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Neuronavigation and Intraoperative Imaging System in Orbital Tumor Surgery: A Review of Recent Literature

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ABSTRACT

Orbit is a small complex anatomic space that contains important structures, ocular globe, extrinsic muscles, cranial nerves, blood vessels, fat, lacrimal gland. In presence of orbital tumors it is mandatory to use a surgical approach that allows to achieve an adequate surgical field while preserving neurological function. Neuronavigation is the set of computer-assisted technologies used to guide or "navigate" the edges of the tumor to allow the surgeon during resection or biopsy. This technology started with use of CT data to get some landmarks of human anatomy defined “targets” that could be readily used in surgery. Finally, the evolution of modern neuroimaging technologies such intraoperative CT and MRI boosted the surgery accuracy. In order to identify advantages and practical use of these technologies we performed a nonsystematic review of the current literature using the keywords “orbital tumor or orbital neoplasia or orbital mass or orbital lesion” and “neuronavigation or navigation” published in last 10 years. We evaluated 29 papers and we can conclude that navigation in orbital surgery helps to reduce surgical damage while at the same time, allowing a more radical tumor resection. CT and MRI scans are complementary in diagnosing and in intraoperative navigation allow the surgeon to avoid and preserve vital structures, particularly in a complex surgical procedure without real anatomical landmarks for intraoperative orientation. Future is going towards rapid changes and the integration with intraoperative procedures is carrying on to new technologies further our contemporary bounds.

Keywords: Orbital tumor, Orbital surgery, neuronavagation, Intraoperative computer tomography, Intraoperative magnetic resonance

Abbreviations: MRI: Magnetic Resonance Imaging; iMRI: Intraoperative Magnetic Resonance Imaging; CT: Computer Tomography; iCT: Intraoperative Computer Tomography; NNS: Neuronavigation System; FNAB: Fine-Needle Aspiration Biopsy; ENT: Ear, Nose and Throat Doctors

INTRODUCTION

The orbit is a quite small, “interdisciplinary” region, being area of interest of many specialists, such as ophthalmologists, ENT (ear, nose and throat) doctors, endocrinologists, neurosurgeons, plastic surgeons and maxillofacial surgeons. Orbital tumor can be a benign tumor or a malignant tumor that can affect all components of the ocular globe, orbital walls, extrinsic muscles, cranial nerves, blood vessels, fat, lacrimal gland. Surgical access (in order to perform biopsy. FNAB or resection), especially in case of intraconal lesions, may be demanding. The ocular globe and the maintenance of its function are the major points of interest whichever treatment is used. In case of orbital tumor the main goal of surgery is to achieve the maximum extent of resection while preserving neurological function. In last year’s usage of iMRI, iCT and neuronavigation systems has been proven to be highly accurate in the resection of intracranial neoplasms [1-3]. In an effort to improve resection safety, this combination has begun to be applied to approach orbital tumors, providing better safety and effectiveness compared to standard endoscopic or microscopic approach, even if prolonged surgical time has been reported by some authors [3].

MATERIALS AND METHODS

In order to identify advantages and disadvantages of these

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approaches we performed a nonsystematic review of the current English literature using PubMed database. The search strategy was to include all published articles involving the keywords "Orbital tumor or orbital neoplasia or orbital mass or orbital lesion" and "neuronavigation or navigation" published in last 10 years. No systematic or Cochrane reviews or meta-analyses were found on the topic. In first screening 66 items were included and after first round search we included 29 paper on the review. We excluded five case reports [4-8] and one paper that had only abstract wrote in English [9].

