The application of i.v. digital subtraction angiography to cranial disease in children.

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The Application of IV Digital Subtraction Angiography to Cranial Disease in Children

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All intracranial IV digital subtraction angiographic examinations performed over the past 2 years were reviewed retrospectively to ascertain the uses and limitations of this technique for the evaluation of pediatric intracranial disease. Of the various abnormalities studied, this imaging technique was particularly useful in diagnosing venous and dural sinus abnormalities; in screening for suspected large aneurysms, vascular malformations, and major arterial occlusive disease; and in preoperative vascular mapping. IV digital subtraction angiography has selected usefulness in confirming brain death, in evaluating cerebral ischemia, in identifying vascular abnormalities underlying intracranial hemorrhage, and in evaluating vascularity and sinus extension of masses. The IV route for digital subtraction angiography is not useful in diagnosing segmental arterial occlusive or small-vessel disease, nor is it useful in preoperative localization of specific arterial supply to arterial venous malformations, aneurysms, or neoplasms. IV digital subtraction angiography can be performed successfully in children of all ages with minimal patient morbidity. For most patients, the diagnostic information obtained was adequate without the need for standard cerebral arteriography.

The use of IV digital subtraction angiography (IVDSA) in the evaluation of adult head and neck disease is well established [1–8]. However, there are few reports of the application of this technique to intracranial disease in children; specifically, to cerebrovascular occlusive disease [9] and to the use of IVDSA in neonates [10]. Since cerebral arteriography [11–13] and femoral punctures [14–16] carry potentially significant risks to children, the use of IVDSA as an alternative angiographic technique offers several advantages [17, 18]. The purpose of our study was to review all intracranial IVDSAs to ascertain the value of this technique for assessing pediatric intracranial disease. Correlations were made with other imaging techniques, including standard cerebral arteriography (SCA), CT, and radionuclide brain scintigraphy (RBS), and comparisons were made with clinical data. No comparison was made with intraarterial DSA.

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Subjects and Methods

Thirty-one intracranial IVDSA examinations were performed over a 2-year period on 26 patients with neurologic disease. These patients (19 boys and 17 girls) ranged in age from 3 months to 19 years (mean age, 8.2 years).

Our technique has been described previously but is reviewed briefly [19]. The majority of patients were sedated, usually with IV meperidine hydrochloride (1–5 mg/kg). Three major routes of venous catheter insertion were used. Preferentially, a 3.0–5.5-French catheter was placed centrally in the superior or inferior vena cava via the antecubital or femoral vein, respectively. In some of the younger children, when central catheter placement could not be achieved, a 20–22 gauge angiocatheter was inserted into the external jugular vein. Using an Angiomat 3000 power injector (Liebel-Flarsheim, Cincinnati, OH) 1 ml/kg of contrast material (MD-76, sodium and meglumine diatrizoate, 370 mg/ml iodine; or Hexabrix, ioxaglate meglumine 39.3% and ioxaglate sodium 19.6%, 320 mg/ml iodine, Mallinckrodt, St. Louis, MO) was injected at a rate of 0.7–1.0 ml/kg/sec. The total volume was limited to a maximum of 4

