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Endovascular Interventional Neuroradiologic Procedures: Who Is Performing Them, How Often, and Where? A Survey of Academic and Nonacademic Radiology Practices

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BACKGROUND AND PURPOSE: **In this report, the authors assess practice patterns at both academic and nonacademic centers regarding the treatment of aneurysms with Guglielmi detachable coils (GDCs), thrombolysis of the carotid-vertebral arteries, and stent placement with angioplasty of the carotid arteries.**

METHODS: **A neurovascular radiology survey was sent to 102 directors of neuroradiology fellowship programs in the United States and Canada ("academic centers"). The survey was also sent to senior members of the American Society of Neuroradiology (three per state) who were not affiliated with fellowship programs ("nonacademic centers").**

RESULTS: **Fifty-seven surveys from academic practices and 70 surveys from nonacademic practices were returned. A total of 4361 procedures (2283 GDC; 949 thrombolysis; 1129 stent placement) were performed; 84% were performed at academic centers and 16% at nonacademic centers. Ninety percent of GDC, 71% of thrombolysis, and 82% of stent placement procedures were performed at academic centers. Seven academic and three nonacademic centers performed 48% of all GDC procedures; eight academic and four nonacademic centers performed 45% of all thrombolysis procedures; eight academic centers performed 50% of all stent placement procedures. A total of 544/4361 (12%) procedures were performed by nonradiologists. At academic centers, 14% of procedures were performed by nonradiologists; participation by nonradiologists was greatest for carotid stent placement (24% of procedures). At nonacademic centers, only 5% of procedures were performed by nonradiologists.**

CONCLUSION: **According to this survey, most endovascular interventional neuroradiologic procedures are performed at academic centers; given the survey population, this study likely identifies the lower limit of participation by nonradiologists (12%). Performance of these procedures is concentrated in relatively few centers, and these data raise questions about the overall use of intraarterial thrombolytic therapy for acute infarction.**

The past decade has seen the proliferation of a variety of procedures in interventional neuroradiology (INR) for the treatment of aneurysms, acute infarction, and carotid stenosis. The development of Guglielmi detachable coils (GDCs) has resulted in the replacement of surgical clipping of aneurysms by endovascular therapy in certain circumstances; this is especially true in the posterior fossa (1, 2). The rapid treatment of "brain attack" (acute cerebral infarction) has been popularized in both the lay press and the medical literature (3, 4). At some institutions, multidisciplinary stroke teams have been assembled to provide an extremely rapid response to patients who might benefit from intraarterial thrombolytic therapy. Research in the past decade, including the North American Symptomatic Carotid Endarterectomy Trial (5) and the more controversial Asymptomatic Carotid Atherosclerosis Study (6), has led to a more systematic and aggressive approach to the treatment of carotid stenosis. Carotid stent placement with angioplasty is being increasingly used as an alternative to carotid endarterectomy for the treatment of carotid stenosis (7). Of note, some of the newer interventional techniques have replaced rather than facilitated surgical procedures.

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The specialty of neuroradiology has also changed in the past decade. The certificate of added qualification in neuroradiology was first offered by the American Board of Radiology in 1995. Subspecialty societies—including the American Society of Interventional and Therapeutic Neuroradiology (ASITN), American Society of Head and Neck Radiology, American Society of Spine Radiology, and American Society of Pediatric Neuroradiology—have grown in importance. At the same time, interest in fellowship programs in neuroradiology is declining (8). Regarding INR, the ASITN sponsors a joint meeting with the American Association of Neurologic Surgeons/CNS section in cerebrovascular surgery, as well as has programming in conjunction with the American Society of Neuroradiology (ASNR) annual meeting. Moreover, fellowship training in INR has become more standardized; approximately one-third of fellowship training programs in neuroradiology offer a separate fellowship in INR. Pathways now exist for the training of neurosurgeons in this subspecialty, and at approximately one-fifth of programs, neurosurgeons perform some or all of the procedures in INR (8).

With all of these changes in the landscape of clinical and neuroradiologic practice, we performed a nationwide survey to assess practice patterns at both academic and nonacademic centers regarding the treatment of aneurysms with GDCs, intraarterial thrombolysis of the carotid and vertebral arteries, and carotid stent placement with angioplasty. More specifically, we attempted to answer the following questions: Who is performing these procedures? How often are they being performed? Where are they being performed?

