Obsessive-compulsive disorder and cingulotomy

TO THE EDITOR: We read with interest the article by Sheth et al.⁵ (Sheth SA, Neal J, Tangherlini F, et al: Limbic system surgery for treatment-refractory obsessive-compulsive disorder: a prospective long-term follow-up of 64 patients. Clinical article. *J Neurosurg* 118:491–497, March 2013). The authors published their results with anterior cingulotomy (cingulotomy) for obsessive-compulsive disorder (OCD) with a long-term follow-up. Their results have been very good and comparable to those of other major studies. In this context, we would like to share the work done by Prof. V. Balasubramaniam at the Madras Institute of Neurology in Chennai, India.^{1–4} Stereotactic cingulotomy has been performed at the institute since 1972 for OCD and other disorders, including drug addiction. In the pre-MRI era, angiography and ventriculography were used. The target in the cingulum was localized to the area between pericallosal and callosomarginal arteries. The Madras Institute of Neurology has the largest series of cases of drug addiction treated with stereotactic cingulotomy.

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Disclosure

The authors report no conflict of interest.

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RESPONSE: We thank the authors for their thoughtful comments regarding our paper. Functional neurosurgery

continues to provide novel therapeutic options for patients with otherwise intractable medical and psychiatric conditions. As always, the enthusiasm for these procedures must be tempered with a cautious and ethical approach to patient selection and treatment.

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Petroclival tumors

TO THE EDITOR: With great interest, we read the recent article by Gupta and Salunke¹ (Gupta SK, Salunke P: Intradural anterior petrosectomy for petroclival meningiomas: a new surgical technique and results in 5 patients. Technical note. *J Neurosurg* 117:1007–1012, December 2012), in which they presented a variation of the seminal anterior petrosectomy by Kawase et al.^{2,3} Gupta and Salunke¹ described 5 patients affected by petroclival meningiomas who underwent an intradural anterior petrosectomy tailored according to tumor extension. They claimed significantly minimized bone removal, which was addressed in their anatomical study. As they correctly pointed out, the main limitation of all supratentorial approaches occurs when tumors extend far inferiorly to the internal auditory meatus.¹ Even though technical variations for petroclival meningiomas were introduced in their work, we have been performing intradural anterior petrosectomy for chordomas and chondrosarcomas combined with an extended pterional approach.⁷

With the coming of age of skull base surgery, the initial trend toward extensive bone resection—which has contributed enormously to improvements in surgical exposure, tumor resectability, and patient outcome—has been replaced by less invasive approaches as experience has increased. In 1983 Samii et al.^{4,5} introduced the retrosigmoid intradural suprameatal approach (RISA) for large petroclival meningiomas with invasion of the middle fossa. This approach is based on suprameatal tubercle drilling and eventual division of the tentorium, bringing the carotid arteries, oculomotor nerves, posterior clinoid,

posterior cerebral arteries, and even the optic nerves into surgical view.⁵ When compared with large petrous bone exposures, the RISA makes for very straightforward access, is not time-consuming or technically demanding, and reduces the risk of hearing loss, facial palsy, and CSF leakage. Seoane and Rhoton⁶ provided a detailed description of the RISA surgical anatomy.

Apart from the controversy behind the best surgical approach to the petroclival area, we believe that the approach should be tailored to the type of tumor extension.⁵ It is worth mentioning that for most petroclival meningiomas, the surgical corridor is created by the surgeon when performing supratentorial approaches, whereas access is provided by the tumor during posterior fossa approaches. As a matter of fact, the amount of bone drilling in the report by Gupta and Salunke¹ corresponds exactly to the suprameatal bone, which is also safely resected through a RISA. Note, however, that while suprameatal bone drilling is crucial for tumor removal during supratentorial approaches, it is supplementary for posterior fossa approaches.

As experience with RISA has been gained, we have noted that small petroclival tumors are completely blocked by the suprameatal bone and the petrosal vein. In such cases, bone drilling is essential for tumor resection. Conversely, for large tumors, the role of suprameatal drilling has been overestimated. Since the tumor provides the surgical corridor, most of the surgery is performed above the cerebellum, and the middle fossa is reached after tentorium division. Thus, we hypothesize that the term “RISA” indicates a simplification of the surgical procedure. In this regard, surgical access would be better defined as a retrosigmoid intradural supracerebellar suprameatal transtentorial approach (RISSTA). The term “RISSTA” seems more appropriate by illustrating a complete overview of the extension of the surgical approach. The RISSTA particularly profits from the semisitting position because of the fall of the cerebellum and facilitated CSF and blood drainage, what we have called the “Tübingen concept.”

