Safety and Complications of Percutaneous Kidney Biopsies in 715 Children and 8573 Adults in Norway 1988–2010

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Summary

Background and objectives Skepticism about performing renal biopsies is often because of uncertainty regarding risk of complications. The aim of this study was to evaluate safety and relevant complications of renal biopsies in pediatric and adult patients in a large national registry study.

Design, setting, participants, & measurements Kidney biopsies reported in the Norwegian Kidney Biopsy Registry from 1988 to 2010 were included. Risk factors for major complications (blood transfusion and/or surgical or catheter intervention) were analyzed using logistic regression statistics.

Results Of the 9288 biopsies included, 715 were from children, and 8573 were from adults (≥18 years). Median age was 49 years (range=2 weeks to 94 years). Gross hematuria appeared after biopsy in 1.9% of the patients; 0.9% of patients needed blood transfusion, and 0.2% of patients needed surgical intervention/catheterization. The frequencies were 1.9%, 0.9%, and 0.2% in adults and 1.7%, 0.1% and 0.1% in children, respectively; 97.9% of the biopsies were without complications. In unadjusted analyses, risk factors for major complications were age>60 years, estimated GFR<60 ml/min per 1.73 m^2, systolic hypertension, acute renal failure, and smaller clinical center size (<30 biopsies/yr). Adjusted analyses (adjusted for age and/or estimated GFR) showed higher odds ratios (OR) only for smaller clinical center (OR=1.60 [1.02–2.50]) and low estimated GFR (estimated GFR=30–59 ml/min per 1.73 m^2 [OR=4.90 (1.60–14.00)] and estimated GFR<30 ml/min per 1.73 m^2 [OR 15.50 (5.60–43.00)]).

Conclusions Percutaneous renal biopsy is a low-risk procedure in all ages. Reduced estimated GFR and smaller center size are associated with an increased risk of major complications.

Clin J Am Soc Nephrol 7: 1591–1597, 2012. doi: 10.2215/CJN.02150212

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Introduction

Renal biopsies have been performed for more than a century (1), and percutaneous biopsy methodology was established in the 1940s (2,3). The technical advances in imaging diagnostics and biopsy procedure have evolved from indirect visualization to real-time ultrasound guidance (4). Most centers use an automated spring-loaded biopsy device constructed in the end of the 1980s (5–7). As a consequence, the general safety and complication rate of the procedure has substantially improved. Kidney morphology is essential in the diagnosis and subsequent evaluation of disease activity (8,9). Indeed, knowledge of the morphologic changes in kidney biopsies has been shown to alter the treatment in a high percentage of the patients (10,11). Postbiopsy bleeding (hematoma and hematuria) is the primary complication of renal biopsies (12–14). However, most of the perirenal hematomas are minor and without clinical significance, and major complications are infrequent in both adults and children when traditional risk factors, like hypertension and bleeding diathesis, are respected (15,16).

In this study, we report the procedure-related complications and safety issues in the period from April of 1988 to November of 2010 from the Norwegian Kidney Biopsy Registry comprising 8573 adult and 715 pediatric cases.

Materials and Methods

Norwegian Kidney Biopsy Registry has registered clinical and histopathologic data for nearly all patients with a native renal biopsy in Norway (current population of 5 million inhabitants) since April of 1988. All included patients or their designees signed informed consent. The local nephrologists (26 different hospitals) report clinical data in a registry notification form, and histopathological data are reported by a limited group of nephropathologists that examines all the biopsies in one center (Haukeland University Hospital). Information regarding biopsy-related complications was lacking in 357 (3.7%) reports, and these cases were excluded from the study. The remaining 9288 cases were included for the statistical analysis.

All cases were biopsied with percutaneous techniques: 99.7% were ultrasound-guided, and 0.3% were computer tomography-guided.

In the report forms, there were five complication alternatives: hematoma, gross hematuria, blood transfusion, surgery, and a free text field. Angiographic embolization in the free text field was included in the surgery group. The pathologist reported whether the biopsy was representative (*i.e.*, containing sufficient or insufficient material for adequate evaluation). The term complications used in the current study was confined to gross hematuria, blood transfusions, and/or surgery/arterial embolization (*i.e.*, hematoma was not regarded as a significant complication unless associated with one of the other complications listed). The term major complications was defined as blood transfusions and/or surgery/arterial embolization. The following variables were explored: age, estimated GFR (eGFR; calculated with the Modification of Diet in Renal Disease formula in adults [17] and the revised Schwartz formula in children [18]), systolic BP, proteinuria (u-protein≥0.3 g/d or reported proteinuria or nephritic syndrome), hematuria (u-dipstick≥1 or reported hematuria or nephritic syndrome), CKD stages 3–5 (eGFR<60 ml/min per 1.73 m^2), nephrotic syndrome (u-protein≥3.0 g/d and s-albumin<35 g/L or clinician-marked nephrotic syndrome), acute renal failure, rapidly progressive glomerulonephritis, amyloidosis, biopsy needle size (gauge), number of needle passes, specialty of the doctor performing the biopsy, and center size (≥650 or <650 biopsies performed during the study period corresponding to ≥30 or <30 biopsies/yr).