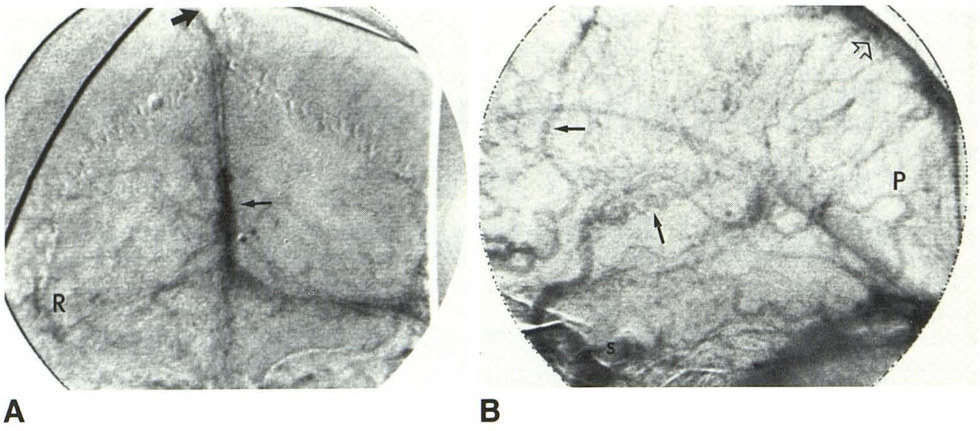

Fig. 1.—**A**, Towne view. Venous phase of IV digital subtraction angiogram showing nonfilling of superior sagittal sinus secondary to thrombosis (*large arrow*). *Small arrow* = straight sinus, R = right. **B**, Lateral view. Venous phase of IV digital subtraction angiogram (obtained several weeks later) showing collateral flow through tortuous superficial frontoparietal veins (*closed arrows*). Note revascularization of superior sagittal sinus (*open arrow*). P = posterior, S = sella turcica.

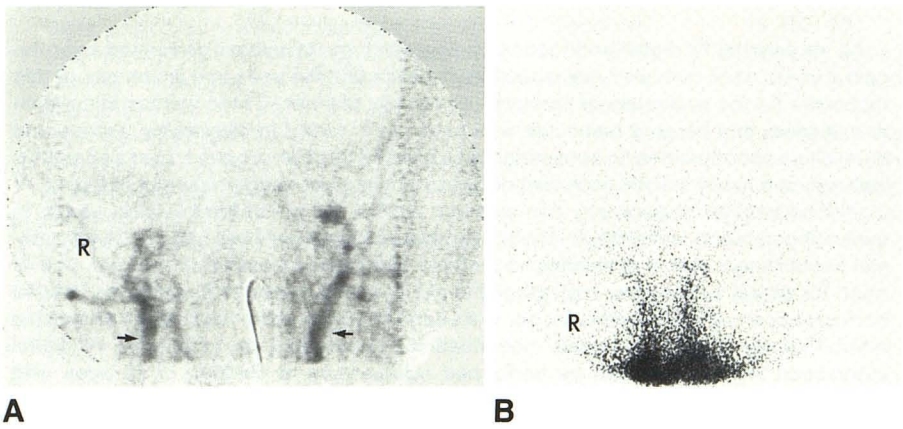

Fig. 2.—**A**, Anteroposterior view. Arterial phase of IV digital subtraction angiogram showing only extracranial flow consistent with brain death. Subsequent frames did not show any venous sinus opacification. *Arrows* = common carotid arteries, R = right. **B**, Anteroposterior view. Correlative radionuclide brain scintigraphy flow study in same patient as **A**. R = right.

ml/kg per study. Most studies were performed at a rate of 2–4.29 frames/sec. The digital angiographic system is an ADAC DPS-4100 coupled to a General Electric (Milwaukee, WI) ultralow-dose fluoroscopy unit. This system provided a substantial reduction in patient exposure [20]. An Apple II computer, which has been electronically interfaced to the MPX generator, continuously monitors, sums, and records total patient entrance exposure [21].

Of the many innovative radiographic projections reported for IVDSA [3, 22, 23], we have found standard positioning to be the most useful. All intracranial IVDSA examinations included a lateral, Towne, or posteroanterior projection; additional oblique or basal views were obtained only in selected patients.

Results

Thirty successful intracranial IVDSA examinations were performed in 25 patients. Only one study could not be completed because of technical problems. Of the 30 examinations, 22 had central injections and eight had peripheral (five external jugular) injections. Patient radiation entrance exposure ranged from 8–72 mR (2.06–18.6 μC/kg)/frame.

The clinical indications for obtaining IVDSA studies included dural sinus assessment, cerebral death, masses, vascular malformations, preoperative vascular mapping, and ischemia/infarction.

Two patients were evaluated for dural sinus abnormalities. The IVDSA ruled out dural sinus thrombosis in a 5-month-old boy following a head trauma, and confirmed superior sagittal sinus thrombosis in an 8-year-old boy who presented with elevated intracranial pressure. In the latter patient, the IVDSA also showed the altered deep venous hemodynamics and, with three follow-up IVDSAs, documented the development

