Improved Provocative Test for the Embolization of Arteriovenous Malformations
—Technical Note—

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Abstract
A modified provocative test to assess the safety of embolization of cerebral and spinal arteriovenous malformations is described. The modified test uses successive amobarbital and lidocaine injections to elicit any possible neurological deficit, both mixed with radiopaque material to visualize the distribution of the anesthetic in the vessels. The modified provocative test caused no false negative results in 11 patients tested, compared to six of 27 patients with the unmodified method.

Key words: arteriovenous malformation, provocative test, radiopacity, lidocaine

Introduction
The provocative test is important in the endovascular treatment of cerebral and spinal arteriovenous malformations (AVMs), but false negative results resulting in the development of neurological deficits are a critical problem. False negative results may occur because of a discrepancy in the distributions of the injected embolic material and the anesthetics used to provoke neurological symptoms. The distribution of radiopaque lidocaine has been visualized in testing extracranial arteries in conjunction with fluoroscopic control.

Here, we propose a method of provocative testing using radiopaque amobarbital and lidocaine to ensure any potential neurological deficit is identified, and to provide a digital subtraction angiography (DSA) image for accurate delivery of embolic material.

Methods
The radiopaque amobarbital contained 0.5 ml of 10% amobarbital sodium and 0.5 ml of iopamidol (Iopamiron 300; Schering, Berlin, Germany) mixed just before injection, since the mixture may precipitate after 20 minutes. The radiopaque lidocaine mixture contained 0.4 ml of 10% cardiac lidocaine and 1.6 ml of Iopamiron 300.

The anesthetic mixtures were injected superselectively using a Tracker catheter (Target Therapeutics Inc., San Jose, CA, U.S.A.) or a Magic catheter (Balt, Montmorency, France) into the feeding vessels prior to the occlusion. DSA was performed with 1 ml of the amobarbital mixture (50 mg amobarbital) and 1 ml of distilled water. Neurological examination tested for any new deficit elicited by the anesthetics. If positive, occlusion of that vessel was abandoned. If the amobarbital test was negative, the same procedure was repeated with 2 ml of lidocaine mixture (40 mg lidocaine). The provocative test was considered negative only when neither anesthetic provoked a new neurological deficit.

Embolization material was injected carefully to occlude only those vessels opacified during the provocative test. Ethylene vinylalcohol copolymer, a radiopaque liquid embolization material, was used on most occasions.
Fig. 1 A patient with a cerebral AVM. left: Lateral projection of the angiogram by superselective injection of radiopaque amobarbital mixture. The microcatheter was navigated into the left posterior cerebral artery. A part of the nidus and a small normal branch were opacified. right: Lateral angiogram by injecting radiopaque lidocaine mixture. The distribution is almost identical with that of amobarbital. The provocative test was negative.

Fig. 2 A patient with a cerebral AVM. upper: Lateral angiogram by superselective amobarbital injection into the right anterior cerebral artery. lower: Lateral angiogram by lidocaine injection, showing another normal branch not visualized in the amobarbital testing (arrow). The provocative test was negative.

Results

Twenty-six feeding vessels in 11 patients (2 spinal AVMs, 8 cerebral AVMs, and 1 dural arteriovenous fistula) were evaluated with this method.

In all patients except one, the distributions of both anesthetic mixtures were identical (Fig. 1). In one patient, a small discrepancy was seen in the distribution (Fig. 2). DSA clearly visualized the destination of the anesthetics (Fig. 3). This allowed the embolization to be performed without occluding untested branches. Provocative testing of the 26 feeders resulted in 24 negative and two positive results. The symptoms provoked were leg monoparesis in a spinal AVM patient (Fig. 3) and hearing disturbance in a cerebellar AVM patient. No neurological deficits occurred during or after the embolization procedure when the test was negative. No convulsions occurred.

Discussion

Our method for provocative testing allows embolization to be performed with more safety and certainty. Radiopaque anesthetics clearly demonstrate the affected vessels and avoid the ambiguity of blind injection, while careful selection of the vessels for occlusion is possible. The distribution of embolic material may change during injection as the distal part of the feeding artery is occluded. Radiopaque embolic material flowing into a vessel not visualized during the preceding provocative test can be rapidly identified and injection stopped immediately. Radiopaque anesthetic was particularly effective in spinal AVM to ensure that the anesthetics reached the nidus. Most spinal AVMs have small feeding vessels distant from the nidus which prevent proximal catheterization. Therefore, blind injection might result in substantial amounts of anesthetics entering the radiculomedullary artery or refluxing to the intercostal artery and aorta before reaching the nidus affecting the provocative test outcome (Fig. 3). Any distribution discrepancy between the two anesthetic mixtures, although rare in our preliminary study, requires repeat injection or consideration of the distribution difference in judging the result.

The choice of anesthetic is under discussion, although amobarbital is usually used in cerebral AVMs, and lidocaine in the extracranial arteries. We repeated the provocative test with both anesthetics to assure complete safety for the embolization. The pharmacological actions of these drugs are different, so negative results in both tests ensure the absence of neurological complications after embolization. In our institute, provocative testing...
testing had previously used amobarbital alone. False
negative results had occurred in six of 27 cerebral
AVM patients (22.2%) resulting in permanent
neurological deficits. After these frustrating ex-
periences, 24 AVMs were tested with amobarbital
and lidocaine. The first 13 patients were tested with
anesthetics without contrast material, thus testing by
blind injection. Two false negatives occurred in these
13 patients (15.4%), but both lead to temporary
neurological deficits. The latter 11 patients were
tested with radiopaque anesthetic mixtures, and no
false negatives occurred (0%). The combination of
two anesthetics and radiopaque material both con-
tribute to reducing the occurrence of false nega-
tives. The test itself caused no complications in our study,
although lidocaine injection may cause convulsion.²)

Amobarbital was delivered as sodium amobarbital
to achieve high water solubility. The solution of
sodium amobarbital is alkaline and precipitates at
lower pH.¹) As lidocaine is acid, it is essential to ir-
rigate the delivery catheter between injections of the
two anesthetics. Amobarbital also precipitates in 20–
30 minutes after mixing with Iopamiron, so the mix-
ture must be prepared immediately before injection.
A mixture of lidocaine and Iopamiron has been used in
the embolization of hepatoma without any prob-
lem.⁴) No changes in the chemical structure of either
amobarbital or lidocaine by mixing with iodine con-
trast material have been reported.¹)
The use of two anesthetics with different phar-
macological action decreased the incidence of false
negative results, while visualizing the distribution of
the injected drugs avoided the occlusion of untested
vessels. These modifications increase the reliability
of the provocative test.

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