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Case Report

Computed tomography-guided navigated transcranial magnetic stimulation for preoperative brain motor mapping in brain lesion resection: A case report

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ABSTRACT

Background: Navigated transcranial magnetic stimulation (nTMS) is a well establish a noninvasive method for preoperative brain motor mapping. We commonly use magnetic resonance imaging (MRI) to supply the nTMS system. In some cases, MRI is not possible or available, and the use of computed tomography (CT) is necessary. We present the first report describing the association of CT and nTMS motor mapping for brain lesion resection.

Case Description: CT imaging of a 59-year-old man suffering from acquired immune deficiency syndrome for 17 years, presenting with seizure and right hemiparesis, revealed a small single hypodense ring-enhancing lesion in the left central sulci suggesting cerebral toxoplasmosis. After 3 weeks of neurotoxoplasmosis treatment, due to four consecutive tonic-clonic seizures, a new CT scan was performed and showed no lesion changes. MRI was in maintenance at that time. Infectious diseases department suggested a brain lesion biopsy. Due to lesion's location, we decided to perform a presurgical nTMS motor mapping. After a small craniotomy, we could precisely locate and safely totally remove the lesion. The pathology report revealed a high suspicious toxoplasmosis pattern. The patient was discharged after 2 days and continued toxoplasmosis treatment. After 6 months follow-up, he showed no signs of any procedure-related deficits or radiological recurrence.

Conclusion: We report the feasibility and applicability of nTMS motor mapping using CT scan as an image source. It gives neurosurgeons another possibility to perform motor mapping for brain lesion removal, especially when MRI is not available or feasible.

Keywords: Brain biopsy, Brain lesion, Brain tumor, Computed tomography, Motor mapping, Navigated transcranial magnetic stimulation

INTRODUCTION

The imaging modality of choice in patients with brain lesions is magnetic resonance imaging (MRI).[15] Besides primary information on the size and localization of the tumor, especially MRI provides additional information about secondary phenomena such as mass effect, edema, hemorrhage, necrosis, and signs of increased intracranial pressure and with high tissue contrast.[9] MRI spectroscopy also gives important information on the metabolic state and molecular events within the tumor.[9] If MRI cannot be performed, as in patients with metallic implants, embedded devices, and claustrophobia, or are not available, head computed tomography (CT) may be acceptable.[3,15] This imaging modality has some advantages including a rapid acquisition time for emergency and claustrophobic patients and has a relatively lower cost.[21]

Since Barker *et al.*[1] started the transcranial magnetic stimulation (TMS) experiments, the method gained importance and rapidly spread all over the world for different purposes.[5,6,14,22] Further, navigated TMS (nTMS), which associates the neuronavigation system with TMS, was developed, allowing the precise presurgical motor and language mapping.[16,17,20] It is a very useful tool when dealing with brain lesions near or on eloquent areas,[8,16,17] where the goal is to obtain a biopsy or total lesion removal and preserve neurological function.

We present the first report describing the association of CT and nTMS motor mapping for brain lesion removal. This report shows the feasibility and usefulness of this method, enlarging possibilities in the neurosurgical armamentarium.

CLINICAL PRESENTATION

A 59-year-old man, previously diagnosed with acquired immune deficiency syndrome 17 years ago, had been treated at the infectious diseases department under antiretroviral therapy, using lamivudine, zidovudine, and efavirenz. He was admitted to our hospital with generalized tonic-clonic seizure and progressive right hemiparesis. Cranial CT scan (Phillips Diamond Select Brilliance 64-slice, slice thickness 1 mm, and slice interval 0.5 mm, Phillips, Eindhoven, Netherlands) revealed a single 8.8 mm × 10.5 mm × 9.2 mm ring-enhancing hypodense lesion in the left central sulci suggesting neurotoxoplasmosis. Cerebral toxoplasmosis therapy with sulfadiazine, pyrimethamine, and folinic acid was started and combined with lamotrigine for seizures. A good neurological recovery was observed, but after 3 weeks, he had four consecutive seizure episodes in a 3-h interval without impairment of motor function. A new cranial contrast CT scan showed the same lesion without improvement despite treatment. After discussion with infectious diseases staff, we decided to perform a diagnostic brain biopsy to guide treatment.

