Intraoperative Computed Tomography

Computer-assisted navigation (CAN) may guide spinal instrumentation and requires alignment of patient anatomy to imaging. Iterative closest-point (ICP) algorithms register anatomical and imaging surface datasets, which may fail in the presence of geometric symmetry (congruence), leading to failed registration or inaccurate navigation. Guha et al. computationally quantified geometric congruence in posterior spinal exposures, and identify predictors of potential navigation inaccuracy.

Midline posterior exposures were performed from C1-S1 in four human cadavers. An optically-based CAN generated surface maps of the posterior elements at each level. Maps were reconstructed to include bilateral hemilamina or unilateral hemilamina with/without the base of the spinous process. Maps were fitted to symmetrical geometries (cylindrical/spherical/planar) using computational modeling, and the degree of model fit quantified based on the ratio of model inliers to total points. Geometric congruence was subsequently assessed clinically in 11 patients undergoing midline exposures in the cervical/thoracic/lumbar spine for posterior instrumented fusion.

In cadaveric testing, increased cylindrical/spherical/planar symmetry was seen in the high-cervical and subaxial cervical spine relative to the thoracolumbar spine ($p<0.001$). Extension of unilateral exposures to include the ipsilateral base of the spinous process decreased symmetry independent of spinal level ($p<0.001$). In clinical testing, increased cylindrical/spherical/planar symmetry was seen in the subaxial cervical relative to the thoracolumbar spine ($p<0.001$), and in the thoracic relative to the lumbar spine ($p<0.001$). Symmetry in unilateral exposures was decreased by 20% with inclusion of the ipsilateral base of the spinous process.

Geometric congruence is most evident at C1 and the subaxial cervical spine, warranting greater vigilance in navigation accuracy verification. At all levels, the inclusion of the base of the spinous process in unilateral registration decreases the likelihood of geometric symmetry and navigation error. This work is important to allow the extension of line-of-sight based registration techniques to minimally-invasive unilateral approaches [1)].

CT-guided navigation allows for 3-dimensional visualization of the cervicothoracic junction (CTJ) and minimizes complications associated with inadequate surgical visualization of vascular and deep organ structures [2)].

Currently, intraoperative computed tomography (iCT) is a scarcely used technique in neurosurgery. It remains unclear whether this phenomenon is explained by unfavorable iCT-related workflows and/or a limited number of indications.

Systems

see Intraoperative Computed Tomography systems.

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18 patients underwent DBS with bilateral implantation of directional electrodes applying a 32-slice portable CT scanner in combination with microelectrode recording.

iCT led to a significant decrease in overall procedural time, despite performing multiple scans. In three of the initial 5 cases iCT caused an adjustment of the final electrodes demonstrating the learning curve and the necessity to integrate road mapping for the exchange of microelectrode to final electrode. Implementation of low-dose CT protocols added microelectrode iCT to the refined workflow, resulting in an intraoperative adjustment of a trajectory in one patient. Low-dose protocols lowered the total effective dose to 1.15 mSv, i.e. a reduction by a factor of 3.5 compared to a standard non-iCT DBS procedure, despite repeated iCTs. Intraoperative lead detection based on final iCT revealed a radial error of 1.04 ± 0.58 mm and a vector error of 2.28 ± 0.97 mm compared to the preoperative planning, adjusted by the findings of microelectrode recording.

iCT can be easily integrated into the surgical workflow resulting in an overall efficient time saving procedure. Repeated intraoperative scanning ensures reliable electrode placement, while low-dose scanning protocols prevent extensive radiation exposure. iCT of microelectrodes is feasible and led to an adjustment of one electrode [3].

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i-CT combined to awake surgery is reliable and effective. It does not significantly affect surgical time and it does not add stress to patient. The possibility to correct for brain shift also in awake patients can increase precision and accuracy of surgery, particularly in cases of Low-Grade Gliomas, avoiding resection of normal white matter or tumor remnants in non-eloquent areas [4].