The SPSS 17 package (SPSS Inc., Chicago, IL) was used for statistical analysis. Significance testing was performed by *t* test and Mann–Whitney test. Differences of proportions between patient groups were compared with the chi-squared test (Pearson). A *P* value of 0.05 was considered statistically significant, and all tests were two-tailed. Logistic regression analysis was performed for the analysis of risk factors, and both unadjusted analyses and analyses adjusted for categories of age (categorized as <18, 18–59, and ≥60 years) and eGFR (categorized as ≥60, 30–59, and <30 ml/min per 1.73 m^2) were performed. Age was only adjusted for eGFR, and eGFR was only adjusted for age.

Results

The median age of the 9288 patients was 49 years (range=2 weeks to 94 years). There were 715 children (<18 years of age), with a mean age of 12.0 years (SD=4.9; range=2 weeks to 18 years); 8573 patients were adults (≥18 years), with a mean age of 50.6 years (SD=17.7; range=18–94 years). The clinical characteristics at the time of renal biopsy are shown in Table 1. The most common clinical sign was proteinuria, which was seen in approximately four of five of all the patients, and similar figures were seen in both adults and children (Table 1). Hematuria and nephrotic syndrome were more frequent in children than adults, and chronic renal failure and acute renal failure were more common in adults; 5.9% of the biopsies in the study period were rebiopsies.

The biopsy-related complications are shown in Table 2. Serious complications were infrequent in both children and adults (Table 2). The total frequency of blood transfusion or intervention (surgery or angiography) was low (0.9% and 0.2% of all cases, respectively). There was a significantly lower frequency of blood transfusions in children (only one child) than adults. Less than 2% had macroscopic hematuria (Table 2), whereas hematoma was reported in 3.9% of all cases. The frequency of hematoma was significantly higher in children (8.1%) than adults (3.5%; $P<0.001$). During the last 5 years of the study period, the number of hematomas was higher (7.4% compared with 3.9% in the whole study period), and this change was more evident in children (18.9% compared with 8.1% in the whole study period). The registry did not specify the criteria for the diagnosis of postprocedural hematoma in terms of size or associated clinical symptoms. The total number of hematoma should, therefore, be taken with caution and may reflect an increasing use of systematic safety routines, including postbiopsy ultrasound examination, especially in children. The rates of gross hematuria, blood transfusion, and invasive procedures remained stable throughout the study period (Figure 1).

In the free text field, one patient was reported with arteriovenous fistula, one patient was reported with urosepsis and one patient was reported with ascites leakage. No patient was reported with death. A total of 97.9% of the patients (9092 patients) had no complications.

Figure 2 shows the change in biopsy needle size used in the study period. There was an overall shift from 14 to 16

Table 1. Clinical characteristics at the time of renal biopsy given as percentages (total numbers in parentheses) separately for adults and children

Clinical Characteristics	Total (%) (9288)	Adults (%) (8573)	Children (%) (715)	*P* Value
Proteinuria (>0.3 g/d)[a]	81.0 (7522)	81.1 (6955)	79.3 (567)	0.23
Hematuria[b]	68.8 (6393)	68.4 (5862)	74.3 (531)	0.001[c]
CKD stages 3–5[d]	61.6 (5726)	64.9 (5568)	22.1 (158)	<0.001[c]
Nephrotic syndrome[e]	28.7 (2667)	27.8 (2380)	40.1 (287)	<0.001[c]
Acute renal failure	18.6 (1723)	19.0 (1630)	13.0 (93)	<0.001[c]
Rapidly progressive glomerulonephritis	3.4 (314)	3.3 (284)	4.2 (30)	0.21

[a]u-Protein≥0.3 g/d or clinician marked proteinuria or nephritic syndrome.
[b]u-Dipstick≥1 or clinician marked hematuria or nephritic syndrome.
[c]Significant difference between adults and children.
[d]CKD stages 3–5 indicate eGFR<60 ml/min per 1.73 m^2.
[e]u-Protein≥3.0 g/d and s-albumin<35 g/L or clinician marked nephrotic syndrome.

Table 2. Frequency of different complications given as percentages (total numbers in parentheses) separately for adults and children

Type of Complication	All Patients (%) (9288)	Adults (%) (8573)	Children (%) (715)	*P* Value
Gross hematuria	1.9 (178)	1.9 (167)	1.5 (11)	0.44
Blood transfusion	0.9 (79)	0.9 (78)	0.1 (1)	0.03[a]
Surgery/arterial embolization	0.2 (18)	0.2 (17)	0.1 (1)	0.73
Complications[b]	2.6 (215)	2.7 (233)	1.8 (13)	0.15
Major complications[c]	0.9 (88)	1.0 (86)	0.3 (2)	0.06

[a]Significant difference between adults and children.
[b]Complications were gross hematuria, blood transfusions, and/or surgery/arterial embolization.
[c]Major complications were blood transfusions and/or surgery/arterial embolization.

