Percutaneous Ultrasound-Guided Kidney Transplant Biopsy Outcomes: From the Nephrologist to the Radiologist Standpoint

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Key Points
- Ultrasound-guided kidney transplant biopsy is considered safe, with similar complications rates regardless of the performing team.
- Besides well-known risk factors for complications, we found that sex and race are also predictors.
- The performance of kidney transplant biopsy remains an integral part of nephrology training.

Abstract
Background Kidney transplant biopsies are the gold standard for evaluating allograft dysfunction. These biopsies are performed by nephrologists and radiologists under real-time ultrasound guidance. A few studies have examined the outcomes of ultrasound-guided kidney transplant biopsy in transplant recipients; however, none have compared these outcomes between both specialties.

Methods We retrospectively analyzed a cohort of 678 biopsies performed in a single center during a 44-month study period. Biopsies were stratified into two groups based upon the specialist performing the procedure: interventional radiology (IR; N=447) and transplant nephrology (TN; N=231).

Results There were 55 (8%) complications related to biopsies in the entire cohort: 37 (8.2%) in the IR group and 18 (7.7%) in the TN group, without statistical difference between the groups (P=0.94). Blood pressure control and prior use of anticoagulation were significant predictors of complicated biopsies (P=0.004 and 0.02, respectively). Being a woman and prior use of anticoagulation were significant predictors of transfusion of blood products (P=0.01 and 0.01, respectively). Being a woman and blood pressure control were significant predictors of overall perinephric hematoma (P=0.01 and 0.01, respectively), and Black race was a significant predictor of perinephric hematoma without worsening of renal function (P=0.005). The specialist team performing the procedure was not a statistically significant predictor of biopsy complications, transfusion of blood products, or perinephric hematoma with comparable sample yield.

Conclusions Percutaneous ultrasound-guided kidney transplant biopsy performed by transplant nephrologists have similar complication rates when compared with interventional radiologists in an academic center.

Introduction Percutaneous kidney biopsy was described in 1951 by Iversen and Brun (1), and it remains the gold standard for diagnosis in native and transplanted kidneys. Since then, the procedure has evolved as complications have declined (1–6). Nowadays, percutaneous ultrasound-guided kidney transplant biopsy (US-KTB) is performed by transplant nephrologists (TN) and interventional radiologists (IR). Although it is a relatively safe procedure, it is not exempt from complications. Complications such as hematuria, arteriovenous fistula (AVF), and small hematoma occur in up to 17% of kidney biopsies between day 1 and 14 post procedure.
(4–10). Severe complications such as Page kidney, or hydro-nephrosis, AVF, or perinephric hematoma associated with worsening renal function (WRF) range between 0.33% and 3% (7,8) and can result in significant morbidity.

Similar complication rates have been described for native kidney biopsies by both subspecialties (11,12), but no studies have described outcomes in US-KTB performed by IR compared with TN in kidney transplant recipients. The aims of this study were to evaluate the incidence of nonsevere and severe complications related to US-KTB, compare the rates of biopsy complications between specialists performing the procedure, and identify risk factors of post US-KTB complications in a single academic center.

Materials and Methods

We retrospectively identified 573 kidney transplant recipients undergoing US-KTB between January 2013 and August 2016 in our center. Demographics, laboratory data, pathology report on the basis of Banff’s classification, and imaging were reviewed using electronic medical records. Patients <18 years of age, guided computed tomography scan, or intraoperative kidney biopsy were excluded. The groups were stratified on the basis of the specialty performing the procedure (IR versus TN). As transplant nephrology literature differs on the definition of severity of complications, for the purpose of our study, we divided them on the basis of the need for nonsurgical interventions versus surgical intervention according to the absence or presence of WRF as recently described. Nonsevere complications were defined as perinephric hematoma, hydronephrosis, AVF, hemoglobin (Hb) drop >2 g/dl, and transfusion of blood products; severe complications were defined as Page kidney, or hydronephrosis, AVF, or perinephric hematoma associated with WRF.

Anemia was defined as Hb lower than the normal inferior value at our center (<11.1 and <13.3 g/dl for women and men, respectively).

