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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Neuroprotective role of neurophysiological monitoring during endovascular procedures in the brain and spinal cord

Le rôle neuroprotecteur de la surveillance neurophysiologique lors des procédures endovasculaires dans le cerveau et la moelle épinière

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Summary The goal of endovascular neurosurgery is to occlude aneurysms and arteriovenous malformations (AVMs) or to reduce the vascular supply to hypervascularized tumors, while preserving function in the normal neural tissue. However, the intra-arterial injection of embolizing materials into the cerebral or spinal circulation exposes to the risk of ischemic complications. Under general anesthesia, unless a wake-up test is performed, the only way to assess the functional integrity of sensory and motor pathways is to use neurophysiological monitoring. Somatosensory (SEPs) and muscle motor evoked potentials (mMEPs) can be used in combination with pharmacological provocative tests (PTs) to predict the effects of embolization. Amytal® blocks neuronal activity, while lidocaine blocks axonal conduction. Therefore, a positive Amytal® or lidocaine test (i.e. more than 50% decrease in SEP amplitude and/or mMEP disappearance) indicates that the vessel distal to the tip of the microcatheter supplies the functional gray or white matter of the spinal-cord respectively and cannot be embolized. Brain and spinal cord vascularization and hemodynamics are extremely complex and even more unpredictable in the presence of a vascular malformation, but using a combined SEPs,

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MEPs and PTs protocol, morbidity related to endovascular procedures is very low. Given the high sensitivity of peripheral recordings to spinal-cord ischemia, experimental and clinical studies support the concept that whenever the mechanism of spinal cord injury is purely ischemic, recording mMEPs may suffice. Reports on the use of PTs and neurophysiological monitoring during embolization of brain AVMs in critical areas are more anecdotal and mainly limited to the use of short-acting barbiturates. Our preliminary experience using lidocaine and combining SEP and mMEP monitoring is encouraging, since no false negative results were observed. Finally, if the sensitivity of this method is very high, its specificity has not been tested because embolization is abandoned whenever PTs are consistently positive. Accordingly, the possibility of false positive results cannot be excluded.
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MOTS CLÉS
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Monitorage neurophysiologique ;
Potentiels évoqués somesthésiques ;
Potentiels évoqués moteurs

Résumé La chirurgie endovasculaire vise à occlure les anévrismes et malformations artérioveineuses (Mav) ou à diminuer la vascularisation des tumeurs hypervascularisées, tout en sauvegardant la fonction du tissu nerveux normal. Cependant, l'injection intra-artérielle de matériel embolisant dans la circulation cérébrale ou spinale comporte un risque de complications ischémiques. À moins de réaliser un test de réveil, le monitorage neurophysiologique constitue, lors d'une anesthésie générale, le seul moyen de vérifier l'intégrité des voies sensitives et motrices. Les potentiels évoqués somesthésiques (PES) et moteurs (PEM) peuvent être utilisés conjointement à des tests de provocation pharmacologique (TPP) pour prédire les effets d'une embolisation. L'Amytal® bloque l'activité neuronale et la Lidocaïne bloque la conduction axonale. La positivité du test à l'Amytal® ou à la Lidocaïne (définie comme une diminution de plus de 50 % de l'amplitude du PES et/ou la disparition du PEM) permet de conclure que le vaisseau situé en regard de l'extrémité distale du microcathéter d'injection alimente des régions fonctionnelles de la substance blanche ou grise de la moelle épinière et ne peut, dès lors, être embolisé. La vascularisation et les propriétés hémodynamiques du cerveau et de la moelle épinière sont extrêmement complexes et, de surcroît, encore moins prédictibles en présence d'une anomalie vasculaire. L'utilisation d'un protocole basé sur les PES, PEM et TPP a permis de réduire considérablement la morbidité liée aux procédures endovasculaires. Vu la grande sensibilité des enregistrements périphériques à l'ischémie spinale, les études expérimentales et cliniques suggèrent qu'en présence d'une ischémie spinale, l'enregistrement des PEM peut suffire. L'utilisation du monitorage neurophysiologique et des TPP durant l'embolisation des Mav n'a fait l'objet que de rapports anecdotiques, généralement limités à l'utilisation de barbituriques à courte durée d'action. Notre expérience préliminaire, basée sur la combinaison Lidocaïne, PRS et PEM, est encourageante puisque nous n'avons rencontré aucun faux négatif. Enfin, si la sensibilité de la méthode est très élevée, nous n'avons pas pu en tester la spécificité, puisque l'embolisation est interrompue chaque fois que les TPP s'avèrent positifs de façon répétable. On ne peut donc exclure la possibilité de faux positifs.
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Introduction

Vascular neurosurgery has dramatically changed in the recent past along with the development of a more sophisticated neuroimaging and the advent of interventional neuroradiology. From aneurysms to arteriovenous malformations (AVMs), from dural fistulas to hypervascularized tumors, interventional neuroradiology has established itself as a therapeutical alternative to surgical treatment [6,7,26].

The goal of endovascular treatments is to occlude AVMs or reduce the vascular supply to hypervascularized tumors, while preserving function in normal neural tissue.

Different embolizing materials are used: detachable balloons, coils, polyvinyl alcohol particles, and liquid polymerising embolic glues like *N*-butyl-cyanoacrylate and the most recent Onyx™. This latter, due to its longer polymerisation time and lack of adherence is more easily handled by the interventional neuroradiologist [39,40]. However, higher morbidity rates are reported with the use of Onyx™ due to embolization-induced hemorrhages and arterial ischemic complications [39].

Overall, the intra-arterial injection of embolizing materials into the cerebral or spinal circulation still exposes to the risk of ischemic complications due to vasospasm or unrecognised/undesirable obliteration of vessels feeding the normal brain or spinal cord. Morbidity secondary to endovascular embolization of vascular lesions in the brain cannot be underestimated and the risk increases for AVMs located in eloquent areas [1,14,25,42]. For spinal endovascular procedures, neurological deterioration after embolization has been reported following the treatment of both AVMs and spinal tumors [3,5,8].

Nowadays, endovascular procedures for complex vascular malformations can last several hours. To avoid discomfort to the patient and to control his breathing in order to obtain high-resolution images during the procedure, general anesthesia is increasingly used. Under general anesthesia, unless a wake-up test is performed, the only way to assess the

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