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Research Article

Methodology for Standardised Mono/ Bipolar Cortico-Subcortical Stimulation-Mapping

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Introduction

Cortical and subcortical direct electrical stimulation-mapping have become the gold standard in resection of intrinsic supratentorial brain tumors, as gliomas. Nevertheless, the methodology of application of stimulation differs among centers; usually, for cognitive mapping as language bipolar mode Low Frequency (LF) (Ojemann) is preferable, while motor evaluation is better quantifiable with monopolar High Frequency (HF) Train of 5 (Taniguchi). This could interfere with the ergonomics, since switching from mono- to bipolar and inversely needs manipulation; this can be prevented either by sequential stimulation or by constant monopolar stimulation interrupted by intermittent bipolar. Distinction must be made between cortical and subcortical stimulation-mapping: in the former, motor mapping and cognitive mapping can be realized separately and thus consecutively; in the latter, in the vicinity of the Cortico Spinal Tract (CST) the task must be evaluated immediately with the dichotomy resectable/ not resectable tissue: so mono- and bipolar stimulation also must follow each other directly.

Since the risk of seizures is negligible during white matter HF stimulation, this should precede bipolar LF stimulation, while fast motor evaluation also precedes cognitive evaluation, which is more time consuming. Continuous monopolar HF motor mapping can be regarded as basic, combined with Motor Evoked Potentials (MEP), while intermittent 4 second bipolar LF stimulation is preferably used in association with a cognitive task, lasting about 5sec. This could imply the use of different probes (one monopolar and one bipolar with 2 poles usually distant of 5mm), which reduces ergonomics.

Rationale and Methods

For ***cortical_mapping***, this can be overcome by first applying monopolar probe stimulation over the CST-area, epidural or subdural or both, while bipolar probe stimulation-mapping is realized with the patient fully awake and cooperative. Since the cortex presents as an immobile 2D-surface, for cortical stimulation-mapping, the points can be predefined during the navigation planning (Figure 1 and 2) and registered in an Excel-like grid. This offers many advantages: the geometrical accuracy of each site is maximal, before any brain shift and thus testing reproducibility enhanced; besides the center of bipolar contact, also the rotation of the probe can be indicated, regarding the importance of the orientation in bipolar stimulation.

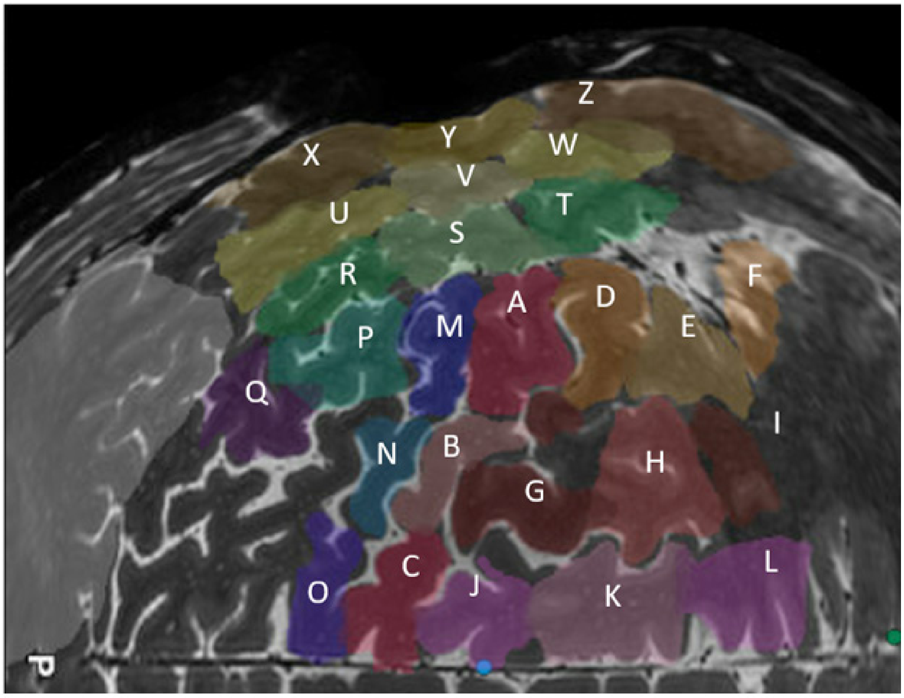

Figure 1: Preoperative Definition of Parcels on pancake Brain Projection.