Methods

In September 2001, a cover letter, survey (designed by one of the authors and titled "Neurovascular Radiology Survey"), and self-addressed, stamped reply envelope were mailed to the 102 program directors of each fellowship in neuroradiology throughout the United States and Canada. These practices were designated as "academic centers." In addition, the survey was mailed to an additional 146 senior members of the ASNR who were not affiliated with fellowship programs. Three surveys were mailed per state, with the exception of Alaska and Vermont, which each list only one senior member. Wherever possible, neuroradiologists practicing in larger population areas, as well as within different cities, were selected ("judgment sampling"); otherwise, the selection was random. This methodology largely precluded multiple neuroradiologists in the same practice from receiving the survey. Moreover, each neuroradiologist identified his or her practice, thereby allowing detection of duplication. We identified one practice (in a less populous state) from which two surveys were completed; one survey was discarded, and a replacement was mailed to a different neuroradiologist. These practices were designated as "nonacademic centers." Because there is currently no strict definition of an endovascular interventional neuroradiologist, we did not attempt to identify such individuals among the group of neuroradiologists surveyed. The 2001 *Membership and Resource Directory* of the ASNR was used as a reference for identification of all fellowship programs, as well as locations for senior members. In November 2001, the cover letter and survey were faxed to those program directors who had not yet responded. For those states in which three responses had not been received, the cover letter and survey were mailed to additional, similarly selected, senior members of the ASNR in those states; in total, more than 200 surveys were mailed to nonacademic practices. The study was considered closed as of January 2002, and all data were tabulated.

The survey sought responses to 26 questions pertaining to various aspects of the practice of neurovascular radiology, including equipment; performance of CT angiography, MR angiography, carotid sonography, and carotid-vertebral conventional angiography; treatment of aneurysms with GDCs (or, by implication, other types of coil embolization); carotid/vertebral thrombolysis; and carotid stent placement with angioplasty. The responses to eight questions form the basis of this study. The answers to these questions could be readily provided by each neuroradiologist, irrespective of whether he or she actually performed interventional procedures. Respondents were asked whether treatment of aneurysms with GDCs was performed at their institutions, to provide the approximate number of procedures performed per year, and to provide the percentage of procedures performed by various specialists at their institution, for example, neuroradiologists, cardiovascular-interventional radiologists, neurosurgeons, cardiologists, vascular surgeons, or other (which they were asked to specify). The same questions were asked regarding carotid-vertebral thrombolysis and carotid stent placement with angioplasty. Respondents were also asked whether stent placement with angioplasty was ever performed as a primary treatment for carotid atherosclerotic disease in patients who otherwise had no contraindication to carotid endarterectomy. If the answer was "yes," the respondent was asked whether such patients were enrolled in any protocol evaluating the long-term efficacy of this procedure. Finally, respondents were asked to estimate the percent of carotid-vertebral conventional catheter angiograms performed by various specialists at their institution. The name of the responding institution or practice, approximate number of beds, city and state, and name of the radiologist (optional) were recorded at the top of the survey. χ^2 tests were conducted to compare procedures performed at academic and nonacademic centers, as well as the number of procedures performed by nonradiologic specialists at academic and nonacademic centers.

Results

Of the 102 academic centers surveyed, 57 (56%) responded. The mean number of beds at these centers was 733 (range, 250–2,500 beds; SD 388). Of the 146 possible responses from nonacademic centers, 70 (48%) were obtained. Responses were received from nonacademic centers in 43 states. The mean number of beds at these centers was 388 (range, 34–1,000; SD 204).

Treatment of intracranial aneurysms with GDCs was performed at 51/57 (89%) academic centers. A total of 2048 cases per year were performed at 43 centers (eight centers did not indicate their case volume) (mean, 48 cases/year; median, 30 cases/year; range, 1–200 cases/year). Seventeen centers performed 20 or fewer cases per year; seven centers performed 960 cases per year (47% of the total). At 41/51 (80%) centers, neuroradiologists performed these procedures; at 9/51 (18%) neuroradiologists, as well as neurosurgeons, performed them; at 1/51 (2%) they were performed exclusively by neurosurgeons. A total of 221/2048 (11%) procedures were performed by neurosurgeons.

