Intravenous digital subtraction angiography for evaluation of the renal arteries in pediatric patients[1]

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Intravenous digital subtraction angiography (IV-DSA) was used to image the renal arteries of 24 children and adolescents. A total of 27 examinations was performed. Seventeen of these examinations were obtained to screen for renovascular causes of hypertension, with positive findings in three. Eight were performed following renovascular surgery. Two were used to assess renal arteries preoperatively. Good diagnostic-quality images were achieved in 24 of 27 examinations (89%). IV-DSA is a safe and effective means of evaluating the renal arteries of children and adolescents with a variety of clinical problems.

Index terms: Angiography · Pediatrics · Renal artery · Subtraction technic

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Renal arteriography formerly played a major role in the evaluation of various renal disorders in children, but recent advances in ultrasound, computed tomography, and radionuclide imaging have replaced it in many cases. Arteriography, however, is still indicated in some clinical settings, particularly for evaluating renovascular disease. Conventional catheter arteriography has been used in children with relative safety. Nevertheless, arteriography is an invasive procedure often performed in children under general anesthesia and is not without risk. Intravenous digital subtraction angiography (IV-DSA) has developed as a relatively noninvasive technique for evaluating the cardiovascular system, and several medical centers have reported good results in imaging the aorta and renal arteries in adults.[1–4] IV-DSA for imaging the renal arteries in children

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Table. Renal IV-DSA studies in 24 patients ≤19 years old

Indications (no. studies)	Image Quality			DSA Findings	
	Good	Fair	Inadequate	Normal	Lesion
Hypertensive (17)	15	2	0	14	3
Postoperative (8)	7	1	0	8	0
Preoperative (2)	2	0	0	2	0
Total (27)	24	3	0	24	3

and adolescents with various clinical problems is the subject of this report.

Methods

Twenty-seven IV-DSA examinations of the renal arteries were made in 24 patients. Two patients were younger than 2, three were ages 2 to 6, four were ages 7 to 12, and 15 were ages 13 to 19. Seventeen examinations were performed to evaluate hypertension, eight following vascular surgical procedures, and two to assess the renal arteries preoperatively.

Buonocore et al. have described in detail the instrumentation and techniques used in IV-DSA imaging at The Cleveland Clinic.[1] We briefly describe the technique here: Twenty-five milliliters of diatrizoate meglumine and diatrizoate sodium (Renografin-76) is injected with a pressure injector through a 16-gauge cannula at 10 to 15 mL/sec into an antecubital vein. (In two infants, injections were made in the superior vena cava at the time of cardiac catheterization). The intravenous cannula size and the rate and amount of contrast material injection were adjusted appropriately for younger children. The total contrast material dose injected did not exceed 3 mL/kg. Fifteen to 20 abdominal exposures at one frame per second were then obtained. An image obtained before the contrast media arrived (mask frame) was collected in the digital mode and stored in the computer. Subsequent image frames were then subtracted digitally from the mask frame, and the resultant subtracted images were displayed on a TV monitor.

Initial views were obtained in the anteroposterior or 10-degree left anterior oblique projection. Additional views in varying degrees of obliquity were obtained when deemed necessary. Intravenous glucagon (1 mg) was usually administered to prevent bowel peristalsis and its resultant artifacts, and abdominal compression was used to compress gas-filled loops of bowel. Children under the age of 6 years were usually sedated.