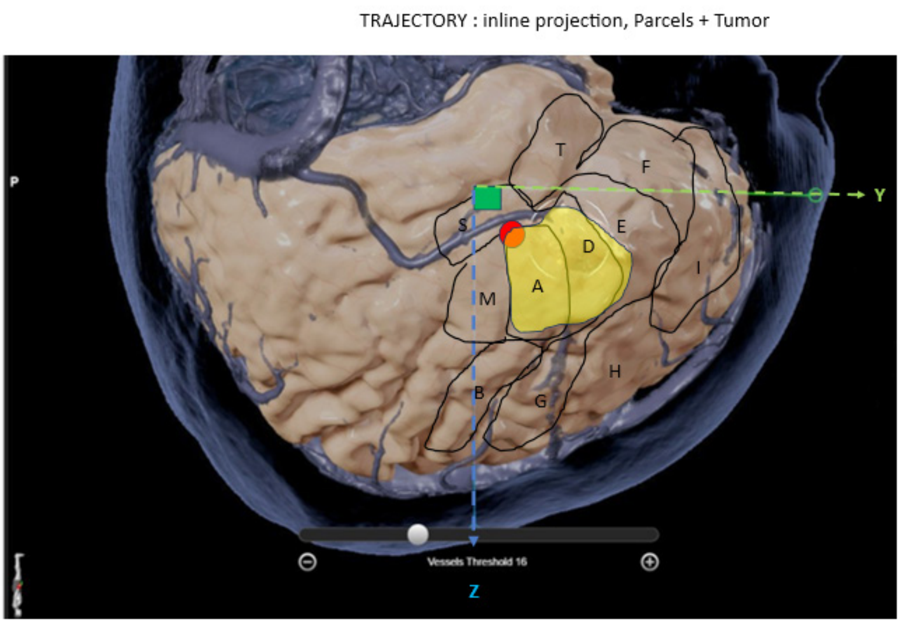

Figure 2: Preoperative Definition of Parcels on 3D Brain Projection.

Selection of tasks predominantly is based on gyral and parcellar location; to avoid seizures, it is preferable not to stimulate consecutively adjacent areas, even better different gyri: so, jumping from one site to another implicates different tasks, impossible to define instantly by the neuro-/ psycho-/ linguist. It could be determined by navigating the bipolar probe, but this increases the margin of error, while the attribution of tasks can anyway be defined preoperatively. To each site, predefined tasks are attributed, depending on the supposed function of each parcel; besides standard tasks as picture naming, specific tasks are proposed. Since the cortical stimulation sites are pre-labelled according to the parcellar distribution (letter-number combination: A-Z and 0-9 or more), a standard sequence of stimulation can be used (A0, B0, C0…A1, B1, C1…) avoiding nearby electrical current and risk for seizures [1].

After definition of the motor and language thresholds with counting and automatic speech, first *Picture Naming* is proposed (Object or Action Naming) as basic standard evaluation. Second, a *multimodal test* is submitted. The presented tasks are based on the

Dutch Linguistic Intraoperative Protocol (DuLIP) [2] and are broad-scanning to obtain a maximal sensitivity : they can implicate as well visual, auditory as reading inputs, with phonological, semantic, syntactic and articulatory processing , e.g. four object pictures are displayed in the corners of the screen, with a subject written and/or a verb spoken- suggesting the con) struction of a short sentence, englobing most essential communication pathways : Global Evoked Naming Task (G.E.N.Tasks) [3]. Finally, *parcel-specific* tasks are proposed; these are quite demanding for the patient, reason why it is kept as last testing mode. Together, each cortical site within the bone flap has been tested trice, which is considered as sufficient with optimal sensitivity/specificity/time ratio.