Gupta and Salunke¹ are to be congratulated for their minimally invasive approach and good surgical results, which demonstrate the recent trend in the literature toward easier, faster, and safer exposures. Over time, we realized that suprameatal bone drilling is part of the surgical procedure as required, but it should not be acknowledged as a sine qua non condition for complete tumor removal given that incomplete resection is frequently associated with tumor invasiveness and not with inadequate exposure.

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RESPONSE: I appreciate the comments by Tatagiba et al. and tend to agree with most of their observations. In my clinical practice, practically all of the petroclival tumors are surgically treated with either of the 2 following approaches: 1) a frontotemporo-orbitozygomatic craniotomy followed by a transsylvian transtentorial approach² or 2) a retrosigmoid approach. With the first technique, the long axis of the tentorial edge is the line of approach. The technique is used for tumors that have a large supratentorial extension and are primarily anterior and superior to the internal acoustic meatus. There may be an additional need for an intradural anterior petrosectomy in some patients—and this decision is made intraoperatively—and the extent of bone drilling is need based. We have observed that the amount of bone that must be drilled is often only a few millimeters, and its removal allows tumor behind the petrous apex to be delivered into the operative field and removed under direct visualization, as we described in our article. We use the second approach, which is excellent, in most patients with petroclival and cerebellopontine angle tumors when the lesion extends inferior and/or posterior to the internal acoustic meatus. The philosophy in selecting one of these approaches is based on the desire to avoid transgressing the course of intracranial nerves. I have also described a variation of the retrosigmoid approach, which I like to call the “extended retrosigmoid approach.”¹ In it the standard retrosigmoid craniotomy is used and augmented by either a tentorial incision or drilling of the suprameatal portion of the petrous bone. It is helpful in tumors with a supratentorial extension of the tumor along the medial side of the temporal lobe or tumor extension anterior to the petrous apex (Fig. 1). It is similar to the technique described by Tatagiba et al.

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Fig. 1. Magnetic resonance images (A–D) showing a large petroclival tumor. White arrows indicate supratentorial extension of the tumor. Postoperative CT scans (E and F) demonstrating total excision using the retrosigmoid approach. The supratentorial tumor was accessed by a tentorial incision.

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Intraoperative diagnosis

TO THE EDITOR: We read with great interest the recent article by Shioyama et al.³ on a rapid intraoperative characterization of resected gliomas by flow cytometry (Shioyama T, Muragaki Y, Maruyama T, et al: Intraoperative flow cytometry analysis of glioma tissue for rapid determination of tumor presence and its histopathological grade. Clinical article. *J Neurosurg* 118:1232–1238, June 2013). The authors evaluated within 10 minutes the malignancy index (MI), defined as the ratio of the number of cells with greater than normal DNA content to the total number of cells, of 328 biopsy specimens obtained during the resection of 81 intracranial gliomas. The results showed that MI differed significantly between neoplastic and perilesional brain tissue. An optimal cutoff value of 6.8% could identify tumor in the biopsy specimen.³

In neurosurgical procedures for tumors, the need for

rapid and accurate diagnosis is indeed great, and frozen sections do not always provide essential information. Currently, we are also investigating the value of cell-cycle analysis for rapid intraoperative characterization of brain tumors. We have modified a previously published protocol, reported by our group,^{1,2} and we are able to provide, within 6 minutes, an accurate and reproducible characterization of a brain tumor. Briefly, immediately after tumor excision, samples of the tumor are minced using a Medimachine System for 1 minute in phosphate-buffered saline buffer (Ca^{2+} and Mg^{2+} free, with 0.5 mg/ml RNase), and a cell suspension is obtained. The suspension is then filtered and cells are counted using an automated hematology analyzer to a final concentration of 1.0×10^6 cells/ml. Cells are then processed immediately for staining by adding propidium iodide (125 $\mu\text{g}/\text{ml}$) and after 3-minute flow cytometric analysis is performed. All the stained samples are analyzed using a FACSCalibur flow cytometer, equipped with 2 lasers (488 nm and 635 nm) and 6 parameters (FSC, SSC, and FL1–FL4) and using CellQuest software. Chicken red blood cells and normal cells obtained from the peripheral blood mononuclear cells are used as the standard to define the position of the diploid G_0/G_1 peak in the DNA histograms. These cells can be mixed with the sample in a second tube before staining and then used as a reference to determine the degree of DNA content aberration.