Prebiopsy Protocol

Biopsies were done per protocol (surveillance) and percause (elevated creatinine from baseline, new onset or worsening proteinuria, or donor-specific antibodies). The patients were instructed to stop antiplatelets or anticoagu-lant medications at least 7 days before biopsy. Desmopres-sin (0.3 μg/kg) was administered intravenously when platelet dysfunction was suspected and there were no contraindications. Patient were nil per os after midnight before the procedure. Complete blood count, basic metabolic panel, coagulation parameters, type and screen, and vital signs were obtained before the procedure. US-KTB were cancelled if international normalized ratio (INR) was >1.5, platelet counts were <50,000/mm³, or BP ≥160/90 mm Hg (uncontrolled) was noted after treatment with oral clonidine or intravenous hydralazine.

Biopsy Technique

TN performed biopsies at the bedside using a real-time portable ultrasound Sonosite M-Turbo, C60 x Convex Probe (2-5 MHz) with a 16G automated biopsy needle and performed an ultrasound immediately after each pass to identify any signs of bleeding. TN are trained to visualize glomeruli in samples at the bedside. IR performed biopsies in their suite using a Sonosite edge portable ultrasound C60 x Convex Probe (2-5 MHz) and HFL38x Linear Probe (6–13 MHz) for real-time guidance of all biopsies with an 18G automated biopsy needle. Pathology residents evaluated their samples for the presence of glomeruli. Both specialties performed an immediate postbiopsy ultrasound to diagnose immediate complications and used a cortical tangential approach. Biopsies were done by TN or IR on a first-come-first-serve basis.

Postbiopsy Protocol

All patients were closely monitored for gross hematuria, flank pain, and/or hypotension. TN patients remained in a supine position in the transplant unit with a 5 pound “sandbag” applied to the biopsy site for 6 hours. Vital signs were monitored every 15 minutes for the first 2 hours and then hourly for the next 4 hours along with macroscopic evaluation of the urine and pain assessment by the nursing staff. Complete blood count was obtained 3 hours after the procedure. IR patients remained in their recovery room for 2–4 hours and were transferred to the transplant unit to continue with postbiopsy monitoring. If any complication was suspected, an emergent ultrasound of the transplant kidney or/and computed tomography scan of the abdomen and pelvis was obtained. The study was approved by our Institutional Review Board (20170575).

Statistical Analyses

All statistical analyses were performed using R Studio v1.4.1106 (The R Foundation for Statistical Computing, Vienna, Austria). Differences in categorical measures between IR and TN groups were assessed using Pearson’s chi-squared test with Yates’s continuity correction. Differences in quantitative measures between the groups were assessed using the Welch two-sample t test. Multivariable logistic regression was conducted to predict the incidence of all outcomes. The logistic regression included the following variables: age, sex, specialty team, race, BP control, body mass index (BMI), comorbidities, prior renal transplant, transplant type and location, antiplatelet therapy, anticoagulation therapy, desmopressin use, steroid use, creatinine, BUN, platelets, INR, Hb level, biopsy indication, needle size, degree of kidney fibrosis, and simian virus 40 positivity. The statistically significant variables found in the regression analyses were identified as the predictors of transfusion of blood products and perinephric hematoma outcomes. These predictors were then put into a simplified multivariable regression model to report the adjusted odds ratio (AOR) and 95% confidence intervals (95% CIs). The fit of these models was evaluated by the significance of the overall model and the coefficient of multiple determination ($R^2$). P<0.05 indicated statistical significance.

Results

Demographics

A total of 678 US-KTB were performed in 573 patients in a 44-month period. Of these, 447 were done by IR and 231 by TN. Median patient age at the time of the biopsy was 53
years. Sixty percent of the biopsies were performed in men and 40% in women. The most common comorbidities were hypertension (88%), diabetes mellitus (36%), coronary artery disease (15%), systemic lupus erythematosus (SLE; 8%), hepatitis (7%), and HIV (3%). Seventy-four percent received a transplant from a deceased donor and 26% from a living donor. Forty-one percent were on antiplatelet therapy and 6% on anticoagulation therapy, held 1 week before the biopsy. Nineteen percent had a BMI between 30 and 34.9 kg/m², and 10% had a BMI ≥35 kg/m². BP at the time of the biopsy was uncontrolled in 24% and controlled in 76% of cases. Mean serum creatinine at biopsy was 2.7 mg/dl (2±SD), BUN 38 mg/dl (22±SD), platelets 216 K/μl (79±SD), INR 0.99 (0.1±SD), and Hb 10.7 g/dl (1.8±SD). Desmopressin was administered in 120 cases. Steroids were initiated before biopsy in 232 cases. Patients’ BP control, diabetes mellitus, and transplant location were among the demographic variables that showed a statistical difference between the IR and TN group. Eighty-two percent of the biopsies were per cæ. The median numbers of core biopsies were three for IR and two for TN. The median glomeruli were 14 (0–56) in the IR group and 13 (0–51) in the TN group. The only statistical difference found between the groups were the level of Hb, hematocrit (Hct), and needle size (P=0.001; Table 1).

