Catheter Tip Actuation Mechanism for Endovascular Intracranial Interventions

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Introduction

A cerebral aneurysm is “a dilation, ballooning out part of the wall of a vein or artery in the brain.” Aneurysms are a medical concern due to the risk of rupture which may lead to brain damage.

Imaging for diagnosis and treatment

Some of the common imaging techniques used to diagnose intracranial aneurysms are:
- Computed Tomography (CT)
- CT Angiography
- Magnetic Resonance Imaging (MRI)
- 3D Angiography
- Digital Subtraction Angiography (DSA)

These techniques are also used to detect subarachnoid hemorrhages (SAHs) that can be a direct consequence of aneurysm rupture. Multiple imaging techniques are often used.

Rationale

Current micro-endovascular devices for treatment of intracranial lesions are very elemental. Navigation and deployment are inaccurate, relying on distal actuation which leads to lengthy and multiple procedures. We are proposing a micro-catheter system based on computer assisted tip actuation and device deployment.

Approach

• System functional requirements identified after analysis of the treatment methods for intracranial aneurysms include catheter tip bending and rotation, automated linear translation, and device deployment.
• Intuitive controls for a surgeon that allow accuracy are identified.
• A field programmable gate array (FPGA) is used to process several inputs simultaneously.
• Code controls the signal processing and signals hardware to produce appropriate output signals to control the different movements of the catheter tip.
• Scalability is an important feature of the design, and is important to actuate tips of different sizes of catheters.
• Aids are included in the design to allow easy visualization using a fluoroscope.

Schematic diagram for catheter actuation

Figure 3: Layout of catheter actuation system

Materials and methods

Step 1: Construction of catheter tip based on experimentally determined design

The design is evaluated using three dimensional computer aided design (CAD) and simulation. Existing catheters are modified using specialized equipment to replicate the design at the catheter tip. Other available equipment includes baking ovens for shape memory materials.

Step 2: Construction of patient data-based aneurysm-containing phantoms for actuation testing

Aneurysm-containing vascular phantom can be created in different ways. In the currently employed method, a wax model of the vasculature is prepared by softening wax in a negative mold created by a 3D printer. The information to create the negative mold is extracted from volumetric patient scan data such as CT angiography data. The model is then transformed into a solid block phantom, or a phantom similar to vasculature as seen here. The solid block is made by immersion in Silgard 862 and removal of wax with heat. The vessel phantom seen here are created by using repeated layers of coating painted onto the wax model. The wax is then removed by heating.

Alternatively, the phantoms can be created using a 3D printer alone.

Step 3: Device control and testing

Data acquisition and processing is done using hardware and software from National Instruments. The FPGA board inside the device in figure 8 can process multiple inputs and outputs at a single time.

Stent Deployment

Stents are often used to seal wide necked aneurysms. The standard procedure for stent deployment involves maneuvering the catheter with the cramped stent to the desired location and inflating a balloon beneath the stent to release it. In the case of asymmetric stents with sections of low porosity, the stent must be oriented such that the low porosity block is over the aneurysm mouth. The rotational control of the catheter aids in deployment.

Bending Movement

Incorporating a control of bending movement in the tip actuation will allow surgeons to navigate the blood vessels without using pressure between the catheter and vessel wall to round the curves.

Translational Movement

The control of translational movement at the distal end of the catheter is done by the use of a linear motor. The motor moves the catheter at a steady speed controlled by the surgeon.

Rotational Movement

The most innovative mechanism in the tip actuation system is the control of rotational movement. The ability to control the rotation of the catheter tip allows the surgeon to direct the bending movement and the placement of asymmetrical stents.

The rotation is controlled at the tip by the use of a threaded component, converting translational motion to rotation.

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References


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