Microvascular doppler associated with neuronavigation to intraoperative identification and location of internal carotid artery in transsphenoidal endoscopic pituitary macroadenomas surgery

Doppler microvascular associado a neuronavegação para identificação e localização de artéria carótida interna em cirurgia endoscópica transsefenoidal de macroadenomas pituitários

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RESUMO
Os avanços em técnicas de doppler pulsado facilitaram sua utilização na Neurocirurgia, especialmente para o acesso às artérias envolvidas por tumores, através da identificação e localização das mesmas. O objetivo desse estudo é descrever a técnica de doppler microvascular associado à neuronavegação em cirurgia endoscópica transsefenoidal para remoção de macroadenomas pituitários em três pacientes. Material e Métodos: Uma sonda de 16 MHz (2 mm) foi inserida em uma cânula de 17 cm de comprimento e anexada a um indicador de neuronavegação. O planejamento pré-operatório foi realizado com RM e angiotomografia. Resultados: O doppler microvascular intraoperatorio identificou fluxo arterial compatível com a localização anatômica da porção cavernosa da artéria carótida interna, conforme demonstrado pelo sistema de neuronavegação, possibilitando a manipulação do tumor sem risco de danos à artéria. Em todos os três casos ocorreu a remoção total de tumor sem o comprometimento da artéria carótida interna. Conclusão: O método com doppler microvascular associado à neuronavegação foi essencial ao diagnóstico vascular intraoperatório, permitindo ressecções tumorais radicais e, ao mesmo tempo, evitando danos arteriais.

Palavras-Chave: doppler transcraniano, doppler microvascular, macroadenoma pituitário

ABSTRACT
Context: Enhancements in pulsed doppler techniques have made easier to apply those techniques not only to diagnose brain vascular diseases but also in brain surgery, especially to disclose arteries close to tumors and avoid their manipulation. The aim of this paper is to describe the technique of microvascular doppler associated with neuronavigation in transsphenoidal endoscopic surgery to remove pituitary macroadenomas in three patients. Material And Methods: A sterile 2mm 16-MHz probe was used inside a long curved canula of 17 cm length, attached with a neuronavigation reference. The neuronavigation mapping was done with MRI and angiotomography, which took place 24 hours before the procedure. Results: Intraoperatively, the doppler identified arterial flow compatible with the anatomical localization of the cavernous portion of internal carotid artery, as shown by the neuronavigation system, and this place was avoided during surgery, allowing manipulation of the tumor without risk of damage to the internal carotid artery. The results after surgery were total removal of the tumor in all three cases. No postoperative vascular complications were present. Conclusion: The method with microvascular doppler associated with neuronavigation was essential to the intraoperative vascular diagnosis allowing radical tumoral resections while preventing damage to the internal carotid artery.

Keywords: transcranial doppler, microvascular doppler, pituitary macroadenomas
INTRODUCTION

Transphenoidal endoscopic surgery is already a well-established procedure with low morbidity and mortality. A low index of complications peroperative was described in the literature, such as cerebrovascular effects. The lack of orientation in space and errors in trajectory inside the sella turcica were the main reasons of intraoperative damage of the internal carotid artery (ICA), which is in close relation with the sella turcica. Lesions to the cavernous portion of the ICA may cause not only uncontrollable intraoperative bleeding and death, but also occlusion of the carotid artery, vasospasm, late onset formation of carotid cavernous shunt and pseudo aneurisms. These abnormalities are generated by the direct trauma on the arterial wall, increasing the morbidity and mortality of the surgical procedure.

The use of this technology has allowed the real time identification and precise localization of the ICA, reducing the risk of intraoperative bleeding and optimizing the tumor resection. This article, presents the association of pulsed microvascular doppler and neuronavigation with imaging fusion (angiotomography and magnetic resonance) to identify the intracavernous portion of the ICA, after the opening of the dura mater of the sella turcica floor, in transphenoidal endoscopic procedure to remove pituitary macroadenomas.

SUBJECTS AND METHODS

The research had the approval of Human Research Ethics Committee from the Neurological Institute of Curitiba (INC). All the patients who were included signed an informed consent before undergoing the surgical procedure and to allow the use of their cases in this study.

