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LETTERS

Use of Xenon and Ultrafast CT to Measure Cerebral Blood Flow

I would like to compliment Drs Gobbel, Cann, and Fike for their continued efforts to extract quantitative cerebral blood flow information from computed tomography (CT)-based technologies. Because CT continues to be a universally used first screening technology, efforts to expand the information obtained from the initial visit to the CT scanner are warranted. The ability to extract vital cerebral blood flow information from a 30-second high-speed CT study would seem desirable, but the high degree of variability reported in their article (1) suggests that this technique would become increasingly unreliable in an injury model.

Although xenon-enhanced CT also has limitations, especially its sensitivity to motion during the 5-minute study time, it provides highly useful and stable information that is closely linked to function. Repeat studies at 20-minute intervals are useful in studying normal and abnormal cerebral physiology. As noted by Gobbel et al, early scanning sequences minimize the effects of flow activation which can be induced either by xenon or by carbon dioxide decreases, which often occur during a study. The authors do not mention the article by Marks et al (2), which closely examined the effects of adding carbon dioxide to inhaled mixtures of xenon. This study concluded that the addition of carbon dioxide was contraindicated because carbon dioxide normally falls 2 to 4 mm Hg with xenon inhalation and thereby tends to compensate for the tendency of xenon to raise cerebral blood flow. Thus the addition of carbon dioxide may significantly and falsely raise cerebral blood flow values generated with the xenon-enhanced CT method.

Also, the authors may not have been aware of the studies by Good et al (3, 4), which examined errors associated with xenon-enhanced CT in relation to region-of-interest size. Although the relative error associated with a region of interest measuring 0.3 cm^3 in tissue with flow about 50 mL/100 g per minute is about 25%, the error is reduced to 10% when regions of interest measuring 1.2 cm^3 are used.

Although the ability of ultrafast CT to define asymmetry in flow between hemispheres is of interest, I am concerned that a cerebral blood flow technology that does not provide truly quantitative flow values that are accurate throughout the actual range of normal flow values will not provide the type of clinical information that permits vital decision making. The unique capacity of xenon-enhanced CT to measure flow values of zero, even in the depths of the brain, is one reason this technology may be more clinically useful than ultrafast CT in regional cerebral blood flow.

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Reply

Dr Yonas's pioneering work with xenon-enhanced CT has improved the diagnosis and management of patients with neurologic disorders. It is to be hoped that the development of new methods of noninvasive monitoring of brain physiology, such as ultrafast CT, will further enhance the care of these patients. One of the primary aims of our study was to compare and contrast the abilities of xenon-enhanced CT and ultrafast CT to detect alterations in regional cerebral blood flow that are confined to small regions such as might occur in patients with brain tumors, infarctions, or arteriovenous malformations. A simple and sensitive way of detecting such alterations is to compare the flow in the region of interest to a similar region within the contralateral hemisphere. This is similar to using the knowledge of the usual anatomic side-to-side symmetry of the brain to detect unilateral brain lesions based on conventional CT or magnetic resonance images. Use of this side-to-side comparison method can simplify the analysis, assist in the location of abnormal regions, and help to determine whether flow in that region is increased or decreased. Such a method of detecting alterations has been used by other groups studying patients with stroke and epilepsy using xenon-enhanced CT (1, 2). However, to use a side-to-side comparison method effectively, there has to be a strong side-to-side correlation. The effectiveness will also depend on how well the correlation holds at low flows and in small regions of interest. The side-to-side correlation demonstrated using the ultrafast CT method suggests that it may be particularly effective at detecting alterations in flow in small regions by side-to-side comparison.

Dr Yonas noted that the relative errors associated with xenon-enhanced CT can be reduced by using larger regions of interest. We also noted this point in our paper in a reference to Gur et al (3). However, the advantage of increased precision associated with using larger regions of interest has to be weighed against the disadvantage that abnormal flow in small regions might not be detected when using large regions of interest.

