Direct Puncture Embolization for Paragangliomas: Promising Results but Preliminary Data

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Direct Puncture Embolization for Paragangliomas: Promising Results but Preliminary Data

In this issue of the *AJNR*, Abud and colleagues report their experience with direct percutaneous injection of cyanoacrylate for preoperative devascularization of head and neck paragangliomas (1). They achieved impressive results in nine patients, with angiographic and clinically complete devascularization in five cervical tumors. No complications related to the embolization procedure were observed.

Paragangliomas, or glomus tumors, are uncommon neoplasms of the head and neck. They are remarkably vascular and surgical resection can be complicated by rapid and dramatic blood loss. Safe and relatively effective transarterial embolization techniques have been made possible by the same advances in imaging and catheter design that have allowed the routine endovascular treatment of intracranial aneurysms. However, while transarterial embolization may be effective in reducing operative blood loss, it by no means eliminates it. This is attributable to several factors, the primary one being the frequent presence of very small feeding branches from the internal carotid or vertebral arteries that cannot be directly catheterized.

In an effort to overcome this well-recognized limitation, investigators from two different groups, including authors of the present study, developed the technique of direct injection of cyanoacrylate from a percutaneous approach. These first two reports were published 10 years ago (2, 3). While this method certainly results in more complete reduction of tumor vascularity, it has not been widely adopted. There may be several reasons for this, but a key issue is the unanswered question of whether the additional risks of this technique outweigh the benefits.

Risks specific to the direct injection technique can be broken down into four components: distal embolization of glue, chemical toxicity, hemorrhage risks from direct puncture, and procedural risks of general anesthesia. None of these complications were encountered in this small series. The risk for distal glue embolization is real. Casasco et al (4) reported a large series of 65 hypervascular head and neck tumors, including 22 paragangliomas, treated with direct intratumoral injection of cyanoacrylate. They observed distal ischemic complications in two patients with juvenile angiofibromas. Glue was inadvertently injected retrograde into a distal internal carotid artery branch, ultimately occluding the distal middle cerebral artery in one patient and the ophthalmic artery in another. They emphasized the careful inspection of direct injections of contrast medium in multiple planes before the injection of glue, as well as the use of more concentrated glue suspensions (50% N-butyl −2-cyanoacrylate [NBCA]) to achieve more rapid polymerization. This second recommendation runs counter to the recommendations of the present series (20% NBCA plus an additive to extend polymerization time). The risk for distal embolization will be greatest for skull base tumors.

None of the limited data to date have described chemical toxicity of NBCA on cranial nerves or other intracranial or intralabyrnthine structures. This remains a possibility, however, particularly in skull base tumors in contact with these structures. Similarly, hemorrhagic complications in the soft tissues of the neck or within the cranial vault were not observed here, but could certainly occur. Preprocedural arrangements for possible emergent surgical care would be reasonable, until more experience is gained.

Finally, the need for general anesthesia adds an invasive procedure to the care of these patients, in addition to the inherent risks of general anesthesia. For example, a balloon occlusion test or simply diagnostic angiography may be necessary before determining whether percutaneous injection under general anesthesia is necessary or feasible. In contrast, transarterial embolization can be performed at the time of the diagnostic angiography or following the balloon occlusion test.

The final and most important issue is that of effectiveness. While transarterial embolization has become widely accepted as a preoperative adjunct to reduce blood loss with resection, there is no level-one evidence to support this practice. The best data are from a nonrandomized single center case series (5). Whether the risks of direct tumoral injection are outweighed by the benefits of the procedure remains to be established. To study this in the most rigorous manner, an accurate and precise measurement of residual tumor vascularity needs to be developed. Postcontrast volumetric CT or MR studies could provide this information. Postprocedural CT findings were obtained in the present series but their results are not presented. The relationship between the degree of devascularization, objectively measured, and operative blood loss could be investigated. Given the infrequency of these lesions, a randomized study would be difficult to perform.

In summary, this method has potential and should be considered for the management of selected patients with head and neck paragangliomas and other hypervascular tumors. There are several risks specific to this technique, and whether these risks are worth it remains to be determined.

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Is a Large Hat Size Hazardous to Your Health?

In this issue of the *AJNR,* Bradley et al postulate that normal pressure hydrocephalus (NPH) begins in infancy as benign external hydrocephalus due to impaired drainage of CSF by the arachnoid villi and granulations. As the cranial sutures allow for calvarial vault expansion in infants with this condition, their heads are larger than normal. To support their hypothesis, the authors measured intracranial volume in patients with suspected NPH and found the volumes to be larger than with age-matched control subjects. Their speculation is unlikely to ever be proved, for it would require imaging studies from a large number of normal infants to determine the incidence of benign external hydrocephalus, a confirmed relationship between benign external hydrocephalus to intracranial volume, and a follow-up period spanning more than 50 years to correlate the findings in infancy with those individuals who subsequently develop NPH. Benign external hydrocephalus may be under diagnosed, because most infants do not undergo CT or MR imaging studies. It is more common to see benign external hydrocephalus associated with big heads, because an infant whose head circumference is at or above the 98th percentile will more likely undergo imaging. In most cases, the infant has a big head on an inherited basis, because large heads are often present in the family. There also appears to be a correlation between body size and head size. The authors of this study did not have any data relating body size to head size.