Our brain tumor material consists of surgically removed tissue from 63 patients undergoing surgery for brain tumors, mainly gliomas and meningiomas. Of those,

39 lesions were analyzed using the standard method and 24 lesions were evaluated using the fast cell-cycle analysis protocol (submitted data). After performing analyses using both methods, we found that the results were equal. The frozen-section diagnosis was done independently from the flow analysis, and the results were reported without knowledge of the flow cytometry data. The permanent section diagnosis was considered the gold standard. In our study protocol, different from that of Shioyama et al., we have evaluated the G_0/G_1 , S-phase, G_2/M phase fraction and ploidy status. In gliomas (18 high grade and 6 low grade), a cutoff value of 78% of G_0/G_1 fraction and 4.3% of S-phase fraction could accurately differentiate low-grade from high-grade gliomas (82.2% sensitivity and 100% specificity vs 94.1% sensitivity and 100% specificity, respectively) (Fig. 1). Furthermore, glioblastomas (14 of 18 high-grade tumors) with a G_0/G_1 value of $\leq 69\%$ and an S-phase fraction more than 6% had significantly lower survival. Similar findings were demonstrated in meningiomas (19 benign, 5 atypical, and 2 anaplastic). Benign meningiomas could be accurately differentiated from anaplastic tumors based on G_0/G_1 , S-phase, and G_2/M phase fraction levels (Fig. 1). Metastatic tumors (9 cases) exhibited low G_0/G_1 phase fraction, high S-phase and G_2/M phase fraction levels, and nearly all tumors were aneuploid.

In conclusion, cell-cycle analysis by flow cytometry, as also reported by Shioyama et al.,³ has several advantages over microscopic investigation of pathological material on frozen tissue sections. Apart from the identification of tumor margins, this technique has the potential to offer an accurate and rapid characterization of the malignancy of a brain mass and possibly provide a rapid assessment of a patient's overall prognosis. In this letter, our findings support those of Shioyama et al. and provide evidence that, methodologically, fast cell-cycle analysis by flow cytometry gives reproducible results among laboratories worldwide, and it can be further improved, with an even shorter time to establishing a correct diagnosis.

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RESPONSE: We thank Dr. Vartholomatos and colleagues for their interest in our work. It is good to know that their data also confirm the usefulness of intraoperative flow cytometry for brain tumor characterization. However, the protocol for tissue analysis that they presented is different from ours. It seems that our method includes fewer steps due to simultaneous cell isolation and staining. Moreover, with our technique, just 1–2 mm³ of tissue is required for investigation, whereas a larger amount may be needed if mincing with the Medimachine System is performed. In fact, the volume of the specimen required for effective flow cytometry analysis constitutes a rather important point for the intraoperative application of the technique. First, the smaller the sample is, the lower is the risk of possible diagnostic errors caused by averaging of the DNA content of cells obtained from different areas of the histopathologically heterogeneous glioma.² Second, the limited required volume of the specimen permits one to perform very precise sampling under the guidance of intraoperative neuronavigation, even from the affected or adjacent eloquent brain structures.⁴

Analysis of the flow cytometry data according to our protocol and to the method presented by Vartholomatos and colleagues also differs. Calculation of the original MI applied in our study considers composite evaluation of the number of cells in S- and G_2/M phases, aneuploid cells, and cells containing more DNA than G_2/M phase

FIG. 1. **Left:** A case of benign meningioma tissue analyzed by flow cytometry. Ploidy histogram from the patient showing G_0/G_1 of 87.4%, S-phase of 2.5%, and G_2/M of 8.9%. **Right:** A case of glioblastoma. Ploidy histogram from the patient showing G_0/G_1 of 29.2%, S-phase of 9.3%, and G_2/M of 61.7%.

cells. However, Vartholomatos and colleagues perform separate assessment of G₀/G₁, S-, and G₂/M phase fractions and ploidy status. While such multiparametric analysis may be helpful for detailed characterization of the pathological tissue,^{1,3} the interpretation of its results may be less straightforward and may complicate surgical decision making.

