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Directional Deep Brain Stimulation

WSSFN Webinar August 2018

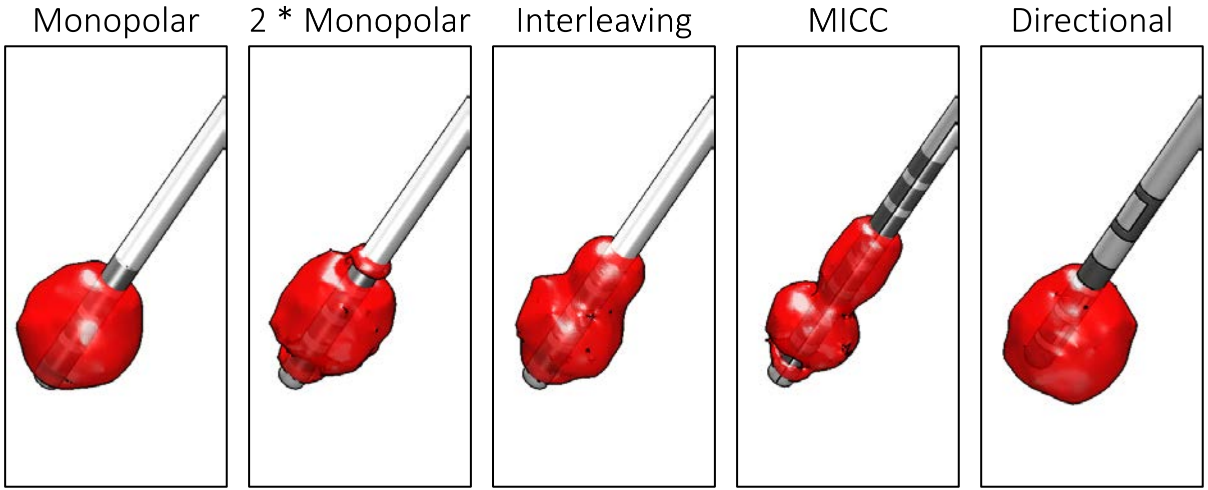
29.08.2018 Till A. Dembek | Department of Neurology | University Hospital of Cologne

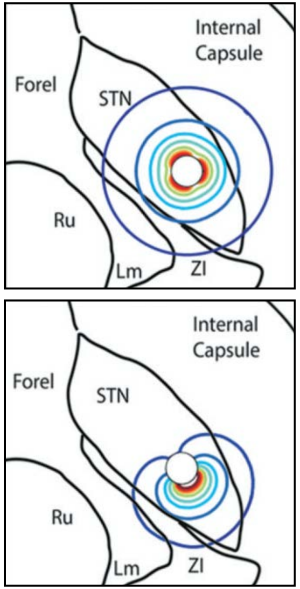
Agenda

- The rationale behind directional DBS
- Clinical trials of directional DBS
- Programming directional DBS
- Orientation of directional leads
- Computer-assisted programming

The Rationale Behind Directional DBS

- DBS aims at spatially specific stimulation of a neuroanatomical target structure
- Current-spread into adjacent structures should be minimized





Pollo et al. 2014

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Clinical Trials of Directional DBS

- Short-term, ‘monopolar review’ studies
- Comparison between directional to circular DBS

Study	Design	N	Lead	Target	Side-Effect Threshold	Efficacy Threshold	TW increase
Contarino 2014	Intraoperative, double-blind	8	Sapiens	STN	↑	↔	n.a.
Pollo 2014	Intraoperative, double-blind	13	Aleva	STN,VIM	↔	↓	0.6 mA
Steigerwald 2017	Retrospective	7	BSCI	STN	↑	↔ (↓)	0.4 mA
Dembek 2017	Prospective, double-blind	10	BSCI	STN	↑	↔	1.0 mA
Rebelo 2017	Retrospective	8	Abbott	VIM	↔	↓	0.9 mA
Choe 2018	Prospective	8	Abbott	VIM	↔	↔	n.a.