DISCUSSION

Neuronavigation systems

Intraoperative navigation was introduced in head and neck surgery more than 20 years ago in order to reduce overall operation time, making radical tumor surgery more reliable and allowing safer manipulations in close proximity to delicate structures. Small or minimally invasive approaches allow only limited exposure and are a promising field for intraoperative navigation systems. The main problem is the topographic changes caused by surgery resulting in discrepancies between the preoperative image data and the surgical site [10-12]. The application of neuronavigation in cranio-orbital neurosurgery has been rarely reported [13-15]. Enchev et al. [16] described 9 papers in the literature that describe the application of neuronavigation in this field; most cases are concerning with orbital reconstruction following post traumatic injury. In this survey navigation has demonstrated to be useful to improve the accuracy in restoration of orbital volume [17-20]. Nevertheless, at today only few studies report the effectiveness of this technique in orbital tumors removal. Using this approach, eventually in combination with the surface scanning systems using a Class I laser device, thanks to the use of microsurgical techniques, orbital lesions can be excised in very direct surgical routes, mostly without intracranial invasion or significant external facial incisions. In addition, it has been assessed that the so-called "brain-shift", that in brain procedure is reported to increase inaccuracy, is unimportant in case of orbit surgery, since in this case the surgical targets are fixed structure (bone), so that intraoperative anatomical localization at the state of the surgery was found to be accurate and to remain stable during operative time [21]. Obviously, in order to prevent major shift in the position of the orbital structures at the beginning of surgery, the aspiration or opening of cystic components of the lesion before finding and identifying of the borders must be avoid. Surgical time is not significantly prolonged and due to the fact that operative manipulation and trauma of intra orbital structures is reduced, the benefits of the procedure balance the relative additional operative time required [21]. Sieskiewic et al. [22] described the use of NNS associated with endoscopic trans-nasal approach to facilitate localization and biopsy of intra orbital tumors, in particular in case of small, retro bulbar tumors, limiting the extent of opening of medial orbital wall and relative prolapse of intra orbital tissue into nasal cavity. The use of neuronavigation and endoscopic trans-nasal approach has been reported to be effectiveness also in case of intraconal cavernous hemangioma [23]. Different techniques in order to plan NNS are described [24]. The use of CT and MRI combined to obtain exact extension of the lesion was described: all patients included in Hejazi's study underwent neuronavigation assisted microsurgical removal of the lesions [21]. Access was planned preoperatively on a workstation monitor, and the automatic fusion of image sets (CT, MRI T1-weighted and MRI T2-weighted) demonstrated to be important and helpful in order to identify the exact extension of the lesions. Hejazi at al. describe the complete removal of the lesion performed via a frameless navigation-aided trans-conjunctival approach in the treatment of orbital lymphoma [25]. 11 cases with lymphomas located in the intraconal front or anterior compartment of the orbit. In seven cases, the frameless neuronavigation technique was used in combination with the transconjunctival approach or with the pterional approach; they described a low rate of ocular complications, including corneal injuries in particular in patients with Corneal Dystrophies [26].

Combined neuronavigation system

With the use of intraoperative imaging-based neuronavigation the topographic changes caused by surgery resulting in discrepancies between the preoperative image data and the surgical site are eliminated. In addiction it allows for control of resection; Terpolilli et al. [1] reported that in more than half patients, included in their study, tumor removal was extended after the intraoperative control, indicating that iCT significantly influenced extent of excision. Finally, iCT with intraoperative navigation-guided system is effective to assess if the orbital reconstruction re-establishes orbital volume and globe projection in subjects with post-ablative orbital defects. In fact it has demonstrated to be a viable tool to assist the surgeon even during the reconstruction. Heiland et al. [10] described their experience about orbital surgery, including removal of foreign bodies, which is an effective application of intraoperative navigation. From their point of view, further promising indications include extended or recurrent tumors because of altered anatomy with lost landmarks during surgery. Software advancements should allow not only marking of certain structures but simulation of their shifting. In combination with intraoperative imaging, the surgical result could be verified in the sense of quality management. Flat panel detector CT(FD-CT) and associated navigation software have been used to safely and accurately guide percutaneous interventions during the treatment of intra orbital vascular malformation (low-flow and high-flow lymphatic and vascular malformations). The use of trans-arterial or percutaneous embolization is well established for vascular malformations and hyper-vascular masses within the head and neck. The use of CT guidance improves accuracy, especially with regard to bony structures, although this can be insufficient in soft tissue differentiation. In light of these limitations, a three-dimensional image overlay technique has been developed for FD-CT systems whereby an existing MR examination can be accurately superimposed into a FD-CT combining the detailed bony detail of CT with the soft tissue definition of MR [27]. Nesbit et al. [28] described their experience using integrated cone-beam CT and fluoroscopic navigation in treatment of head and neck vascular malformations and tumors in 27 patients, 5 of these with intra orbital localization. This technique demonstrated to allow more accurate trajectory planning and needle location, those are critical for the success of embolization treatment, avoiding complications. Reinbacher et al. [29] developed a method for a minimal-invasive biopsy of an intraconal lesion using a 3D navigation system based on combined technique of hardware fusion between 18F-FDG Positron Emission Tomography (18F-FDG PET), magnetic resonance imaging (MRI) and Computed Tomography (CT). They presented 6 patients with a total of 7 intra orbital lesions; all patients underwent fine-needle aspiration with intraoperative image-guided navigation. They demonstrated that the lesion was reached on the first pass in five lesions attempt, underlining that there has not been an increase in operating times with the use of NNS. Intraoperative-MRI resection control is also described. MRI imaging is advantageous due to the absence of exposure to x-rays. However, iMRI is quite time consuming, requires a dedicated operating theater and operating room equipment and is significantly more costly than CT [1,30]. Future could be the use of new advanced techniques in NNS like O-arm System (Medtronic Inc., Minneapolis, Minnesota, USA) currently already used in trans-nasal endoscopic cranial base surgery. With the O-arm assisted technique the images obtained localizes the tumor during the surgery the real time, images are transferred to the neuronavigation workstation, where they are merged with preoperative CT and/or MRI [31].