The sample consisted of 3 patients, who underwent surgical transphenoidal endoscopy surgery to pituitary macroadenoma resection. Microvascular pulsed doppler (Compumedics® DWL Box Digital) was used along with neuronavigation (BrainLAB® Vector Vision). The first was used to identify the sound and wave spectrum of the blood flow (arterial or venous) in the insonated sellar region concurrently evaluating the anatomical position with the use of the neuronavigator.

Images from previously acquired brain magnetic resonance (MRI) and cerebral angiotomography (ACT) were fused. The result was an adequate visualization of the tumor and the blood vessels.

The day prior to the surgery, the patients underwent a brain ATC and MRI. ACT consisted of thin axial cuts (0.6 mm) and the MRI echo gradients of sequences in T1 (minimal TE; 350 TR; 4.00 NEX; 256x224 matrix; 24 FOV; 2.0 mm thickness; 0.3 GAP), pre- and post-paramagnetic contrast usage. The acquired images were then recorded in DICOM format.

Prior to surgery, the MRI and ACT images were fused in the neuronavigator workstation. The ICA was identified in red, as well as the M1 portion of the middle cerebral arteries and the A1 and A2 portions of the anterior cerebral arteries. The vertebral and basilar arteries were identified in green (Figures 1 and 2).

Figure 1: Neuronavigator workstation monitor depicting a tumor (yellow) and adjacent structures.
In all cases, the patients were operated in a supine position. The surgery began with an endoscopic transnasal and transsphenoidal approach, followed by the opening of the sella turcica, the dura mater, and resection of the tumor.

A 16-MHz microprobe with 2mm was used with a long curved tip canula (17 cm) to manipulate the microprobe during surgery. In the distal portion was attached a neuronavigation reference (Figure 3).

The set of the microprobe was entirely compatible with the video processor used by the neuronavigation allowing all recordings to be saved and be shown at any moment.

The doppler was adjusted to the axial flow of each vessel in 0.1 mm of increment. The insonation depth was selected in a range from 0.5 mm until 8 mm of the surface of contact. With the use of the microprobe, the vessels up to 8 mm of the probe could be detected rapidly, non-invasively, with no modification of the operative field.

The microprobe generates a high frequency oscillation through a piezoelectric crystal emitter and receptor, in which ultrasound is generated and then transmitted into the blood vessels. Partially the energy sent reaches red blood cells in movement and is reflected back; through the doppler principia, a changing in the frequency between the sound sent and received can be detected. The received signal is amplified and transformed into audible sound and spectral imaging. A detection of a vessel inside an acoustical window of insonation by the microprobe can yield an insight about the position, direction and flow velocity in the vessel. When the doppler identified the flow of the intracavernous portion of the ICA, the neuronavigator attached to the microprobe could get a clearly identification of the insonated artery in all its extension and curves inside the cavernous sinus.

Before opening the sella turcica, and dura mater, the microvascular doppler was used to identify and locate the ICA and guide the opening of the lateral portion of the sella turcica, as well as to open the dura, as safe and as wide as possible.

During the resection of the lesion, the neuronavigator associated with the microvascular doppler probe was used to locate the intracavernous ICA, its curvatures and sinuosities (Figures 4, 5 and 6). In the same way, it was possible to identify areas of high venous flow and avoid them in the opening of the lateral portion of the tumor or its capsule.

In all cases, after the tumor resection, patients underwent an intraoperative MRI to confirm the total resection of the lesion. After the MRI was done, the reconstruction of the sella turcica floor and the nasal mucosa were performed.
RESULTS

The ICA was easily identified bilaterally during the tumor resection, in real time, in all patients through the use of microvascular doppler and neuronavigation. In all cases, the intraoperative damage of the cavernous ICA could be prevented and the tumor dissection was done with accuracy and safety due to the real time monitoring of the vessels.

Due to neuronavigation, a precise identification could be performed depicting the structures along the sella turcica, as well as the limits of the sphenoid sinus. Residual tumor was not possible to be identified with this equipment. In all cases, the intraoperative MRI showed a complete resection of the lesion.