Due to the lesion's location, we decided to do a presurgical mapping of the motor area using nTMS system. This includes a TMS (Rapid2, Magstim Corporation, Whitland, Wales, United Kingdom) combined with a navigation system (Brainsight 2.4, Rogue Research, Montreal, Canada) and tracking system (Polaris, Northern Digital Instruments, Waterloo, Canada). We depict stimulation sites on reconstructed brain surface CT images. Our nTMS routine consists of a patient seated comfortably in a chair with headrest [Figure 1a]. Subjects are examined in a relaxing condition, with eyes open and superior limbs supported as previously described [Figure 1a].[11,19] The monitoring of the first dorsal interosseous muscle was used for hand representation. We judged unnecessary mapping primary motor face, tongue, or inferior limb area due to the lesion's location. We positioned the head coil for the first current in the anterior (AP) to posterior (PA) direction and the second current in the PA to AP direction.[7,10,19] We used the 45° rule to position the coil, that is, the coil is rotated 45° to the midline in the tangential plane, perpendicular to the central sulcus.[4,19] To determine the stimulation location that elicited the strongest motor evoked potential (MEP) for the respective muscle, called the hotspot, we applied single pulse stimulation at the same point over or around the hand knob.[17,18] The resting motor threshold (RMT) was defined as the lowest stimulation capable of eliciting MEPs in at least 5 of 10 trials with peak-to-peak amplitude exceeding 50 microvolts.[17,18] In this case, it was not necessary to use active motor threshold. To perform mapping, we centered a 5 × 5 cm^2 grid on the lesion and started the stimulation of 110% RMT [Figure 1b].[17] Any MEP amplitude >50 microvolts (peak-to-peak) were considered positive and visualized in the mapping cartography. The result showed a very close relationship between the AP aspect of the lesion and the primary motor cortex hand area [Figure 1c]. Positive locations were colored with white [Figure 2a and b]. We exported reconstructed images in digital imaging and communications in medicine format to an intraoperative neuronavigation system (BrainLab 3.2, Munchen, Germany). During surgery, we used a neuronavigation system to localize the lesion and perform a small craniotomy [Figure 3a and b]. Then, we could precisely locate and remove completely the lesion [Figure 3c and d]. After the procedure, a postoperative head CT was performed and compared with the preoperative images [Figure 4a and 4b]. The pathology report revealed a necrotic material with a mixed inflammatory infiltrate and small hematoxylin stain particles that arose high suspicious of toxoplasmosis. The patient was discharged on the second postoperative day, and during follow-up, he continued sulfadiazine, pyrimethamine, folinic acid, and lamotrigine, resulting in good motor recovery and no more seizures. Since then, he is being regularly monitored at the neurosurgery and infectious diseases department. At the 6 months follow-up, he showed no signs of any procedure-related deficits or radiological recurrence. Patient consent for this manuscript has been obtained. This case report was conducted in accordance with ethical standards of the Rio de Janeiro State University and the local ethics committee.

DISCUSSION

The use of CT instead of MRI was necessary in this case because at that time the MRI was unavailable under maintenance and we needed to perform brain biopsy as soon as possible. The patient had four consecutive seizure episodes despite apparently successful initial treatment. Zoubi *et al.*[23] described a similar case of a 39-year-old man admitted to their hospital with behavioral disturbance, generalized headache, and human immunodeficiency virus-positive that required urgent stereotactic brain biopsy. In our specific situation, the lesion was located in an eloquent area, namely between precentral and postcentral gyrus and the anatomical relationship between functional and pathological regions had to be considered. Conventionally, this has been accomplished using just anatomical landmarks. Since mass effect associated with brain lesions can distort the cortical anatomy obscuring anatomic landmarks and displacing functional areas, preoperative functional localization is of special interest.[13,16]