As Dr Yonas has pointed out, the ability to measure regional cerebral blood flow accurately is important and can be useful in clinical decision making. Both xenon-enhanced CT and ultrafast CT-based quantitation of regional cerebral blood flow have been shown to be accurate over a wide range of flow values in normal brain (4, 5). In addition, repeated measures of flow in a focal radiation injury model showed a close agreement of regional cerebral blood flow values measured by the radioactive microsphere method and the ultrafast CT method (4). Ultrafast CT has also been used effectively in a brain injury model to study the relationship between cerebral edema and alterations in cerebral blood flow (6).

The differences in the absolute flow values derived using the two methods may be related to the indicators used by the two methods and the types of flow detected by those indicators. Xenon-enhanced CT flow measurement uses a diffusible tracer and therefore measures the flow in small vessels through which the xenon indicator can diffuse. In contrast, ultrafast CT uses a nondiffusible tracer and thus measures total flow in the tissue in both large and small vessels. Thus, we believe that both methods are accurate and quantitative, but they measure slightly different parameters.

A concern expressed by Dr Yonas was that the addition of 0.6% to 0.8% carbon dioxide to the xenon inhalation mixture used in our studies may have increased absolute regional cerebral blood flow. Although it might be best in a clinical situation to minimize these effects by refraining from the addition of carbon dioxide, we found that, under the experimental conditions of our study, the addition of carbon dioxide maximized the reproducibility of the xenon uptake curves and thus the reproducibility of the xenon-enhanced CT-derived blood flow data.

At the present time, there has been relatively little research on the use of ultrafast CT to quantify regional cerebral blood flow, so that further studies to optimize the methodology and determine its clinical utility are indicated. However, even the few preliminary studies that have been done indicate that flow values obtained using ultrafast CT are truly quantitative. Dr Yonas raises a concern about whether the mathematical method used in our study to quantify ultrafast CT data could be used at low flow values. Modifications that we have made to that method since the publication of our study indicate that the ultrafast CT data, like xenon-enhanced CT data, also can be used to measure flow values to zero. Thus, we believe that ultrafast CT is a promising new method of regional cerebral blood flow quantitation and that it, like xenon-enhanced CT, can be useful in the diagnosis and management of patients with neurologic disorders.

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The "Hypoteloric Happy Face" Sign: A Misleading Indicator of Complete Aneurysm Closure with Guglielmi Detachable Coils

Intravascular treatment of aneurysms is becoming a major challenge to the interventional neuroradiologist.

After the early period of detachable balloons (1), the reliability and safety of Guglielmi detachable coils (GDCs) has now widened the field of treatable aneurysms with respect to shape, size, and location (2).

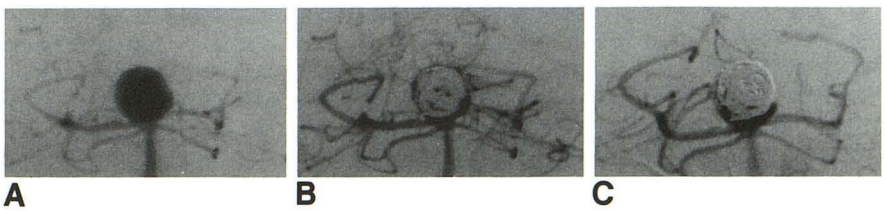

Fig. 1. *A*, Large tip of the basilar artery aneurysm in a 74-year-old woman, presenting with subarachnoid hemorrhage.

B, Five GDCs (two 8-mm × 40-cm, Tracker 18; two 8-mm × 40-cm, Tracker 10; one 8-mm × 20-cm, Tracker 10) have been positioned within the aneurysm. The "happy face" sign, with a slight hypotelorism, could indicate successful treatment.

C, One month later the happy face has disappeared; a crescentic portion of the aneurysm, close to the neck, still fills.

