Clinical Neurology and Neurosurgery 139 (2015) 159–165

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Pre-operative image-based segmentation of the cranial nerves and blood vessels in microvascular decompression: Can we prevent unnecessary explorations?

Parviz Dolati[a,*], Alexandra Golby[a], Daniel Eichberg[a], Mohamad Abolfotoh[a], Ian F. Dunn[a], Srinivasan Mukundan[b], Mohamed M. Hulou[a], Ossama Al-Mefty[a]

[a] Department of Neurosurgery, BWH, Harvard Medical School, United States
[b] Department of Neuroradiology, BWH, Harvard Medical School, United States

ARTICLE INFO

Article history:
Received 20 May 2015
Received in revised form 1 October 2015
Accepted 7 October 2015
Available online 13 October 2015

Keywords:
Trigeminal neuralgia
Hemifacial spasm
Cranial nerve segmentation
Endoscopic and microscopic view

ABSTRACT

Objectives: This study was conducted to validate the accuracy of image-based pre-operative segmentation using the gold standard endoscopic and microscopic findings for localization and pre-operative diagnosis of the offensive vessel.
Patients and methods: Fourteen TN and 6 HS cases were randomly selected. All patients had 3T MRI, which included thin-sectioned 3D space T2, 3D Time of Flight and MPRAGE Sequences. Imaging sequences were loaded in BrainLab iPlanNet and fused. Individual segmentation of the affected cranial nerves and the compressing vascular structure was performed by a neurosurgeon, and the results were compared with the microscopic and endoscopic findings by two blinded neurosurgeons. For each case, at least three neurovascular landmarks were targeted. Each segmented neurovascular element was validated by manual placement of the navigation probe over each target, and errors of localization were measured in mm.
Results: All patients underwent retro-sigmoid craniotomy and MVD using both microscope and endoscope. Based on image segmentation, the compressing vessel was identified in all cases except one, which was also negative intraoperatively. Perfect correspondence was found between image-based segmentation and endoscopic and microscopic images and videos (Dice coefficient of 1). Measurement accuracy was 0.45 ± 0.21 mm (mean $\pm$ SD).
Conclusion: Image-based segmentation is a promising method for pre-operative identification and localization of offending blood vessels causing HFS and TN. Using this method may prevent some unnecessary explorations on especially atypical cases with no vascular contacts. However, negative pre-operative image segmentation may not preclude one from exploration in classic cases of TN or HFS. A multicenter study with larger number of cases is recommended.

1. Introduction

Trigeminal neuralgia (TN) and hemifacial spasm (HFS) are due to a compression of the trigeminal and facial nerves, respectively, usually by a blood vessel. Such neurovascular conflicts most often occur in the cerebellopontine angle (CPA) at the root entry/exit zone close the brainstem [11]. Surgical microvascular decompression (MVD) is a highly efficacious surgical treatment for medically refractory TN and HFS [1–5]. MVD has been performed with the surgical microscope since the technique was first pioneered. The endoscope has quickly become an adjunct to the surgical microscope in MVD [7–19,27,28]. Regardless, preoperative diagnosis of a vascular cause for these pain syndromes is sometimes indefinite and very challenging. It is not uncommon that during MVD, surgeon may not find any obvious artery or vein compressing the nerve.

Interactive intraoperative image guidance is rapidly becoming an indispensable neurosurgical technique [20–23]. Benefits over traditional neuronavigation include optimized craniotomy site positioning and improved approach vectors for reaching deeply seated cranial nerves that minimize cerebellar trauma. Image-guidance has been shown to reduce surgical morbidity while increasing the surgeon's confidence of achieving full

* Corresponding author at: Brigham and Women's Hospital, Department of Neurosurgery, Harvard Medical School, 75 Francis Street, Boston, MA 02215, United States.
E-mail address: neuro81ward@yahoo.com (P. Dolati).

http://dx.doi.org/10.1016/j.clineuro.2015.10.006
0303-8467/

resection without impinging upon nearby critical structures [24]. Image-guided surgery ensures advanced warning of proximity to important pre-segmented anatomical structures and identifies the full spatial extent of the cranial nerve-compressing vessel interface [25].

The primary objective of our current pilot study was to validate the accuracy of image-based pre-operative segmentation using the gold standard endoscopic and microscopic findings to predict the responsible vascular element. We are actually trying to validate the predictive capability of our navigation system.

2. Patients and methods

2.1. Participants, study size and setting

A total of 14 patients with typical clinical presentations for trigeminal neuralgia (TN) and 6 patients with hemifacial spasm (HFS) randomly underwent image-based pre-operative vascular and neural element segmentation with 3D reconstructions. Patients with atypical clinical presentations, well responsive to the medical managements or those who were medically ill were excluded. Data were prospectively collected and reviewed after approval by the Hospital Institutional Review Board.