The diagnosis of NPH still remains difficult. Most would agree that a patient older than 60 years with progressive dementia, ataxia, and incontinence with large ventricles who responds to CSF diversion most likely has NPH. Often the ventricular size before the development of symptoms consistent with NPH is not known. With idiopathic NPH, no known cause is evident, whereas secondary NPH results from subarachnoid hemorrhage, meningitis, trauma, and so forth. In retrospect, all NPH may be secondary; the idiopathic form is of unknown etiology. It would appear, however, that both forms of NPH are a result of increased resistance to CSF drainage.

The authors selected 51 patients that met their criteria for inclusion in the study. Only MR imaging data were used to make a diagnosis. Because no clinical data were supplied, we do not know how many fulfilled the criteria of having NPH preoperatively nor do we know whether these patients responded to CSF diversion. Although the intracranial volume was significantly larger in the patient population studied, there is no guarantee that the next 51 patients studied for NPH would necessarily have a significantly increased intracranial volume. Thus, this finding may just be a statistical fluke akin to flipping a coin and getting 10 heads in a row.

The authors postulate that benign external hydrocephalus is secondary to decreased absorption from immature arachnoid villi. The observation that several laboratory animals and infants have arachnoid villi, but no arachnoid granulations, was cited by Dandy and Blackfan (1) as an argument against these structures having an important role in CSF absorption. Subsequent investigations have shown that the arachnoid villi and granulations are anatomically and functionally the same, the only difference being that the arachnoid villi are not visible to the unaided eye. If the arachnoid villi are the major site of CSF absorption, their numbers and individual structures should have some bearing on the development of hydrocephalus, including the benign external variety. That the number and size of arachnoid granulations increase with age need not have any implications, because there does not appear to be any correlation with size and number of granulations and their ability to absorb CSF. If a significant fraction of CSF and its constituents drain via the lymphatics, what is occurring at the arachnoid villus is less relevant (2–4). Regardless of whether the CSF is being drained by the villi or the lymphatics, a generous subarachnoid space could indicate increased resistance to CSF absorption. As the name implies, however, the situation is benign, as the amount of CSF over the convexities of the brain does not progressively increase (in fact, the CSF volume on the brain surface diminishes as the infants age) nor do the ventricles appear progressively larger on follow-up studies in most of these infants. This finding also raises the question as to why in benign external hydrocephalus, the volume of fluid in the subarachnoid spaces increases but not in the ventricle, whereas in the nonbenign form of progressive hydrocephalus, it is the ventricles that enlarge.

The extracellular space in the parenchyma is approximately 15%. There is a continuous movement of fluid in the extracellular space either toward the ventricles or subarachnoid space, depending upon concentration and osmotic gradients, as there is no barrier at the ependymal or pial surfaces. Water in and of itself is freely diffusible across the blood vessels in the

parenchyma. Because the only known force responsible for bulk CSF absorption is a pressure gradient, if the pressure on the outside of the capillary is higher than inside, it would cause the capillary to collapse and prevent any absorption. Thus, there is no bulk absorption of CSF from the parenchyma. This does not, however, mitigate free water exchange. A good example of this is the use of an osmotic diuretic such as mannitol to shrink the brain. The attenuation or signal intensity changes in the periventricular region seen on CT and MR imaging studies, respectively, in acute, but not chronic hydrocephalus, is indicative of migration of fluid but does not equate with absorption.

As the authors note, there are often changes seen in the deep white matter in patients with NPH on MR imaging studies. The idea that age-related increased resistance to CSF flow through the parenchyma or changes in elastance might be a factor in the development of idiopathic NPH is an interesting concept to explore.

NPH is indeed a treatable disease with CSF diversion. The problem is trying to diagnose the disease in those patients with large ventricles who would benefit from shunt surgery. The main concern is the high complication rate associated with CSF diversion. If one could markedly reduce shunt complications, then the criteria for shunt surgery could be liberalized as a decrease in shunt complications would alter the risk-benefit ratio.

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Reply

After reading McComb's editorial on our article, "Increased Intracranial Volume: A Clue to the Etiology of Idiopathic Normal-Pressure Hydrocephalus?" that appears in this issue of the *AJNR*, I must say I agree with most of his observations. However, I do have some comments.