Thrombolysis of the carotid-vertebral arteries was performed at 50/57 (88%) academic centers. A total

of 675 cases per year were performed at 43 centers (seven centers did not indicate their case volume) (mean, 16 cases/year; median, 10 cases/year; range, 2–50 cases/year). Eight centers performed 304 cases per year (45% of the total). At 40/49 (82%) centers, radiologists (neuroradiogists, 74%; interventional radiologists, 8%) performed these procedures; at 7/49 (14%), radiologists, as well as nonradiologic specialists (neurosurgeons, cardiologists, neurologists), performed them; at 2/49 (4%), they were performed exclusively by nonradiologic specialists. A total of 70/675 (10%) procedures were performed by nonradiologic specialists.

Carotid stent placement with angioplasty was performed at 49/57 (86%) academic centers. A total of 923 cases per year were performed at 39 centers (10 centers did not indicate their case volume; mean, 24 cases/year; median, 10 cases/year; range, 1–100 cases/year). Eight centers performed 565 cases per year (61% of the total). At 33/49 (67%) centers, radiologists (neuroradiologists, 55%; interventional radiologists, 6%; both, 6%) performed these procedures; at 13/49 (27%), radiologists, as well as nonradiologic specialists (neurosurgeons, vascular surgeons, cardiologists, neurologists), performed them; at 3/49 (6%), they were performed exclusively by nonradiologic specialists. A total of 218/923 (24%) procedures were performed by nonradiologic specialists. At 14/46 (30%) academic centers, carotid stent placement with angioplasty was used as a primary treatment for carotid atherosclerotic disease. At 5/14 (36%) of these centers, patients were not enrolled in any protocol evaluating the efficacy of these therapeutic techniques.

Treatment of intracranial aneurysms with GDCs was performed at 10/70 (14%) nonacademic centers. A total of 235 cases were performed (mean, 24 cases/year; median, 20 cases/year; range, 5–50 cases/year). Three centers performed 135 cases per year (57% of the total). At 7/10 (70%) centers, neuroradiologists performed these procedures; at 3/10 (30%), they were performed by neuroradiologists as well as interventional radiologists.

Thrombolysis of the carotid/vertebral arteries was performed at 35/70 (50%) nonacademic centers. A total of 274 cases were performed (mean, eight cases/year; median, five cases/year; range, 1–50 cases/year). Four centers performed 125 cases per year (46% of the total). At 33/35 (94%) centers, radiologists (neuroradiologists, 51%; interventional radiologists, 9%; both, 34%) performed these procedures. At 2/35 (6%) centers, nonradiologic specialists (cardiologists, emergency physicians) performed them. A total of 21/274 (8%) procedures were performed by nonradiologic specialists.

Carotid stent placement with angioplasty was performed at 27/70 (39%) nonacademic centers. A total of 206 cases were performed at 22 centers (five centers did not indicate their case volume) (mean, nine cases/year; median, 10 cases/year; range, 1–25 cases/year). At 22/27 (81%) centers, radiologists (neuroradiologists, 44%; interventional radiologists, 19%; both, 19%) performed these procedures; at 5/27 (19%) radiologists, as well as nonradiologic specialists (cardiologists, vascular surgeons), performed them. A total of 14/206 (7%) procedures were performed by nonradiologic specialists. At 3/24 (13%) centers, stent placement was used as a primary treatment for carotid atherosclerotic disease; all of these patients were enrolled in a protocol evaluating the efficacy of these therapeutic techniques.

TABLE 1: Number of academic and nonacademic centers performing interventional procedures

Procedure	Academic (n = 57)	Nonacademic (n = 70)
GDC	51 (89%)	10 (14%)
Thrombolysis	50 (88%)	35 (50%)
Stenting/angioplasty	49 (86%)	27 (39%)

Seven academic and three nonacademic centers performed 1095/2283 (48%) of all GDC procedures. Eight academic and four nonacademic centers performed 429/949 (45%) of all thrombolysis procedures. Eight academic centers performed 565/1129 (50%) of all stent placement with angioplasty procedures.

