Diagn Interv Radiol 2013; 19:15–19

PEDIATRIC IMAGING
ORIGINAL ARTICLE

Doppler US evaluation of renal biopsy complications in children

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PURPOSE
Percutaneous renal biopsy plays an important role in the diagnosis and management of renal disease in children, but it does carry some complications. As most cases are vascular in origin, Doppler ultrasonography (US) has clear benefits in terms of detecting bleeding and assessing vascular damage. The aim of this study was to investigate the effectiveness of Doppler US in detecting possible complications after percutaneous renal biopsy in pediatric patients.

MATERIALS AND METHODS
This retrospective study was performed using the data obtained from all pediatric patients who underwent renal biopsy in our institution between 1999 and 2011.

RESULTS
A total of 175 biopsies were performed in 172 patients (48.3% male, 51.7% female) ranging in age from 1 to 17 years (mean, 8.7 years). Of 175 biopsies, 42 (24.0%) led to complications. Overall, 52 complications (25% major, 75% minor) occurred following 42 biopsies.

CONCLUSION
Doppler US examination is capable of and helpful in detecting possible vascular complications such as pseudoaneurysm and arteriovenous fistula and improves the management of these patients after biopsy. It is important to recognize the Doppler US appearance of complications associated with percutaneous renal biopsy and to perform close follow-up with Doppler US in the first 24 hours.

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Received 25 April 2012; revision requested 18 May 2012; revision received 21 May 2012; accepted 23 May 2012.

Published online 20 December 2012
DOI 10.4261/1305-3825.DIR.5968-12.1

Percutaneous renal biopsy (PRB) plays an important role in the diagnosis, prognosis, and management of renal disease in children (1). Developments in ultrasonography (US) and automated-gun biopsy devices have improved the PRB technique over the past two decades, making it a relatively safe procedure with the ability to obtain adequate tissue for definitive diagnosis. Even after these technical improvements, some complications are associated with PRB, as with every other invasive procedure, necessitating interventions such as transfusion of blood products or surgery (2). The majority of PRB complications do not require surgical intervention but do require pain management, close clinical observation, and often additional laboratory tests. Serious complications related to PRB are rare, estimated at ~0.1% to 6.6% in recent reports (2–7).

The US is the most frequently used imaging method for the diagnosis of complications of PRB because of its well-known advantages as an easily accessible, simple, rapid, and noninvasive imaging technique. As most PRB complications are vascular in origin, Doppler US has clear benefits in terms of identifying bleeding and assessing vascular damage. Whether to administer a blood or blood products transfusion largely depends on clinical and laboratory findings, but in many cases, the need for surgical or interventional procedures is decided by Doppler US findings. For this reason, it is important to evaluate the Doppler US appearances of PRB complications so as to improve the management of these cases. The aim of this study was to investigate the role of Doppler US in the follow-up of pediatric patients and its ability to detect complications related to PRB.

Materials and methods

This retrospective study was performed using the data obtained from all pediatric patients who underwent PRB in our institution from June 1999 to May 2011. The Institutional Review Board approved the study based on the 1993 multidisciplinary evaluation algorithm for children.

Technique of US-guided percutaneous renal biopsy

Coagulation profiles, including prothrombin time, partial thromboplastin time, international normalized ratio, and total platelet count were evaluated in all patients, and only the patients with normal values were accepted for biopsy. Informed consent was obtained from the parents before each procedure. Out-patient PRB biopsy was not performed in any patient. All procedures were performed under sedation administered by an anesthesiologist. Children were placed in a prone position, and a pillow was placed under the abdomen to correct lumbar lordosis. A prebiopsy US scan was used to identify the optimal biopsy site. The lower pole of the kidney (usually left) was selected as a target. Following

local anesthesia, the skin was lanced, and the biopsy needle was inserted. Using real-time US guidance, the needle was advanced to the kidney, and a biopsy of the cortex was obtained with the needle tip placed against the renal capsule before firing the biopsy needle. After a maximum of two attempts, one or two core samples were obtained in each case. All PRBs were performed by a team of pediatric nephrologists and interventional radiologists. Postprocedural imaging studies were performed by an experienced radiologist using Doppler US. A total of 175 biopsies were performed in 172 patients. A 14-gauge or 16-gauge needle automated biopsy gun (C. R. Bard Inc., Murray Hill, New Jersey, USA) was used for the PRB.

Postbiopsy follow-up

All children were evaluated by Doppler US for complications after PRB. The first Doppler US exam was performed immediately after the biopsy procedure. Patients were confined to bed rest for 24 hours under close observation following the procedure, and an additional Doppler US exam was performed as needed during this period. When the child was stable, the second Doppler exam was done at the 24th hour. If there were any complications associated with PRB, additional follow-up Doppler US studies were repeated in the three days. After discharge, the patients underwent follow-up Doppler US only if clinically indicated.