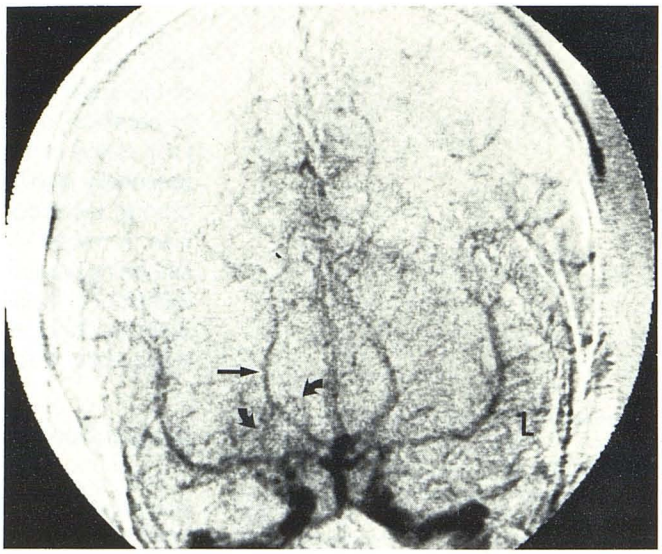

Fig. 3.—Towne view. Arterial phase of IV digital subtraction angiogram showing vascular blush in region of right cerebellopontine angle (*curved arrows*). There is associated lateral displacement of right posterior cerebral artery (*straight arrow*) secondary to malignant glioma. L = left.

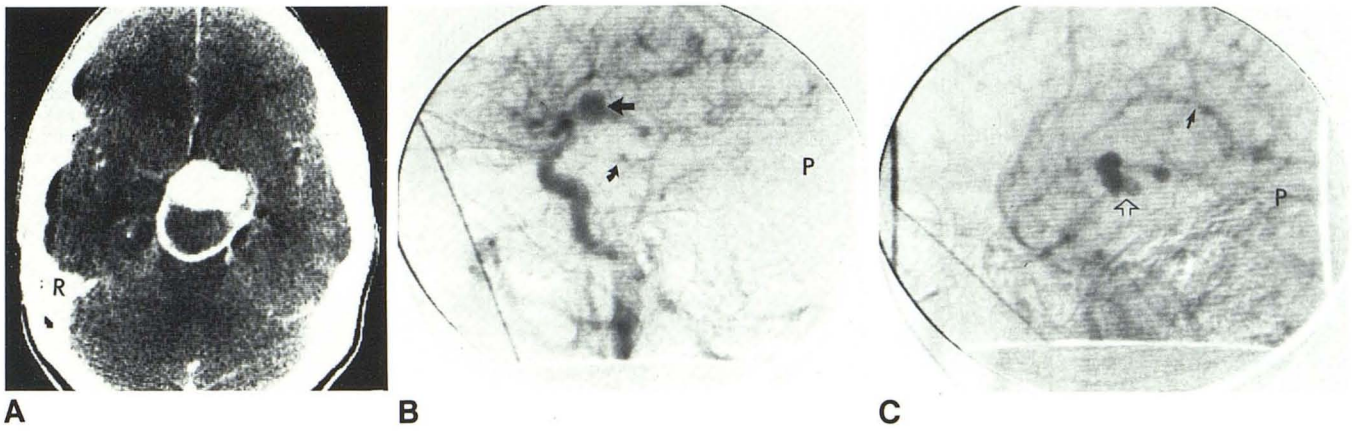

Fig. 4.—**A**, Axial CT. Large, partially enhancing suprasellar mass. R = right. **B**, Right lateral view. Arterial phase of IV digital subtraction angiogram showing aneurysm originating from proximal left posterior communicating artery (*straight arrow*). Right posterior communicating artery is inferiorly displaced due to mass effect (*curved arrow*). P = posterior. **C**, Right lateral view. Venous phase of IV digital subtraction angiogram showing further irregular filling of inferior aspect of aneurysm (*open arrow*). *Closed arrow* = internal cerebral veins, P = posterior.

of venous collateral flow and recanalization of the superior sagittal sinus (Fig. 1). IVDSA results correlated with the CT scan in the first patient and with the RBS and CT scans in the second patient.

In the three patients with suspected cerebral death, the IVDSA studies were performed through indwelling central venous catheters. The IVDSA readily confirmed the diagnosis in two patients and invalidated this diagnosis in the remaining patient, directly correlating with the RBS (two patients) and the clinical examinations (one patient) (Fig. 2).