A total of 4361 procedures of all types was performed: 3646/4361 (84%) were performed at academic centers and 715/4361 (16%) were performed at nonacademic centers. A total of 2048/2283 (90%) GDC procedures, 675/949 (71%) thrombolysis procedures, and 923/1129 (82%) stent placement with angioplasty procedures were performed at academic centers. By contrast, 235/2283 (10%) GDC procedures, 274/949 (29%) thrombolysis procedures, and 206/1129 (18%) stent placement with angioplasty procedures were performed at nonacademic centers. At academic centers, 3137/3646 (86%) of all procedures were performed by radiologists; 509/3646 (14%) procedures were performed by nonradiologic specialists. At nonacademic centers, 680/715 (95%) of all procedures were performed by radiologists; 35/715 (5%) procedures were performed by nonradiologic specialists. Overall, 544/4361 (12%) procedures were performed by nonradiologists.

Comparing academic and nonacademic centers, there was a statistically significant difference between the percentage of sites performing GDC procedures ($P < .001$), thrombolysis procedures ($P < .05$), and stent placement with angioplasty procedures ($P < .01$). There was also a statistically significant difference between the number of all procedures performed by nonradiologic specialists at academic and nonacademic centers ($P < .001$). Tables 1–3 summarize many of these results.

Carotid-vertebral conventional angiography was performed exclusively by neuroradiologists at 30/57 (53%) academic centers. At 15/57 (26%) centers, neuroradiologists shared these procedures with cardiovascular radiologists; at these centers, neuroradiologists performed 72% of studies and cardiovascular radiologists performed 28% of studies. At 1/57 (2%) centers, cardiovascular radiologists performed these procedures exclusively.

TABLE 2: Interventional procedure volumes: academic and nonacademic centers

Procedure	Total	Academic	Nonacademic
GDC	2283	2048 (90%)[a]	235 (10%)
Thrombolysis	949	675 (71%)[b]	274 (29%)
Stenting/angioplasty	1129	923 (82%)[c]	206 (18%)[d]
All procedures	4361	3646 (84%)	715 (16%)

[a] Forty-three of 51 centers reported case volume.
[b] Forty-three of 50 centers reported case volume.
[c] Thirty-nine of 49 centers reported case volume.
[d] Twenty-two of 27 centers reported case volume.

At 10/57 (18%) centers, radiologists shared these procedures with nonradiologic specialists (neurosurgeons, neurologists, vascular surgeons, cardiologists); at these centers, the nonradiologists performed an average of 23% of studies (range, 1%–50%). At 1/57 (2%) centers, neurosurgeons performed these procedures exclusively.

Sixty-eight nonacademic centers responded to the question regarding the performance of carotid-vertebral conventional angiography. This procedure was performed exclusively by neuroradiologists at 7/68 (10%) nonacademic centers and exclusively by cardiovascular radiologists at 5/68 (7%) centers. At 46/68 (68%) centers, neuroradiologists shared these procedures with other radiologists. At 10/68 (15%) centers, radiologists shared these procedures with nonradiologic specialists (cardiologists, vascular surgeons, neurosurgeons); at these centers, the nonradiologists performed an average of 37% of studies (range, 5%–95%).

Discussion

Questionnaires are a cost-effective method of gathering information, especially for studies involving large geographic areas. There is uniform presentation of the questions, the data are easy to analyze, and there are no verbal or visual cues to influence the respondent. In addition, individuals who are actually involved in the questionnaire's activity are more likely to respond. Response rates can range from 10% to 90%. Radiologists receiving the survey could answer the questions themselves or, if necessary, acquire the appropriate information from a colleague (or even have a colleague complete the survey). Our methodology resulted in sample sizes for academic and nonacademic practices that were similar (56 and 70, respectively). We believe that the response rate, along with the sample size, support the validity of our results. For example, Klotz et al (9) estimated that, currently, as many as 5400 aneurysms per year could be treated with GDCs (the actual number could be considerably less). Our survey captured 2283 GDC procedures (42% of the maximum possible total), and eight additional centers responded to the survey but did not indicate their GDC case volume.