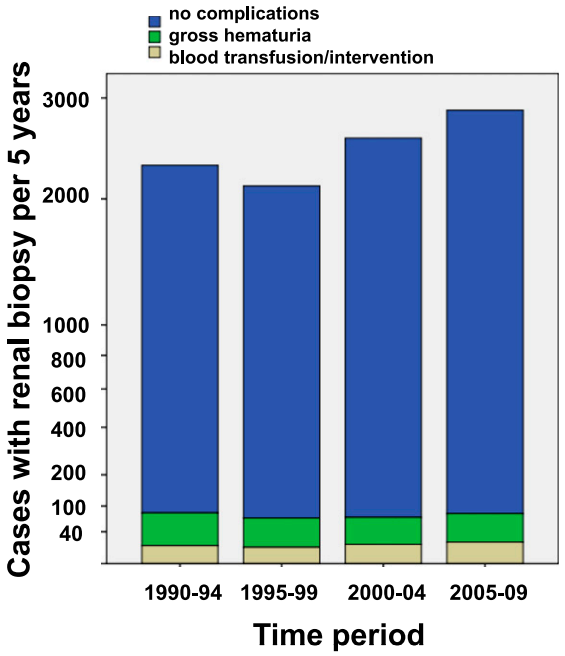

Figure 1. | Kidney biopsy complications.

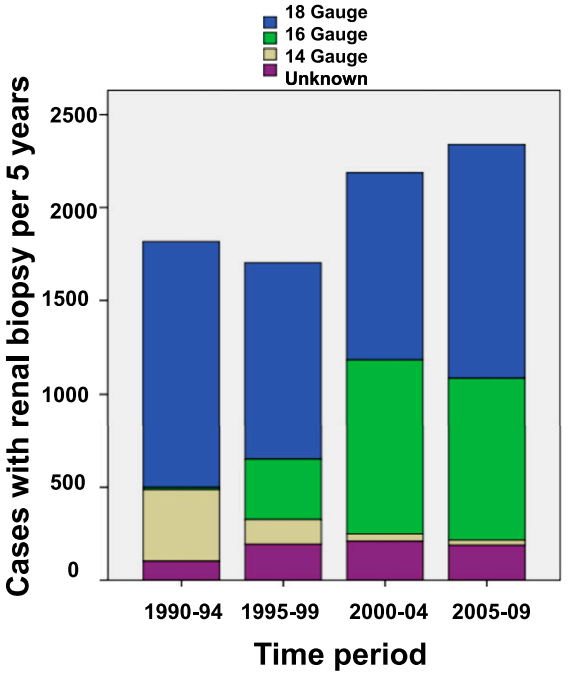

Figure 2. | Kidney biopsy needle sizes.

gauge (G) size, and in the majority of the biopsies (82%), the needle size was 16 or 18 G (Table 3). A significantly higher rate of macroscopic hematuria was reported after use of 18 G compared with 16 G. Major complications (Table 3) were not related to needle size. The percentage of biopsies containing representative tissue was similar across all needle types (94.3%). The median number of glomeruli in the tissue samples per subject was 10 (range=0–86), and the number was lowest when an 18-G needle was used (9, range=0–76). In 3.0% of the biopsies, no glomeruli were found.

Analysis of the number of needle passes per biopsy procedure showed that one or two passes were performed in the majority of the patients (47.5% and 37.9%, respectively). The biopsy was performed by a nephrologist in 33.4% of the cases, and this number decreased during the study period (data not shown). Radiologists performed the biopsy in 53.5%, and in 13.1% of the cases, the nephrologist and the radiologist handled the procedure together.

Risk factors for major complications (blood transfusions, surgery, or angiographic embolization) are analyzed in Table 4. Older age, lower eGFR, higher systolic BP, acute renal failure, and smaller center sizes were all highly significant risk factors in the unadjusted analyses. The unadjusted relative risk of major complications was significantly lower in children; when corrected by eGFR level, the risk was similar in children and adults. The needle size, number of passes, and physician specialty did not influence the rate of major complications. The diagnosis of rapidly progressive glomerulonephritis or amyloidosis did not carry any increased procedural risk. A lower eGFR (CKD stages 3–5) and smaller center size (<30 biopsies/yr) were the only significant risk factors after adjustment for age and/or eGFR.

Discussion

The main finding in the present study is that a renal biopsy should be regarded as a safe procedure (both in adults and children) provided that general contraindications are respected, and the overall rate of major complications was less than 1% (Table 2). Of note, the relative risk

Table 3. Comparison of complications and number of glomeruli for different needle diameter