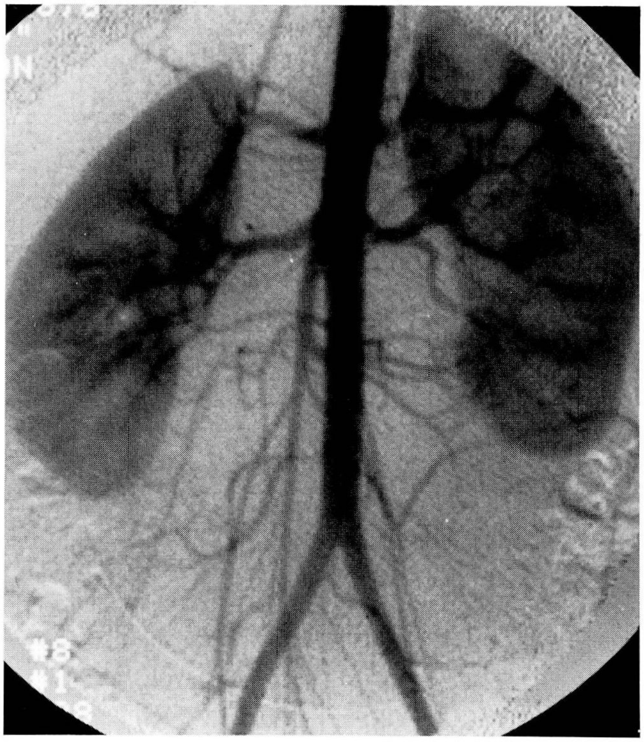


Fig. 1. Normal renal IV-DSA in an adolescent screened for hypertension.

Results

The image qualities obtained and angiographic findings are listed in the *Table*. Both a radiologist and a urologist graded the images as good, fair, or inadequate based on the following criteria: Good quality studies were those in which the origins and entire length of the main renal arteries were visualized (*Fig. 1*). Renal branches beyond the main renal arteries were visualized in most cases, but because of the spatial limits of current IV-DSA techniques, assessment of these branches was not reliable. Fair quality studies were those in which the renal arteries were visualized and the number and patency of arteries could be assessed, but portions of the arteries were obscured by overlapping vessels or bowel. The image qualities of 24 of the 27 examinations (89%) were good, and three (11%) were fair.

None of the examinations in this study was considered diagnostically inadequate.

Renal artery stenosis was identified in three of the 17 IV-DSA examinations obtained to screen for renovascular hypertension. These included two examinations of one patient, the first of which was of fair diagnostic quality, showed two renal arteries bilaterally, and suggested a tight stenosis in the proximal inferior artery on the right side. The second examination confirmed this finding (*Fig. 2a*), and the stenosis was further defined with conventional arteriography before it was repaired surgically (*Fig. 2b*). The second patient who was found to have a renal artery stenosis showed apparent occlusion of both renal arteries with distal filling via collateral vessels; again these findings were confirmed with standard arteriography.

Conventional arteriography confirmed IV-DSA findings in another two patients who were evaluated for renovascular hypertension. One patient was found to have a very small renal artery supplying an atrophic but functional right kidney and a normal left renal artery supplying a hypertrophied left kidney. This patient's hypertension is being treated medically. The other patient's renal arteries appeared normal in the IV-DSA examination, and this was confirmed by conventional angiography. The conventional angiogram, however, showed that this patient had an extra-adrenal pheochromocytoma in the right para-aortic region at the L4 level.

Eight IV-DSA examinations were made in six patients following vascular surgery. Two patients had surgery to repair coarctation of the aorta. Each had an IV-DSA study, which showed their renal arteries were normal and their coarctation was adequately repaired. Four patients had renal revascularization surgery. This group included the aforementioned patient with bilaterally occluded renal arteries; she had a saphenous-vein, aortorenal bypass to her right kidney and autotransplantation of her left kidney with bench surgical repair of a branched renal artery stenosis. The postsurgical IV-DSA examinations showed adequate surgical revascularization. Two of these patients had autotransplantation with bench repair of branched renal artery stenosis. Again, IV-DSA demonstrated adequate surgical revascularization (*Fig. 3*). The fourth patient who underwent revascularization surgery had two IV-DSA studies, one at one month and one at one

