Selective stimulation of the Subthalamic nucleus using a high density DBS lead.

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Introduction:

Deep brain stimulation (DBS) is widely used in advanced stages of Parkinson's disease (PD) and has proven to be an effective treatment of various motor symptoms. The clinical procedure involves the implantation of a DBS lead through which continuous high frequency electric pulses are delivered in a the subthalamic nucleus (STN). The clinical outcome of the therapy is rather sensitive to the precise location of the DBS lead within the STN. Unfortunately, despite careful planning and precise stereotactic surgery, a lead displacement may occur. The conventional cylindrical contact (CC) lead is only able to correct for a displacement in dorsal-ventral direction by using one or a combination of the 4 cylindrical contacts. Interestingly, a new high density (HD) lead, which consist of 40 individual circular contacts, facing different directions, has been created. This lead design provides additional degrees of freedom in steering the stimulating electric field and can be used to increase the selectivity of the stimulation. With this increased selectivity it is in principle possible to compensate to a certain extend for a lead displacement without the need to reposition the DBS lead [1].

In this study, we assess selective stimulation of STN cells using the CC lead and the HD lead.

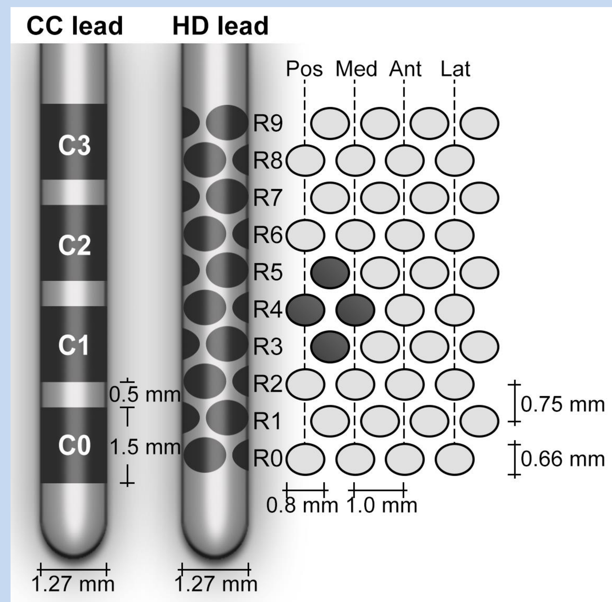
Methods:

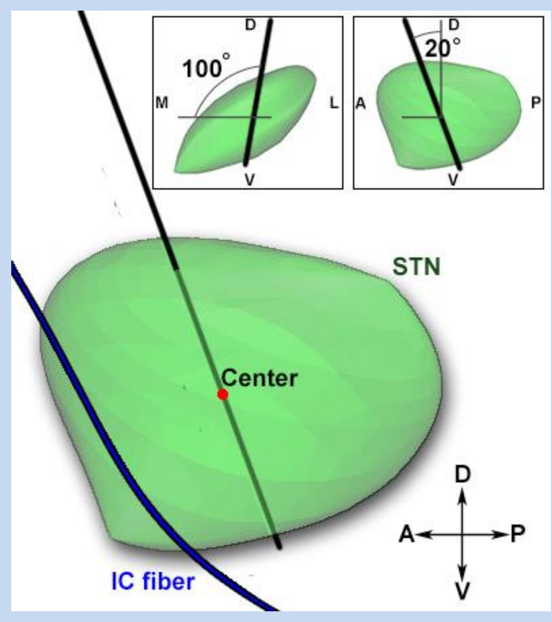
Computational model:

The anatomic model consists of two parts [2]:

1. Finite element method (FEM) model to calculate the evoked potential field in the subthalamic region.
2. Multi compartment neuron models to calculate stimulation effects of the evoked potential field on three neural populations in the subthalamic region (STN projection neurons, globus pallidus internus (GPi) fibers, and internal capsule (IC) fibers).