**Post-KTB Complications**

Overall complications were found in a total of 55 (8%) biopsies, with 37 cases in the IR group and 18 cases in the TN group (P=0.94). The median number of days for postbiopsy complications for the IR group was 2 (0–30), with 70% during the first 15 days: 13% of the complications were on the day of biopsy, 26% occurred 24 hours post biopsy, and 11% were >15 days post biopsy. For the TN group, the median number of days for post biopsy complications was 1 (0–32), with 46% up to 15 days post biopsy: 21% of the complications were on the day of biopsy, 26% occurred 24 hours post biopsy, and 14% were >15 days post procedure. There was no significant difference in the rate and type of complications for recipients up to 3 months post transplant between the groups (P=0.24). There was no significant difference in the rate of nonscvere or severe complications between the IR and TN group (9% and 2% versus 10% and 2%; P=0.5 and 1, respectively; Table 2). IR intervention was required to coil one case of AVF with WRF, and another case of AVF with WRF that was associated with Page kidney also needed surgical intervention. No graft or patient losses were associated directly with complications of the kidney biopsies.

**Multivariable Logistic Regression Analyses**

**Risk Factors for Complications**

The test of the full model against a constant only model was statistically significant, indicating that the predictors as a set did reliably distinguish between whether a complication post biopsy occurred (chi square=12.05, P=0.007 with df=3). The Nagelkerke R² was 0.04, indicating a weak relationship between prediction and grouping. The Wald criterion demonstrated that uncontrolled BP and use of anticoagulants before biopsy made a significant contribution to the prediction of postbiopsy complications (P=0.004 and 0.02, respectively). Exp(B) values indicate that the risk of postbiopsy complications was higher in patients with uncontrolled BP (AOR=2.31; 95% CI, 1.29 to 4.09) and patients who used anticoagulants before biopsy (AOR=2.77; 95% CI, 1.06 to 6.37).

The model was applied on each individual complication, and we only found significant risk factors in the complications detailed below Table 3.

**Risk Factors for Transfusion of Blood Products**

The test of the full model against a constant only model was statistically significant for the prediction of transfusion of blood products (chi square=12.56, P=0.004 with df=2). The Nagelkerke R² was 0.06, indicating a weak relationship between prediction and grouping. The Wald criterion demonstrated that being a woman and use of anticoagulants before biopsy made a significant contribution to the prediction of the transfusion of blood products (P=0.01 and 0.01, respectively). Exp(B) values indicate that the risk of transfusion of blood products was higher in women (AOR=3.10; 95% CI, 1.31 to 7.9) and in patients who used anticoagulants before biopsy (AOR=4.29; 95% CI, 1.17 to 12.56).

**Risk Factors of Perinephric Hematoma**

The test of the full model against a constant only model was statistically significant for the prediction of perinephric hematoma with and without worsening renal function (chi square=16.92, P=0.001 with df=4). The Nagelkerke R² was 0.089, indicating a weak relationship between prediction and grouping. The risk of perinephric hematoma was higher in women (AOR=2.92; 95% CI, 1.29 to 7.04; P=0.01) and in patients with uncontrolled BP (AOR=2.79; 95% CI, 1.21 to 6.30; P=0.01). We identified Black race as a stronger predictor of hematoma without WRF (AOR=12.9; 95% CI, 2.5 to 100; P=0.005).