Acoustic artifacts were identified because of the microprobe excessive manipulation and the absence of ultrasonographic signal due to the lack of filling the insonated region with a saline solution. In one case, the insonation of the lateral wall of the sellar region was difficult because of low capacity of inclination presented by the probe.

DISCUSSION

Enhancements in endoscopic surgical techniques and developments in optics and power sources have allowed surgeons to recognize relations between anatomical structures of the sella turcica, especially in the transsphenoidal approach. The distinction between tumors and normal pituitary tissue can be done by images studies, such as MRI, and direct intraoperative observation performed by experienced surgeons. Through the imaging exams is possible to identify the impairment of the ICA, and the cavernous sinus caused by the pituitary macroadenoma. However, in the operative act, when the surgeon excessively manipulate those regions without direct visualization, these identifications are not safe. There is an increased risk of ICA and cavernous sinus damage, leading to a bleeding of difficult control. Preoperative study of the compromised region by the pituitary macroadenoma with an adequate MRI and ACT allows planning and increase the peroperative safety. The development of a method to improve the safety during the microdissection of tumors allowing to identify and to locate the vascular structures in real...
time is of extreme importance due to the close relation with the cavernous sinus and the ICAs.

The association between microvascular pulsed doppler and neuronavigation contributed to turn out the method into a more efficient and reliable one. It was possible to notice that the use of this method, besides bringing new information about localization of the cavernous ICA, may also help to identify regions of high blood flow, such as the intracavernous sinus or anatomical variations, like persistency of the trigeminal artery, contributing to increase the safety through a technically simple, and reliable way, with no need of a complex training.

The intraoperative use of microvascular doppler associated to neuronavigation has greatly helped us to avoid direct manipulation of vascular flow regions, without a significant increase in surgical time when compared with the same method with no microvascular doppler aid.

The acoustic signs of the doppler added to neuronavigation images may help to define the pattern of vessels in the sella turcica region, such as distance, directions and blood flow speed, at the same time neuronavigation helps to evaluate the limits of the tumor to be removed.

It is widely known that residual tumors are common in endoscopic transsphenoidal resections of pituitary macroadenomas, which has been proven in some series to be as high as 41%, depending on the size of the tumor and the extension to lateral and superior regions of the sella turcica. The complete tumor resection may become safer with an accurate location of the cavernous ICA.

There are descriptions with good results of the use of B-mode ultrasound to evaluate the total resection of lesions. Other series suggests monitoring through transcranial doppler while removing pituitary macroadenomas, and correlates the amount of the tumor resected with the blood flow increase in the anterior cerebral artery. Our experience with intraoperative transcranial doppler was unspcific and low reproducible for these cases. On the other hand, the use of B-mode ultrasonography during surgery may be meaningful in detecting residual tumor, even more if associated with doppler to identify vascular structures. Elsewhere an article described the usefulness of ultrasonography in transsphenoidal surgeries. Although neuronavigation was not used with MRI and ATC images, the author described the usage of B mode ultrasound, power-doppler and color-doppler, which has gained in the last few years great importance in the diagnosis field. There are still many limitations to the use of intraoperative ultrasonography in transsphenoidal surgeries, mainly due to the lack of development of materials, such as probes and an extended support in bayonet shape with curved tips, as the one used in this study. Our 2mm 16-MHz probe was introduced inside an extended 30 degrees canula, improving the adequate study of the sella turcica lateral and posterior walls.

The correct identification and location of the intracavernous ICA during pituitary macroadenomas resection is of extreme importance. In the two first cases of this study, the obtained data interpretation was unfamiliar and the manipulation of the probe attached to the navigator apparatus was difficult due to the weight and narrow angulations of the instrument tip. However, in the third case, the experience of the previous procedures was enough to get familiarized with the use of the doppler and neuronavigation informations. Development of instruments with different tip angulations, as well as thinner probes, manufactured specially for the task of working side by side with endoscopy and neuronavigation is necessary.

**Conclusion**

The intraoperative association of microvascular pulsed doppler and neuronavigation helps to identify the location of the ICA during resection of pituitary macroadenomas through transsphenoidal endoscopic approach. This method is safe and easy to reproduce. Complications intra and postoperative due to direct trauma to the ICA were prevented. New material development is necessary to improve the appliance of this technique.

**References**


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