A

B

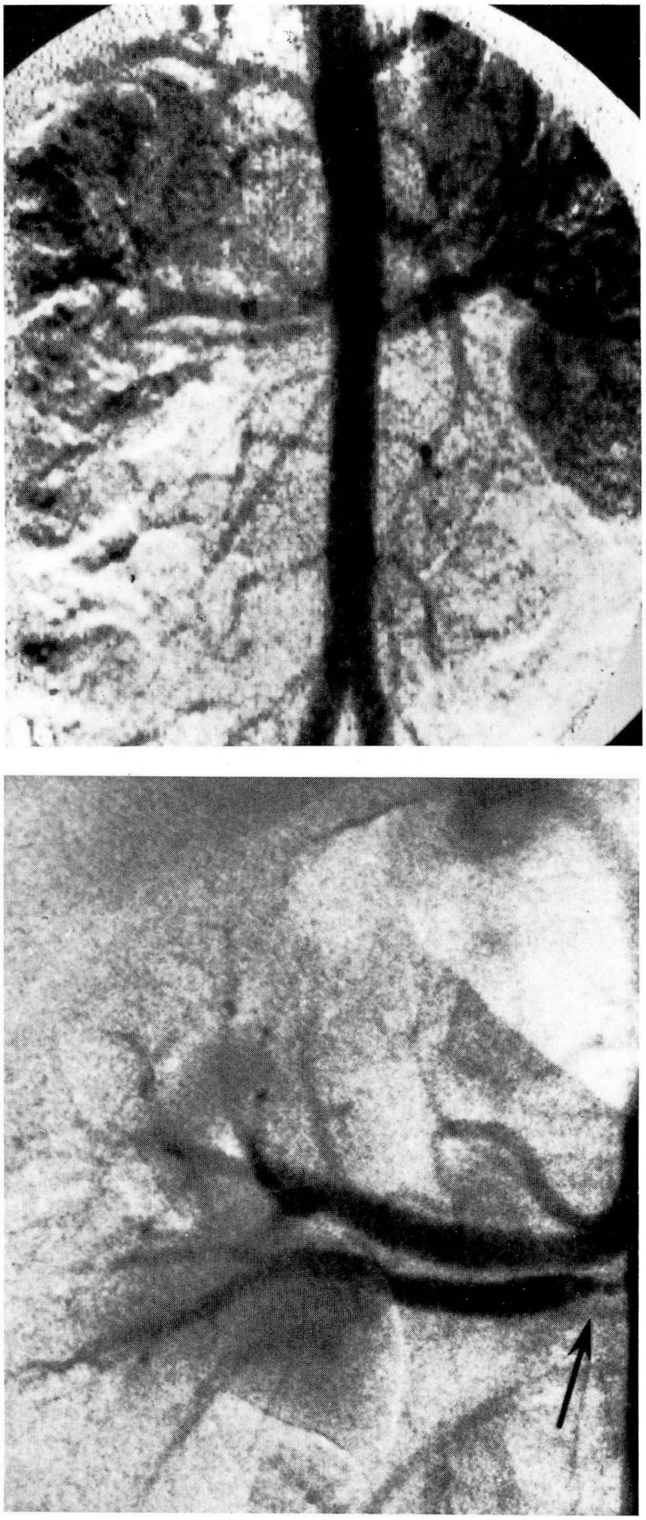
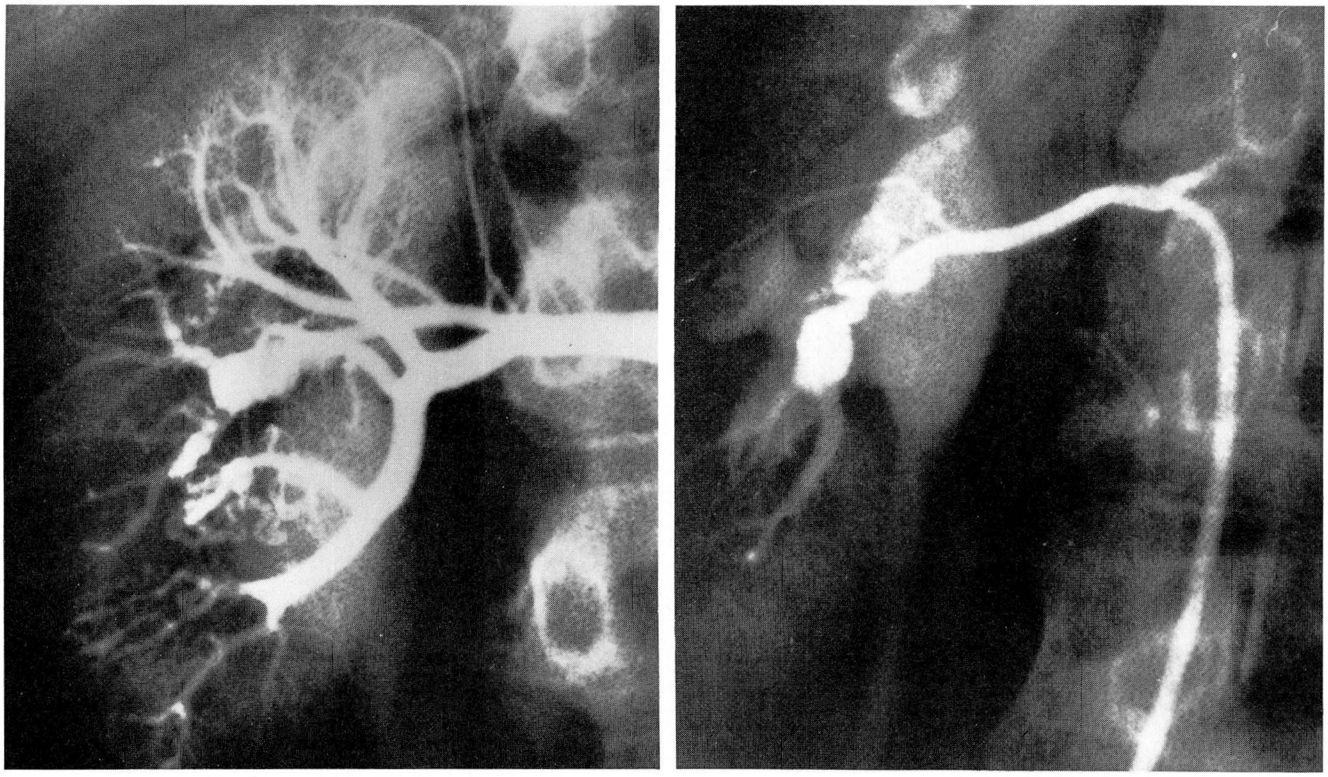