Needle Thickness	14 Gauge	16 Gauge	18 Gauge	Unknown	Total
N total	858	2146	4998	744	8746
Percent total	9.8	24.5	57.1	8.5	100
Percent (*N*) complications[a]	2.6 (22)	2.0 (43)[b]	3.0 (151)	2.3 (17)	2.7 (233)
Percent (*N*) major complications[c]	0.6 (5)	1.2 (25)	0.9 (46)	0.8 (6)	0.9 (82)
Percent (*N*) gross hematuria	2.2 (19)	1.0 (22)[d]	2.4 (118)	1.6 (12)	2.0 (171)
Percent (*N*) blood transfusions	0.2 (2)	1.1 (23)	0.9 (43)	0.7 (5)	0.8 (73)
Percent (*N*) surgery/angiographic embolization	0.4 (3)	0.2 (5)	0.1 (7)	0.3 (2)	0.2 (17)
Percent representative tissue	94.6	93.5	94.5	94.9	94.3
Median number of glomeruli (range)	12 (0–86)[d]	12 (0–61)[d]	9 (0–76)	11 (0–69)[d]	10 (0–86)

[a]Complications were gross hematuria, blood transfusions, and/or surgery/arterial embolization.
[b]$P<0.05$ (P value compared with 18-gauge needle).
[c]Major complications were blood transfusions and/or surgery/arterial embolization.
[d]$P<0.001$ (P value compared with 18-gauge needle).

was even lower in children, and only 2 of 715 children (0.3%) were affected. Importantly, the lowest complication rates were seen in centers performing more than 30 biopsies/yr, indicating the best clinical routines occur when biopsies are done approximately on a weekly basis.

To our knowledge, the current study is the only nationwide registry-based and largest report of renal biopsy complications, and our findings confirm the general impression of low complication rates and improved safety of modern renal biopsy procedures (19). Similar low complication rates have been reported in recent studies (16,19,20) in contrast to earlier studies (reporting 5%–7% complication rates) (21–25). The crucial safety evaluation of kidney biopsies is characterized by the overall risk and frequency of major complications, which in our study, are defined as need of blood transfusion and/or surgery or catheter-based intervention (embolization) secondary to bleeding, and they should not be jeopardized by procedural events of minor clinical relevance. Therefore, the description of kidney biopsy complications should be restrained to clinically meaningful complications, especially because there often is an unfounded skepticism toward biopsies because of many reports of frequent occurrence of clinically less relevant events, like microscopic hematuria, transient gross hematuria, and asymptomatic minor perirenal hematoma. The latter should, in fact, be regarded as an epiphenomenon because of the high incidence (reported in up to 60%–90% of cases after examination prospectively with ultrasonography or computertomography). Of note, several authors found that a hematoma alone is not a reliable predictor of a serious adverse outcome (7,16,26,27). Perirenal hematomas should not be regarded as a clinical significant complication in the absence of significant bleeding or persisting pain necessitating delayed hospitalization. The number of hematomas in the present study was significantly higher in children, probably because of a more systematic use of routine ultrasonographic examination, and this finding must, therefore, be interpreted with caution. Such a view is supported by several studies. The work by Kersnik Levart *et al.* (16) found mostly small perinephritic hematoma in 63.2% of 87 children, and 10 of the hematomas (11.5%) were more than 2 cm in diameter. Other authors report that the majority of hematomas are less than 2 cm, and about 1%–2% are described as symptomatic (15,28,29).

In the present large study, gross hematuria was seen in less than 2%, and the benign course supports the view that such events should not be considered serious complications unless bleeding is of a magnitude causing a significant decline in hemoglobin concentration or delayed hospitalization. The great majority of the patients (97.9%) had neither macroscopic hematuria nor blood transfusion or surgery/embolization. These findings are in line with other studies (27,30–32).

In the current study, the risk factors for major complications were older age, low eGFR, systolic hypertension, acute renal failure, and smaller center size (<30 biopsies/yr) in the unadjusted analyses. Only low eGFR and smaller center size were associated with increased risk in the adjusted analyses. In fact, the relative risk was 16 times higher when eGFR was below 30 ml/min per 1.73 m^2 (Table 4). Although elevated risk has been shown previously, the increased risk incurred by kidney failure may be underscored in many reports (14,21,33,34), and the work by Whittier and Korbet (25) found that serious complications were about two times as common in patients with serum creatinine above 5.0 mg/dl. It is conceivable that this observation is associated with the general increased bleeding tendency seen in kidney failure patients (33). Similarly, acute renal failure more than doubled the risk of major complications in our study, and the reason for this finding is probably also related to increased bleeding tendency (Table 4). As a consequence, careful recognition of reduced kidney function before the procedure is important. To minimize biopsy risk, meticulous control of clinical routines (to avoid inappropriate use of anticoagulant medication 1 week before as well as after the biopsy procedure) is mandatory, especially in patients with reduced eGFR.