Two virtual DBS leads are included in the model:

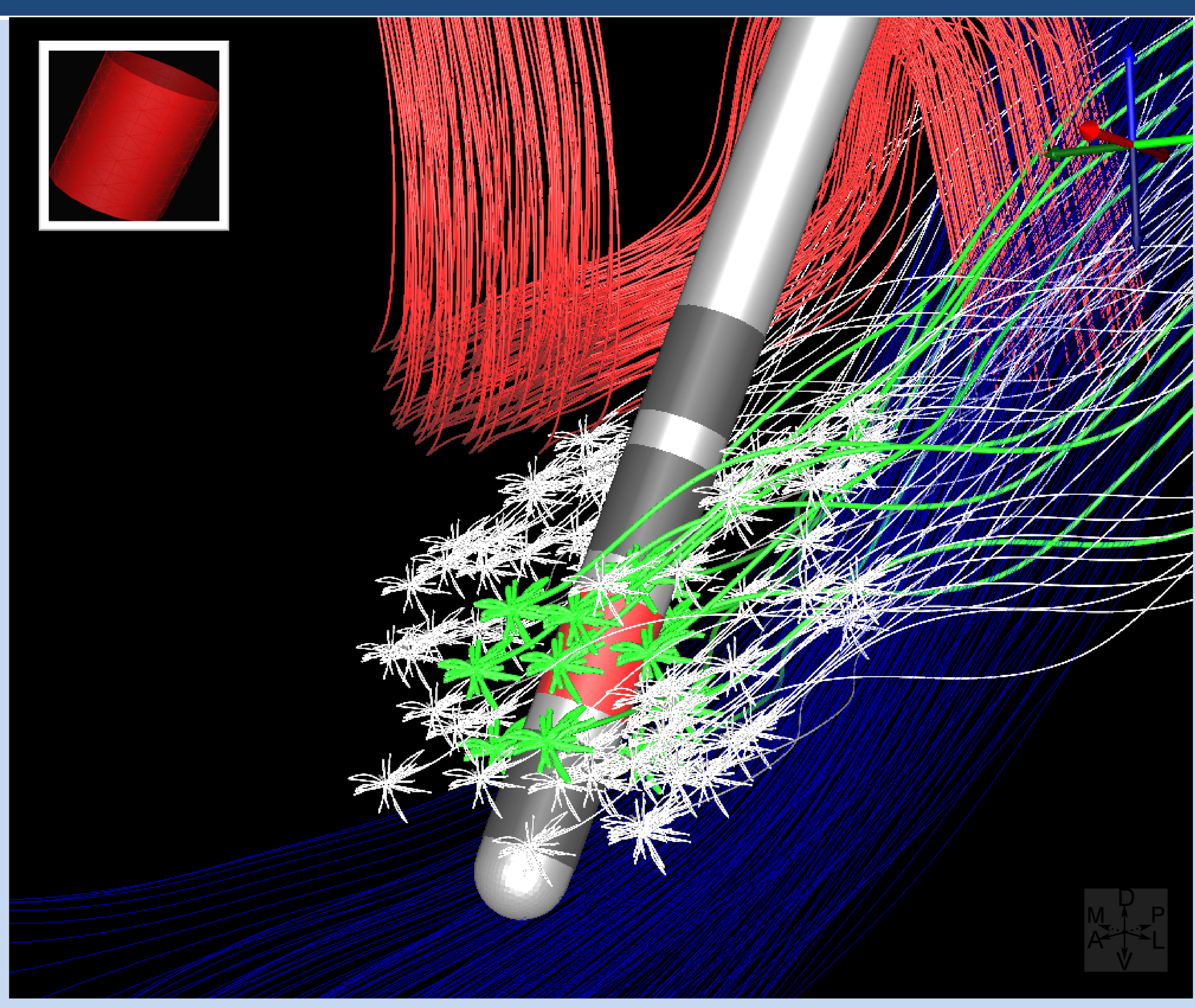


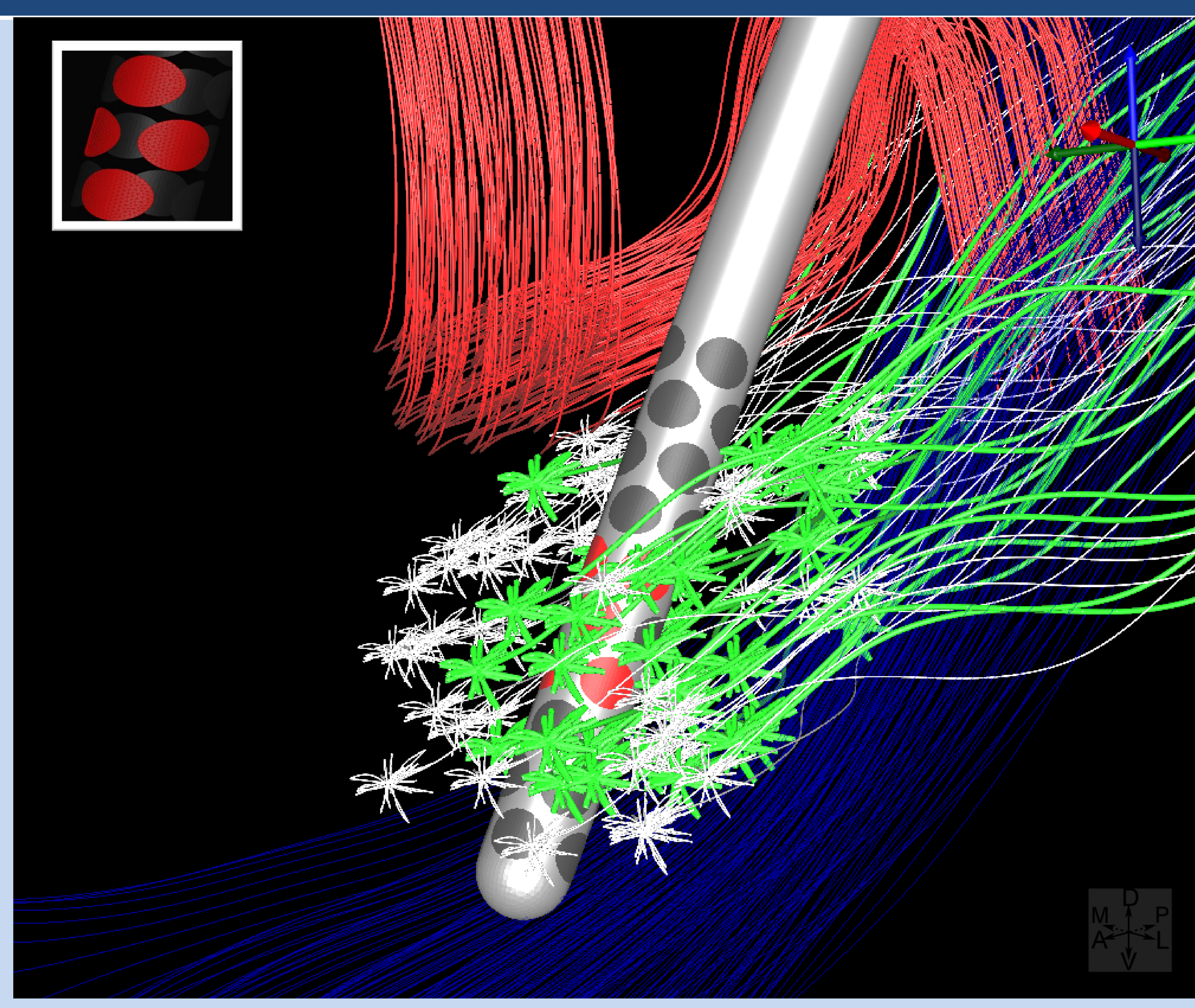


Configuration optimization:

To find the optimal stimulation setting, we maximized the number of activated STN cells without stimulating the internal capsule and GPi fibers, by adjusting the stimulation amplitude and contact configuration.

Results:





The CC lead, with a stimulation current of 1.5 mA, was able to stimulate a maximum of 26.5±2.5 % of the STN cells. The HD lead, with a stimulation current of 2.3±0.45 mA, was able to stimulate 43.8±5.4 % of the STN cells.

Conclusions:

In conclusion, in this model with optimized stimulation parameter selection the HD lead compared to the CC lead in theory should have a better clinical effect, however, at the expense of more energy consumption.

References:

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2. A. Chaturvedi, C. R. Butson, S.F. Lempka, S.E. Cooper, C.C. McIntyre, Patient-specific models of deep brain stimulation: Influence of field model complexity on neural activation predictions, Brain Stimulation (2010) ; 3(2):65-77.

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