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BACKGROUND AND PURPOSE: **Injection rates have attracted scrutiny because of an incident of an aneurysm rupturing during arteriography. We sought to determine the current injection rates for neuroangiography in the setting of aneurysm evaluation.**

METHODS: **An e-mail survey was distributed to 90 neuroradiology program directors within the United States and Canada. The injection rates and total volumes of contrast material injected for the common carotid, internal carotid, and vertebral arteries were provided for an "average" adult individual evaluated for intracranial aneurysms.**

RESULTS: **Sixty-three (70.0%) program directors replied to the survey. Of these, five perform hand injections only and provided approximate values. The mean injection rates (SD) and total volumes (SD) for common carotid arteries were 7.2 cm^3/s (1.8) and 9.9 cm^3 (2.0), respectively; for internal carotid arteries, 5.8 cm^3/s (1.4) and 7.9 cm^3 (1.5); and for vertebral arteries, 5.4 cm^3/s (1.2) and 7.8 cm^3 (1.7). The modes (rate/total) for the common carotid, internal carotid, and vertebral arteries were 7/12, 6/8, and 5/8, respectively. Forty-eight (81.4%) of 59 respondents did not believe a reduction in current injection rates would lead to a diminution in complications of arteriography.**

CONCLUSION: **The rates of injection of contrast material in the United States for neuroradiologic studies show great variability. It does not seem that reducing arteriographic complications is an impetus to reduce injection rates. The values in this survey can provide "industry norms" for injections in the common carotid, internal carotid, and vertebral arteries if these rates are challenged.**

Recently, in the Images of Clinical Medicine section of the *New England Journal of Medicine*, rupture of a posterior inferior cerebellar artery aneurysm during angiography was described (1). Although it is unclear whether this aneurysm was a saccular berry aneurysm or related to a dissection, the article led to a letter to the editor suggesting that the rate of injection of contrast material might have contributed to the rupture (2). A proposal to decrease injection rates to reduce this possibility, including a recommendation to inject the vertebral artery (VA) at 3 mL/s, was published in this seminal journal. With safer contrast agents being produced, nonionic contrast agents being standard, softer catheters being manufactured, and a greater number of specialists performing interventional neuroradiology, the practice patterns of neuroradiologists performing conventional angiography should be assessed. The purpose of this study was to address the issue of current injection rates for angiography in the setting of subarachnoid hemorrhage and a search for intracranial aneurysms. We sought to determine whether the recommendations mentioned in the *New England Journal of Medicine* letter are widely practiced and to what extent injection rates are thought to influence rates of arteriographic complications.

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Methods

An e-mail list of the neuroradiology fellowship program directors in the United States (n = 85) and Canada (n = 5) provided by the American Society of Neuroradiology was used to submit a survey (Appendix) about catheter injection rates for neuroangiography. The fellowship directors were asked to provide the injection rates and total volumes of contrast material administered for average-sized individuals with average-sized blood vessels for common carotid arteries (CCAs), internal carotid arteries (ICAs), and VAs. When responses provided a range of values (eg, 4–6 cm^3/s for 9–10 cm^3), the mean of the range (5 cm^3/s for 9.5 cm^3 in the example cited) was used for statistical analysis. Two attempts to send the e-mail survey were made.

When five respondents stated that they only perform hand-injected catheter studies, an estimation of total volume and/or injection rate was requested of them. For the most part, however, the results reflect the injector-based rates at the various institutions.

The survey also asked whether respondents thought that specific risks of strokes, dissections, and intraarteriography aneu-

Injection rates of CCAs, ICAs, and VAs

	CCA		ICA		VA	
Factor	Rate, cm^3/s	Total Volume, cm^3	Rate, cm^3/s	Total Volume, cm^3	Rate, cm^3/s	Total Volume, cm^3
Mean	7.2	9.9	5.8	7.9	5.4	7.8
Mode	7	12	6	8	5	8
Median	7	10	6	8	5	8
SD	1.8	2.0	1.4	1.5	1.2	1.7

Note.—VA is assumed to be dominant vertebral artery.

rysm ruptures would be influenced by a reduction in injection rates.