Three patients were evaluated for suspected or known intracranial masses. In an 8-year-old boy who at age 5 had had a cerebral infarction, the IVDSA findings of an extraaxial avascular zone with ipsilateral midline shift secondary to the underlying known cerebral hemiatrophy (correlative CT) supported the diagnosis of a widened subarachnoid space secondary to atrophy. In a 4-year-old boy who had had a head trauma, the IVDSA demonstrated a significant shift and probable subdural hematoma, but underestimated the extent of intracerebral injury, which was subsequently identified on CT. In a 12-year-old girl, IVDSA showed a vascular mass in the right cerebellopontine angle (correlative CT) and suggested it was an extraaxial extension of a cerebellar or brainstem neoplasm, which the surgical biopsy confirmed (Fig. 3).

Six patients were evaluated for suspected vascular malformations. In a 7-year-old boy, although the mass effect of the known intracerebral hemorrhage was not apparent on the IVDSA owing to the limited field of view (22.9 cm), the study correlated with the SCA in that an underlying vascular malformation as a possible cause of the hemorrhage was not detected. A 19-year-old man was referred for preoperative evaluation of a suspected suprasellar tumor. The IVDSA documented a large aneurysm that was subsequently confirmed at surgery. This aneurysm was not identified on bilateral carotid arteriography pre- or postoperatively (Fig. 4). IVDSA was performed to identify an underlying cause for the cerebral hemorrhage (correlative CT) in a 9-year-old girl with known subacute bacterial endocarditis. Although the IVDSA demonstrated decreased perfusion of the right cerebral hemisphere, it provided insufficient detail to diagnose or exclude

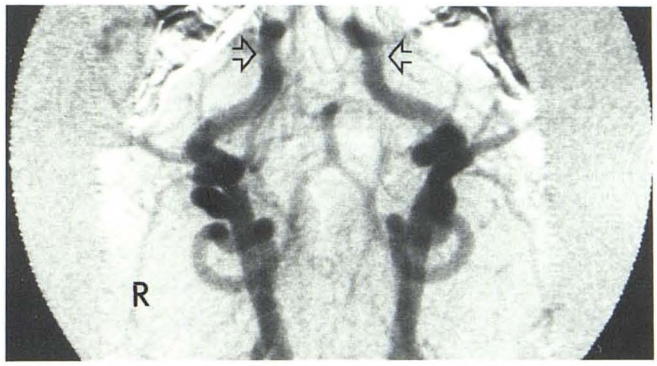

Fig. 5.—Basal view. Arterial phase of IV digital subtraction angiogram before transphenoidal resection. Note normal course and placement of juxtasellar carotids (*open arrows*). Also note excellent demonstration of vertebral and basilar arteries. R = right.

mycotic aneurysms. In a 9-year-old boy who had cortical calcification on CT, both the IVDSA and SCA showed no underlying venous malformation. In a 7-year-old girl who presented with an intracranial bruit, the IVDSA demonstrated a small vascular malformation, but there has been no confirmatory SCA. In a 10-year-old boy presenting with headaches, the IVDSA confirmed that the areas of increased activity on a RBS were due to prominent superficial veins.

Four patients were evaluated preoperatively to aid in surgical planning. In a 16-month-old boy, a biopsy of a lytic calvarial lesion was not performed as a direct result of the IVDSA, demonstrating that the right transverse sinus underlay this defect. In two patients referred with known sellar masses before transphenoidal resection, IVDSA demonstrated normal placement and course of the carotid arteries (Fig. 5). In a 7-month-old boy with a posterior fossa quadrigeminal plate arachnoid cyst, elevation of the deep venous system directed the surgical approach to planned marsupialization.

Seven patients were evaluated for suspected or known vascular ischemia and/or infarction. In two patients, the sensitivity of IVDSA in detecting infarctions was illustrated by the demonstration of luxury perfusion (correlative RBS). In one of