We acknowledge that because ASNR members, rather than ASITN members, were surveyed, this study may underestimate the number of interventional procedures actually performed in the community; however, despite the fact that this survey evaluated, for the most part, larger nonacademic practices (mean number of beds, 389), the results show that most (84%) of these interventional neuroradiologic procedures are performed at academic centers. This is especially true of GDC procedures; in the nonacademic setting, hospital practices representing more than 27,000 beds performed, on average, less than one case per day. On the other hand, in light of the time constraints inherent in intraarterial thrombolytic therapy for acute cerebral infarction, as well as the common occurrence of carotid stenosis in the United States, it is not surprising that thrombolysis and stent placement with angioplasty have greater representation in the nonacademic setting than GDC procedures. Indeed, a significant minority (29%) of thrombolysis procedures was performed at nonacademic centers. Our results, however, also show that performance of these procedures tends to be concentrated in relatively few centers. For each interventional technique evaluated in this survey, less than 10% of all centers performed approximately half of the procedures reported. Klotz et al (9) indicated that 282 centers in the United States treat aneurysms with GDCs; treatment of 5400 aneurysms (see above) yields an average rate of 19 cases per center per year. In our study, however, just 10 centers reported performing 1095 cases. Clearly, many centers perform only a small number of GDC procedures each year.

Our data also raise questions about the extent of intraarterial thrombolytic therapy for acute cerebral infarction in the United States. Academic and nonacademic hospital practices, representing more than 60,000 beds, performed, on average, approximately three cases per day. Of equal concern, just twelve centers performed 45% (429/949) of the total. There are several possible explanations for these observations. Maintenance of a "hyperacute" stroke service, with availability 24 hours per day, is both expensive and labor intensive. Because of the extremely narrow time window (generally not greater than 3–6 hours) for institution of therapy, patient recruitment for intraarterial thrombolysis is very difficult. The PROACT II study screened 10,000 patients to identify 180 with M1 or M2 occlusion that could be randomly selected (3). It is very likely that some of the 949 cases of intraarterial thrombolysis reported in this survey represent treatment of in-hospital complications of diagnostic angiography, neurointerventions, carotid endarterectomy, or other cardiothoracic surgical procedures (rather than out-of-hospital infarctions). This would indicate that the use of intraarterial thrombolysis for the treatment of community acquired "brain attack" is even less frequent. Although intraarterial thrombolytic agents are approved by the Food and Drug Administration (FDA) for use on the order of a physician, carotid-vertebral thrombolysis represents an "off-label" use of these agents (ie, the manufacturer cannot advertise the agent specifically for this purpose); however, off-label use is completely permissible and, in certain cases, represents the standard of care. Misunderstanding of this concept is likely an

TABLE 3: Interventional procedure volumes: radiologists and nonradiologists

Procedure	Total	Radiologists	Nonradiologists
		Academic	
GDC	2,048	1,827 (89%)	221 (11%)
Thrombolysis	675	605 (90%)	70 (10%)
Stenting/angioplasty	923	705 (76%)	218 (24%)
All procedures	3646	3,137 (86%)	509 (14%)
		Nonacademic	
GDC	235	235 (100%)	0 (0%)
Thrombolysis	274	253 (92%)	21 (8%)
Stenting/angioplasty	206	192 (93%)	14 (7%)
All procedures	715	680 (95%)	35 (5%)

important reason for the lack of more extensive use of intraarterial thrombolysis. On the other hand, administration of intravenous tissue plasminogen activator is more widely available, less invasive, and approved by the FDA for a narrowly defined patient population (10). The fear that intraarterial thrombolytic therapy will cause intracranial hemorrhage remains strong, although such hemorrhage does not usually affect patient outcome (3, 4). Although use of intraarterial thrombolysis in selected patients has been supported by the American Heart Association (11) and the executive committee of the ASITN (12), it seems clear that this procedure has not been universally embraced as a mainstream therapy by the clinical community.

Our data show that a large number of sites performed a rather small number of these complex procedures each year. At academic centers, the median number of cases of thrombolysis and stent placement with angioplasty performed is 10 per year; at nonacademic centers, these figures are five per year and 10 per year, respectively. Although patient recruitment issues are clearly contributing to this situation, it is likely that overall patient outcome for these procedures will be partly related to the skill of the operator and volume of procedures performed. This survey demonstrated that carotid stent placement with angioplasty is an infrequently performed procedure; academic and nonacademic hospital practices representing approximately 60,000 beds performed, on average, only three cases per day. This is undoubtedly related to the fact that stent placement with angioplasty is infrequently employed as a primary treatment technique for carotid atherosclerotic disease (14 academic centers; three nonacademic centers); moreover, at 12 of these centers, patients were reportedly enrolled in a protocol evaluating the efficacy of stent placement.