Results

Sixty-three (70%) of 90 program directors surveyed responded to the questionnaire. Two of the five respondents who reported that they only perform hand-injected studies did not quantify the injection rate or total volume for their studies.

The Table shows the means, modes, medians, and SDs for the injection rates of the three vessels. The mean injection rates (SD) and total volumes (SD) for CCAs were 7.2 cm^3/s (1.8) and 9.9 cm^3 (2.0), respectively; for ICAs, 5.8 cm^3/s (1.4) and 7.9 cm^3 (1.5); and for VAs, 5.4 cm^3/s (1.2) and 7.8 cm^3 (1.7).

Forty-eight (81.4%) of 59 respondents who answered the question concerning complications of angiography stated that they did not believe that injection rates substantially contribute to catheter-based complications or potential ruptures of aneurysms. Several comments were made concerning this question, including the suggestion that adding flow delays, using smaller catheters, using softer wires, or reducing vasospasm could likely affect complication rates more than altering injection rates. Some respondents suggested that smaller injection rates could increase complications. They cited examples of a smaller injection that might lead to (*a*) catheterization of both VAs, (*b*) repeat injections because of inadequate opacification, (*c*) nonvisualization of abnormalities, leading to misdiagnosis, or (*d*) the requirement for cross compression of cervical carotid arteries to see the anterior communicating arteries and the attendant risk of such compression. Ten respondents thought that injecting at a lower rate with a lower volume would decrease arteriographic complication rates, whereas one was undecided.

Of the five individuals using only hand injections, four responded to the question regarding complication rates. Two of the four believed that lowering injection rates and volumes could reduce complications.

Discussion

Numerous studies have shown neurologic complication rates of catheter angiography of approximately 0.1% to 1.5% in adults (3–8) to as high as 5% in children (9). The vast majority of the neurologic events associated with cerebral angiography relate to embolic events and reactions to contrast material. A higher average age, longer average procedure time, and greater volume of radiographic contrast material are factors noted in those patients who have neurologic complications when they are being evaluated for carotid stenosis (10). The catheter and wire industries have succeeded in creating more flexible catheters and wires that are less thrombogenic and gentler on the vessels. By the same token, contrast agents have undergone scrutiny concerning their thrombogenic potential. That the currently used nonionic contrast agents have more thrombogenic potential than prior nonionic agents has been fairly well documented (3). Nonetheless, their safety profile is excellent. Partial anticoagulation during the angiographic procedure with heparin administration has served to decrease the clot-forming potential.

Whether alteration of the injection rates of catheter angiography can contribute to the rate of thromboembolic complications is unclear. However, a recent letter in the *New England Journal of Medicine* has suggested that an over vigorous injection of a VA could have contributed to the rupture of an aneurysm in the vertebral circulation (though injection parameters were never specified in the original article) (1, 2). The presence of persistent contrast in the cervical segment of the VA in the images shown in the *New England Journal of Medicine* might suggest high intracranial pressure or spasm at the catheter tip. This presumably could result in a pressure wave downstream from the injection site that could have exceeded the normal bounds during angiography. It seems plausible that an arteriographic injection could dislodge or disrupt a newly formed clot that has tamponaded the rupture site of an aneurysm. This assumes that the pressure and power of the contrast material injection has been transmitted throughout the course of the vessel to the junction of the aneurysm and the parent vessel. One might expect that if the injection parameters were physiologic, the risk of rupturing the aneurysm would be no greater than that of a spontaneous rupture occurring at a time before or after the arteriogram. Would using injection rates that are much less than physiologic reduce the risk of such a complication?

The prevailing opinion (81.4%) among respondents to this survey, which represents a broad cross section of predominantly academic training centers in the United States and Canada, is that the impact of injection rate on aneurysm rupture is negligible. The experience of having an aneurysm rupture during catheter-based angiography is rare and was only anecdotally reported by those responding to the survey. Most who responded that they had had an aneurysm rupture were engaged in therapeutic endovascular maneuvers to treat the aneurysm at the time (see also Reference 11).