An integrated mapping-registration method, described elsewhere (CoStiMapp; Cortico-Subcortical Stimulation-Mapping app) (Figure 3) allows fast and accurate evaluation by the neuro- / psycho- /linguist and registration of the patient's verbal responses, possibly confirmed by a motor response (indication of the correct answer with the patient's index on the touch screen). Reaction times can be measured. This methodology avoids local gaps and time gaps during the cortical mapping, greatly enhancing the accuracy and its reliability, while reducing the procedural time, but is not applicable for Subcortical Stimulation since this presents in a tridimensional space.

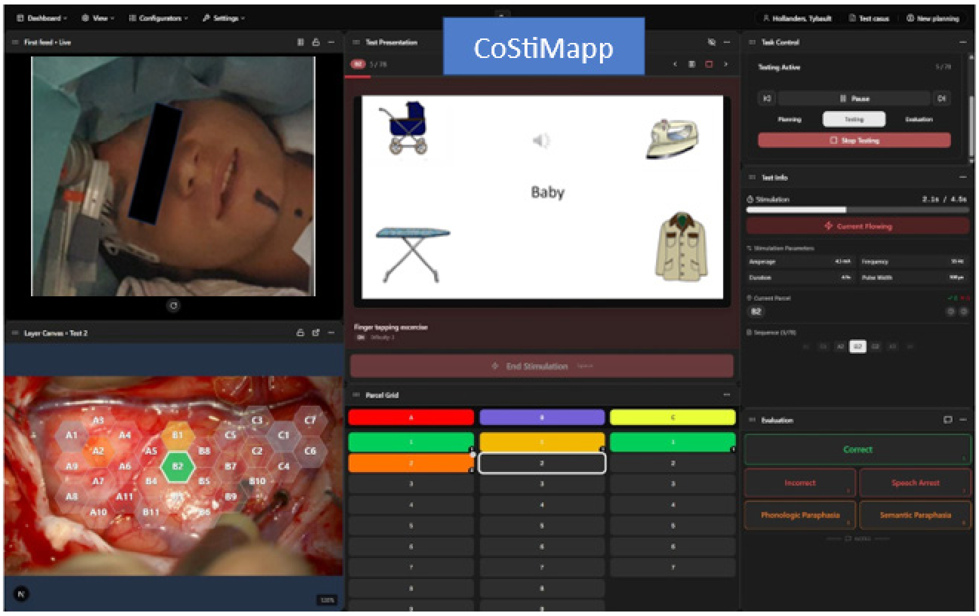

Figure 3: Screen integrating cortical mapping data: CoStiMapp.