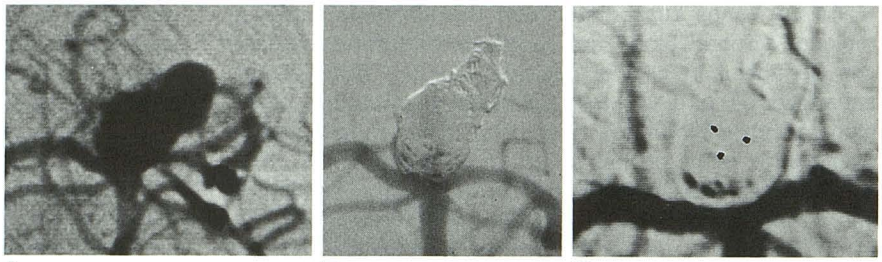

Fig. 2. *A*, Basilar bifurcation aneurysm in a 42-year-old woman. The aneurysm had ruptured 7 days before treatment and the patient was treated while in grade III.

B, The 1-week follow-up angiogram showed residual filling of the right side of the aneurysm. No emotions are shown by the GDCs.

C, One-year follow-up. The GDCs are now smiling! (Eyes and nose have been artificially added). They are happy because the long-term follow-up is satisfying. The patient is neurologically intact.

Fig. 3. Dramatic technical improvement achievable when sizeable GDCs will be available for large aneurysms. Several loops of GDCs must cross the neck area to obtain long-lasting results and the real happy face sign!

One of the problems with GDCs, however, particularly in treatment of large aneurysms, is when to consider the aneurysm sufficiently and effectively packed, at which time the procedure may be terminated. There are no absolute rules: in our practice at one extreme we consider an aneurysm effectively packed when it does not physically accept any more coils; at the other end we stop even if a few crevices are left open and slowly fill with contrast material in the control angiogram.

In one of our recent cases (Fig 1A) we came across an image, the "hypoteloric happy face" (Fig 1B), that we thought could be a reliable indicator, at least on a superstitious if not on a scientific basis, of successful and sufficient packing.

We assumed that when an aneurysm smiles, this means that it is satisfied with what you have done to it.

We correctly performed a 1-month follow-up control angiogram before proposing this new sign to the scientific community and must admit that we were wrong. A small crescentic space is still present and well filled with contrast material in the most proximal part of the aneurysm, close to the neck (Fig 1C).

Since the aneurysm is no longer smiling, we assume that it is now as concerned as we are about what to do next.

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Reply

First of all, the "face" of the aneurysm treated by Dr Scotti does not seem quite happy to me: the GDC "eyes" seem to be sorry and sad while, at the same time, the "lips" seem to smile, hinting a resignation. They are clearly saying, "We did what we could, under these circumstances, but more of us were needed, in this aneurysm! Sorry but we can't do any better." I believe that Dr Scotti could have introduced and detached more GDCs in the aneurysm, being careful not to impinge on the basilar apex. In spite of a loose packing, the follow-up angiogram showed progression of thrombosis with exclusion of the dome and most of the body of the aneurysm. As the residual portion of the aneurysm was still filling, I would recommend catheterization of the residual pouches with further treatment with smaller GDCs.

Certainly, in those cases of wide-necked aneurysms, the diameter of the circular memory of the first and the second GDC is of utmost importance to bridge the aneurysm neck, without impinging on the parent vessel. Subsequent GDCs are then used to pack tightly the center of the aneurysm in order to prevent intraaneurysmal compaction of the coils by the blood flow. To date, the maximum diameter of the circular memory of GDCs is 8 mm, clearly not sufficient for aneurysms like the one showed by Dr Scotti. In his case, the first one or two GDCs should have had a circular memory diameter of 12 or 13 mm to ensure proper crossing of the neck area, preventing the occurrence of residual pouches, lateral to the orifice of the aneurysm. GDCs 0.015 inches in diameter, with a circular memory of 10, 12, and 14 mm, are currently available, but they are not soft enough to be used in ruptured aneurysms. I believe that soon we will be able to obtain softer GDCs with a circular memory diameter greater than 8 mm.

Second, I would like to show a case of a basilar bifurcation aneurysm (Fig 2A) that was occluded with GDCs.

The patient was in grade III. The 1-week follow-up angiogram showed still some residual filling of the aneurysm (Fig 2B). The 1-year follow-up showed that the aneurysm was occluded and, most importantly, demonstrated the real happy face sign (Fig 2C). This patient is now neurologically intact.