An overview of studies from many centers shows the wide variation in complication rates (27). In the current nationwide registry study, we found the lowest complication rates in the most active and experienced centers (*e.g.*, university hospitals performing biopsies, on average, on a weekly basis or >30 biopsies/yr). This finding is a reassuring observation that strengthens the importance of introducing adequate

Table 4. Odds ratios for major complications (blood transfusion, surgery, and/or arterial embolization)

	N Total	*N* (%) with Major Complications	Unadjusted Analyses		Adjusted Analyses[a]	
			Odds Ratio (CI)	*P* Value	Odds Ratio (CI)	*P* Value
Age (years)						
<18	715	2 (0.3)	0.40 (0.10–1.70)		0.46 (0.06–3.40)	
18–59	5609	39 (0.7)	1.00 (ref)	<0.001	1.00 (ref)	0.34
≥60	2964	47 (1.6)	2.30 (1.50–3.50)		1.20 (0.80–2.00)	
eGFR (ml/min per 1.73 m^2)						
≥60	3307	4 (0.1)	1.00 (ref)		1.00 (ref)	
30–59	2307	14 (0.6)	5.00 (1.70–15.00)	<0.001	4.90 (1.60–14.00)	<0.001
<30	3309	66 (2.0)	16.80 (6.10–46.00)		15.50 (5.60–43.00)	
Systolic BP						
<140	4141	27 (0.7)	1.00 (ref)		1.00 (ref)	
140–159	2476	24 (1.0)	1.50 (0.86–2.60)	0.001	1.10 (0.61–1.90)	0.29
≥160	2127	32 (1.5)	2.30 (1.40–3.90)		1.30 (0.77–2.30)	
Proteinuria (g/d)						
0.3–0.99	2435	18 (0.7)	1.00 (ref)		1.00 (ref)	
1–2.99	1933	23 (1.2)	1.60 (0.87–3.00)	0.28	1.60 (0.84–3.00)	0.14
≥3.0	3154	33 (1.0)	1.40 (0.80–2.50)		1.60 (0.89–2.90)	
Acute renal failure						
Yes	1723	30 (1.7)	2.29 (1.50–3.60)	<0.001	1.10 (0.69–1.80)	0.48
No	7576	58 (0.8)	1.00 (ref)		1.00 (ref)	
Rapidly progressive glomerulonephritis						
Yes	314	3 (1.0)	1.00 (0.31–3.20)	0.99	1.70 (0.54–5.50)	0.41
No	8974	85 (1.0)	1.00 (ref)		1.00 (ref)	
Amyloidosis						
Yes	255	3 (1.2)	1.21 (0.38–3.90)	0.75	0.92 (0.28–3.00)	0.88
No	6256	61 (1.0)	1.00 (ref)		1.00 (ref)	
Needle size (gauge)						
14	858	5 (0.6)	0.63 (0.25–1.60)		0.79 (0.31–2.00)	
16	2146	25 (1.2)	1.30 (0.78–2.10)	0.55	1.40 (0.85–2.30)	0.92
18	4998	46 (0.9)	1.00 (ref)		1.00 (ref)	
Unknown	744	6 (0.8)	0.88 (0.37–2.10)		0.93 (0.39–2.20)	
Number of needle passes						
1	698	6 (0.9)	1.60 (0.40–6.40)		1.80 (0.44–7.10)	
2	557	3 (0.5)	1.00 (ref)	0.18	1.00 (ref)	0.35
3	158	4 (2.5)	4.80 (1.10–22.00)		4.00 (0.87–18.00)	
≥4	56	1 (1.8)	3.40 (0.34–33.00)		2.80 (0.28–28.00)	
Specialty						
Nephrologist	2975	22 (0.7)	1.00 (ref)		1.00 (ref)	
Radiologist	4766	50 (1.0)	1.40 (0.86–2.40)	0.17	1.10 (0.65–1.80)	0.66
Both	1163	30 (2.6)	1.50 (0.76–3.00)		1.20 (0.58–2.30)	
Center size (biopsies in study period)						
≥650	4873	32 (0.7)	1.00 (ref)		1.00 (ref)	
<650	4415	56 (1.3)	1.90 (1.30–3.00)	0.003	1.60 (1.02–2.50)	0.04

CI, confidence interval; eGFR, estimated GFR.
[a]Corrected for categories of age and eGFR. Age is only corrected for eGFR, and eGFR is only corrected for age.

training programs (27) and supports the view that modern biopsy procedures are safe in experienced hands. Furthermore, the general low complication rate indicates similar adequate clinical practice among our centers. This finding is in contrast to two recent nationwide surveys from the United Kingdom (19) and France (35) showing relatively great variability in clinical practice and complication rates among centers and highlighting the importance of establishing safe procedural standards.

Although there has been a change in practice (fewer patients with isolated microscopic hematuria and more elderly patients undergo a biopsy), the total frequency of renal biopsies in Norway has remained stable for the last 20 years and was 10.9/100,000 in 2009 (13/100,000 in adults and 3.8/100,000 in children). Other reports have shown a range of biopsy frequencies between 3.3 and 23 per 100,000 inhabitants (36,37).

In many centers, the numbers of kidney biopsies are relatively low in children because of a traditional view of many

nephrologists and pediatricians that the procedure is associated with an unacceptable high complication risk. General skepticism to the routine use of anesthesia is probably also contributing to the restraint of kidney biopsies. In our cohort, kidney biopsies in children below the age of 15 years were usually performed with short-lasting general anesthesia (sedation) without intubation. Our experience supports the findings in the work by Mauer and Drummond (38) that general anesthesia often can be avoided in patients above the age of 12 years (9). No complications caused by general anesthesia were reported in our study. Hence, the present encouraging findings should contribute to attenuating unfounded skeptic attitudes against kidney biopsies in children as long as general clinical safety routines are respected (14).