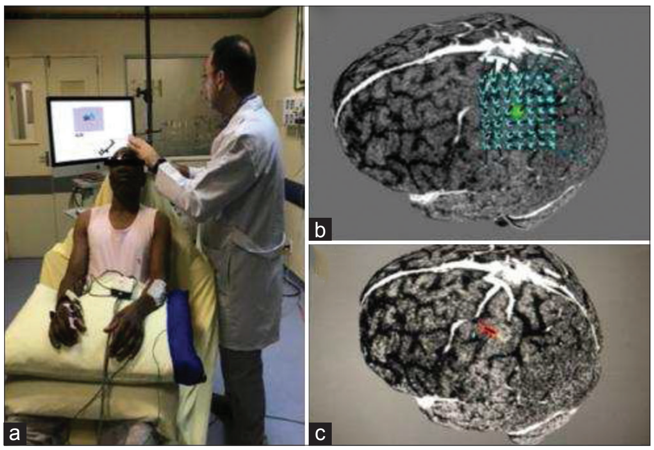

Figure 1: Navigated transcranial magnetic stimulation motor mapping session. (a) Patient in a relaxing condition, with eyes open and superior limbs supported by pillows. (b) We centered a 5 × 5 cm^2 grid on the lesion. (c) Result was a very close relation between anterior aspect of the lesion and the hand region of the primary motor cortex.

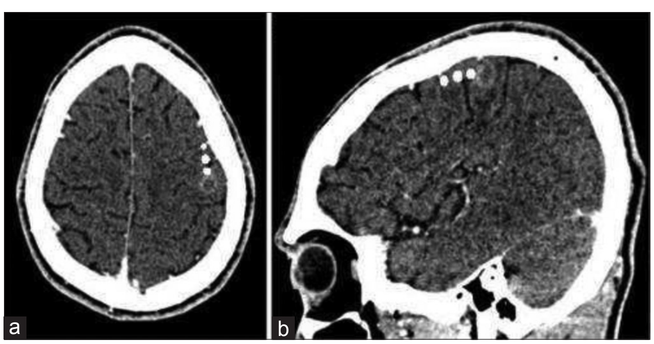

Figure 2: Navigated transcranial magnetic stimulation motor mapping final result. Any motor evoked potential amplitude >50 microvolts (peak-to-peak) were considered positive and exported to digital imaging and communications in medicine format as a white spot. (a) Axial head computed tomography showing the white spots near from lesion area. (b) Sagittal head computed tomography showing the relationship of motor sites and lesion. Again, we can observe close proximity.

To perform the procedure more safely, knowing exactly where was the functional area located, we decided to apply nTMS motor mapping. This technique highlights the motor area allowing preoperative planning and patient counseling about motor risks. Although the use of CT scan as image source is reported in the manufacturer's manual, we did not find any report describing this association in medical literature analysis and retrieval system online basis as of March 2019.