Clinical Trials of Directional DBS

- Case reports:
  - Combining directional and bipolar stimulation (Reker et al. 2016)
  - Combining two neuroanatomical targets (Falconer et al. 2018)

CAVE:

- No long-term studies
- No comparisons against standard DBS devices

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Programming Directional DBS

General Considerations:

- Routine employment of directional DBS?
- Routine monopolar review of directional electrodes?

Pros:

- Therapeutic current might be smaller with directional DBS
- Side-effects might occur less frequently with directional DBS

Cons:

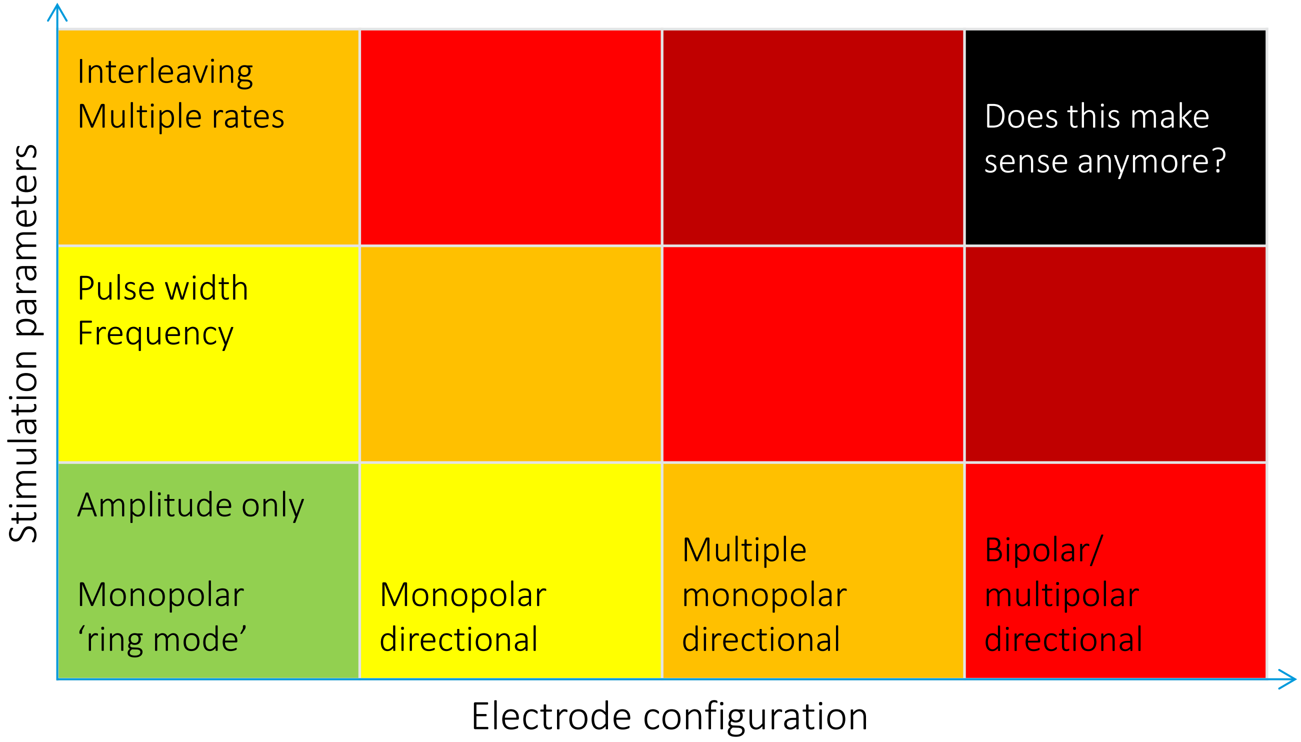
- Effects might be comparable in a well-placed lead
- Patient burden, time, money

Programming Directional DBS

Two-step approach:

