Diffusion tensor technique as a preoperative identification of cranial nerves in skull base tumors

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\begin{abstract}
Objective: The objective of this work is to demonstrate the usefulness of high density diffusion tensor imaging techniques (HD-DTI 32 directions), to visualize the course of the cranial nerves prior to surgery in patients with skull base tumor disease.

Materials and methods: Twenty-six patients with skull base tumor disease were studied with sequences of high density diffusion tensor imaging. The imaging results were correlated with the intra-operative findings.

Results: Pre-surgical identification of the course of the nerves affected by the injuries of the skull base was possible in all the studied patients, with the imaging results correlating with the intraoperative findings.

Conclusion: The visualization of the course of the cranial nerves with high density diffusion tensor imaging was shown to be safe and reproducible for the identification of cranial nerves and their course.

\end{abstract}

\begin{keywords}
High density diffusion tensor imaging; cranial nerves; skull base tumors.
\end{keywords}

\section{Introduction}

The skull base tumors invariably involve one or more cranial nerves as they grow, first distorting their normal course and then altering their integrity.

The use of the high density diffusion tensor imaging technique as a complementary tool permits the identification of cranial nerves in these cases and, in combination with current neurosurgery techniques, it allows for the implementation of a therapy that often results in cure with minimal morbidity.

\section{Objective}

The objective of this work is to demonstrate the usefulness of high density diffusion tensor imaging techniques (HD-DTI 32 directions) to visualize the course of the cranial nerves prior to surgery in patients with skull base tumor disease.

\section{Materials and methods}

We studied 26 patients, 16 women and 10 men, with an age range between 26 and 62 years old. All 26 skull base tumors found were studied using a Philips Achieva 3 Tesla magnetic resonance imaging (MRI) scanner with an 8-channel SENSE-HEAD coil and images obtained were processed using the VistaScan software (Philips Extended Workstation).

High-density diffusion tensor images were obtained using 32 diffusion directions with the following parameters: repetition time (TR) 1690 ms, echo time (TE) 70 ms, b value 800, field of view (FOV) (RL) 224 x (AP) 224 x (FH) 54 mm, matrix 124 x 122 mm, reconstruction voxel 1.75 x 1.75 x 1.80 mm, acquired voxel 1.81 x 1.83 x 1.80 mm, slice thickness 1.8 mm, number of gaps 0, number of slices 30, scan time 8 minutes and 53 seconds, reconstructed voxel size 1.75 mm and number of excitations (NEX) 2.
Then, for identification of the cisternal course of the cranial nerves, T2-weighted 3D images were obtained, which were overlaid onto the images obtained by HD-diffusion tensor imaging, with the following parameters: TE 200 ms, TR 2000 ms, FOV (RL) 150 x (FH) 38 x (AP) 150 mm, matrix 256 x 168 mm, reconstruction voxel 0.29 x 0.29 x 0.50 mm, acquired voxel 0.59 x 0.89 x 1.00 mm, scan time 4 minutes and 34 seconds, and NEX 1. There was no need for intravenous contrast administration.

In some cases of large-volume tumors, T2-weighted balanced fast field echo (B_FFE) sequences were performed to identify the course of cranial nerves. Parameters were as follows: TE 2.5 ms, TR 6.5 ms, FOV (RL) 180 mm x (FH) 60 mm x (AP) 180 mm, matrix 376 x 375 mm, reconstruction voxel 0.28 x 0.28 x 0.50 mm, acquired voxel 0.48 x 0.48 x 1.00 mm, and scan time 8 minutes and 1 second.

Once all sequences were obtained, the tractography was performed using the Philips Extended Workspace software, selecting the “Fiber Tracking” option. The fractional anisotropy (FA) value was set to 0.15, the direction angle at 27° and fiber length at 10 mm. As initial protocol, in some cases it was necessary to adjust these parameters according to the extent of involvement of the fibers. Images were subsequently merged. Using the “single point” option, the cranial nerves fibers were identified and their tract was subsequently drawn using the “Draw ROI” tool.

In all cases a successful reconstruction of cranial nerves II, III, V, VII and VIII was performed, on the affected side and on the opposite side.

Patients were operated on by two of the authors in three neurosurgery centers in the City of Buenos Aires. Surgeries were performed using standard microneurosurgical techniques and, in the case of cerebellopontine angle tumors, intraoperative electroneuropathological monitoring was performed. Finally, surgical findings were compared with preoperative imaging findings.

Figure 1. Bilateral neuroma of the eighth cranial nerve, with greater involvement of the right side and splayed fibers. No evidence of involvement of the fifth cranial nerve.
Figure 2. Meningioma on the petrous temporal bone, anterior to the internal auditory canal (IAC). The right 5th cranial nerve is elevated in the upper pole and the right 7th cranial nerve is visualized from the equator, posterior to the tumor towards the lower third.

Figure 3. Neuroma of the right 8th cranial nerve. (a) DTI of the 7th and 8th pair: the 7th pair is displaced downwards, not affecting its integrity. (b) No evidence of involvement of the 5th pair. (c) Coronal gadolinium-enhanced T1-weighted image at the level of the neuroma of the 8th pair showing intense enhancement.
Results

Preoperative identification of the course of cranial nerves II, III, V, VII and VIII, was possible in all patients studied, as well as visualization of such nerves and their relationship with the tumor (figs. 1 to 4).

The data obtained by imaging were corroborated by intraoperative findings confirming a correlation between both in all cases.

The use of preoperative tractography provided valuable information about the cranial nerves anatomy, leading to safer and more effective tumor resection.

Discussion

Technological advances in MRI have allowed improved visualization of cranial nerves, particularly of those that traverse the cerebellopontine angle cistern. This is because the cerebrospinal fluid (CSF) acts as a natural contrast medium in T2-weighted sequences, such as T2-weighted balanced fast field echo (B_FFE) images.

In patients with skull base tumors, it is usually difficult to identify the course of cranial nerves because of their distorted anatomy in relation to the tumor. In these cases, the use of the high density diffusion tensor imaging technique as a complementary tool allows recognition of cranial nerves fibers that are difficult to identify with standard MR imaging techniques.

A therapy is successful if the cranial nerves involved recover their function and if the therapeutic techniques do not damage unaffected cranial nerves, adding morbidity. At present, this can only be achieved in small- or medium-sized tumors, with previous knowledge of the anatomy and relationships distorted by tumor growth. Previous visualization of the cranial nerves, as reported in this study, remains an absolute priority before performing tumor resection.
Relationships between cranial nerves and the various tumors do not follow defined rules, and preoperative visualization of the nerve tract has so far been restricted to some specific cases and to large nerves (such as the optic or the trigeminal nerves). In our study, we were able to accurately identify the course and anatomic relationships of specific nerves involved in skull base tumors.

Our findings were consistent with those reported by Gerganov et al. and Taoka et al. For this reason, we think the diffusion tensor technique is adequate for patients with this type of lesion. Apart from being a reproducible method that can be performed with short training, it is of paramount importance for the prevention of sequels and provides better results as regards the postoperative quality of life of patients.

Conclusion

Visualization of the cranial nerves course by high density diffusion tensor imaging has proven to be safe and reproducible for the identification of cranial nerves and their course. We believe that in the future the implementation of this technique will have to be included in pretreatment (surgery and radiosurgery) imaging protocols for skull base tumors allowing the preoperative planning and identification of high risk tissues to avoid post-treatment sequels.

Conflicts of interest

The authors declare no conflicts of interest

References