CONCLUSION

In presence of orbital tumors it is mandatory to use a surgical approach that allows achieving an adequate surgical field while preserving neurological function. NNS eventually combined with intraoperative imaging provide better safety and effectiveness compared to standard endoscopic or microscopic approach in more complex cases. In Table 1, are listed all the studies included in our review that use NNS, we have excluded five case report [4-8], one paper that had only the abstract wrote in English [9] and case series that include less than five patients and we have indicated the NNS subtype; for example CT-based or MR-based neuronavigation system. Neuronavigation system was considered accurate for the studies included in this nonsystematic review. However, the quality of these eleven papers show that randomized clinical trials are needed to compare NNS to conventional planning in the surgery intra orbital tumors, in terms of accuracy and operating time to get a high level of evidence to allow us to draw certain indications **(Table 1)**.

Table 1. The table shows the eleven studies included in our non-systematic review and list the NNS subtype: CT-based neuronavigation system, MRI-based neuronavigation system, iCT-based neuronavigation system, MRI-based neuronavigation system and combined system.

Study	Authors	Year	Journal	Subjects	NNS used
Orbit-associated tumors: navigation and control of resection using intraoperative computed tomography.	Terpolilli et al.	2016	J Neurosurg	52	iCT-based neuronavigation
Intraoperative DTI and brain mapping for the surgery oneoplasof the motor cortex and the corticospinal tract: our protocol and series in Brain SUITE.	D'Andrea et al.	2012	J Neurosurg Rev	18	Brain SUITE with 1.5 T intraoperative magnetic field and neurophysiologic al monitoring
The Use of Neuronavigation and Intraoperative Imaging Systems in the Surgical Treatment of Orbital Tumors.	Hodaj et al.	2014	Turk Neurosurg	17	The MRI-based neuronavigation system was used in 16 (94%) patients and the CT-based navigation system was used in 1 patient
Indications and Limitations of Intraoperative Navigation in	Heiland et al.	2004	J Oral Maxillofac	20	Navigation system Vector

Maxillofacial Surgery.			Surg		Vision. The M RI-based neuronavigation system and/or CT-based navigation system
Neuronavigation in cranioorbital neurosurgery - do we really need it?	Enchev et al.	2016	Turk Neurosurg	7	CT-based in 3 cases, MRI-based in another 3 cases and based on image fusion between CT and MRI image sets in one patient.
Orbital lymphoma: diagnostic approach and treatment outcome.	Eckardt et al.	2013	World J Surg Oncol	11	computer-assisted navigation platform (iPlan CMF 3.0; BrainLAB, Feldkirchen, Germany)
Frameless image-guided neuronavigation in orbital surgery: practical applications.	Hejazi	2006	Neurosurg Rev	11	CT and MRI-based neuronavigation assisted (VectorVision, BrainLAB, Heimstetten, Germany)
Endoscopic trans-nasal approach for biopsy of orbital tumors.	Sieskiewic et al.	2008	Acta Neurochir	6	CT and MRI-based neuronavigation
The microsurgical treatment of cranio-orbital tumors assisted by intraoperative electrophysiologic monitoring and neuronavigation.	Gao et al.	2012	Clin Neurol Neurosurg	20	neuronavigator (BrainLAB, Munich, Germany)
Integrated cone-beam CT and fluoroscopic navigation in treatment of head and neck vascular malformations and tumors.	Nesbit et al.	2011	J Neurointerv Surg	27	MRI and CT-assisted navigation + iCT* and 3D rotational angiography (3DRA) in 1 subject
Minimal invasive biopsy of intraconal expansion by PET/CT/MRI image-guided navigation: a new method.	Reinbacher et al.	2014	J Craniomaxillofac Surg	6	18F-FDG PET/CT or 18F-FDG PET/CT plus MRI – navigation system

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