2.1.1. Image acquisition

The patients underwent preoperative 3T MRI, which included thin-sectioned 3D space T2, 3D Time of Flight and MPRAGE sequences. Images were reviewed by an expert independent neuroradiologist with 13 years of experience. Imaging sequences were loaded in BrainLab iPlanNet (BrainLab AG, Munich, Germany) and fused for segmentation and pre-operative planning. Individual segmentation of the affected cranial nerves and the compressing vascular structure was performed by a neurosurgeon and was validated intraoperatively. The results were compared with the microscopic and endoscopic findings by two blinded neurosurgeons (Fig. 1).

2.1.2. Data sources

Correspondence between image-based segmentation, and microscopic and endoscopic view of the compressing vascular structure, cranial nerves, major arteries, veins, and venous sinuses was determined by two blinded neurosurgeons.

2.1.3. Study design

This was a randomly selected prospective validation study. Primary endpoints were defined as correspondence between image-based segmentation, and microscopic and endoscopic view of the compressing vascular structure, cranial nerves, major arteries, veins, and venous sinuses.

2.1.4. Statistical methods

Patients' clinical characteristics (age, sex, follow-up length) and compressing vascular structure identity were evaluated using the mean and range for continuous variables and the frequency count for categorical factors. The Sørensen–Dice index was used to compare the correspondence between image-based segmentation and microscopic view and endoscopic view of the compressing vascular structure, cranial nerves, major arteries, veins, and venous sinuses.

3. Results

3.1. Descriptive data

3.1.1. Participants

The mean age was 65 years, and there were 6 male and 14 female patients (see Table 1). Six patients had a diagnosis of hemifacial spasm (HFS), and 14 patients had a diagnosis of trigeminal neuralgia (TN).

3.2. Operative data

All patients underwent retrosigmoid craniotomy and MVD using both microscope and endoscope. In one case with TN, there was also an ipsilateral petrous apex meningioma close to the trigeminal nerve, which was resected before MVD. Compression of the trigeminal nerve by the superior cerebellar artery was responsible in most cases of TN. Compression by anterior inferior cerebellar artery (AICA) and a large vein was responsible for compression in other cases of TN (Fig. 2). In one case, no vascular contact was found (Fig. 3). Based on image segmentation, the AICA was responsible for 5 cases of HFS (Table 1). In one case of HFS, a tortuous ipsilateral vertebral artery was also compressing the facial nerve. Perfect correspondence (Dice coefficient of 1) was found between image-based segmentation, endoscopic and microscopic images and videos (Fig. 2). In other words, intraoperative findings were exactly the same finding that we had predicted by our pre-operative segmentation, even in that case with no vascular compression.

3.3. Accuracy

For each landmark, the error of the neuronavigation system to the anatomy was measured. The mean accuracy measured was 0.45 ± 0.21 mm (mean ± SD).

3.4. Complications

No perioperative or postoperative complications occurred.

3.5. Clinical outcome

Significant improvement of the spasm was achieved in all cases except one of HFS patients after MVD. Remarkable to complete improvement of the pain was noticed in 12 cases of the TN after MVD. One case of TN showed incomplete pain relief and the last patient, who did not have any obvious vascular compression intraoperatively and was predicted by pre-operative segmentation, did not show any improvement of his pain post operatively. No rhizotomy was performed for this patient.

4. Discussion

Our preliminary study showed that image-based pre-operative vascular and neural element segmentation, especially with 3D reconstruction, is highly informative for both preoperative planning and predicting the vascular agent responsible for trigeminal neuralgia and hemifacial spasm. Microvascular decompression (MVD) is a well-known technique for the treatment of medically intractable hemifacial spasm (HFS) and trigeminal neuralgia (TN). However, because the CPA contains a high density of critical neurovascular structures, MVD confers a risk of postoperative complications, including cerebellar injury (0.45–0.87%), hearing loss (0.8–1.98%) or other cranial nerve damages, and cerebrospinal fluid leakage (1.85–2.44%)[26].

In addition to intraoperative microscope and endoscope navigation of the CPA in MVD surgery, image-based neuronavigation using pre-operatively obtained images is a valuable tool for identification of compressing vessels and other neurovascular structures in the CPA. Refaee and colleagues [6] analyzed the utility of three dimensional steady-state free precession imaging (SSFP) and time-of-flight magnetic resonance angiography (TOF MRA) in identifying the offending vessels in HS. The group found that compared to