- Initial monopolar review and programming in “ring-mode” only
- Routine utilization of amplitudes, pulse widths, and frequencies
- Monopolar Directional DBS in case of limiting side-effects
- More complex multiple-electrode configurations as escalation strategy

Programming Directional DBS



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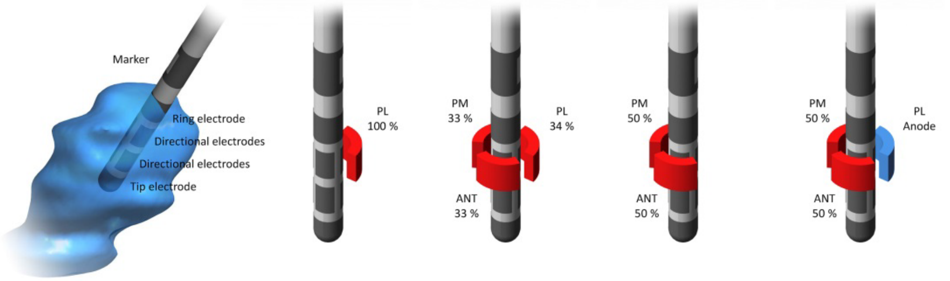
Bipolar Directional DBS

- Reker et al. case report:
  - Increase dysarthria thresholds
  - Resolved motor symptoms
  - Lead to psychiatric side-effects



Condition	postero-lateral	circular	anterior + postero-medial	bipolar directional steering
Dysarthria threshold	2.9 mA	3.6 mA	3.9 mA	> 5.0 mA
Rigidity	not resolved	resolved	resolved	resolved
Bradykinesia	moderate	moderate	slight	minimal

Reker et al. 2016

- Steffen et al. (submitted, n = 14):
  - No general superiority to monopolar directional DBS
  - No general superiority to conventional bipolar DBS

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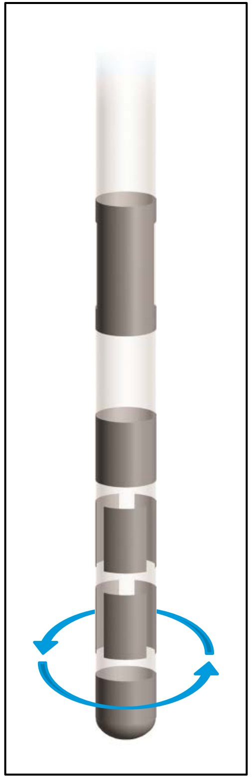
Lead Orientation

- New degree of freedom
- No specialized stereotactic equipment
- 'Fiddly' handling
  - Rotation by 0.1 mm -> Orientation change of 10 °
  - Leads are not stiff objects
- Important for informed programming

Questions:

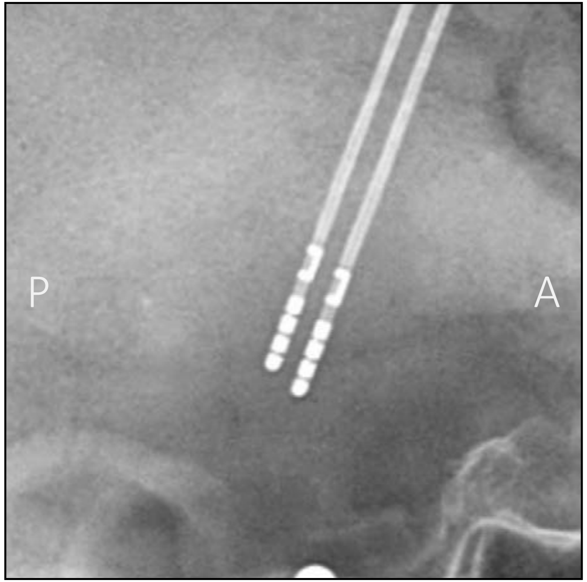
- Can lead orientation be adequately adjusted intraoperatively?
- How can we measure lead orientation?



