Risk of Cerebral Angiographic Complications, Injection Volumes, and Rates

The fatal periangiographic rerupture of a posterior inferior cerebellar (PICA) aneurysm in a 20-year-old woman was published as a pictorial essay in 1998 (1). The angiographic image showed retrograde opacification of the contralateral vertebral artery, indicating vigorous injection of the diseased vessel. At the time, we sent a Letter to the Editor (2), emphasizing that the injection volume and rate should be kept low when vertebral arteries are evaluated in patients with a subarachnoid hemorrhage. The survey published by Yousem and Trinh (3), apparently designed as a reaction to this correspondence, is based on an e-mail questionnaire sent to 90 neuroradiology program directors. In addition to injection volumes and rates, Yousem and Trinh asked the potential respondents whether they thought that they could reduce their complication rates by decreasing injection rates, "within reasonable injection rates." The authors did not indicate what they meant by "reasonable" rates. Perhaps the rates used by the surveyed group were assumed to be reasonable a priori. Forty-eight of 59 respondents "did not believe that injection rates substantially contribute to catheter-based complications." The most precise information provided about periangiographic aneurysm rerupture was that it is "rare and anecdotally reported by those responding to the survey." At the same time, a study (4) quoted by Yousem and Trinh in support of this opinion, and in which the injection volumes and rates are said "to correspond well with the results of this survey," reports a rerupture rate of 1.4%, increasing to 4.8% for angiograms performed within 6 hours of the subarachnoid hemorrhage (ie, almost one rerupture in every 20 patients). This incidence does not qualify as anecdotal evidence, particularly when one considers that the prognosis of periangiographic rerupture is notably poor (even worse than that of spontaneous rerupture, with published mortality rates of greater than 90%).

High injection volumes and rates are inherited from the era before digital subtraction angiography and should be reconsidered. The assumption that lower injection rates introduce a risk of false-negative findings, although reasonable, is purely conjectural. On the other hand, the risk of missing a PICA aneurysm when the contralateral vertebral artery examined by means of reflux only is mentioned in the neurosurgical literature. More importantly, the elevation of distal intra-arterial pressure during the injection of contrast material has been clearly demonstrated. The increase in distal intracarotid pressure was shown to correlate with the injection rates and doses in dogs (2). In humans, intraaneurysmal pressure measurements obtained during angiography reveal "abruptly elevated intraaneurysmal pressure by injection of contrast medium" and that this increase "might cause rerupture of an aneurysm, " as Gailloud and Murphy (2) quoted. Contrary to the impression conveyed by Yousem and Trinh's publication, the suggestion of a possible correlation between injection volumes and rates and angiographic complications is nothing new. Even a leading authority such as Weir (5), who is inclined to believe that early periangiographic aneurysmal rerupture rates "are more a reflection of the natural history of rebleeding than a response to [catheter angiography]," states that it is "prudent to use the minimum pressures of injection and volumes of injectate in the early angiographic investigation of subarachnoid hemorrhage."

In summary, Yousem and Trinh's survey is based on the retrospective recollections and opinions of 62 neuroradiology program directors obtained through an e-mail questionnaire. The study provides no incidence of aneurysmal rerupture and no indication of the rate and volume used during these "rare" cases. The authors provide no information about the angiographic practice of the survey respondents (eg, angiographic case loads or overall complication rates) or their subspecialization (diagnostic neuroradiology versus interventional neuroradiology). On the basis of the findings from this survey, Yousem and Trinh feel that they are authorized to "provide industry norms for injections in the common carotid, internal carotid, and vertebral arteries." We believe that the publication of guidelines regarding patient-safety issues requires more than the reporting of a selected collection of subjective opinions with no statistical value or clinical relevance. At this stage, we continue to recommend the use of low injection volumes and rates during cerebral angiography, particularly in the evaluation of patients with subarachnoid hemorrhage.

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Reply:

Drs Gailloud and Murphy make valid points regarding the limitations of the article we published in

the *AJNR* (1). Philosophically, we agree with Drs Murphy and Gailloud in that the smaller the pressures and amount of contrast agent used, the better. The emphasis of this article was not about the incidence of periangiographic aneurysm rupture; the data provided on this point was purely subjective and anecdotal just as Drs Gailloud and Murphy state. The biases of the program directors, their subspecializations, and their complication rates were not considered. We are not sure how valid the subjective self-reporting of complication rates would be in this arena.