**Sex Analysis**

Women were statistically significantly younger, with a lower BMI, lower Hb and Hct, more SLE diagnoses, higher platelets, and with less uncontrolled hypertension, and required fewer core biopsies than men did (see Supplemental Table 1 and Supplemental Figures 1–4). Of the 23 patients who received blood transfusions post procedure, 81% of women compared with 91% of men were anemic pre biopsy. Women had a lower baseline Hb compared with men and also had a greater change in Hb and Hct post biopsy than men did (ΔHb: -28%±9% versus -20%±6%; P=0.02; ΔHct: -27%±10% versus -10%±7%; P<0.001), with a higher number of blood transfusions (81% versus 33%; P=0.04).

The specialty team that performed the biopsy was not a significant predictor for complications (AOR=1.69; 95% CI, 0.02 to 20.48; P=0.64), the transfusion of blood productions (AOR=0.77; 95% CI, 0.05 to 20.19; P=0.86), or perinephric hematoma (AOR=1.71; 95% CI, 0.15 to 35.23; P=0.69).

**Discussion**

Percutaneous US-KTB is known as a safe procedure and the gold standard for obtaining tissue for histopathological diagnosis, but complications can occur. Complications and their risk factors have been extensively studied in native
Table 1. Demographic data

| Characteristics                  | Total (n = 678) | Interventional Radiology (n = 447) | Transplant Nephrology (n = 231) | P Value |
|---------------------------------|----------------|-----------------------------------|---------------------------------|---------|
| Age, yr, (range)                | 53 (19–84)     | 53 (19–84)                        | 51 (25–83)                      | 0.078   |
| Sex, %                          |                |                                   |                                 |         |
| Men                             | 406 (60)       | 272 (61)                          | 134 (58)                        | 0.526   |
| Women                           | 272 (40)       | 175 (39)                          | 97 (42)                         |         |
| Race, %                         |                |                                   |                                 |         |
| White                           | 368 (54)       | 240 (53)                          | 128 (55)                        | 0.913   |
| Black                           | 298 (44)       | 199 (45)                          | 99 (43)                         |         |
| Other                           | 12 (2)         | 8 (2)                             | 4 (2)                           |         |
| BP, %                           |                |                                   |                                 | 0.002   |
| Controlled                      | 516 (76)       | 315 (70)                          | 201 (87)                        |         |
| Uncontrolled                    | 162 (24)       | 132 (30)                          | 30 (13)                         |         |
| BMI, %                          |                |                                   |                                 | 0.53    |
| <18                             | 10 (1)         | 7 (1)                             | 3 (1)                           |         |
| 18–24.9                         | 205 (30)       | 129 (29)                          | 76 (33)                         |         |
| 25–29.9                         | 270 (40)       | 178 (40)                          | 92 (40)                         |         |
| 30–34.9                         | 126 (19)       | 83 (19)                           | 43 (19)                         |         |
| >35                             | 67 (10)        | 50 (11)                           | 17 (7)                          |         |
| Comorbidities, %                |                |                                   |                                 |         |
| Hypertension                    | 598 (88)       | 387 (87)                          | 211 (91)                        | 0.09    |
| Diabetes Mellitus               | 241 (36)       | 171 (38)                          | 70 (30)                         | 0.05    |
| HIV                             | 23 (3)         | 20 (4)                            | 3 (1)                           | 0.05    |
| CAD                             | 104 (15)       | 71 (16)                           | 33 (14)                         | 0.66    |
| Hepatitis B or C                | 49 (7)         | 34 (8)                            | 15 (6)                          | 0.71    |
| Hepatitis B                     | 10 (1)         | 8 (2)                             | 2 (0.8)                         | 0.51    |
| Hepatitis C                     | 39 (6)         | 26 (6)                            | 13 (6)                          | 0.99    |
| SLE                             | 56 (8)         | 30 (7)                            | 26 (11)                         | 0.06    |
| Prior renal transplant, %       |                |                                   |                                 | 0.09    |
| 0                               | 621 (92)       | 416 (93)                          | 205 (89)                        |         |
| 1                               | 46 (7)         | 27 (6)                            | 19 (8)                          |         |
| 2                               | 9 (1)          | 4 (0.8)                           | 5 (2)                           |         |