Quantifying Lead Orientation

Visual Inspection

- Stereotactic marker provides raw guidance
- Accurate estimation not possible
- No accurate translation to patient anatomy



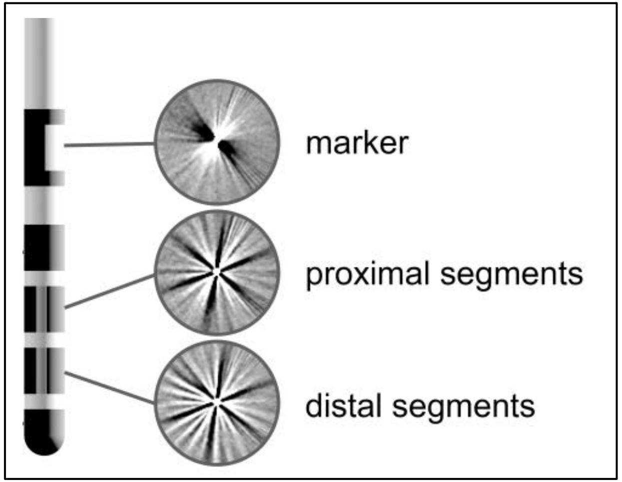
Quantifying Lead Orientation

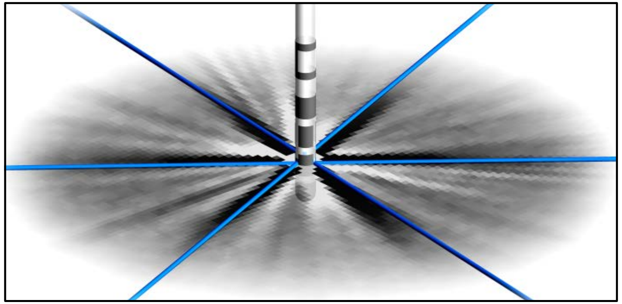
- Algorithms for different imaging have been proposed:

Study	Design	Modality	Accurate	Automatic	Translation to anatomy
Reinacher 2017	Phantom	Rotational Fluoroscopy	Yes	No	Difficult
Sitz 2017	Phantom	Stereotactic X-ray	Yes	No	Easy
Sitz 2017	Phantom	CT	Yes	No	Easy
Hunsche 2018	Phantom	Flatpanel CT	Yes	No	Moderate

The Directional Orientation Detection (DiODe) Algorithm

- Based on Sitz et al. for postoperative CT
- Analyzes characteristic CT artifacts
- Phantom-validated
  (Hellerbach et al., under review)
- Automatic workflow
- Integrated into Lead-DBS toolbox
  (www.lead-dbs.org)





Hellerbach et al. 2018 (under review)