Valid biomarkers are generally lacking in many renal diseases, and several important studies have shown the role of kidney morphology as an important prognostic and therapeutic guide in common renal diseases (*e.g.*, IgA nephritis [39], lupus nephritis [40], and diabetes nephropathy [41]); potential prognostic capacity has been shown in orphan diseases like Fabry disease (42). Furthermore, modern therapies of kidney diseases include potent and potentially toxic drug intervention in many common as well as a rapidly increasing number of rare diseases identified by genetic molecular techniques. The latter is mirrored by an increasing general focus from biotechnology companies on development of orphan drugs (43). Importantly, the Food and Drug Administration and the European Medical Association have recently presented guidelines that highlight the importance of meticulous safety and follow-up control of tolerance and side effects of new medical treatment in children (44). Hence, this fundamental change of attitude should also be reflected in the use of evidence-based risk evaluation when it comes to indications of renal biopsy.

It has been suggested that the complication rate is lower with the use of thin biopsy needles (27,45). However, valid comparative studies on needle size and complications in native kidneys are lacking. In the current study, the shift of needle size from 14 to 16 G over time (Figure 2) and the dominance of 16- and 18-G needles (Table 3) may be seen as a result of higher focus, in general, on minimizing risk factors and the acceptance of less tissue per needle pass. The median number of glomeruli per subject in our study (10, range=0–86) was comparable with the median number in other studies (7) and significantly higher by use of both 14- and 16-G needles compared with 18-G needles ($P<0.001$). However, the percentage of biopsies characterized as representative tissue was in the same level irrespective of needle size. Surprisingly, there was a significantly higher rate of gross hematuria by use of 18 compared with 16 G. This finding has not been reported previously and may be because of the tendency of thinner needles to deviate from the lower pole sector in a proximal direction (where vessel density is higher), with subsequent bleeding into the pelvis. Of note, serious complications, like surgery/embolization and blood transfusions, were of the same order in all needle sizes (Tables 3 and 4).

Interestingly, we did not observe any influence of number of needle passes on the rate of serious complications. The reason for this finding is not known, but it may be related to restraint with multiple needle insertions in high-risk patients and children. In our study, the majority of the biopsy cases (85.4%) had one or two needle passes, and the percentage of patients with three or more passes was low (14.6%). This finding is in contrast to the recent British audit, where the standard target of >80% needing three or less passes was achieved in 86.4% (19). No difference in complication rate was seen between different medical specialists. In our study, most biopsies were performed by a radiologist, whereas 33.4% were done by a nephrologist; the latter percentage has been decreasing over the last decade as reported previously, and it represents an educational challenge in nephrology (27).

Limitations of this study are potential underreporting, reporting bias, and lack of detailed information about other potential complications not prespecified in the registry report form. All GFR analyses were based on eGFR, although imprecision of eGFR is well known in subgroups of patients.

In conclusion, we have shown that kidney biopsies are safe procedures with low complication rates in children and adults when contraindications are respected. Lower eGFR and biopsies performed in smaller centers are risk factors.

Acknowledgments

The authors are grateful to the Norwegian doctors who reported data to the Norwegian Kidney Biopsy Registry.

Disclosures

None.

References

1. Cameron JS, Hicks J: The introduction of renal biopsy into nephrology from 1901 to 1961: A paradigm of the forming of nephrology by technology. *Am J Nephrol* 17: 347–358, 1997
2. Iversen P, Brun C: Aspiration biopsy of the kidney. *Am J Med* 11: 324–330, 1951
3. Alwall N: Aspiration biopsy of the kidney, including i.a. a report of a case of amyloidosis diagnosed through aspiration biopsy of the kidney in 1944 and investigated at an autopsy in 1950. *Acta Med Scand* 143: 430–435, 1952
4. Donovan KL, Thomas DM, Wheeler DC, Macdougall IC, Williams JD: Experience with a new method for percutaneous renal biopsy. *Nephrol Dial Transplant* 6: 731–733, 1991
5. Yoshimoto M, Fujisawa S, Sudo M: Percutaneous renal biopsy well-visualized by orthogonal ultrasound application using linear scanning. *Clin Nephrol* 30: 106–110, 1988
6. Wiseman DA, Hawkins R, Numerow LM, Taub KJ: Percutaneous renal biopsy utilizing real time, ultrasonic guidance and a semi-automated biopsy device. *Kidney Int* 38: 347–349, 1990
7. Riehl J, Maigatter S, Kierdorf H, Schmitt H, Maurin N, Sieberth HG: Percutaneous renal biopsy: Comparison of manual and automated puncture techniques with native and transplanted kidneys. *Nephrol Dial Transplant* 9: 1568–1574, 1994
8. Mauer M, Zinman B, Gardiner R, Suissa S, Sinaiko A, Strand T, Drummond K, Donnelly S, Goodyer P, Gubler MC, Klein R: Renal and retinal effects of enalapril and losartan in type 1 diabetes. *N Engl J Med* 361: 40–51, 2009
9. Steinke JM, Sinaiko AR, Kramer MS, Suissa S, Chavers BM, Mauer M; International Diabetic Nephopathy Study Group: The early natural history of nephropathy in Type 1 Diabetes: III. Predictors of 5-year urinary albumin excretion rate patterns in initially normoalbuminuric patients. *Diabetes* 54: 2164–2171, 2005
10. Richards NT, Darby S, Howie AJ, Adu D, Michael J: Knowledge of renal histology alters patient management in over 40% of cases. *Nephrol Dial Transplant* 9: 1255–1259, 1994
11. Stratta P, Canavese C, Marengo M, Mesiano P, Besso L, Quaglia M, Bergamo D, Monga G, Mazzucco G, Ciccone G: Risk management of renal biopsy: 1387 cases over 30 years in a single centre. *Eur J Clin Invest* 37: 954–963, 2007
12. Shidham GB, Siddiqi N, Beres JA, Logan B, Nagaraja HN, Shidham SG, Piering WF: Clinical risk factors associated with