The severity of complications was categorized as minor or major. Minor complications were defined as those that spontaneously resolved without the need for further intervention, e.g., gross hematuria and/or perinephric hematoma. Major complications were those requiring intervention, such as transfusion of blood products or an invasive procedure (radiological or surgical), and those resulting in acute renal obstruction or renal failure, septicemia, or death.

Results

We performed a total of 175 biopsies in 172 patients (83 males [48.3%], 89 females [51.7%]; mean age, 8.7 years; age range, 1–17 years). A 14-gauge needle automated biopsy gun was used in 170 biopsies (97.1%), and a 16-gauge needle automated biopsy gun was used in the remaining five biopsies (2.9%). We did not evaluate the relationship between needle size and rate of complications due to the small group size of patients that received the 16-gauge needle. We performed 315 attempts for 175 biopsies, for a mean of 1.8 attempts/biopsy. Adequate material for pathological diagnosis was obtained from all biopsies. We found no statistically significant relationship between the number of attempts and the complication rate or between complications and the age of the pediatric patients.

We performed, overall, 482 Doppler US exams in 172 patients, with a mean of 2.8 Doppler US exams/patient. In 133 biopsies (76.0%), no complication was found. Complications associated with PRB were detected in 42/175 biopsies (24.0%). Postbiopsy complications are listed in Table 1. A total of 52 complications (23.1% major, 76.9% minor) occurred in 42 biopsies. No organ loss or death was reported. Multiple complications were observed in some patients (Table 2).

Table 1. Categorization of complications according to clinical outcomes

Complications	n	Percentage (%) of all complications (n=52)	Percentage (%) of all biopsies (n=175)
Minor			
Macroscopic hematuria	3	5.8	1.7
Hematoma	26	50.0	14.9
AVF (asymptomatic)	10	19.2	5.7
Other (urinoma)	1	1.9	0.6
Total	40	76.9	22.9
Major			
Hematoma	7	13.5	4.0
AVF (symptomatic)	3	5.8	1.7
Pseudoaneurysm	2	3.8	1.2
Total	12	23.1	6.9

AVF, arteriovenous fistula.
Minor complications are defined as those that resolve spontaneously without the need for further intervention. Major complications are defined as those that require an intervention.

Table 2. Overall biopsy results

Result of biopsy	Biopsy (n [%])
No complication	133 (76.0)
Perirenal hematoma	11 (6.3)
Subcapsular hematoma	8 (4.5)
AVF	8 (4.5)
Intraparenchymal hematoma	6 (3.4)
AVF+subcapsular hematoma	2 (1.1)
Pseudoaneurysm+AVF+subcapsular hematoma	1 (0.6)
Macroscopic hematuria	1 (0.6)
Pseudoaneurysm+perirenal hematoma	1 (0.6)
Perirenal hematoma+AVF	1 (0.6)
Subcapsular hematoma+macroscopic hematuria	1 (0.6)
AVF+subcapsular hematoma+intraparenchymal hematoma+macroscopic hematuria	1 (0.6)
Urinoma	1 (0.6)

AVF, arteriovenous fistula.

The most common complication was subcapsular, perirenal, and/or intraparenchymal hematoma. Hematomas were easily recognized by gray-scale US without the need for color Doppler mode. A perirenal hematoma was indicated by a poorly defined, hypo-hyper-echogenic collection between Gerota's fascia and the renal parenchyma, mostly in the inferior polar region (Fig. 1). Perirenal hematomas do not deform the shape of the renal parenchyma, even when they are large. Subcapsular hematomas commonly appear as a crescent-shaped collection. In such cases, the capsule maintains the reniform contour, as the hematoma compresses the kidney. We diagnosed 33 patients (18.9% of all biopsies, 78.5% of all complicated biopsies) with hematomas by US. Doppler US examination showed a pseudoaneurysm and an arteriovenous fistula (AVF) accompanied by subcapsular hematoma in one patient and a pseudoaneurysm accompanied by perirenal hematoma in another patient. Doppler US examination revealed AVF with hematomas (subcapsular, perirenal, and intraparenchymal) in another four patients. Hematomas were asymptomatic in most patients (75.7% of all hematomas, 25/33), but flank pain and a decrease in hemoglobin level were present in 24.3% (8/33) of these children. The most frequent intervention was blood transfusion for hematomas, which was required in 21.2% (7/33) of all patients with a hematoma (4.0% of all biopsies). Pseudoaneurysms and symptomatic AVFs detected along with hematomas were treated by successful endovascular embolization at the interventional radiology unit.