It seems that the optimal protocol for investigation should be determined by the desired objectives. Our experience demonstrates that intraoperative flow cytometry may provide valuable diagnostic information, and its use in addition to evaluation of frozen tissue sections may be rather helpful. Because of its speed, the technique may significantly facilitate histopathological monitoring of the resected tissue. Since, in our current practice, surgery for cerebral glioma is always directed at the maximum possible resection of the neoplasm (while preserving functionally important cerebral structures),⁴ we consider precise determination of the lesion border to be very important and represents the main reason for the application of intraoperative flow cytometry. Certainly this method may be also helpful for detailed characterization of the tumor's malignant potential³ and prediction of patient prognosis,¹ but, in our opinion, such goals do not require fast data analysis and use of the technique during the surgical procedure itself.

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Diffuse glioma detection

TO THE EDITOR: We have read with interest the article by Cage et al.² (Cage TA, Pekmezci M, Prados M, et al: Subependymal spread of recurrent glioblastoma detected with the intraoperative use of 5-aminolevulinic acid. Case report. *J Neurosurg* 118:1220–1223, June 2013). We agree with the assertions that “magnetic resonance imaging may not completely detect the presence of diffuse tumor, . . . [and the] intraoperative use of fluorescence-assisted visu-

alization with 5-ALA may be helpful in highlighting and detecting infiltrative tumor.” We have recently published data supporting that role of 5-aminolevulinic acid (5-ALA).¹ However, their statement that 5-ALA “confirmed that there was subependymal and ependymal spread” is unsupported, as they do not provide separate biopsies of those infiltrated areas. Optic radiation spreading would provide an alternative explanation for the connection of the recurrent tumor to the original site and would also explain the clinical symptoms.

In a number of papers, intense fluorescence from 5-ALA has been shown to be highly predictive of tumor histology;^{3–6} however, faint fluorescence in the ependymal wall might be an exception. We reviewed 45 patients with tumors contacting the ventricular wall and found ependymal fluorescence in 28. Selective biopsies were performed when taking the sample was considered safe, and the results were negative in 3 of 8 cases.⁷ Furthermore, clinical evolution of the group of patients with ependymal fluorescence was similar to the group without it, suggesting that there was not true ependymal spreading.

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Disclosure

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RESPONSE: No response was received from the authors of the original article.

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Magnetic resonance–guided focused ultrasound surgery

TO THE EDITOR: I found the article by Monteith et al.³ (Monteith S, Sheehan J, Medel R, et al: Potential intracranial applications of magnetic resonance–guided focused ultrasound surgery. A review. *J Neurosurg* 118:215–221, February 2013) about potential indications for magnetic resonance–guided focused ultrasound surgery (MRgFUS) intriguing. However, there is one other area where this technology may have an even greater potential: target discovery. Recent advances in functional neurosurgery have used PET and functional MRI to identify targets for neuromodulation.² It is, however, difficult to justify making the leap from functional imaging to deep brain stimulation (DBS) or a focused lesioning. Although MRgFUS with the ExAblate System (InSightec) necessitates hair removal and fixation of the head, it permits noninvasive temporary lesioning of discrete areas of the brain by heating the tissue to a lower temperature than would be used in creating a permanent lesion. Temporary lesioning of different areas of the brain in the same session may help determine the optimal target within a circuit. While DBS is not equivalent to lesioning,¹ temporary lesioning may help elucidate the pathways involved in certain disabling conditions, such as pain or tinnitus, and help predict a patient's ability to tolerate lesioning or DBS in those regions.

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Disclosure

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RESPONSE: We appreciate the comments of Dr. Schwalb, and we agree that transcranial MRgFUS has significant potential for the diagnostic exploration of deep functional neurosurgical targets in addition to its obvious near-term use in incisionless, deep brain, stereotactic lesioning. We have explored the thermal thresholds that can

be utilized during thalamotomy procedures to confirm/test the targeted region. It is our hope that future studies will harness the nonthermal effects of acoustic energy by mechanical perturbation of neurons. Already in the laboratory, research has demonstrated the ability to activate or inhibit neuronal circuits in vivo using lower or pulsed intensities that do not result in heating.^{1–6}

We share Dr. Schwalb's enthusiasm for the potential of this technology to noninvasively "map" the brain. This technique could, like Wada testing, be used diagnostically to test neuronal circuits immediately before discrete stereotactic lesioning or to identify new therapeutic circuits and diseases for functional neurosurgical treatment.