Fig. 2. **A.** Renal IV-DSA demonstrating two right renal arteries with apparent stenosis of proximal inferior right renal artery.
B. Standard aortogram demonstrating two right renal arteries with tight stenosis of proximal inferior artery.

A, B



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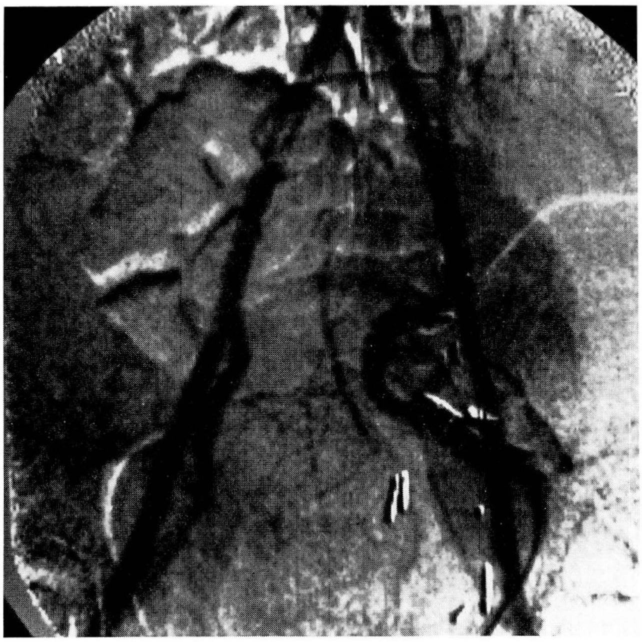

Fig. 3. **A.** Selective routine angiogram of superior right renal artery demonstrating aneurysm of intrarenal branches.

B. Selective angiographic injection of the inferior right renal artery reveals aneurysm and stenosis of intrarenal branches.

C. IV-DSA after surgical revascularization demonstrating patent branched graft to autotransplanted kidney after bench surgical repair.

year following saphenous-vein aortorenal bypass. These studies again showed surgery to have been successful, revealing a patent graft without evidence of anastomotic stricture. The saphenous vein graft, however, appeared dilated at one year. This patient is now normotensive, and further IV-DSA studies are planned for serial evaluation of this dilatation (*Fig. 4*).