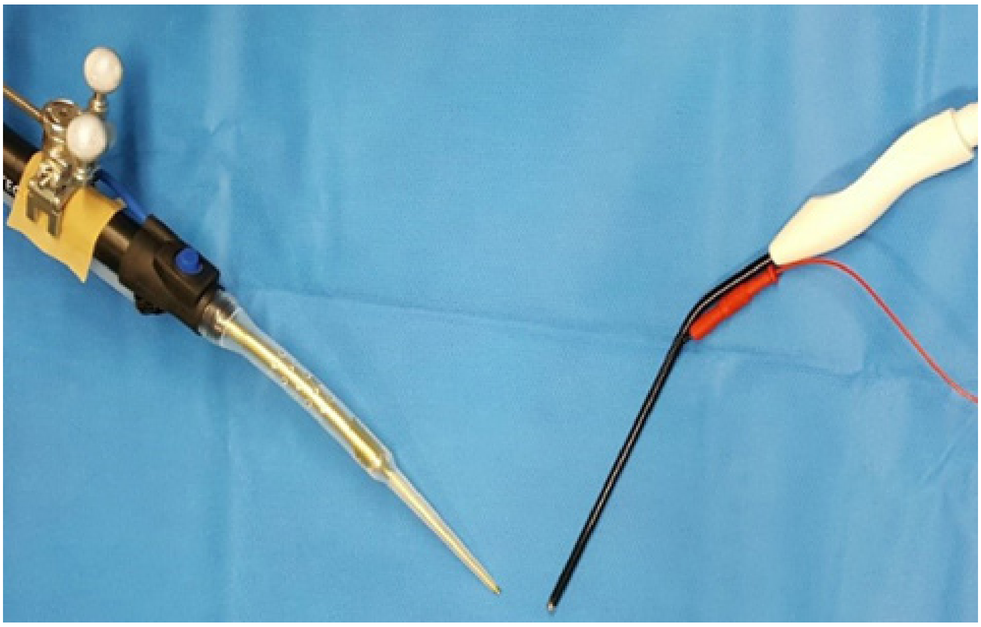

Figure 4: Combined Bipolar Stimulation Suction Tip & CUSA Tip: iBiSCuS.

During *subcortical testing*, currently the two classical devices- the usual resection-CUSA and suction probes- have to be brought in and out the operative cavity alternating with the stimulating probe: this further decreases ergonomics and multiplies risks of traumatizing adjacent tissue. In 2004, we first ever published a method by which monopolar electrical stimulation was applied directly via the tip of the CUSA; since the commercial availability of a suction stimulating tip in 2014, we described the simultaneous use of both instruments to obtain bipolar stimulation at desired parameters (iBiSCuS: Intermittent Bipolar Subcortical Stimulation) (Figure 4).

For *Bipolar Low Frequency stimulation* (Ojemann parameters), both tips should be distant of approximately 5 mm; currently the tips are used in the same horizontal plane, perpendicular to the working trajectory. Moreover, to be reliable, the tips should be immobile in regard to each other during the 4-5 seconds of stimulation, during which a task is proposed; in case of negative testing, i.e. no sensori-motor reaction nor cognition-interruption is observed, resection can be started with the CUSA towards the suction tip till a depth of +/- 5mm.

Bipolar stimulation (on the suction tip, combined with the CUSA- tip) can be applied at different angles, orthogonal favorizing sensitivity and parallel enhancing specificity [4]. In the vicinity of the Cortico-Spinal Tract (i.e. Precentral Gyrus and adjacent Gyri, as well as in the temporal depth and near the brainstem), *Monopolar High Frequency* stimulation (Taniguchi) is preferable since less seizure-inducing and is quantitative with the 1 mA-1 mm thumb rule. This monopolar current can be administered continuously, as realized in Continuous Dynamic Mapping°; this combines continuous motor mapping and monitoring with intermittent cognitive testing, with avoidance of time gaps and local gaps (Figure 5,6 and 7) [5].