Since this survey was not directed to cardiologists, vascular surgeons, neurosurgeons, and other nonradiologists who might perform interventional procedures, it is almost a certainty that our results underestimate the number of procedures that are actually performed by these clinical specialists. According to the survey population, however, most (88%) of these interventional procedures were performed by radiologists. This was especially true in the nonacademic setting; only 5% of procedures (no GDC procedures) were performed by nonradiologists. It is interesting that in the academic setting (depending upon the type of procedure) nonradiologists performed 10–24% of cases at 18–33% of centers. Participation by nonradiologists was greatest for carotid stent placement with angioplasty procedures. Our data showed that 12% of procedures were performed by nonradiologists; we believe that this figure really represents a lower limit and that their true level of participation is even higher. Anecdotally, it is fairly well established that most carotid stent placement is performed by nonradiologists (especially cardiologists); our figure of 20% is a reflection of the survey population.

We believe that these results should be of great concern to the radiologic community, especially in view of the current shortage of radiologists. Do these figures indicate an insufficient degree of expertise by radiologists at some academic centers? Alternatively, are experienced radiologists simply losing turf to their clinical colleagues? As expected, competition for GDC procedures was exclusively from neurosurgeons. Because endovascular treatment of aneurysms can replace surgical clipping in certain circumstances (1, 2), there is likely to be continued, intense interest expressed by neurosurgeons in this technique. Competition for carotid stent placement with angioplasty, and to a lesser extent thrombolysis, was from a more diverse group of nonradiologic specialists (particularly cardiologists and vascular surgeons). If prospective, randomized studies validate the safety and long-term efficacy of carotid stent placement with angioplasty as a primary treatment for carotid athersclerotic disease, who is most likely to perform these procedures in the future? A complete discussion of strategies to retain turf (eg, obtaining admitting privileges for interventional radiologists) is beyond the scope of this article.

Our survey also showed that radiologists share conventional cerebral angiography with nonradiologic specialists at 10/57 (18%) academic centers and 10/68 (15%) nonacademic centers. At 1/57 (2%) academic centers, radiologists do not perform cerebral angiography at all. These figures are comparable to those for the interventional procedures evaluated in this survey. As such, they support our belief that, if neuro-

surgeons are trained to treat aneurysms with GDCs, they will be equally inclined to perform diagnostic cerebral angiograms because of their perception that this is precisely what the patient needs. Using similar reasoning, cardiologists, vascular surgeons and neurosurgeons trained to perform carotid stent placement, angioplasty, and thrombolysis will be inclined to perform diagnostic angiograms of the head and neck vessels. In both of these scenarios, the radiologist could be removed from the decision-making process regarding the need for conventional angiography (as opposed, for example, to CT angiography or MR angiography). Will self-referral cause an increase in the use of certain invasive diagnostic procedures?

In view of the extent of participation in endovascular interventional neuroradiologic procedures by nonradiologists at academic centers, it is imperative that the discipline of neuroradiology provides sufficient numbers of well-trained endovascular interventional *neuroradiologists* for the increasingly sophisticated clinical specialist; however, a recent survey documented that applications to neuroradiology fellowship training programs declined during the period 1996–2000; moreover, one-third of programs decreased in size during that time, and one-fifth of 2-year programs did not offer any training in endovascular interventional procedures. The survey also showed that in approximately one-fifth of centers with training programs in neuroradiology, some or all of the endovascular interventional procedures were performed by neurosurgeons; this figure correlates well with the results of this study (8). Anecdotally, fellowships in interventional neuroradiology are readily filled with qualified applicants, although many of the applicants are neurosurgeons. Some authors maintain that with membership in the ASITN growing at a rate of 10–15% annually, the availability of open positions in INR should soon rapidly decline (9). How many of these new members are neurosurgeons?

Conclusion

The results of this survey show that most interventional neuroradiologic procedures are performed at academic centers. In light of the survey population, this study likely identifies the lower limit of participation by nonradiologists (12%). Performance of these procedures is concentrated in relatively few centers; for each interventional technique, fewer than 10% of all centers performed approximately half of the procedures. These data also raise serious questions about the overall use of intraarterial thrombolytic therapy for acute cerebral infarction.

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