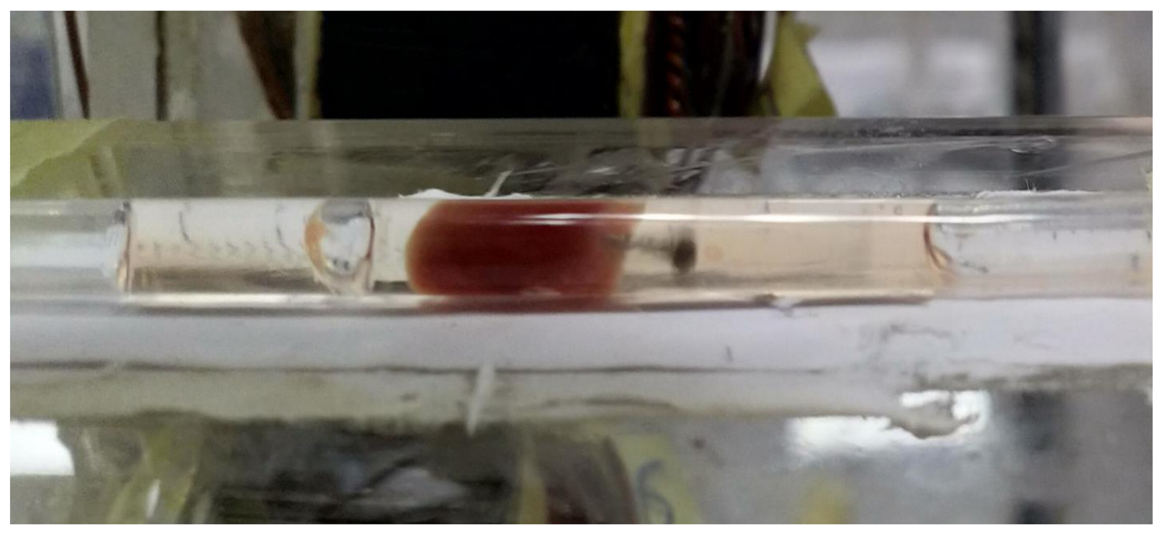
- Brain and Liver had a full head and tail penetration.
- Kidney and Lung had a full tail penetration.
- Heart had semi tail penetration.

In terms of penetration, the brain was the easiest to penetrated followed by the liver, lung and kidney. The heart was the hardest to penetrate. However, we had successful penetration in all tissues.

In conclusion, all tissues were penetrable making this rotating magnetic field setup a promising candidate in tissues penetration. Further research and experiments are needed to investigate the drilling action of microrobots on actual tumors. Needless to say, the use of microrobots for tumor penetration could be a promising future approach for therapeutic purposes.



Displacement vs Tissue graph showing the distance moved by each set of tissues at a constant time of 15 mins in a saline solution



A snapshot of the microrobot penetrating a heart tissue

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