Intraoperative computed tomography (iCT) has gained increasing impact among modern neurosurgical techniques. Multislice CT with a sliding gantry in the OR provides excellent diagnostic image quality in the visualization of vascular lesions as well as bony structures including skull base and spine. Due to short acquisition times and a high spatial and temporal resolution, various modalities such as iCT-angiography, iCT-cerebral perfusion and the integration of intraoperative navigation with automatic re-registration after scanning can be performed. This allows a variety of applications, e.g. intraoperative angiography, intraoperative cerebral perfusion studies, update of cerebral and spinal navigation, stereotactic procedures as well as resection control in tumour surgery. Its versatility promotes its use in a multidisciplinary setting. Radiation exposure is comparable to standard CT systems outside the OR. For neurosurgical purposes, however, new hardware components (e.g. a radiolucent headholder system) had to be developed. Having a different range of applications compared to intraoperative MRI, it is an attractive modality for intraoperative imaging being comparatively easy to install and cost efficient [5].

Intraoperative Computed Tomography is a useful tool to check the correct position of the implants used, the extent of decompression and the realignment as early as possible. It therefore reduces second operations. A postoperative CT is no longer necessary [6].

A study reports the experience of Terpolilli et al with the use of intraoperative CT (iCT) combined with neuronavigation with regard to feasibility and possible benefits of the method.

Those patients with tumorous lesions in relationship to the orbit, sphenoid wing, or cavernous sinus who were surgically treated between October 2008 and December 2013 using iCT-based neuronavigation and in whom an intraoperative scan was obtained for control of resection were included. In all cases a second iCT scan was performed under sterile conditions after completion of navigation-guided microsurgical tumor resection. The surgical strategy was adapted accordingly; if necessary, resection was continued.

Twenty-three patients (19 with WHO Grade I meningioma and 4 with other lesions) were included. The most common clinical symptoms were loss of visual acuity and exophthalmos. Intraoperative control of resection by iCT was successfully obtained in all cases. Intraoperative imaging changed the surgical approach in more than half (52.2%) of these patients, either because iCT demonstrated unexpected residual tumor masses or because the second scan revealed additional tumor tissue that was not detected in the first scan due to overlay by osseous tumor parts; in these cases resection was continued. In the remaining cases resection was concluded as planned because iCT verified the surgeon's microscopic estimation of tumor resection status. Postoperative visual outcome was favorable in more than 80% of patients.

Intraoperative CT allows control of resection in case of uncertainty and can help to improve the extent of maximal safe resection, especially in case of osseous tumor parts and masses within the orbit [7)].

The benefits of Intraoperative magnetic resonance imaging (iMRI) in complex meningioma surgery are doubtful; however, it may still prove to be effective in certain subsets of complex meningiomas [8)].

Atlas fracture and axis fracture are complex and surgical management may be difficult and challenging due to the anatomical relationship between the vertebra and neurovascular structures. The use of a navigation system based on an intraoperative computed tomography allows a real-time visualization of the vertebrae, reducing the risks of screw misplacement and consequent complications [9)].

Case series

A study refers to a consecutive series of patients undergoing either single-room iCT (January 2014-August 2014) or dual-room iCT (DR-iCT) (September 2014-July 2016). A further group undergoing surgery without iCT in the interconnected operating rooms represents the reference group. Workflow measurements and infection rates were calculated. Indications for iCT and utilization rates were compared for each of the devices. CT image quality was rated.

Application of DR-iCT led to a broader use of this technique as compared to the single-room device, which concerned in particular stereotactic neurosurgery. Accordingly, iCT utilization rates significantly increased (up to 50.8 ± 4.6 surgeries per month, $p < 0.001$). Workflow was slightly prolonged in case of DR-iCT imaging; the difference, however, was not statistically significant. Infections rates were low (range 0.0-0.17 infections per month) and not influenced by the utilization rate. Image quality of the DR-iCT was classified as very good in 34/43 evaluated microsurgical patients.

The use of DR-iCT enhances utilization rates with a broader field of indications for intraoperative imaging. Workflow measurements are not significantly prolonged. The technology is safe, and the imaging quality of modern devices can be expected to be good [10)].

Airo Mobile Intraoperative CT

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