bleeding after native kidney biopsy. *Nephrology (Carlton)* 10: 305–310, 2005
13. Soares SM, Fervenza FC, Lager DJ, Gertz MA, Cosio FG, Leung N: Bleeding complications after transcutaneous kidney biopsy in patients with systemic amyloidosis: Single-center experience in 101 patients. *Am J Kidney Dis* 52: 1079–1083, 2008
14. Diaz-Buxo JA, Donadio JV Jr: Complications of percutaneous renal biopsy: An analysis of 1,000 consecutive biopsies. *Clin Nephrol* 4: 223–227, 1975
15. Mendelssohn DC, Cole EH: Outcomes of percutaneous kidney biopsy, including those of solitary native kidneys. *Am J Kidney Dis* 26: 580–585, 1995
16. Kersnik Levart T, Kenig A, Buturović Ponikvar J, Ferluga D, Avgustin Cavić M, Kenda RB: Real-time ultrasound-guided renal biopsy with a biopsy gun in children: Safety and efficacy. *Acta Paediatr* 90: 1394–1397, 2001
17. Levey AS, Coresh J, Greene T, Marsh J, Stevens LA, Kusek JW, Van Lente F; Chronic Kidney Disease Epidemiology Collaboration: Expressing the Modification of Diet in Renal Disease Study equation for estimating glomerular filtration rate with standardized serum creatinine values. *Clin Chem* 53: 766–772, 2007
18. Schwartz GJ, Muñoz A, Schneider MF, Mak RH, Kaskel F, Warady BA, Furth SL: New equations to estimate GFR in children with CKD. *J Am Soc Nephrol* 20: 629–637, 2009
19. Hussain F, Mallik M, Marks SD, Watson AR; British Association of Paediatric Nephrology: Renal biopsies in children: Current practice and audit of outcomes. *Nephrol Dial Transplant* 25: 485–489, 2010
20. Bohlin AB, Edström S, Almgren B, Jaremko G, Jorulf H: Renal biopsy in children: Indications, technique and efficacy in 119 consecutive cases. *Pediatr Nephrol* 9: 201–203, 1995
21. al Rasheed SA, al Mugeiren MM, Abdurrahman MB, Elidrissy AT: The outcome of percutaneous renal biopsy in children: An analysis of 120 consecutive cases. *Pediatr Nephrol* 4: 600–603, 1990
22. Abdurrahman MB: Percutaneous renal biopsy in a developing country: Experience with 300 cases. *Ann Trop Paediatr* 4: 25–30, 1984
23. Edelmann CM Jr, Greifer I: A modified technique for percutaneous needle biopsy of the kidney. *J Pediatr* 70: 81–86, 1967
24. Carvajal HF, Travis LB, Srivastava RN, De Beukelaer MM, Dodge WF, Dupree E: Percutaneous renal biopsy in children—an analysis of complications in 890 consecutive biopsies. *Tex Rep Biol Med* 29: 253–264, 1971
25. Whittier WL, Korbet SM: Timing of complications in percutaneous renal biopsy. *J Am Soc Nephrol* 15: 142–147, 2004
26. Doyle AJ, Gregory MC, Terreros DA: Percutaneous native renal biopsy: Comparison of a 1.2-mm spring-driven system with a traditional 2-mm hand-driven system. *Am J Kidney Dis* 23: 498–503, 1994
27. Korbet SM: Percutaneous renal biopsy. *Semin Nephrol* 22: 254–267, 2002
28. Eiro M, Katoh T, Watanabe T: Risk factors for bleeding complications in percutaneous renal biopsy. *Clin Exp Nephrol* 9: 40–45, 2005
29. Zhang PP, Ge YC, Li SJ, Xie HL, Li LS, Liu ZH: Renal biopsy in type 2 diabetes: Timing of complications and evaluating of safety in Chinese patients. *Nephrology (Carlton)* 16: 100–105, 2011
30. Parrish AE: Complications of percutaneous renal biopsy: A review of 37 years' experience. *Clin Nephrol* 38: 135–141, 1992
31. Hergesell O, Felten H, Andrassy K, Kühn K, Ritz E: Safety of ultrasound-guided percutaneous renal biopsy-retrospective analysis of 1090 consecutive cases. *Nephrol Dial Transplant* 13: 975–977, 1998
32. Manno C, Strippoli GF, Arnesano L, Bonifati C, Campobasso N, Gesualdo L, Schena FP: Predictors of bleeding complications in percutaneous ultrasound-guided renal biopsy. *Kidney Int* 66: 1570–1577, 2004