The article does, however, provide the current standard of care, as judged by fellowship program directors, with respect to injection rates used in neuroangiography. Again, we believe that one should be cautious about greatly deviating from the results cited in the article. The mean values were the following: 7.2 mL/s (SD, 1.8) for a total of 9.9 mL (SD, 2.0) in a typical common carotid artery, 5.8 mL/s (SD, 1.4) for a total of 7.9 mL (SD, 1.5) in a typical internal carotid artery, and 5.4 mL/s (SD, 1.2) for a total of 7.8 mL (SD, 1.7) in a typical vertebral artery. These values reflect the injection rates taught by neuroradiology program directors to neuroradiology fellows. These injection rates are currently in use in 63 institutions in the United States and Canada at which neuroradiologists are trained. Clearly, one must judge each vessel individually, but the values reflect routine injection rates.

The injection rate cited in the letter published in the *New England Journal of Medicine* (2) for the evaluation of the vertebral artery (ie, 3.0 mL/s) is 2 SDs below the vertebral arterial values published in our article.

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White-Matter Hyperintensities and Subcortical Infarcts as Predictors of Shunt Surgery Outcome

Tullberg et al (1) concluded that the presence of deep white-matter hyperintensities and subcortical infarcts in patients with "normal pressure hydrocephalus" were not predictors of a poor outcome after shunt surgery. They further argued that white-matter abnormalities should not be used to exclude patients from surgery. I urge readers to be very cautious in accepting these conclusions from their study.

Subcortical infarcts and gliosis often render the cerebral white matter rubbery to palpation (2–4). The resiliency and support function of the tissues can be affected. Our experience and that of others is that ventricular shunting in patients with Binswanger-type subcortical disease leads to only temporary improvement. Symptoms and signs gradually return to their preshunting levels. The altered support of the ventricles does not maintain the reduced ventricular size. Furthermore, the microvascular disease often progresses, with worsening of neurologic signs (2–4).

Unfortunately, Tullberg and colleagues evaluated their 34 patients at 3 months after shunting. This is far too soon to determine if the surgery has any long-term benefits. Readers of the *AJNR* and I would be interested to know of any long-term follow-up in these patients.

Care must be used to separate periventricular, diffuse, smooth hyperintensities from irregular intensities around the frontal and occipital horns (which are often attributable to the transependymal passage of CSF). The latter findings are predictive of the response to shunting and are not caused by microvascular disease. Irregular white-matter lesions with extension limited to the corona radiata and centrum semiovale are attributable to microvascular disease that are predictive of only a temporary, limited benefit of surgery. The alteration in the physical properties of the supporting white-matter periventricular tissues in patients with microvascular (Binswanger) disease contribute to white-matter atrophy and ventricular enlargement.

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Reply:

In his letter to the editor, Dr Caplan raises some valuable questions regarding the longer-term follow-up of the patients included in our recently published article (1). His experience is that, in patients with Binswanger-type subcortical disease, surgery leads to only temporary improvement. He urges the readers to be cautious in accepting our conclusions that vascular white-matter abnormalities must not be used to exclude patients from shunt surgery. He argues that our postoperative evaluation at 3 months after shunt surgery was performed too soon to evaluate the long-term benefit of the surgery.

We do agree that the long-term result of shunt surgery in patients with normal pressure hydrocephalus (NPH) is an important subject. We are in the process of completing the data analysis in a 5-year

follow-up study of patients with NPH who underwent shunt surgery; these data will be published later. In our experience, however, most patients that improved 3 months after shunt surgery also maintained this improved at 12 months after surgery, unless shunt dysfunction occurred (2). During the past few years, we performed a quantified, clinical, 12-month postoperative evaluation of our patients. In the present study, 25 of the 34 patients included improved 3 months after surgery. Of these, 23 were re-evaluated 12–15 months after surgery (two patients refused re-evaluation). In 22 of the 23, the improvement remained the same as it was at the 3-month postoperative evaluation. The patient whose improvement was not maintained at 12 months after surgery had multiple cerebrovascular incidents, which explained the deterioration.

The group of patients with NPH that causes most diagnostic problems is the one with concomitant cerebrovascular disease. A shunt operation probably does not halt the progress of microangiopathy or prevent new cerebrovascular incidents. However, even a short period of improvement can be beneficial to an older patient, improving his or her quality of life for months or years.

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