| 3                               | 1 (0.2)        | 0 (0.0)                           | 1 (0.4)                         |         |
| >4                              | 1 (0.2)        | 0 (0.0)                           | 1 (0.4)                         |         |
| Transplant type, %              |                |                                   |                                 | 0.04    |
| Deceased donor                  | 500 (74)       | 335 (75)                          | 165 (71)                        |         |
| Living donor                    | 178 (26)       | 112 (25)                          | 66 (29)                         |         |
| Transplant location, %          |                |                                   |                                 | 0.03    |
| Right iliac fossa               | 558 (82)       | 357 (80)                          | 201 (87)                        |         |
| Left iliac fossa                | 120 (18)       | 90 (20)                           | 30 (13)                         |         |
| Prebiopsy medications, %        |                |                                   |                                 |         |
| Antiplatelet therapy            | 275 (41)       | 181 (40)                          | 94 (40)                         | 0.99    |
| Anticoagulation therapy         | 39 (6)         | 29 (6)                            | 10 (4)                          | 0.33    |
| Desmopressin                    | 120 (18)       | 66 (15)                           | 54 (23)                         | 0.07    |
| Steroids                        | 232 (35)       | 151 (34)                          | 81 (35)                         | 0.81    |
| Prebiopsy laboratory test (mean±SD) |            |                                   |                                 |         |
| Creatinine, mg/dL               | 2.71 ± 2.03    | 2.78 ± 1.90                       | 2.57 ± 2.25                     | 0.24    |
| BUN, mg/dL                      | 38.14 ± 21.77  | 39.09 ± 21.70                     | 36.30 ± 21.84                   | 0.12    |
| Platelets, K/uL                 | 215.79 ± 78.97 | 214.80 ± 80.61                    | 217.72 ± 85.74                  | 0.67    |
| INR                             | 0.99 ± 0.11    | 0.99 ± 0.12                       | 0.97 ± 0.10                     | 0.04    |
| Hemoglobin, g/dL                | 10.7 ± 1.84    | 10.48 ± 1.83                      | 11.09 ± 1.82                    | <0.001  |
| Hematocrit, %                   | 33.2 ± 6.13    | 32.56 ± 6.26                      | 34.42 ± 5.71                    | <0.001  |
| Biopsy indication, %            |                |                                   |                                 | 0.45    |
| Protocol                        | 123 (18)       | 77 (17)                           | 46 (20)                         |         |
| Per cause                       | 555 (82)       | 370 (83)                          | 185 (80)                        |         |
| Number of core biopsies, median (range) | 3 (1–7)       | 3 (1–7)                           | 2 (1–5)                         | 0.91    |
| Needle gauge, %                 |                |                                   |                                 | <0.001  |
| 16                              | 238 (35)       | 15 (3)                            | 227 (98)                        |         |
| 18                              | 421 (62)       | 417 (93)                          | 4 (2)                           |         |
| Other                           | 19 (3)         | 19 (4)                            | 0 (0)                           |         |
| Glomeruli, median (range)       | 13 (0–56)      | 14 (0–56)                         | 12 (0–51)                       | 0.66    |
According to a meta-analysis done by Corapi et al., the rate of perinephric hematoma post biopsy was 17% when postbiopsy ultrasonography was regularly implemented (13). Some series describe complications as high as one third of biopsies, with an average of 1% for severe complications (14). For the transplanted kidney, the number of studies describing outcomes and complications post biopsy under ultrasound guidance are limited. There are two studies that have retrospectively evaluated a significant cohort of patients that underwent US-KTB showing a rate of major complications close to 0.4%–2% (7,8). Minor complications such as hematuria, pain requiring analgesia, and AVF were reported in 15%–20% in protocol biopsy from stable kidney grafts (10). A prospective study by Whittier et al. comparing US-KTB done by nephrologists in native and transplanted kidneys found the KTB patients (N=938) to be more hypertensive, with a higher serum creatinine and partial thromboplastin time and a lower baseline Hb than the native kidney biopsy (NKB) patients (N=767). The NKB group had a greater drop in Hb after the biopsy (0.97±1.1 versus 0.73±1.3 g/dl; P<0.001), a higher complication rate (7% versus 4%; P=0.02), and a higher transfusion rate (5% versus 3%; P=0.05). There was one death in each group attributed to the biopsy. The authors concluded that although death is equally rare, the complication rate is higher in NKB compared with KTB, despite KTB having more of the traditional risk factors for bleeding (15). A retrospective analysis by Reschen et al. confirmed that KTB were safe when performed by adequately trained nephrologists (16).