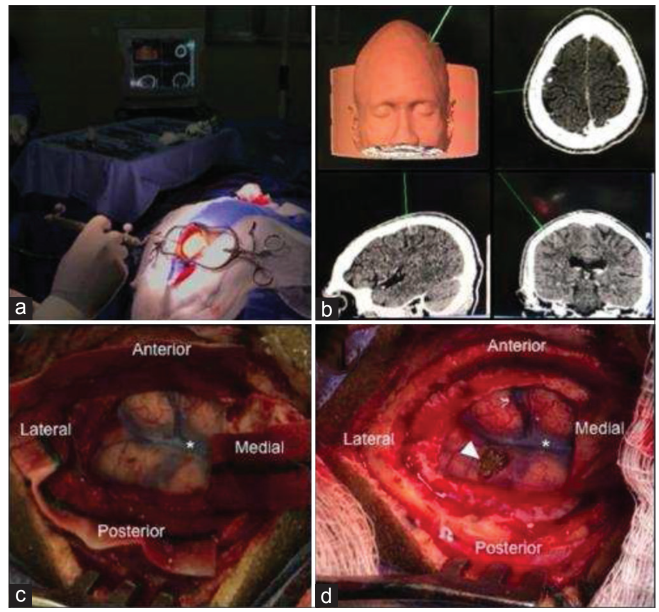

Figure 3: Surgical steps of open brain lesion removal using computed tomography-guided navigated transcranial magnetic stimulation. (a) Localizing craniotomy site guided by neuronavigation system. (b) Neuronavigation system image could precisely localize lesion. (c) After durotomy, we exposed the eloquent cortex and lesion site. Asterisk represents a cortical vein on central sulcus between motor and somatosensory cortex. (d) Final aspect after complete lesion removal as seen in arrowhead.

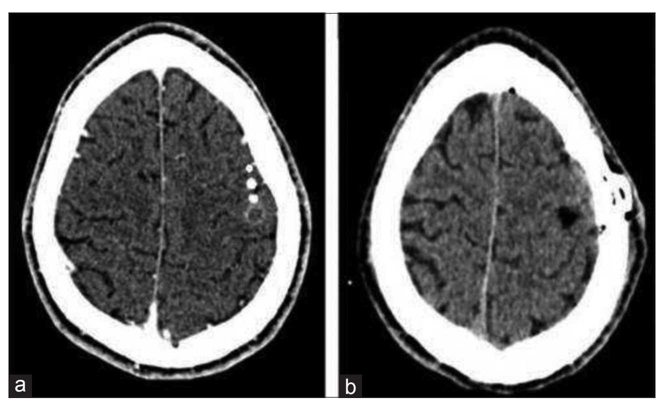

Figure 4: Comparison between preoperative and postoperative head computed tomography. (a) Axial head computed tomography showing the white spots near from lesion area. (b) Postoperative axial head computed tomography with a hypodense image exhibiting a complete lesion resection.

Intraoperative cortical stimulation mapping is the gold standard method, but nTMS has a very good correlation of motor points and can be performed before surgery, allowing presurgical planning.[2,12,20] nTMS has been shown to locate motor positive points within 2–4 mm of that of direct cortical stimulation (DCS) and also has been shown to have higher accuracy than noninvasive methods, for example, functional MRI and magnetoencephalography.[2,12,20] We registered MEPs using single-pulse TMS and used as a positive white marker any site that elicited a MEP amplitude higher than 50 microvolts. After CT brain surface reconstruction, good presurgical planning image was achieved [Figure 1b and c]. During surgery, the white marked points in neuronavigation system, helped us to completely remove the lesion without any neurological damage. Nucleic acid amplification for *Toxoplasma gondii* DNA was not performed, and the diagnosis was based on a very high clinical and pathological suspicious of toxoplasmosis. The intent of this report is not to suggest replacing MRI for CT to serve as nTMS image supplier. As a matter of fact, just in a few cases, CT combined with nTMS can used because, if the patient has any contraindication for MRI such as metallic implants or embedded devices, nTMS will be contraindicated either. The use of head CT is an alternative image method that can make nTMS cortical mapping possible, especially when MRI is not available or feasible and we were very positively surprised by the high-quality images obtained with CT after surface reconstruction in TMS navigation program. It is worth mentioning that DCS was not available as a mapping tool in this case.

CONCLUSION

We report the feasibility and applicability of nTMS motor mapping using CT scan as an image source. This paper does not have the intention to substitute MRI for CT scan in patients with brain lesions. It just gives another possibility to perform motor mapping for brain surgery, especially when MRI is not available or feasible. There is little information about CT guided nTMS in literature and therefore validation through further studies on the subject is necessary.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given her consent for her images and other clinical information to be reported in the journal. The patient understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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