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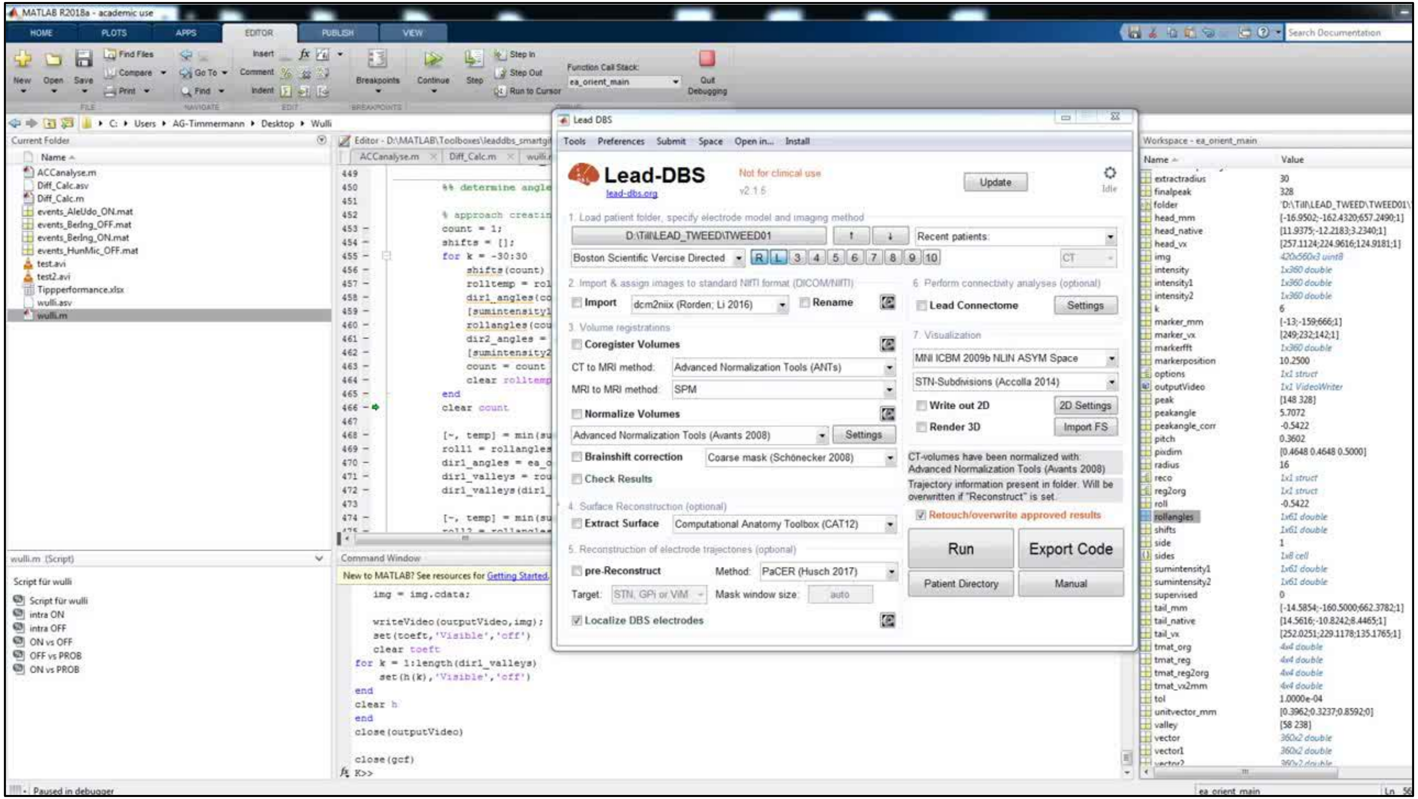
The Directional Orientation Detection (DiODe) Algorithm



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Lead Orientation in Clinical Reality

Study in n = 100 patients and n = 198 directional leads:

- Lead orientation can deviate up to 90 °
- Deviations of > 60 ° in 10% of the leads

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Dembek et al. 2018 (in preparation)

Lead Orientation in Clinical Reality

Study in n = 100 patients and n = 198 directional leads:

- Lead orientation can deviate up to 90 °
- Deviations of > 60 ° in 10% of the leads
- Independent of neuroanatomical target
- Independent of stereotactic frame and intraoperative imaging

➢ Postoperative verification strongly recommended!

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Dembek et al. 2018 (in preparation)