There is no consensus about how to classify the severity of complications after KTB. We use the presence of renal dysfunction and the need for surgical intervention as described in the literature (6,7). In our cohort, we observed significantly lower rates of bleeding complications than those described for NKB (13). Our overall rate of severe complications was 2%, which is similar to the rate described by Morgan et al. (7), with perinephric hematoma with WRF being the most frequent severe complication. The overall rate for nonsevere complication was 9%, with transfusion of blood products being the most frequent complication.

Most of the severe complications described in the literature occurred during the first 24 hours post procedure (7–15). We described 40% of the total complications during the first 24 hours post procedure, including three severe complications. Forty-eight percent occurred between 2 and 15 days post biopsy, and 12% occurred >15 days post biopsy. Of note, only one severe complication of AVF with WRF occurred in this late group, including one as far as 32 days post procedure.

### Table 2. Complications post kidney transplant biopsy

| Characteristics | Total (n=678) | Interventional Radiology (n=447) | Transplant Nephrology (n=231) | P Value |
|-----------------|--------------|---------------------------------|------------------------------|---------|
| Total complications related to biopsies, % | 55 (8.1) | 37 (8.2) | 18 (7.7) | 0.94 |
| Day of post biopsy complication, median (range) | 0 (0–32) | 2 (0–30) | 1 (0–32) | 0.45 |
| Total number of complications | 73 | 45 | 28 | 0.49 |
| Non-severe complications | | | | |
| Hydronephrosis | 3 | 3 | 0 | 0.52 |
| Perinephric hematoma | 19 | 10 | 9 | 0.32 |
| Transfusion of blood products | 13 | 7 | 6 | 0.53 |
| Drop in hemoglobin >2g/dL | 23 | 15 | 8 | 0.99 |
| Arteriovenous fistula | 4 | 3 | 1 | 0.99 |
| Severe complications | | | | |
| Page kidney | 1 | 1 | 0 | 0.99 |
| Arteriovenous fistula with WRF | 1 | 0 | 1 | 0.99 |
| Hydronephrosis with WRF | 1 | 0 | 1 | 0.99 |
| Perinephric hematoma with WRF | 7 | 6 | 1 | 0.48 |
| Hemoperitoneum with WRF | 1 | 0 | 1 | 0.99 |

WRF, worsening renal function.
Our finding of complications as high as 60% beyond the first 24 hours post US-KTB could be explained by the continuing awareness and high suspicion for potential postbiopsy complications beyond the immediate postprocedure period that had led us to obtain or repeat images along with laboratory test as part of the differential diagnosis of kidney transplant dysfunction post biopsy. As has been described in the literature, we confirmed that uncontrolled BP ≥160/90 mm Hg at the time of biopsy and prior use of anticoagulation were statistically significant predictors of all postbiopsy complications (P = 0.004 and 0.02, respectively). Uncontrolled BP was also an additional predictor for overall perinephric hematoma (P = 0.01), and the use of anticoagulation was a predictor of the need for transfusion of blood products (P = 0.01).

We were able to correlate that being a woman was also a significant predictor for the transfusion of blood products (P = 0.02) and overall perinephric hematoma (P = 0.01). When we further explore the potential risk factors of these findings in our population, beside being significantly younger, with an SLE diagnosis, lower BMI, higher platelet count, less uncontrolled BP, and requiring fewer core biopsies, similar to the general population, women had lower Hb and Hct at the time of biopsy. In patients who were transfused, Hb and Hct pre biopsy did not differ between the sexes. However, women had a greater decline on post biopsy than men, leading to a higher requirement for blood transfusions. It would be interesting whether this sex effect, also recently described in native renal biopsies (17), persists in a larger prospective trial because currently sex is not a relevant factor to trigger indication for blood transfusions (18,19). As we also found that being a woman is a risk factor for overall perinephric hematoma, one can only hypothesize the presence of a technical factor leading to potential deeper tissue sample that will increase the risk for bleeding with the concomitant need for blood transfusions. It remains unclear why Black race was found to be a risk factor for perinephric hematoma without WRF, and further research is needed.