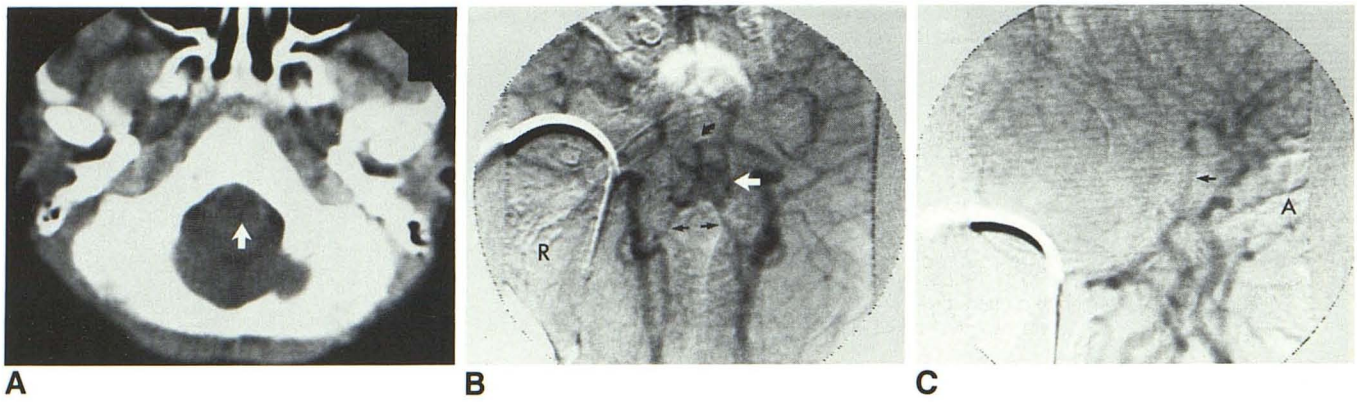

Fig. 6.—**A**, Axial CT. Low-density region in brainstem consistent with infarction (*arrow*). **B**, Basal view. Arterial phase of IV digital subtraction angiogram showing vascular blush in brainstem secondary to luxury perfusion (*white arrow*). *Small arrows* = vertebral arteries; *curved arrow* = basilar artery. R = right. **C**, Left lateral view. Arterial phase of IV digital subtraction angiogram showing nonfilling of posterior cerebral arteries. *Arrow* = basilar artery, A = anterior.

these patients, a 7-year-old girl who presented with acute quadriparesis, ischemia of the posterior fossa was also demonstrated (Fig. 6). A confirmatory SCA was not obtained owing to the patient's poor clinical status, but a follow-up IVDSA 2 months later showed normal posterior fossa perfusion and a normal vertebral-basilar arterial system; this correlated with interval improvement in the patient's quadriparesis and lends support to the initial diagnosis. In the other patient, an 18-year-old man with a left hemiparesis, a CT scan 1 month later confirmed the cerebral infarction. In an 11-year-old boy, who had SCA documentation of an arterial occlusion in the posterior distribution of the left-middle cerebral artery, a follow-up IVDSA showed definite improvement in perfusion. The four remaining patients, ultimately clinically diagnosed as having migraine, were initially evaluated to exclude underlying vascular abnormalities. In two patients, all diagnostic investigations were normal. In the remaining two patients, a vascular blush was identified on the IVDSA (correlative RBS), presumably representing luxury perfusion secondary to ischemia.

TABLE 1: **Comparison of IVDSA and SCA**

Advantages	Disadvantages
Diagnostic	
1. High contrast resolution	1. Low spatial resolution
2. Total vascular opacification	2. Limited field of view
3. Postprocessing enhancement	3. Image degradation with movement
	4. Total vascular opacification
Patient	
1. Safety of multiple examinations	1. High contrast load
2. Minimal morbidity	
3. Prevention of arterial complications	
4. Lower radiation exposure	
5. Less costly	

Note.—IVDSA = IV digital subtraction angiography; SCA = standard cerebral arteriography.

Discussion

Digital subtraction angiography (DSA) has initiated a new era in vascular imaging with significant patient and diagnostic advantages (Table 1). There has been recent enthusiasm for intraarterial DSA, used by some as the vascular procedure of choice [24]. The advantages of intraarterial DSA over SCA include increased contrast sensitivity, decreased contrast concentration and dose, decreased procedure time and patient discomfort, decreased need for selective catheterization, immediate image availability, instantaneous subtraction capability, and decreased film cost [25–31]. However, potential complications related to femoral arterial puncture remain unchanged [14–16]. Empirically, therefore, we have elected to use the less invasive approach in vascular imaging, namely, the IV route.