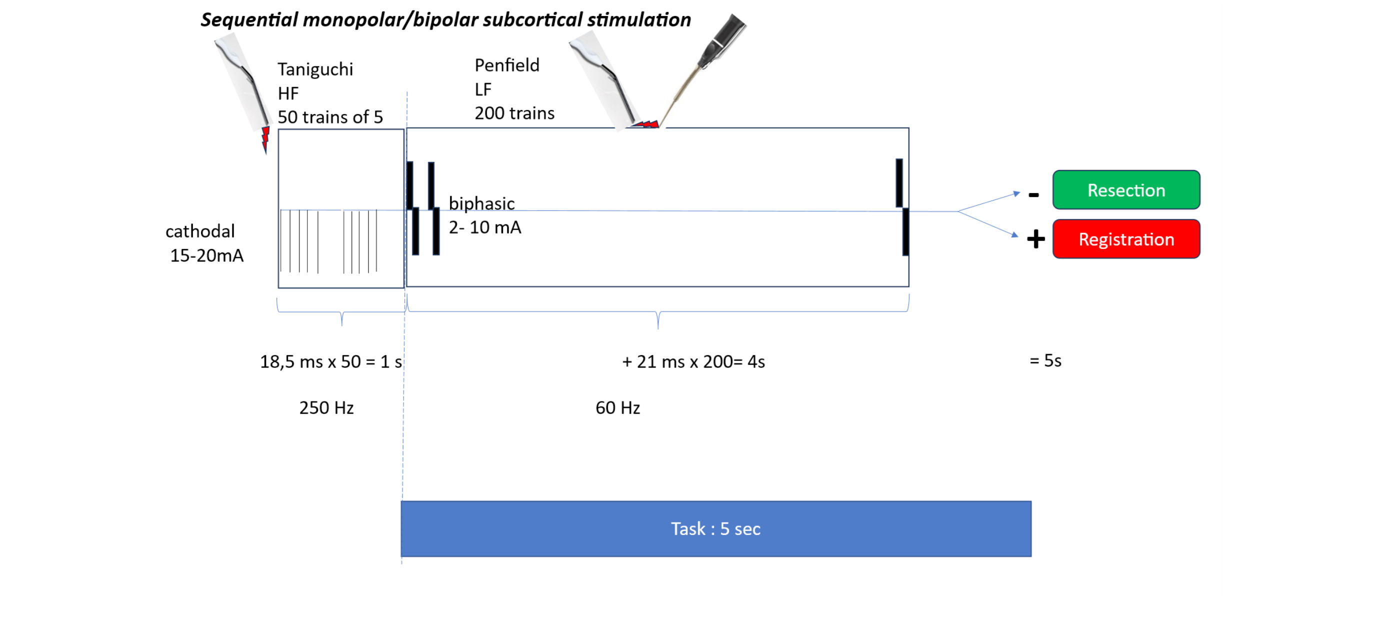

Figure 5: Sequence of monopolar and bipolar subcortical stimulation.

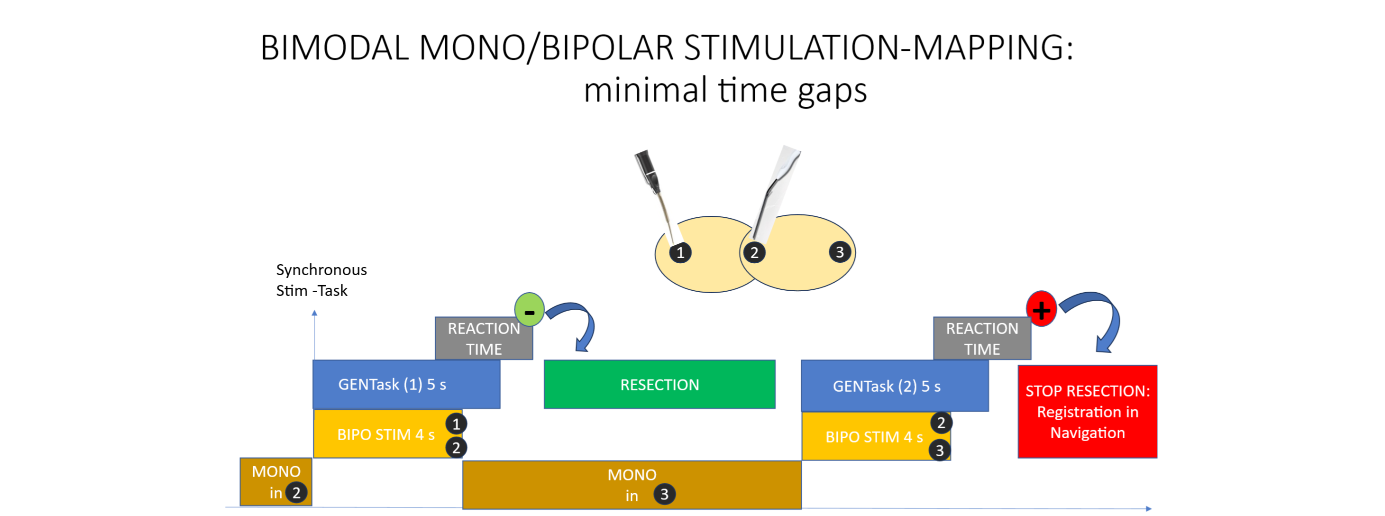

Figure 6: Time frame of Stimulation & Resection.