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Gamma Knife thalamotomy

TO THE EDITOR: Kondziolka and coauthors¹ make a strong case for Gamma Knife thalamotomy as a noninvasive therapeutic option for patients with severe tremor who are not candidates for or who choose not to undergo surgical procedures such as deep brain stimulation or radiofrequency ablation (Kooshkabadi A, Lunsford LD, Tonetti D, et al: Gamma Knife thalamotomy for tremor in the magnetic resonance imaging era. Clinical article. *J Neurosurg* 118:713–718, April 2013). Furthermore, they suggest that this option fulfills an unmet clinical need and is under-utilized.

In the early 1950s, Lars Leksell conceived of the Gamma Knife as a noninvasive approach to perform functional neurosurgery. What should not be forgotten is that he originally invented focused ultrasound for this purpose and later abandoned it after treating a number of patients be-

cause, at that time, there was no way to focus ultrasound through the intact skull and a craniotomy was required. Furthermore, there was no imaging technology to guide and control the treatment.

Recently, there has been a resurgence of interest in focused ultrasound as a technology for noninvasive lesioning in the brain. With contemporary computer technology, multiple beams of ultrasound energy can be accurately and precisely focused deep within the cranium. Furthermore, MRI provides real-time guidance and control.

Focused ultrasound for essential tremor was initiated by W. Jeffrey Elias and colleagues at the University of Virginia. Dr. Elias conducted a pilot study of feasibility, safety, and preliminary efficacy in 15 patients, all of whom have been followed up closely for over 1 year. The first patient was treated in February 2011. The results of this pilot study have been presented at the October 2011 meeting of the CNS in Washington, DC, and at the AANS meeting in April 2012 in Miami, Florida. More recently, Lipsman et al. reported on the results of the first 4 patients in a 6-patient study at the University of Toronto.² Both studies utilized the protocol developed at the University of Virginia; they were conducted under the auspices of the Focused Ultrasound Foundation Movement Disorder Steering Committee and were funded by the Focused Ultrasound Foundation. Based on the encouraging results of these two studies, an international, multicenter pivotal study for safety and efficacy employing a randomized, double-blind, sham-controlled design will begin enrolling patients in the latter part of 2013.

If the pivotal trial confirms the results of the two pilot studies, MR-guided focused ultrasound surgery will become a viable noninvasive option for treating essential tremor and perhaps a variety of other intracranial disorders. The advantages of this noninvasive approach are that it does not use radiation, the results are immediate and verifiable, and thermal neuromodulation can be used to confirm the location of the target.

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Disclosure

Dr. Kassell is a shareholder in InSightec.

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RESPONSE: The editorial that accompanied our recent article on Gamma Knife thalamotomy for tremor was written by Dr. Jeffrey Elias, one of Dr. Kassell's colleagues. Dr. Elias noted the recent research on the use

of focused ultrasound as a lesion generator. Dr. Kassell points to the recent report in *Lancet Neurology* that describes 4 patients, one of whom developed a sensory deficit from the thalamic lesion, and another who developed a deep venous thrombosis, thought to be related to the length of the procedure. That research will continue.

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Arteriovenous malformations and radiosurgery

TO THE EDITOR: I read with interest the recent paper on the outcomes after stereotactic radiosurgery (SRS) for patients with unruptured intracranial arteriovenous malformations (AVMs)⁴ (Ding D, Yen CP, Xu Z, et al: Radiosurgery for patients with unruptured intracranial arteriovenous malformations. Clinical article. *J Neurosurg* 118:958–966, May 2013).