Two patients had IV-DSA evaluation of the renal arteries before renal surgery. One was a five-year-old male with aniridia and Wilms' tumor in the lower segment of a duplicated right kidney. Renal IV-DSA showed that a single renal artery supplied both portions of the duplicated kidney. Although IV-DSA effectively demonstrated the renal arteries in this case and in the previously mentioned case of an adolescent with pheochromocytoma, the small tumor vessels could not be reliably imaged because of this technique's limitations in spatial resolution. The other patient requiring preoperative evaluation was an 18-year-old male who had had prior traumatic injury to the midureter. The initial treatment was percutaneous nephrostomy diversion. The patient was then referred to The Cleveland Clinic. One possible operation was autotransplan-

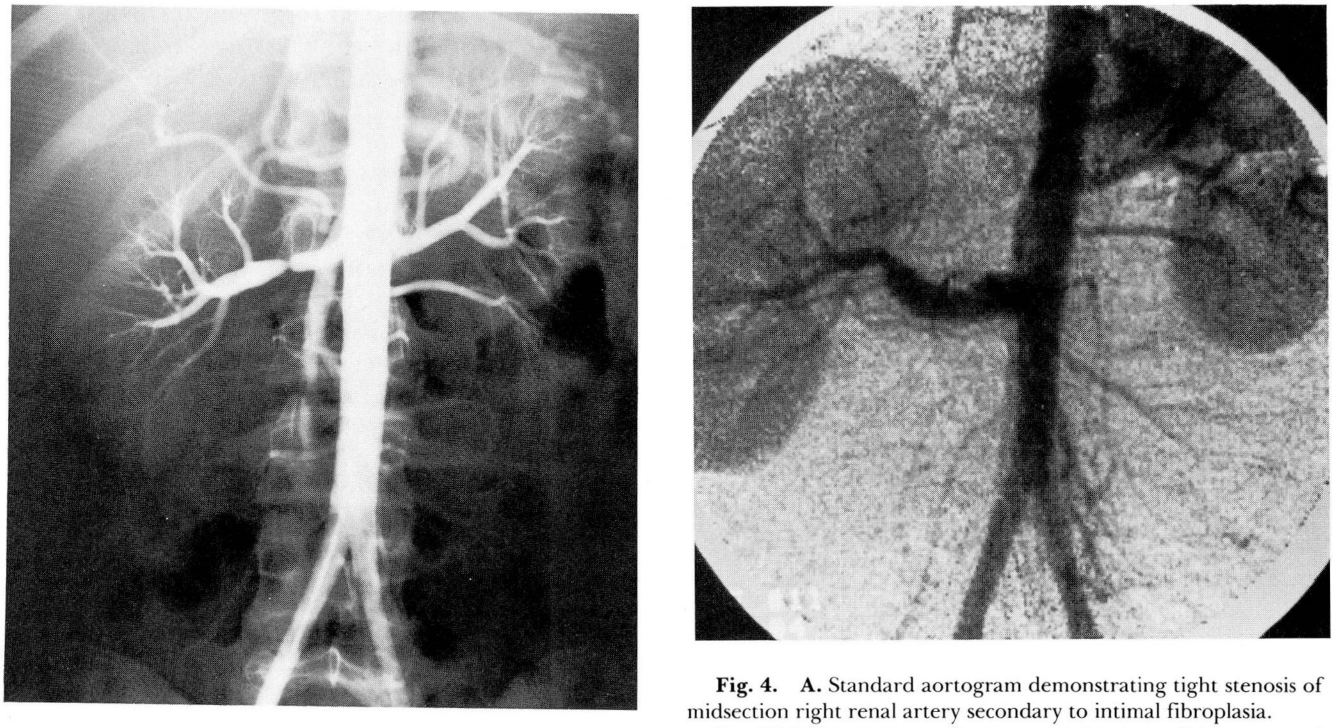

Fig. 4. **A.** Standard aortogram demonstrating tight stenosis of midsection right renal artery secondary to intimal fibroplasia. **B.** IV-DSA one year after surgery showing mild aneurysmal dilatation of saphenous vein graft.

tation of the kidney, so an IV-DSA examination of the renal arteries was performed. A normal, single renal artery was found to supply this kidney. At surgery, a primary ureteral repair was performed, so autotransplantation was not required.