In our article, we do not present clinical histories, but all patients had clinically suspected normal pressure hydrocephalus (NPH). They all had a gait disturbance out of proportion to dementia and +/- incontinence. (No one in private practice orders a CSF flow study and MR imaging if the patient is asymptomatic.)

The entire point of statistical significance is that the first 51 patients will be the same as the next 51. A *P* value of 0.002–.003 is hard to argue against.

Whether they are called "arachnoid villi" or "granulations" is immaterial. The number of these structures may not track directly with their function; that is, with their absorptive capability.

Because most of these patients will *not* undergo imaging examinations past infancy, the status of their ventricles is indeterminate. In the few cases of NPH wherein we have obtained CT or MR images from 10–20 years earlier (before the onset of symptoms), the ventricles have already been enlarged—without a history of subarachnoid hemorrhage or meningitis.

I do not think NPH becomes "nonbenign" until the patient develops deep white matter ischemia (DWMI) in his/her later years. Because we know that DWMI is characterized histologically by myelin pallor, there is a relative lack of lipid and a more hydrophilic environment. It would, therefore, be reasonable to assume that there is increased attraction between the centrifugally migrating CSF and water in the extracellular space and the myelin protein. If this increased protein binding slows the peripheral migration of CSF, it may well lead to worsening hydrocephalus—but that is the subject for another article.

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3T MR Imaging: The Pros and Cons

After reading Dr. Ross's editorial "The High-Field-Strength Curmudgeon" (1) in the February 2004 issue of the *AJNR* and the two letters by Shapiro et al and Tanenbaum in response to it in the current issue, I have concluded that the editorial and two letters made valid points about clinical use of 3T MR imaging systems on the basis of each individual experience. Manufacturers have made advances in software and hardware development to improve image quality and reduce imaging times, but one has to be very careful when using the 3T system in a clinical setting to avoid compromising image quality. To illustrate my point, let us assume that, all else being equal, there is an approximately 60% improvement in signal-to-noise ratio at 3T over 1.5T. In this editorial, I will discuss how one can alter imaging parameters at 3T to a point at which the signal-to-noise ratio in the image is lower than that at 1.5T.

Both the editorial and the two letters mentioned that the chemical shift artifacts are worse at 3T, and this is a particular problem with T2-weighted fast spin-echo (FSE) imaging. The chemical shift frequency between water and fat is doubled at 3T, so to reduce these artifacts to the level of 1.5T, one has to

double the receiver bandwidth at 3T, which will reduce the signal-to-noise ratio by approximately 40%. If all other imaging parameters are unchanged, images obtained at 3T will therefore have a 20% better signal-to-noise ratio compared with that obtained at 1.5T. If one then tries to improve spatial resolution by increasing the in-plane matrix, decreasing the section thickness at 3T, or both, it will lead to further degradation in signal-to-noise ratio. There are other alternatives to reducing chemical shift artifacts at 3T without degrading image quality; one alternative is to use fat saturation, but this will further reduce the number of sections one can acquire, because of an increase in specific absorption rate (SAR). Another approach is to use water excitation, which does not significantly increase SAR and will improve image resolution and maintain signal-to-noise ratio that is similar to that at 1.5T. There are other alternatives to acquiring high-spatial-resolution images by using 3D methods, but not all manufacturers have developed 3D acquisition methods; an issue mentioned in one of the letters concerning 3D T2-weighted FSE sequences. Other modifications that the manufacturers and researchers are making to reduce radio-frequency deposition are to modify the FSE sequences by varying the refocusing flip angles (TRAPS and hyperechos). This was mentioned in one of the letters, but these methods are not available by all manufacturers.

As far as the coils are concerned, the phased-array head coil improves the image quality significantly compared with that with the quadrature coil and enables one to use parallel imaging methods that reduce imaging time. However, it also has a deleterious effect on signal-to-noise ratios. Hence, one needs to be careful about how much spatial resolution can be increased in conjunction with parallel imaging factors. At 3T, the phased-array coils have limited sensitivity; this is particularly noticeable in head coils, where one observes lower signal intensity at the center of the coil compared with periphery. Similarly, the coil sensitivity is not as good in the cervical, thoracic, and lumbar phased-array coils at 3T as compared with at 1.5T. The manufacturers are at various stages of coil development, be it quadrature or phased-array coils, and not all the coils are available through the manufacturers. Independent coil manufacturing companies do provide additional coils that do not come with the system, but this represents an additional expense to the user.

In summary, 3T systems have their advantages and disadvantages. There is inherent improvement in the signal-to-noise ratio, but that does not mean that one can provide very high-spatial-resolution images with shorter acquisition times without degrading the image quality below what one gets with 1.5T. This is a major pitfall when one initially starts using a 3T system with high expectations of markedly improved image quality. There is a learning curve one needs to navigate. This is not one sided, because manufacturers are also going through the growing pains with customers' demands for better image quality and lower total acquisition times.

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