Systemanforderung an mechatronische Assistenz, abgeleitet von der chirurgischen Genauigkeit eines Navigationssystems

System demands for mechatronic assistance, derived from investigating the surgical accuracy of a state of the art navigation system

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Problem

Computer Assisted Surgery (CAS) is an integral part of many head surgical clinics in Germany. The surgical accuracy and safety of these systems is of major interest. Investigating accuracy using phantoms does not take clinical environment into account sufficiently. Our study uses a clinical approach describing the accuracy of a navigation system undergoing realistic operational procedures. The question is: Of what value is this accuracy? Thus we receive digital navigation data, but then the surgeon himself operates manual-only in the surgical field.

Methods

3D-CT-navigation-data of five human cadaver heads was transferred to a BrainLAB™ Vector Vision® System. Three heads were registered with a headset, two were surface registered with a laser surface scanning method. Eleven different anatomical landmarks were navigated ten times each. Navigated were point like structures that could be determined through the endoscope and that have an exact correlative within the 3-D-CT scan. This correlative was declared for the rated value. The position of the pointer tip (displayed as a cross hair) in the CT screen was stored by taking a screenshot. For control, the endoscopic picture was stored as well. The vector´s amount between rated and actual value represents the navigational deviation (a).

Results

404 measurements could be evaluated. The structure touched by the pointer corresponded in only a few cases exactly with the anatomical correlative on the navigational screen.
We received a mean value of a=2,29mm, standard deviation was 1,83mm. The accuracy fluctuated up to 9,01mm. Laser surface registration showed results of a significantly higher precision. After variance analysis three homogeneous groups of landmarks were established with the following mean values for a:
- 0,86-1,88mm: interdental gaps, middle nasal concha, nasal septum
- 2,00-2,99mm: drill holes in the frontal and temporal skullcap
- 3,36-4,31mm: lateral ends of the eyelid, drill hole in the occipital skullcap

The calculated registration error (CRE) had a mean value of 0,56mm.

Conclusion

The CAS-System we used had a sufficient accuracy when using as a pointing device. Laser registrations proved to be more accurate and easier in handling. In case of deviation the surgeon serves as the human corrective factor, yet the surgeon operates uncontrolled and therefore also worsens accuracy. At this point interactive mechatronic assistance could connect digital navigation data with the controlled employment of an instrument (e.g. a drilling device which only functions in save regions). The global inaccuracy of a state of the art navigation system is essentially depending on:
- CT-Data-acquisition (resolution: min=0,391mm)
- Quality of registration
- Accuracy of the cameras (0,1-0,3mm)
- Mechanical quality of navigational instruments
- Ergonomic factors of the navigation system (turning the head to the monitor)
- Physiological tremor

For future mechatronic applications, CAS-Systems need to achieve a higher reproducible accuracy. The number of potential sources of inaccuracy is too high, the path to (controlled) navigation needs to be shortened and improved.