No complications were associated with the 27 IV-DSA examinations. Specifically, no patient's renal function changed, as determined by serum creatinine. In five patients abdominal radiographs were obtained before and after contrast material injection to provide intravenous urograms. These images showed no other problems. Patients who did not have these studies done at the Clinic generally had already had urograms that showed hypertension.

Discussion

Because IV-DSA's accuracy for visualizing the renal arteries ranges from 71% to 91%,[1–6] it has been proposed as a method superior to the traditional intravenous urogram for screening for renovascular disease. Most children's hypertension is the essential type, but it is more likely to have a secondary cause than adult hypertension. Neurofibromatosis is another cause of renovascular disease in children that characteristically causes stenosis at the origin of the renal artery. Fibrous dysplasia, however, usually involves the more distal renal artery and can extend into the renal artery branches. Because the small renal artery branches are beyond the spatial resolution of current IV-DSA methods, the technique cannot be used as the sole imaging study before therapeutic intervention.

Digital subtraction angiography has greater contrast resolution than conventional film-screen angiography, so the usual dose of contrast material used for conventional catheter aortography can be delivered intravenously to visualize the aorta and its major arterial branches. IV-DSA is therefore much less invasive and is associated with no significant risk other than exposure to contrast material. IV-DSA examinations can be made on an outpatient basis and can be performed more rapidly and less expensively than conventional angiography. Radiation exposures from IV-DSA examinations approximate half those received during conventional angiography (Moodie DS, McIntyre R. Radiation exposure during cine angiography compared with DSA study, Cleveland Clinic, unpublished). But digital subtraction angiography does have limitations, with decreased spatial resolution and motion sensitivity among them.

Subtraction techniques, whether they use conventional radiographs or the digital method, are highly sensitive to motion. Movement by the preschool-age child can be difficult to control, especially when the bolus of contrast material causes discomfort. Usually sedation, and in some cases anesthesia, may be necessary for very small children, so in some cases IV-DSA will not be feasible. Respiratory motion or bowel peristalsis also can degrade the images and result in false-positive or false-negative interpretations. In our series, three of 27 examinations had only fair visualization of the renal arteries because of overlapping noncompressible bowel gas and peristalsis, despite the use of compression and intravenous glucagon.

Another potential problem in IV-DSA examinations is vessel overlap. The intravenous delivery makes all the abdominal arteries opaque, and one or both of the renal arteries may be obscured by opacified overlapping vessels, particularly the superior mesenteric artery and its branches. Multiple views requiring additional contrast material injections are often needed to visualize the renal arteries in their entirety. Adequate visualization of the aorta also depends on delivery of a good bolus of contrast material. Poor cardiac output or extravasation at the injection site will result in a suboptimal bolus and, therefore, poor contrast material visualization. Neither of these was a problem in our patient group.

Despite the potential problems with IV-DSA, 89% of our images were of diagnostic quality. This is similar to our recent report of 91% diagnostic examinations in a large series of adult patients screened for renovascular disease.[6]

When evaluating patients for a renal artery or renal parenchymal abnormality, Cleveland Clinic physicians often use other tests that also require intravenous contrast material. For example, in evaluating hypertension, a preliminary abdominal radiograph is followed by IV-DSA of the renal arteries; then further abdominal radiographs are obtained to provide intravenous urography. This was accomplished in five of the patients in the current series.

IV-DSA can replace the early urograms usually obtained to evaluate hypertension. In evaluating renal masses or renal trauma, IV-DSA can be the initial examination used to establish the anatomy or integrity of the renal artery. This can be followed by a urogram or a CT scan to better delineate the parenchymal mass or extent of injury.

The other setting in which renal IV-DSA will likely assume a prominent role is in the long-term follow-up of children undergoing renovascular surgery or percutaneous transluminal angioplasty of the renal arteries. IV-DSA provides a noninvasive, easily repeatable means for following the results of renal artery bypass grafts or percutaneous angioplasty. This direct anatomic vascular imaging is superior to functional studies like intravenous urography or radionuclide imaging of the renal arteries, which had previously been used to follow these patients.

We have found that IV-DSA can be used safely and effectively to image the renal arteries in children and adolescents. With further technical improvements, renal IV-DSA may well replace conventional arteriography for these patients.

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