This study provides useful information in the discussion of one of the most controversial topics in cerebral AVM management, which is, should patients with an unruptured AVM be observed or should they undergo treatment to eliminate the malformation and reduce the risk of future intracranial hemorrhages.¹⁹ As mentioned by the authors, a randomized trial of unruptured brain arteriovenous malformations (ARUBA) was funded by the National Institute of Neurological Disorders (U01 NS051483) and began enrolling patients in April 2007. This trial is designed to compare the risks of observation versus those of prophylactic intervention for patients diagnosed with unruptured intracranial AVM. Exclusion criteria for the ARUBA trial, in addition to prior bleeding, include age less than 18 years, prior AVM treatment, presence of multiple AVMs, and a modified Rankin Score (mRS) ≥ 2 . The primary end points of the ARUBA trial are the combined risk of death or stroke and risk of clinical impairment, defined as an mRS ≥ 2 . The ARUBA trial has been criticized for a number of reasons, including the intended follow-up period after randomization (planned, 5–10 years), which is considered insufficient for a disorder that is commonly diagnosed in patients with life expectancies of 30 years or more.^{2,11}

Ding and colleagues from the University of Virginia report the outcomes of single-fraction SRS in a large cohort of patients (n = 444) with unruptured AVM (median clinical follow-up, 74 months).⁴ The mean AVM volume was 4.2 cm³; the median margin dose was 20 Gy. Of note, 122 patients (27.4%) underwent pre-SRS embolization and 20 patients (4.5%) had prior microsurgery. Overall, the authors reported a cumulative AVM obliteration rate of 62% after one or more SRS procedures. Clinical deterioration was noted in 30 patients (6.8%). The most frequent cause of neurologic decline was post-SRS bleeding. The authors concluded that SRS provided a reasonable benefit-to-risk

ratio and recommended treatment for younger patients, patients with larger-volume AVMs, and patients with a higher radiosurgery-based AVM score (RBAS).¹³ We recently published the outcomes of 174 patients with unruptured AVM having SRS at our center from 1990 to 2005 using the same eligibility criteria and outcome measures as the ARUBA trial (median follow-up, 64 months).¹⁶ In our series, the obliteration rate after one or more procedures was 79%. Overall, the risk of hemorrhagic stroke or death was 10% at 5 years and 12% at 10 years. The risk of patients' having clinical impairment (mRS ≥ 2) was 8% at 5 years and 12% at 10 years. Larger AVM volume was associated with an increased risk of stroke resulting in death or clinical impairment after SRS. The 10-year risk of mRS ≥ 2 for patients with an RBAS ≤ 1.50 was 2% in comparison with 18% for patients with an RBAS > 1.50 . Thus, like Ding et al., we found that SRS was a safe and effective option for patients with unruptured intracranial AVM, especially if they were younger, with many years of risk for AVM hemorrhage.

I was surprised to see the authors refer to the "Pittsburgh radiosurgery-based AVM score" throughout this paper. In contrast to the Spetzler-Martin grading system, which was designed to predict outcomes after AVM resection,¹⁸ the RBAS was developed by the Mayo Clinic in collaboration with the University of Pittsburgh over a period of 15 years as a method to specifically predict outcomes after AVM SRS.^{13,14} Since its publication in 2002, 5 years after I left the University of Pittsburgh and joined the Department of Neurological Surgery at the Mayo Clinic, the original and modified versions of the RBAS have been cited more than 175 times. This grading scale has been shown to be valid after not only Gamma Knife SRS,¹ but also after LINAC-based and CyberKnife procedures.^{3,17} To the best of my knowledge, only one publication erroneously referred to Pittsburgh as the origin of this grading scale in its abstract.²⁰ In fact, the University of Pittsburgh group did not use this misnomer in its recent six-part opus on AVM radiosurgery published last year in the *Journal of Neurosurgery*,⁵⁻¹⁰ and Dr. Lunsford himself, in a commentary on an article by Pollock et al., has referred to it as "the Mayo Clinic's proposed AVM grading system."¹⁵ Proper citation of appropriate references lies at the heart of intellectual exchange, as it allows scholars to give credit to other scholars for their hard work and their ideas. Also, proper citation provides a guide for readers who are interested in learning more about a topic. The history of the development and testing of the RBAS has recently been published.¹²

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Disclosure

The author reports no conflict of interest.

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RESPONSE: We thank Dr. Pollock for his letter regarding our article. We agree that there is a favorable benefit-to-risk ratio for radiosurgery in selected cohorts of patients with unruptured AVM. In particular, those patients who are younger and whose AVMs exhibit features indicating a greater likelihood of rupture over time are likely to benefit from radiosurgery.

