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Minimal invasive biopsy of intraconal expansion by PET/CT/MRI image-guided navigation: A new method

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ABSTRACT

Intraorbital tumours are often undetected for a long period and may lead to compression of the optic nerve and loss of vision. Although CT, MRI's and ultrasound can help in determining the probable diagnosis, most orbital tumours are only diagnosed by surgical biopsy. In intraconal lesions this may prove especially difficult as the expansions are situated next to sensitive anatomical structures (eye bulb, optic nerve). In search of a minimally invasive access to the intraconal region, we describe a method of a three-dimensional, image-guided biopsy of orbital tumours using a combined technique of hardware fusion between ^{18}F-FDG Positron Emission Tomography (^{18}F-FDG PET), magnetic resonance imaging (MRI) and Computed Tomography (CT).

Method and material: We present 6 patients with a total of 7 intraorbital lesions, all of them suffering from diplopia and/or exophthalmos. There were 3 female and 3 male patients. The patients age ranged from 20 to 75 years. One of the patients showed beginning loss of vision. Another of the patients had lesions in both orbits. The decision to obtain image-guided needle biopsies for treatment planning was discussed and decided at an interdisciplinary board comprising other sub-specialities (ophthalmology, neurosurgery, maxillofacial surgery, ENT, plastic surgery). All patients underwent 3D imaging preoperatively (^{18}F-FDG PET/CT or ^{18}F-FDG PET/CT plus MRI). Data was transferred to 3D navigation system. Access to the lesions was planned preoperatively on a workstation monitor. Biopsy-needles were then calibrated intraoperatively and all patients underwent three-dimensional image-guided needle biopsies under general anaesthesia.

Results: 7 biopsies were performed. The histologic subtype was idiopathic orbital inflammation in 2 lesions, lymphoma in 2, Merkel cell carcinoma in 1, hamartoma in 1 and 1 malignant melanoma. The different pathologies were subsequently treated in consideration of the actual state of the art. In cases where surgical removal of the lesion was performed the histological diagnosis was confirmed in all cases.

Conclusion: There is a wide range of possible treatment modalities for orbital tumours depending on the nature of the lesion. Histological diagnosis is mandatory to select the proper management and operation. The presented method allows minimal-invasive biopsy even in deep intraconal lesions, enabling the surgeon to spare critical anatomical structures. Vascular lesions such as cavernous haemangioma, tumour of the lacrimal gland or dermoid cysts present a contraindication and have to be excluded.

1. Introduction

Since the introduction of image-guided surgery about two decades ago, nearly all surgical specialities have expanded the indications, and the technique has gained in importance. In combination with the practical experience of the surgeon, the planning and the course of interventions have become more predictable (Edwards, 2010; Rana et al., 2012).

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Particularly in surgical oncology, the planning and administration of the interacting specialists (surgeon, oncologist, radiotherapist) demands the maximum information about the lesion. Thus, progress in radiology and the integration of different examinations into intraoperative navigation now opens a wide range of options. ^{18}Fluorodeoxyglucose (^{18}FDG)-positron emission tomography (PET) combined with computed tomography (CT) is now an integral diagnostic tool for oncologic staging and response assessment (Czernin et al., 2010). Fused PET/CT imaging with ^{18}FFDG and native CT scanning enables accurate diagnosis in 93% of lesions and 90% of patients with head and neck oncology (Feichtinger et al., 2010). The detection of an increased glucose metabolic rate is characteristic for most malignant cells and can reveal biochemical differences between malignant and normal tissue (Feichtinger et al., 2008), one of the fundamental aspects of surgical treatment.

A retrospective study of 47 patients by the University of Pittsburgh group suggested an excellent sensitivity of 95%, but a limited specificity of only 60%, in PET/CT in head and neck cancer (Zimmer et al., 2005). Reasons for this low specificity included asymmetrical physiological FDG uptake and inflammation (Czernin et al., 2010). Thus, the implications of adding ^{18}FFDG to PET/CT, known to be useful for the detection of malignant tumours and their metastases in head and neck oncology (Rödel et al., 2004), in image-guided surgery adds a further dimension to the intraoperative situation.

The intraconal space is affected by different pathological processes, with various malignancies: venous vascular malformations, capillary haemangiomas, optic nerve lesions, optic neuritis, optic nerve gliomas, optic nerve meningiomas, idiopathic orbital inflammation, venous dilatation (carotid cavernous fistula, varices) and schwannomas of the third, fourth, and sixth cranial nerves. We are also faced with thyroid eye disease, usually enlargement of the inferior and medial rectus muscle, pseudo tumours, idiopathic orbital inflammation, adjacent inflammation (sinusitis), and uncommon causes of enlargement of the extraocular muscles, including glycogen storage disease and lymphoma. Different pathological entities need different treatments and not always surgical treatment.

