Public summary of PhD-thesis of Marc Janssens
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New tools enable less experienced surgeons to perform Deep Brain Stimulation surgery

Deep brain stimulation (DBS) surgery is a surgical procedure which dates back to the 1990’s. Its goal is the implantation of a ‘pacemaker system’ for the brain. An electrode is implanted in the brain and connected to a pacemaker which is usually placed under the patient’s collarbone. DBS can provide symptom relief for various neurophysiological diseases, like Parkinson’s disease and epilepsy. The location of the stimulation target depends on which disease is being treated. Unfortunately, physically determining the stimulation target in the patient’s brain, as decided based on fused MRI and CT scans, proves to be challenging and full of risk.

After the surgeon has located the stimulation target on an MRI scan of the patient’s brain, the surgeon is faced with the difficult task of accurately placing the stimulation electrode in the target. This often concerns the deep-seated subthalamic nucleus (STN), which measures only 8 by 4 millimeters. The electrode has to be placed in the STN-part that controls movement. If the electrode ends up elsewhere, the electrical stimulation will result in undesirable side effects, and the surgery will be considered a failure. Furthermore it is important that the electrode does not damage any delicate structures in the brain, which would lead to surgical complications.

In the current day surgical procedure, the surgeon uses a special instrument called a stereotactic frame (which looks a bit like a bow sundial) to implant the electrode along the chosen trajectory, based on the MRI scan of the patient’s brain. This scan does not include a frame reference, as the frame cannot go in the MRI-scanner with the patient because of the strong electromagnetic fields of the scanner. To link the MRI coordinates of the stimulation target to the frame, an additional CT scan is made, with part of the frame attached. After this, the CT and MRI scans are fused and the MRI-derived coordinates can finally be translated to frame settings. The fusion of the MRI and CT scan introduces an error of up to several millimeters to the initial imaging accuracy. Combined with the inherent limited stiffness in the stereotactic frame, this leads to only highly experienced surgeons being able to implant the stimulation electrode accurately.

In order to also enable less experienced surgeons to perform this surgery, this PhD thesis describes two new surgical instruments for implanting DBS electrodes in the brain. First I focused on how to achieve an unambiguous translation of target (location in physical brain) and skull entry point coordinates to instrument settings. I came up with an adapter disc which gets fixated with three small surgical screws to the back of the patient’s skull. This is less painful and more comfortable than the currently used frame, which is clamped on the head with four pins forced into the skull bone. The adapter disc serves both as a visual reference in the MRI scan, and as a structural reference for the instrument.

After this, I started with the design of the first prototype of the new instrument. As it would be nice to allow for electrode implantation under guidance of real-time MRI, I chose to make the prototype MRI-compatible. This led me to the decision to design the instrument completely in plastics; mostly PEEK, because of its rigidity and high melting point. Upon realization of this PEEK prototype, it became clear that the material choice implied higher cost and a more bulky design than would be the case when MRI-compatibility would not be required. This led to the design of the second, non-MRI-
compatible prototype, in which I exploited the freedom in material choice, together with all the experience I had gained from the PEEK instrument. The result is a more compact instrument, although conserving the same style as the PEEK instrument.

Alongside the two instrument prototypes, I have developed an MRI-compatible actuator, which is controlled by the surgeon. It is required for the possible application of the PEEK instrument in the confined environment of an MRI scanner. Since the other instrument settings are adjusted before attaching the instrument to the patient’s head, only the straight lined insertion of the electrode needs to be motorized. The goal of the design process was to keep the drive as compact as possible, in line with the limited forces at play during electrode insertion in the brain.

The goal of both instruments is to enable all neurosurgeons to perform successful DBS surgery; not only the highly experienced ones. Furthermore, the instruments permit a reduction in preparation time, risk and cost, compared to the current-day procedure. This could eventually lead to more patients receiving the treatment and in an earlier stadium of their disease.