Again, in wide-necked aneurysms, crossing the neck area with several loops of sizeable GDCs (Fig 3) is the next technical challenge in the development of this still-evolving endovascular technique. In small-necked aneurysms (neck diameter equal or less than 4 mm) it is already possible, with the currently available GDCs, to fill the body and neck of an aneurysm with complete aneurysm occlusion. Ciao, Giuseppe!

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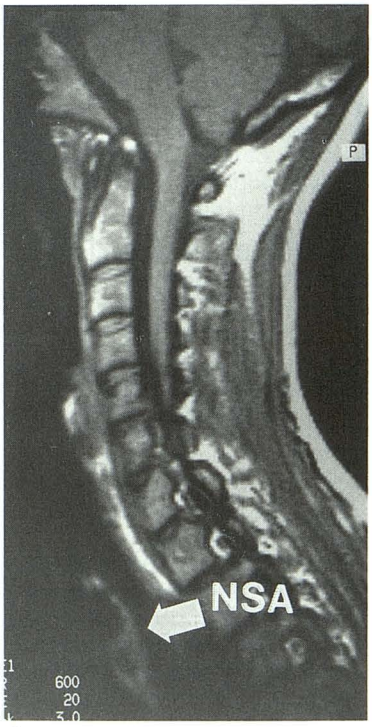
Erratum

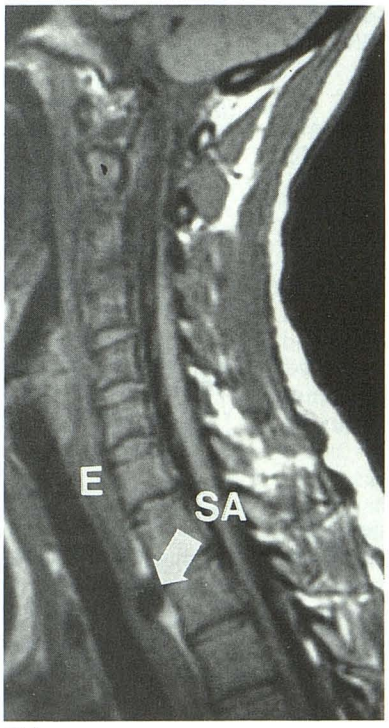
In our November/December 1993 issue, the second sentence in the first paragraph on page 1406 of the article "Recognition of the Aberrant Right Subclavian Artery on Cervical Spine MR" should have read, "MR can show the ARSA as it arises from the most cephalad portion of the aorta and crosses to the right, passing posterior to the esophagus (Fig 2)." (The article was published with the word *anterior* instead of *posterior*.)

Figures 1 and 2 (*A* and *B*) from the article appear below. The arrows mentioned in the figure legends were inadvertently omitted from the figures published. Figure 2 shows the ARSA passing posterior to the esophagus.

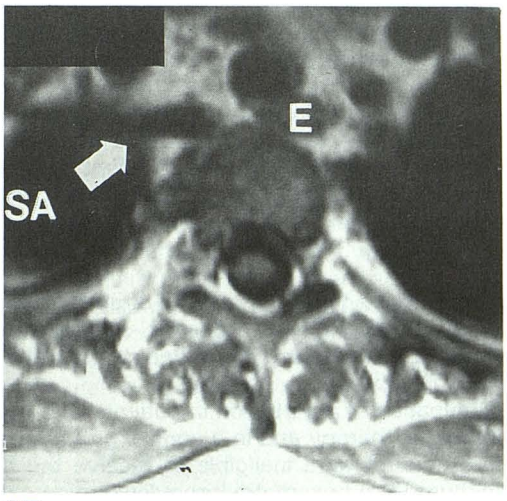
The editors regret the errors.



1



2A



2B

Fig 1. Sagittal MR image of a normal right subclavian artery (*NSA arrow*).

Fig 2. *A*, ARSA (*SA arrow*) coursing posterior to the esophagus (*E*) seen in sagittal plane.
B, ARSA (*SA arrow*) seen in the axial plane. Notice the relation of the subclavian artery to the esophagus.