Saitoh et al (12) assessed the incidence of angiography-related rerupture of intracranial aneurysms in 144 patients with acute subarachnoid hemorrhage from ruptured intracranial aneurysms. They reported two (1.4%) cases of rerupture occurring during angiography with a spontaneous rerupture rate of 9.7%. The rate of rupture when angiography was performed within 6 hours after the initial subarachnoid hemorrhage was higher (4.8%) than that after a longer interval (0%). They found no significant correlation between the rerupture rate and the injection volume of contrast medium, aneurysm location, or patient age or sex. Thus, the following argument might be advanced: the aneurysm rupture in the *New England Journal of Medicine* article was less a matter of injection rates and more an issue of the timing of the angiographic study. Saitoh et al cited injection rates and total voumes for CCAs of 7–8 cm^3/s and 12–15 cm^3, respectively; for ICAs, 7–8 cm^3/s and 9–12 cm^3; and for VAs, 5–7 cm^3/s and 5–9 cm^3. These values correspond well with the results of this survey. Ruptures occurred in one CCA injection of 8 cm^3/s for 12 cm^3 and in one ICA injection of 6 cm^3/s for 10 cm^3.

What biases are prevalent in this survey? One would assume that, by virtue of surveying neuroradiology fellowship training directors, there is a bias toward older, more experienced angiographers in academic centers. This experience might not include significant case loads of microcatheter manipulations. By the same token, the fellowship training directors might not be the most active angiographers currently in the neuroradiology division. The number of respondents who were members of the American Society of Interventional and Therapeutic Neuroradiology (ASITN) was small. Presumably, ASITN physicians would have more experience with diagnostic, as well as therapeutic, angiography.

Nonetheless, the more senior individuals would have the benefit of a larger number of cases having been diagnosed, including some at a time when injection rates might have been even greater than currently performed. One might expect, however, that the injection rates of the neuroradiologic division chiefs may be what is now taught to neuroradiology fellows.

The results of this survey may be used to estimate usual and customary practice in neuroradiology centers in the United States and Canada. One might suggest that a value beyond 2 SD from the means of these injections (ie, < 3.6 cm^3/s for 5.9 cm^3 total or > 10.8 cm^3/s for 13.9 cm^3 total for the CCA, < 3.0 cm^3/s for 4.9 cm^3 total or > 8.6 cm^3/s for a total of 10.9 cm^3 for the ICA, or < 3.0 cm^3/s for a total of 4.4 cm^3 or > 7.8 cm^3/s for a total of 11.2 cm^3 for the VA) should be limited to isolated circumstances unique to the patient, the angiographic indication, or the vessel. One must always recognize the individuality of the specific case, but guidelines are helpful for establishing practice patterns.

Conclusion

Injection rates for vessels supplying the intracranial circulation have been surveyed to provide a sense of current practice patterns. Most respondents thought that, within the ranges submitted for the CCA, ICA, and VA, reducing injection parameters would not lead to a significant reduction in arteriographic complications when evaluating patients for aneurysms.

Appendix: E-mail Survey

We have been having a small debate in our section regarding the benefits of reducing our injection rates. Can I trouble you to provide me with, for an average sized vessel, your arteriographic injection rates and volumes for:

	Rate per second	Total injected
CCA:		
ICA:		
Vertebral:		

(assuming you are squirting to look for an aneurysm).

Also, please answer this one question:

Within reasonable values for injection rates, do you believe that complications of strokes, dissections, and intraarteriogram aneurysm ruptures are influenced by injection rates? In other words do you think you could reduce your rate of complications by dropping your injection rates by, say 2 cc/second and volume by 2 cc total? (Example by dropping from 6 cc per second for a total injection of 8 cc to 4 cc per second for total 6 cc?). Would that affect complications? Would it lead to a lesser chance that an aneurysm would rupture on you during the case?

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