In our series the most common vascular complication was AVF (n=13, 7.4% of all biopsies, 25% of all complicated biopsies). On Doppler US, AVF appears as a nonspecific mosaic pattern and perivascular soft tissue color speckling due to tissue vibration, reflecting a rapid flow rate. We demonstrated increased flow velocity, decreased arterial resistance, and arterial waveforms in the outflow vein on spectral analysis (Fig. 2). Large AVFs were seen as cyst-like lesions on gray-scale US. Heterogeneous fill-in on color Doppler US and turbulent blood flow were indicative of a fistula on spectral analysis. Ten of the AVFs were diagnosed in the first Doppler US exam after biopsy. Three AVFs were diagnosed in the second Doppler examination at the 24th hour. Ten AVFs (76.9% of all AVFs) remained asymptomatic and/or resolved spontaneously during the follow-up Doppler evaluations within two days to four months. However, three patients with AVF developed secondary hypertension, and a prominent draining vein with turbulent flow was seen on Doppler US. All three patients were treated by endovascular embolization at the interventional radiology unit. Fig. 3 demonstrates the angiographic appearance of an AVF before and after embolization.

Another important vascular complication is pseudoaneurysm, which can be overlooked in an US exam if Doppler US is not performed. We diagnosed two patients with pseudoaneurysms following PRB. One was detected immediately after biopsy, and the second was detected eight hours after biopsy on Doppler US, along with a large hematoma. The pseudoaneurysm appeared as a nonspecific anechoic cyst-like mass on gray-scale US; however, the Doppler US revealed typical findings such as vascular color coding, the characteristic Yin-Yang phenomenon, and spectral findings (Figs. 4 and 5) (8). One of these two patients also had an accompanying AVF, and both were treated by endovascular embolization.

Only one complication was detected after the first 24 hours, which was a persistent flank pain at the biopsy site, and US revealed a large urinoma around the kidney.

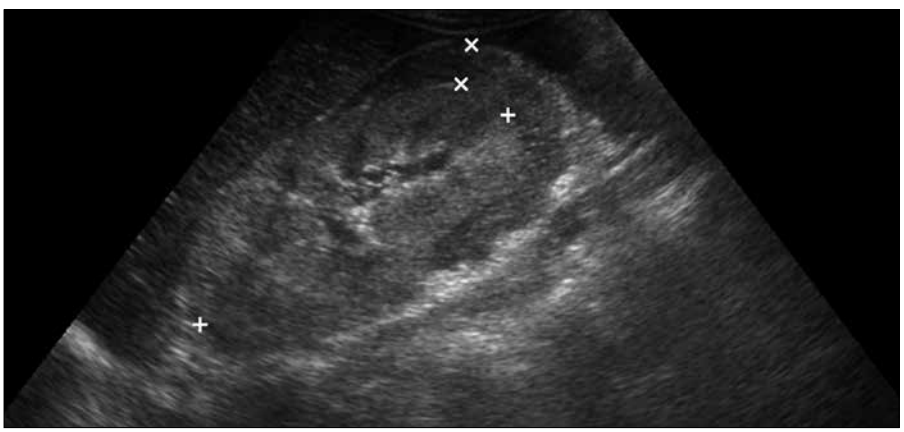

Figure 1. On gray-scale US, a perirenal hematoma (between x cursors) appeared as a poorly-defined, isoechogenic collection at the inferior pole of the kidney. +, longitudinal axis of the kidney.