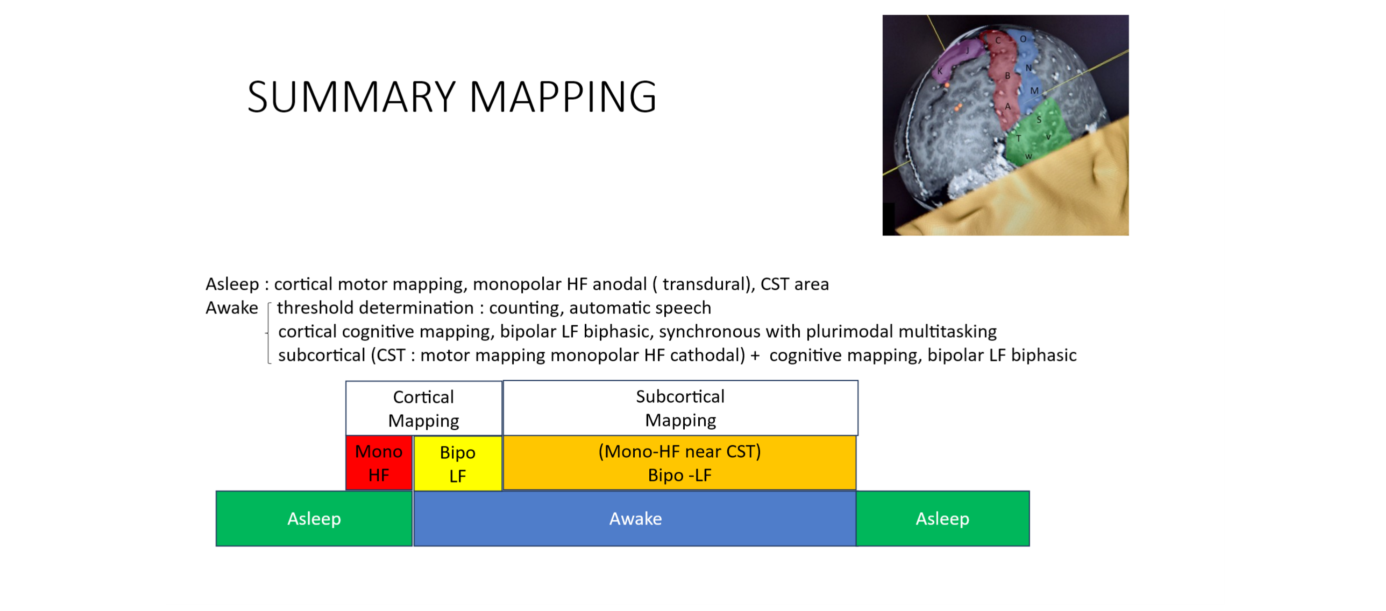

Figure 7: Time Sequence of Mapping Modi Asleep-Awake -Asleep.

The rational *sequence* of electrical stimulation is first monopolar (HF, To5) during 5 sec for MEP-evaluation, followed by bipolar (LF) during 4sec, during which synchronously a cognitive task is presented for 5 seconds; since this testing implicates decision about resection or not and thus possible irreversible neurological damage, a multimodal is proposed. We use the GEN Task, offering a maximal sensitivity but also a variation in tasking, avoiding annoyance to the patient.

Results

The described cortical mapping method has been used with Picture Naming since 2002, with DuLip since 2010, with GEN Tasks since 2015, combined with Excel registration since 2012. Subcortical mapping with CUSA-tip is performed since 2004 in monopolar mode, and since 2015 bipolar with suction probe. Over 500 patients were submitted to the multimodal testing. No seizures occurred; no negative mapping was encountered.

Conclusion

Consensus about stimulation methodology and parameters is generalized, while selection of sites and coupling them with tasks still is subject of discussion.

A novel method is proposed for cortical mapping, integrating 3 types of predefined tasks with increasing difficulty, adapted to each cortical parcel, combined with possible alternation of mono- and bipolar subcortical stimulation and multimodal task.

This methodology is principally developed to avoid false negative mapping, with accuracy in the relationship Site/Stimulation/Task and completeness of testing, not to overlook task modalities; moreover, absence of local and time gaps enhances the reliability and ergonomics of the mapping, while reducing its duration.

Acknowledgment

None.

Conflict of Interest

None.

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