Regarding the name of the radiosurgery scale cited in our paper, we utilized the name noted in the recent peer-reviewed journal article published by Dr. Pollock and colleagues in which it was referred to as the Pittsburgh modified radiosurgery-based AVM grading scale.⁵ The modified radiosurgery-based AVM system (RBAS) was derived from 220 AVM patients treated with radiosurgery at the University of Pittsburgh from 1987 to 1992 and subsequently tested in a cohort of 247 patients treated at the Mayo Clinic from 1990 to 2001.¹ The system has been revised over the years, and it was the modified radiosurgery-based arteriovenous malformation grading scale outlined in the publication by Wegner et al. (2011) that we utilized in our study.^{2,3,5} The modified scale has been validated by a number of centers, and we have also done so in our current study. We have recently developed a new AVM grading system that we believe will prove simpler to use, as it does not involve an algebraic equation, but this new system appears no less reliable.⁴ The Radiosurgery AVM scale was derived from a series of 1012 AVM patients.⁴

Dr. Pollock's contributions to the development of the RBAS and stereotactic radiosurgery as a whole are substantial. We appreciate his insight into the derivation of AVM grading schemes for radiosurgery and his seminal contribution to the same.^{1–3,5}

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Boot camp

TO THE EDITOR: Selden et al.² should be congratulated for their evaluation of the neurological surgeons' boot camp courses (Selden NR, Anderson VC, McCartney S, et al: Society of Neurological Surgeons boot camp courses: knowledge retention and relevance of hands-on learning after 6 months of postgraduate year 1 training. Clinical article. **J Neurosurg** [epub ahead of print April 16, 2013. DOI: 10.3171/2013.3.JNS122114]). Course participants demonstrated improved knowledge scores, and learners clearly liked and appreciated the course. However, readers should exercise caution before universally reproducing the methods described; there are still some unanswered questions about the educational intervention.

First of all, although there was improvement in knowledge, there was no report of improvement in performance among learners at the boot camp. There was no audit of their work, no results of multisource feedback on their behavior, and no direct assessment of their procedural skills by a senior trainee. Doctors are notoriously unreliable at reporting on their own knowledge and skills; only by means of objective methods will we come closer to knowing their actual ability. Perhaps if a follow-up study is planned, some of these outcomes might be measured.

Secondly, the boot camps were a multifaceted intervention, and so it is difficult to say which facet of the boot camp led to the positive outcomes. Perhaps a study in which different groups of students received different interventions would be worthwhile.

Thirdly and lastly, like many medical education interventions, the cost of the boot camps was not evaluated. Even if we assume that the boot camps were effective, it is impossible to say whether or not they were cost-effective. According to Liam Donaldson "in the current, cost-constrained environment, those funding the education of our doctors will no longer tolerate an approach of quality at any cost."¹ Increasingly the providers of medical education will have to thoroughly cost out their interventions and prove that those interventions are not just effective but cost-effective also.

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RESPONSE: My coauthors and I thank Dr. Walsh for his thoughtful comments. Furthermore, we agree fully with his expressed priorities for further development of educational science related to the neurosurgical boot camp courses. As mentioned in our discussion, the principal current activity of the course curriculum committee is to introduce validated assessments of course hands-on skills. Dr. Walsh is also correct that we did not control for or independently vary which of the multifaceted course interventions may have contributed to the markedly positive educational outcomes. As previously described,² these courses were introduced in 2010 after all US neurosurgical residencies incorporated the postgraduate Year 1 in order to replace introductory curricular material previously provided by general surgery training programs. Like the vast majority of medicine and surgery we practice, very little medical and surgical education is validated in any way. Although additional validation is a laudable goal, which we continue to pursue, we do not feel that it should stand in the way of efficiently introducing carefully designed and purposed curricular material to fill obvious gaps in training. Furthermore, the face validity of trainees creating their first bur holes in a beef scapula rather than the cranium of a living patient, for example, is almost inescapable.

A cooperative group of educators working under the supervision of the neurosurgical program directors' organization, the Society of Neurological Surgeons, designed and implemented the boot camp courses. The courses were

piloted and refined before national adoption.¹ They continue to undergo iterative curriculum improvement based on trainee and faculty input.¹ The unique aspect of the neurosurgical boot camp effort is its introduction of a uniform preparatory curriculum for all Accreditation Council for Graduate Medical Education (ACGME)-accredited training programs in a major specialty. All available outcome parameters to date support the value of these courses and provide direction for the further important investigation of their educational effectiveness and cost-effectiveness.

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