Discussion

Complications after PRB can be categorized as minor or major. Macroscop-

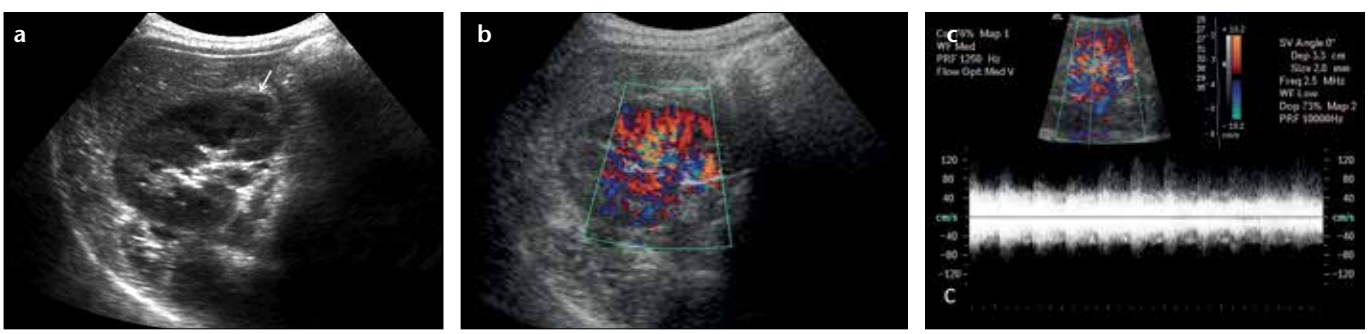

Figure 2. a–c. On gray-scale US **(a)**, only a small perirenal hematoma was seen (*arrow*). On color Doppler US **(b)**, a heterogeneous mosaic pattern associated with a renal AVF was seen. Spectral analysis **(c)** showed turbulent flow, with an increased flow velocity of 140 cm/s.

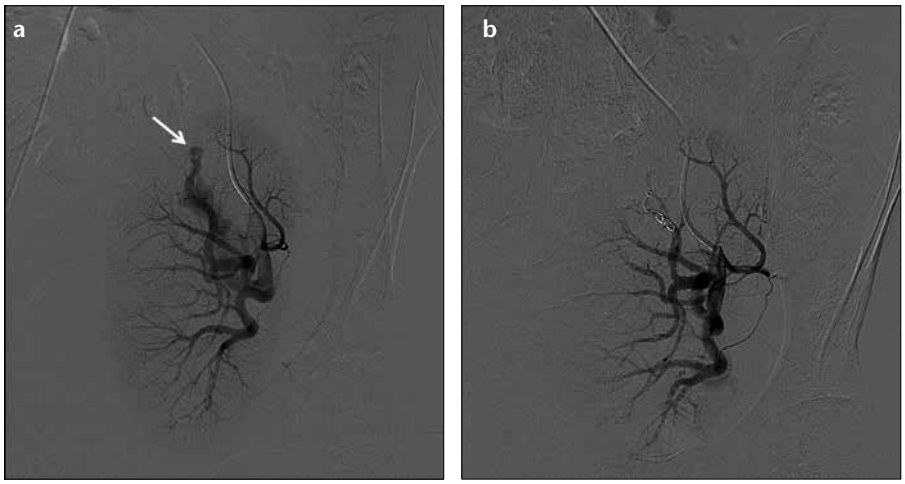

Figure 3. a, b. On the pre-embolization angiographic image **(a)**, AVF and early venous filling were clearly seen (*arrow*). After embolization **(b)**, neither a fistula nor early venous filling was observed.

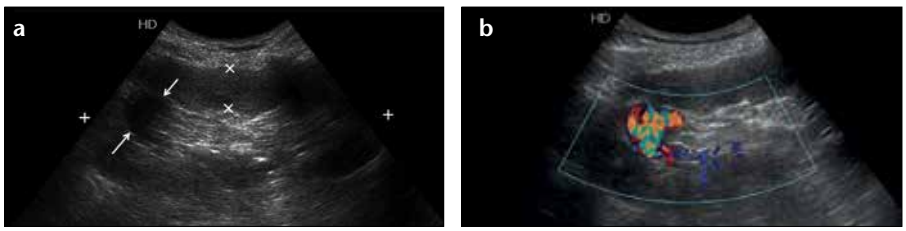

Figure 4. a, b. Pseudoaneurysm. On gray-scale US **(a)**, a cyst-like lesion at the upper pole of the kidney was seen (*arrows*), which had heterogeneous fill-in on color Doppler US **(b)**.

Figure 5. Extrarenal pseudoaneurysm with perirenal hematoma. Color Doppler US revealed a pseudoaneurysm (*arrows*) with heterogeneous fill-in with extrarenal extension into the perirenal hematoma. IVC, inferior vena cava.

ic hematuria, intraparenchymal, perirenal, or subcapsular hematoma, and asymptomatic AVF are considered minor complications that resolve without the need for further intervention (5). Pseudoaneurysm, symptomatic AVF, infection, damage to adjacent organs, renal loss, and death are considered major complications that require intervention, such as a transfusion of blood products or an invasive procedure. Hematoma (subcapsular, perirenal, and intraparenchymal) is a general complication and may accompany other complications. It was the most common complication associated with PRB in our study (19.4% of all biopsies), in accordance with previous reports. Only seven patients (4.0% of all biopsies) who had a significantly decreased hemoglobin level required a blood or blood products transfusion. This rate is similar to that in previous reports (3).