33. Ferguson JH, Lewis JH, Zucker MB: Bleeding tendency in uremia. *Blood* 11: 1073–1076, 1956
34. Escolar G, Díaz-Ricart M, Cases A: Uremic platelet dysfunction: Past and present. *Curr Hematol Rep* 4: 359–367, 2005
35. Bollée G, Martinez F, Moulin B, Meulders Q, Rougier JP, Baumelou A, Glotz D, Subra JF, Ulinski T, Vrigneaud L, Brasseur J, Martin L, Daniel L, Kourilsky O, Deteix P, Sie P, Ronco P, Houillier P: Renal biopsy practice in France: Results of a nationwide study. *Nephrol Dial Transplant* 25: 3579–3585, 2010
36. Briganti EM, Dowling J, Finlay M, Hill PA, Jones CL, Kincaid-Smith PS, Sinclair R, McNeil JJ, Atkins RC: The incidence of biopsy-proven glomerulonephritis in Australia. *Nephrol Dial Transplant* 16: 1364–1367, 2001
37. Schena FP; The Italian Group of Renal Immunopathology: Survey of the Italian Registry of Renal Biopsies. Frequency of the renal diseases for 7 consecutive years. *Nephrol Dial Transplant* 12: 418–426, 1997
38. Mauer M, Drummond K: The early natural history of nephropathy in type 1 diabetes: I. Study design and baseline characteristics of the study participants. *Diabetes* 51: 1572–1579, 2002
39. D'Amico G: Natural history of idiopathic IgA nephropathy: Role of clinical and histological prognostic factors. *Am J Kidney Dis* 36: 227–237, 2000
40. Weening JJ, D'Agati VD, Schwartz MM, Seshan SV, Alpers CE, Appel GB, Balow JE, Bruijn JA, Cook T, Ferrario F, Fogo AB, Ginzler EM, Hebert L, Hill G, Hill P, Jennette JC, Kong NC, Lesavre P, Lockshin M, Looi LM, Makino H, Moura LA, Nagata M; International Society of Nephrology Working Group on the Classification of Lupus NephritisRenal Pathology Society Working Group on the Classification of Lupus Nephritis: The classification of glomerulonephritis in systemic lupus erythematosus revisited. *Kidney Int* 65: 521–530, 2004
41. Tervaert TW, Mooyaart AL, Amann K, Cohen AH, Cook HT, Drachenberg CB, Ferrario F, Fogo AB, Haas M, de Heer E, Joh K, Noël LH, Radhakrishnan J, Seshan SV, Bajema IM, Bruijn JA; Renal Pathology Society: Pathologic classification of diabetic nephropathy. *J Am Soc Nephrol* 21: 556–563, 2010
42. Fogo AB, Bostad L, Svarstad E, Cook WJ, Moll S, Barbey F, Geldenhuys L, West M, Ferluga D, Vujkovac B, Howie AJ, Burns A, Reeve R, Waldek S, Noël LH, Grünfeld JP, Valbuena C, Oliveira JP, Müller J, Breunig F, Zhang X, Warnock DG; all members of the International Study Group of Fabry Nephropathy (ISGFN): Scoring system for renal pathology in Fabry disease: Report of the International Study Group of Fabry Nephropathy (ISGFN). *Nephrol Dial Transplant* 25: 2168–2177, 2010
43. Thompson CA: Companies look for profit in orphan drugs. *Am J Health Syst Pharm* 67: 1892–1896, 2010
44. Borrell Fontelles J, Pekkarinen M: Regulation (EC) No 1901/2006 of the European Parliament and of the Council of 12 December 2006 on medicinal products for paediatric and amending Regulation (EEC) No 1768/92, Directive 2001/20/EC, Directive 2001/83/EC and Regulation (EC) No 726/2004. Available at http://ec.europa.eu/health/files/eudralex/vol-1/reg_2006_1901/reg_2006_1901_en.pdf. Accessed July 14, 2012
45. Piotto GH, Moraes MC, Malheiros DM, Saldanha LB, Koch VH: Percutaneous ultrasound-guided renal biopsy in children—safety, efficacy, indications and renal pathology findings: 14-year Brazilian university hospital experience. *Clin Nephrol* 69: 417–424, 2008

Received: February 29, 2012 **Accepted:** June 27, 2012

Published online ahead of print. Publication date available at www.cjasn.org.

See related editorial, "Nephrology and the Percutaneous Renal Biopsy: A Procedure in Jeopardy of Being Lost Along the Way," on pages 1545–1547.