Investigation of the Precision of a Neuro-Navigation System: Results of Using a Three level Mixed Effects Regression Model

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Introduction and Problem: Improvements of computer technology and neuro imaging software have led to the development of intra-operative computer assistance and of its wide use in head surgery ([1], [2]). Neuro-navigation systems allow an exact transfer of the individual patients image data onto the operative field. Thus, the surgeon will get precise information about the position and the contours of the operative field. This procedure helps the surgeon to define tumour margins or margins of other areas of the brain [3]. Of special interest in practical use of a neuro-navigation system is to know, which factors influence the precision of such a complex system. In our trial, a phantom was used as a dummy head to investigate the influence of different factors on the precision of the neuro-navigation system. The investigated neuro-navigation system consists of a *digital instrument* (pen and patient tracker), an *infrared camera* for transmission of the signals, and a *workstation* with image analysis software.

Material and Methods: A plexiglass cylinder with cone-shaped bores ("landmarks", which present the position of points of interest in a head) and nearly eight markers ("fiducials ", which are special markers for the registration of the phantom) was used as a dummy head (phantom 'Lucy') in the trial. The experiment involved the following four steps:

1. Measuring the Euclidian coordinates of all landmarks with CNC. This procedure is the "gold standard" for the measurement of the coordinates. The results from the CNC measurements are regarded as the "true coordinates".
2. Registration of the phantom, which involves the fixation of the fiducials, the scanning of the phantom by CT or any kind of MRT, and the migration of the measured data into an image analysis software. The result of step 2. is a three-dimensional reconstruction of the surface and the landmarks of the phantom in an image analysis software. In practice, every registration corresponds to a new registration of a patients head.
3. Fixing of the phantom and the patient tracker and definition of fiducials. This step involves the touch of the fiducials by the pen and the visualization of the coordinates of the fiducials in the image analysis software.
4. Measuring of the coordinates every landmark by the pen, which involves the "soft touch" of every landmark by the pen. Every measurement is done repeatedly. The outcome is the Euclidean distance (the 'precision' of the neuro-navigation system), between the pen-measured coordinates and the "true coordinates", measured in step 1..

There were 51 independent registrations (repetition of step 2.) in the experiment. The procedure from step 4. was repeated for every registration. Additionally, the variation of other variables (i.e. imaging procedure, localisation of the surface registration, existing of a special structure) was realized in every registration.

Because of the complex dependence structure, mixed effects models ([4], [5]) are suitable tools to perform the statistical analyses. We used a three level linear mixed effects regression model for the analysis. The statistical analyses were carried out using the software "R".

Results and Discussion: The main goal was an evaluation of the 'mean' precision and to assess, which factors have the most influence on the precision of the neuro-navigation system. Especially, we were interested in the effect of the localisation of the surface registration on the precision. In our presentation, we introduce the data structure, we develop the appropriate regression model, and we present and interpret the main results from the fitted model.

References:

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