The AVF was the most frequently encountered vascular complication in our study; AVF is an abnormal connection between the arteries and veins in the kidney following the biopsy, causing shunting of arterialized blood into the low-pressure venous system. Small fistulas may be asymptomatic and not visible by gray-scale US, but they can be detected by color Doppler US. A prospective study in which angiography was performed immediately after renal biopsy revealed a 9%–11% incidence of AVF (9). Stiles et al. (6) found AVFs in 10.8% of patients by color Doppler US, and 95% of these resolved spontaneously within two years. Our incidence of AVF was 7.42% (n=13), and all AVFs were diagnosed on Doppler US. Three patients with symptomatic AVFs were treated by transcatheter arterial embolization. In the remaining 10 patients, the AVFs remained asymptomatic and/or resolved spontaneously, and Doppler US follow-up was sufficient.

Pseudoaneurysm is a rare vascular complication that arises when an arterial injury within the kidney leads to a contained hemorrhage. We detected a pseudoaneurysm in two patients, one of whom was diagnosed by a second Doppler scan eight hours after the PRB. Both patients were treated by immediate superselective transcatheter arterial embolization. These lesions are usually unstable, and rupture can lead to life-threatening hemorrhage. Close follow-up with Doppler US allowed us to detect the pseudoaneurysm, and the patients were treated without any mortality.

In our series, we had a relatively high rate (24.0%) of postbiopsy complications compared with the reported incidence rate of complications, 5.8%–23.5% (2, 3, 5, 10). There are several

possible explanations for this high rate. Our study population consisted of only children between the ages of 1 and 17 years. Most of the reported data are from studies containing adults, and it is possible that pediatric PRBs are more prone to complications. Only a few studies have evaluated PRB complications in pediatric patients. Skalova and Rejtar (5) reported only minor complications and no major complications after PRB in their group of pediatric patients (39/166, 23.5%). Al Menawy et al. (11) reported a 10.2% minor complication rate among 108 consecutive renal biopsies in children and adolescents. The complication rates in these studies were lower than in our group of patients, but the studies used different follow-up protocols compared to our close Doppler US follow-up policy. We used Doppler US, which is capable of detecting even asymptomatic tiny AVFs and hematomas, possibly leading to a higher detection rate. However, follow-up with Doppler US offers invaluable benefits, such as the detection of late-onset dominant AVFs and pseudoaneurysms, which can be life saving.

The standard of care after PRB is bed rest with close observation for 24 hours. However, some institutes discharge patients after only 6–8 hours of observation due to the safety profile of the procedure and a desire to decrease costs. Marwah and Korbet (12) found that 77% of complications were apparent by eight hours of observation and concluded that the optimal observation period was 23 to 24 hours, capturing 98% of complications overall and 100% of serious complications after PRB. In another report by Stiles et al. (6), 46% of major complications were detected in the first 4 hours, 79% in the first eight hours, and 100% in the first 12 hours. Similarly, Whittier and Korbet (3) suggested that 24 hours remains the optimal observation period, whereas less than eight hours risks missing 33% of complications after biopsy. We performed the second Doppler US scans at the 24th hour after biopsy, and we detected all vascular complications in our study group. By the aid of intensive Doppler US follow-up, we were able to detect three clinically significant AVFs and a pseudoaneurysm that could have been fatal if overlooked. Only one complication (urinoma) was diagnosed on US more than 24 hours after PRB, based on the patient's complaints. We may have missed some minor complications that occurred after 24 hours, but none of the patients returned with signs of a significant complication after 24 hours, and none showed any signs of a complication during the long-term follow-up.

We found no statistically significant association between the number of biopsy attempts and the complication rate. We performed all biopsies with only one or two attempts, and this could be the reason for this result. We found no significant relationship between the rate of complications and demographic variables, clinical data, or baseline chemistry. Similarly, Manno et al. (10) evaluated the predictive value of demographics, clinical data, baseline chemistry, and needle size for bleeding complications in US-guided PRB and found that only gender, age, and baseline partial thromboplastin time had significant predictive value for postbiopsy bleeding complications. Biopsies were not performed in patients with an abnormal coagulation profile in our study.

There may be some limitations of the current study. First, complications occurring after discharge may have been missed, but clinical follow-up showed no signs of late-onset complications. Second, detailed clinical information (such as arterial blood pressure) at the time of PRB, which may have been related to complications, was not considered.

In conclusion, renal biopsy remains fundamental to the diagnosis, prognosis, and treatment of kidney disease in pediatric patients. PRB remains a relatively safe procedure, but there is some risk of serious complications. Vascular complications may develop acutely following a PRB, and they can be dangerous. Doppler US examination is an effective imaging method to detect vascular complications, improving the management of patients after PRB. It is important to recognize the Doppler US appearance of complications associated with PRB and to perform close follow-up with Doppler US within the first 24 hours.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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