As clinical symptoms (visual acuity, restricted eye movement and exophthalmos) are not specific, a biopsy is essential for diagnosis in most cases. The goals of surgery depend on the histology and extent of the lesion (Snyderman et al., 2008). With open access to a lesion, the macroscopic experience was formerly sufficient. In areas of complex anatomy and in aesthetically sensitive areas wide surgical exploration of a tumour of unknown malignancy almost always causes problems. The risk of iatrogenic injury of the neural and vascular structures increases as the extent of the approach increases, so a thorough understanding of the landmarks of the region and, especially, the anatomy of the optic canal is essential before attempting an approach to this region (Yilmazlar et al., 2012).

Since the introduction of fine-needle aspiration biopsy (FNAB) for the diagnosis of orbital tumours by Schyberg (Schyberg, 1975), in 1975, this minimally invasive procedure has become widely accepted. Different centres of ophthalmology developed minimally invasive biopsy and gained a high degree of safety in the procedure (Kennerdell et al., 1979; Dubois et al., 1979; Spoor et al., 1980, Kennerdell et al., 1985; Shields, 1989; Shields and Shields, 1993; Ing and Kennerdell, 1996). Today, it is relatively simple, safe and sufficiently diagnostically accurate (Yarovoy et al., 2013). In our clinical practice PET/CT is routinely used to assess tumour extension and to plan the resection (Feichtinger et al., 2010). Thus, we developed a method for a minimal-invasive biopsy of an intraconal lesion using a 3D navigation system based on PET/CT MRI image fusion.

2. Materials and methods

This study complied with the Declaration of Helsinki. The Ethics Committee approved the study.

2.1. Patients

Six patients were selected from those referred for biopsy or resection to our outpatient department between September 2009 and January 2012. The patients included in this prospective study had intraconal lesions, seen on CT or MRI. All lesions were deep in the intraconal space, in close proximity to sensitive structures. All patients were at least 18 years old (mean 52, range 20–75). All patients, three females and three males, were being investigated for suspected intraconal expansion, provoking exophthalmos or the early stages of vision loss.

One patient referred for biopsy had a long history of melanoma. Due to a multilocular pathology, the ophthalmologists did not consider surgical treatment, but sought histological confirmation before further treatment. The remaining five patients were scheduled for biopsies as part of treatment planning.

All six patients underwent ^{18}FFDG PET/CT scans preoperatively. All lesions clearly showed enhanced ^{18}FFDG uptake within the range of the malignancy (Tables 1 and 2). In five of the six patients, the intraconal lesion was the only uniform PET activity. It was presumed that targeting the PET avid portion of the lesion would have a higher diagnostic yield.

The greatest mean lesion diameter was 18.8 (range, 13–28) mm. Software on the navigation workstation enables the operator to segment a tumour in all three planes, based on previous imaging, and determines its volume based on that segmentation. Measurements were performed by the authors, the surgeon, and the radiologist. Median lesion volume, measured by the segmentation tool, was 1.85 (range, 0.63–2.18) cm^3 on conventional imaging, and the median PET avid volume per lesion was a 3.6 V/threshold 42% cm^3 (range 2.7–4.6). When a lesion was not visible on conventional imaging, the volume was scored as zero. A visual manual threshold was used to define PET avid volumes.

2.2. PET/CT imaging

The mean time between PET/CT imaging and the PET-guided biopsy procedure was 3.6 (range, 1–7) days. For patients with no contraindication, a biphasic bolus of 80110-mL iodinated contrast (Visipaque 320 mg iodine/mL i.v.) was used. Whole-body scans were performed with the PET-CT scanner (GE Discovery ST). The patients fasted for at least 12 h before examination. The blood glucose concentration was between 80 and 130 mg/dL. At 1 h before the acquisition, 280–370 MBq FDG (considering weight and height) was injected. To define the body axial extension, a CT scout scan was performed, followed by a low-dose CT for attenuation correction. Alternatively, a diagnostic helical CT followed 20 min after PET. Finally, a whole-body PET scan was performed with an emission scan of 3 min per scanning position.

PET images were corrected for random scatter and attenuation and were reconstructed on a 128 × 128 image matrix using iterative algorithms with 3D OSEM, 21 subsets, and two iterations. Resulting images using a reconstructed slice thickness of 3.75 mm were calculated. The face and neck region was reconstructed separately, with a pitch of 1.25 mm.

The images were accessed on a Xeleris workstation (GE, Waukesha). ^{18}FFDG PET/CT images were evaluated visually by two nuclear medicine physicians including senior staff physicians. The diagnostic CT scans were interpreted separately by two experienced radiologists on a Radiologic AW workstation. The readers

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