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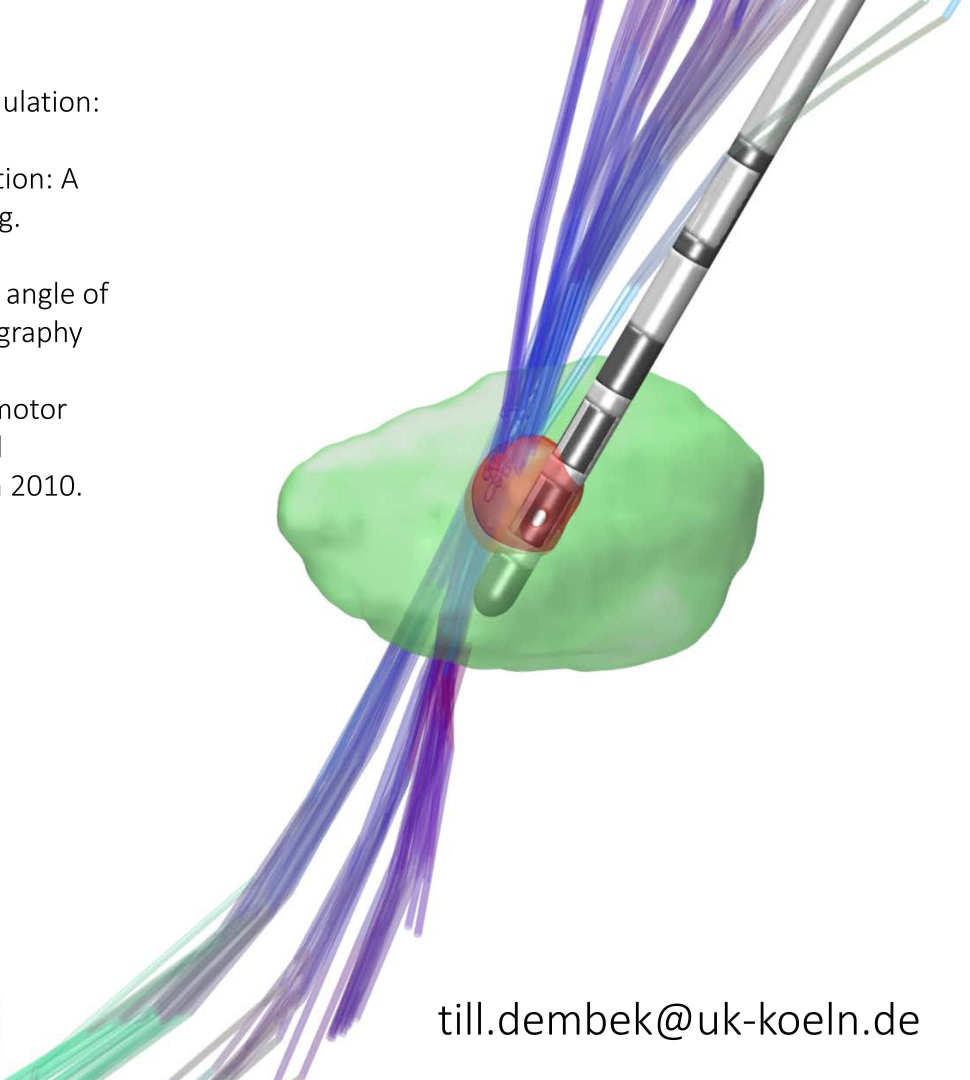
Conclusion

- Directional DBS…
    - increases acute side-effect thresholds
    - decreases acute efficacy thresholds
    - increases the therapeutic window

  …but only to a certain degree
- No data regarding long-term benefits
- Lead orientation should be analyzed postoperatively
- Directional DBS increases the complexity of DBS programming
- Programming based on functional hotspots might assist clinicians

Figure References:

1. Pollo C, Kaelin-Lang A, Oertel MF, et al. Directional deep brain stimulation: an intraoperative double-blind pilot study. Brain 2014.
2. Reker P, Dembek TA, Becker J, et al. Directional deep brain stimulation: A case of avoiding dysarthria with bipolar directional current steering. Parkinsonism Relat. Disord. 2016.
3. Sitz A, Hoevels M, Hellerbach A, et al. Determining the orientation angle of directional leads for deep brain stimulation using computed tomography and digital x-ray imaging: A phantom study. Med. Phys. 2017.
4. Frankemolle AMM, Wu J, Noecker AM, et al. Reversing cognitive–motor impairments in Parkinson’s disease patients using a computational modelling approach to deep brain stimulation programming. Brain 2010.



Thank you!

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