ON THE DESIGN OF INTRACRANIAL MULTI-SITE MICROELECTRODES FOR ELECTRO IMPEDANCE TOMOGRAPHY.

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INTRODUCTION

The measurement of physiological data using harmless and painless techniques is one of the major advantages of modern monitoring techniques. One potentially interesting area for the application of these procedures lies in clinical neurosciences, where measurements are used to obtain impressions of functional changes of the human brain. In diagnostics and treatment of patients with severe head injuries, intracerebral bleeding and other space-occupying intracranial lesions, measurement of short-term changes, e.g. intracranial pressure (ICP) and cerebral perfusion pressure, are necessary to prevent secondary brain injury like brain infarction due to cerebral ischemia. The ICP is a result of a constantly changing interplay between the cerebrospinal-fluid-system, the cerebral blood volume and brain tissue. Various attempts have been made to develop bed-side-procedures of ICP-monitoring. It has been proven that ICP monitoring in severe head trauma provides an early warning sign of neurological deterioration and predicts and improves outcome, if adequate treatment is started started [1-4].
However, one of the major disadvantages of all the currently available technologies to monitor ICP is their doubtful accuracy, caused by technological problems as well as by using single transducers placed either extradurally or into the brain parenchyma, which can hardly reflect the whole-brain situation.

We wish to apply a quite new technique called electrical impedance tomography, EIT, to this problem by utilizing it bedside, to produce brain resistivity maps with a high resolution [5-7].

ELECTRICAL IMPEDANCE TOMOGRAPHY

In standard EIT, an array of electrodes is attached on the boundary of an object (Fig.1) and small sinusoidal currents are applied to the volume by two driving electrodes. The resulting voltages on the other electrodes are measured and the internal resistivity distribution map is computed based on this boundary data. Many applications of this technology are
developed both for medical and industrial use [8-12].

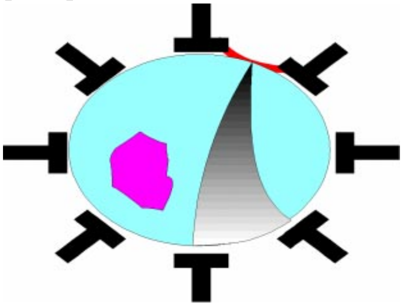

Fig. 1: Standard EIT setup: Electrodes (black T) are arranged outside the body. A small current is injected into the body (here shown as line between electrodes at 12 and 2 o'clock) and the resulting potential (gray wedge) is measured by all other electrodes (shown at sites 5 and 6o'clock). Backprojection algorithms are then used to localize the object with a different resisitivity.

One of the disadvantages of standard EI tomography used to access the brain is the huge resistivity of the skull, obscuring all other resistivity changes inside it. This and further above mentioned shortcomings of current monitoring techniques may be overcome by using EIT methods intracranially to determine images of functional changes in the human brain by implanting minute microelectrode arrays (Fig. 2, not to scale!).

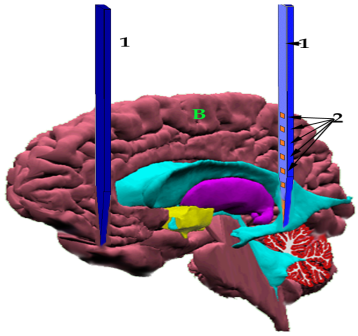

Fig. 2: Schematic outline of the application of microelectrode arrays for intracranial EIT. B: Brain; 1: Probe carrier; 2: Electrode site.

Our projected medical indication (post OP or deeply traumatized patients) already requires an opening to be made in the skull, so we propose to increase the accuracy of standard EIT methods by utilizing needle like probes carrying a multiplicity of suitable electrodes. Probes (2 or more) are then stereotaxically inserted **into** the brain, flanking the traumatized area.

Alternating pairs of two of these electrodes are then used to inject a safe, high frequency alternating current into the injured tissue, whereas the other electrodes are used to pick up the developing current profile. A backprojection algorithm will then in the easiest case visualize impedance distributions and changes thereof in the measured body. Accordingly, we would become capable to monitor fast changes in resistivity of the tissue between them (Fig.3).

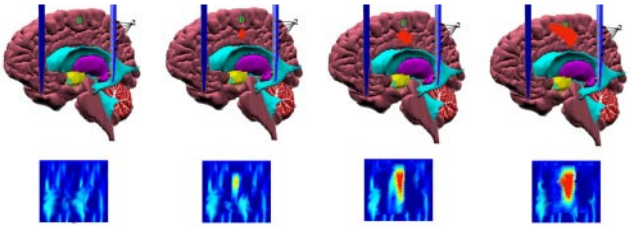

Fig. 3: Artistical sketch of a change in resistivity in the plane between 2 electrode carriers. From left to right an increasing brain volume is replaced by blood, requesting immediate surgical attention.

MULTIELECTRODE PROBES

One major requirement for all medical applications is their product safety. In our case, the need for unbreakable, but nevertheless photolithographically treatable probe carriers will be satisfied by neither using silicon, nor a ceramic process. Instead we utilize biocompatible metal for that purpose. In order to make an improvement step compared with standard, single unit brain electrodes, we design our probes to become smaller than 1mm in width and thinner than 0,5mm in thickness.

Due to the novelty of our approach, the sizes (between 200 and 500µm squared) and shapes (circular, cross-like, rectangular) of our electrodes are not finally fixed and need to be verified by experiments. However, following the process available at our micro-machining lab, our primary electrode material will become gold.

All the above will allow us to use either titanium or medical grade stainless steel as substrate. Titanium, although the arguable best metal for medical purposes, unfortunately shows the disadvantage of quite a poor surface quality, when purchased for reasonable prices.

Since both, stainless steel and titanium may be isolated by titanium oxide deposition, the following lift-off process is the same for both of the substrates.

This process consists of deposition of photoresist on the oxide layer and developing it by illumination through a mask. The illuminated photoresist is washed off by organic solvents and the unmasked areas are gold covered by vapour deposition. The following rinsing step removes all photoresist traces and only gold traces are left on the titanium oxide layer. One more step produces the gold electrode sites and bonding pads and is followed by another insulating, photolithographically controlled deposition of insulator oxide. The resulting multielectrode probes are then laser-cut from the substrate (Fig. 4) and assembled with appropriate multi-channel plugs.

Experiments in saline tanks will be performed with dummy probes as shown on a 3 inch wafer in Fig. 4.

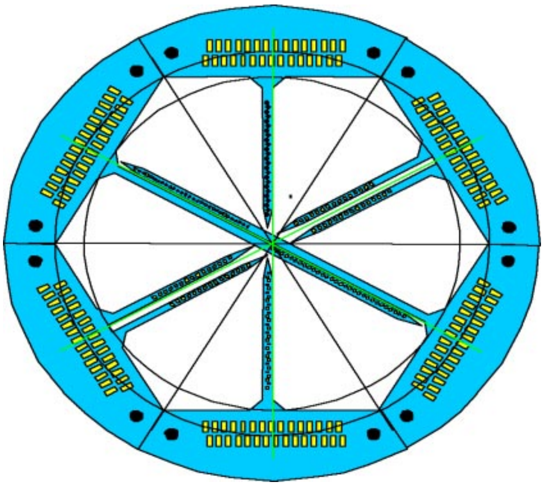

Fig.4: Design of probes from 3 inch wafer of titanium for dummy and test use.

Models and real titanium probes will be shown which might eventually show useful for intracranial EIT as well as potential recording - even single cell recordings are in the reach of this approach based on metal electrode carriers.

LITERATURE

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