Our results indicate that IV angiograms can be adequate in many clinical settings (Table 2). The high contrast sensitivity allows IV arteriography with minimal risk of complications [19]. Since our initial report we have not had any complications in over 70 additional patients. With respect to intracranial disease in children, the goal is to decrease the need for SCA with its attendant risks and complications while maintaining diagnostic accuracy. Therefore, it is important that pediatric indications and limitations for IVDSA be enumerated. Because of significant image degradation with even minimal patient movement, one must optimize digital acquisition. To improve contrast resolution of the intracranial vasculature, the largest catheter suitable for the vein is placed centrally [32] and a bolus is injected rapidly. Subjectively, we have noted less patient movement during digital acquisition when using the lower-osmolality agent Hexabrix, rather than MD-76. Additional benefits are gained by the rapid circulation time and excellent cardiac output in most pediatric patients. Further-

TABLE 2: **Applications of IVDSA to Pediatric Intracranial Disease**

Useful
1. Diagnosing venous and dural sinus abnormalities
2. Documenting the time course of known vascular abnormalities
3. Screening for suspected vascular malformations and large aneurysms
4. Identifying major arterial occlusive disease
5. Preoperative arterial vascular mapping
6. Preoperative evaluation of venous displacement
Selected Value
1. Screening for vascular abnormalities underlying intracranial hemorrhage
2. Substantiating suspected cerebral ischemia
3. Confirming brain death
4. Evaluating vascularity and sinus extension of masses
Not Useful
1. Diagnosing small-vessel or segmental arterial occlusive disease
2. Definitively excluding small vascular malformations or aneurysms
3. Preoperative localizing of specific arterial supply to arteriovenous malformations, aneurysms, or neoplasms

Note.—IVDSA = IV digital subtraction angiography.

more, by coupling a DSA system to an ultralow-dose fluoroscopy unit, we have minimized patient exposure while maintaining high-quality examinations. Total patient entrance exposure from the entire IVDSA procedure, including digital acquisition, fluoroscopy, and spot films, is less than 5000 mR (1290 μC/kg) in most patients.

The Towne projection has been the most useful for arterial evaluation by providing direct side-to-side comparison of vascularity while maximizing separation of the main branches of the intracerebral arteries. Both the lateral and frontal views are helpful in evaluating the veins and dural sinuses. Additionally, the basal view has been particularly valuable in preoperative assessment of sellar tumors and imaging of the vertebral arteries. On the other hand, simultaneous opacification coupled with vessel superimposition significantly limits the usefulness of the lateral projection in evaluating vessels distal to the carotid arteries. We have not found off-laterals or oblique views to be of much additional diagnostic value. The field-of-view limitations are less important, particularly in small children, since the entire cranium can be imaged on the 9-in. (22.9-cm) mode. The lower spatial resolution of IVDSA (compared with SCA) is for the most part offset by the high contrast resolution and is a limiting factor in a minority of children.

Table 2 summarizes our approach to the application of IVDSA to cranial disease in children. Many of the general applications documented in adults can be applied to pediatric patients, since age and size are not limiting factors. However, specific indications will vary, since many diseases are unique to children. Our experience has shown that IVDSA can diagnose sagittal sinus thrombosis, masses, brain death, aneurysms, vascular malformations, luxury perfusion, and tumor vascularity.

The ability to map major intracerebral vessels with minimal morbidity and without significant risk to the patient is a preoperative advantage that has not been available for pediatric patients in the past. An additional advantage is improved patient management through multiple sequential IVDSA examinations that can be used to follow the course of a specific disease. We believe that the reliability of a normal IVDSA for excluding disease is significant, but direct correlative data are not available for many of these patients, since the reliability of IVDSA could not be "proved" using SCA. The relatively poor ability of IVDSA to evaluate mass effects is of little consequence, since this type of evaluation can best be accomplished using CT and, recently, MRI.

We have observed that the sensitivity of IVDSA in identifying subtle vascular abnormalities (luxury perfusion, tumor stains, and ischemia) is similar to that of RBS, but IVDSA has the added advantage of offering better spatial resolution, which will often improve specificity. We do not wish to suggest that all patients with suspected ischemia or infarction should have an IVDSA examination, but only to point out that it is an extremely effective technique in identifying perfusion alterations. Nor are we recommending that IVDSA replace RBS as a means of confirming brain death [33, 34]; however, IVDSA will be useful in selected cases with equivocal results and in false-positive RBS secondary to poor boluses. Technically, the examination is simplified, since these ill patients generally have indwelling central venous catheters through which the study can be performed.

In summary, our experience demonstrates that IVDSA is a relatively safe and effective procedure that can be performed in children of all ages to aid in the diagnosis and management of intracranial disease.

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