It is necessary to highlight that biopsies were performed at an academic institution where both cases—the TN and IR group—are performed mainly by fellows under direct attending supervision.

The significant transition overtime in the performance of US-KTB by nephrologist to IR is not unique because it follows the same trend as NKB. US-KTB outcomes and risk complications have been evaluated in limited large cohorts but without mentioning which team did the biopsies. Here, we described outcomes on the basis of the specialty team at an academic institution in order to evaluate the implications of using different techniques, equipment, and protocols, and the effect of the increasing reduced exposure to this procedure in the transplant nephrology field, given the tendency of IR to perform most of the procedures.

The advantages of the TN doing this procedure is that theoretically they are more capable of making real-time decisions about the adequacy of the sample size for a given suspected diagnosis, on the basis of better understanding of indications, contraindications, and patient condition. On the other hand, IR have had greater exposure to this type of procedure, acquiring major expertise especially in challenging cases, with a better understanding of how to manage some severe complications.

Similarities and differences found in both groups are: procedures at our institution are mainly done by physicians on training under close supervision; there was no difference in the number of glomeruli obtained between the groups; and IR mainly uses 18G needles and TN 16G needles because that has been described in the literature to result in better histologic quality and lower frequency of complications compared with 18G needles (20–23).

As part of the TN protocol, a sandbag is applied on the biopsy site for 6 hours with strict bed rest; the IR department’s ultrasound machine is technically superior to that used by the TN department; procedures done by the IR group are done in the IR suite, whereas the TN group performs the procedure at the bedside.

Our study has several limitations. First, this was a retrospective, observational study; therefore, conclusions cannot be directly extrapolated because unmeasurable variables not accounted for by multivariable analysis may have affected the results. In addition, because most of the data

### Table 3. Predictors of complications

| Characteristics                                      | Odds Ratio | 95% Confidence Interval | P Value |
|------------------------------------------------------|------------|-------------------------|---------|
| **Predictor of all complications**                   |            |                         |         |
| Uncontrolled BP                                      | 2.32       | 1.3 to 4.1              | 0.04    |
| Use of anticoagulants                                | 2.77       | 1.1 to 6.4              | 0.02    |
| **Predictors of transfusion of blood products**      |            |                         |         |
| Women sex                                            | 3.11       | 1.32 to 7.91            | 0.02    |
| Use of anticoagulants                                | 4.29       | 1.2 to 12.6             | 0.01    |
| **Predictors of perinephric hematoma without WRF**   |            |                         |         |
| Black race                                           | 12.90      | 2.56 to 101             | 0.01    |
| **Predictors of perinephric hematoma with and without WRF** | | | | |
| Women sex                                            | 2.93       | 1.3 to 7.04             | 0.01    |
| Uncontrolled blood pressure                          | 2.79       | 1.22 to 6.3             | 0.01    |

Uncontrolled blood pressure defined as BP ≥160/90 mm Hg at the time of biopsy. BP, blood pressure; WRF, worsening renal failure.
were gathered from electronic medical records, there is likely selection bias due to missing data. Another major limitation is the operator-dependent factor because IR has many different fellows performing the procedures, whereas in TN, the procedure is performed by the nephrology fellow, who is consistent for the year. Last, this is a center-specific study from a high-volume academic institution where meticulous training is required during TN and IR fellowships, and the results cannot be generalized.

In conclusion, percutaneous US-KTB is the gold standard in the clinical practice of TN to determine diagnosis, prognosis, and treatment of graft dysfunction. This procedure is considered safe if it is performed in centers where competent training is provided. In our center, there are similar complication rates and comparable glomerular tissue samples beside using different needle sizes when performed by either TN or IR. BP control and management of anticoagulation are fundamental in decreasing the risk of complications. Prospective studies are needed to understand further why sex and race were predictors for complications such as blood transfusion need and perinephric hematoma development.

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Author Contributions
F.H. Cabeza Rivera, K.G. Carias Martinez, C.A. Cortesi, G. Guerra, A.D. Mattiazzi, R.J. Patil, and M. Sedki were responsible for the methodology; F.H. Cabeza Rivera, K.G. Carias Martinez, C.A. Cortesi, A.D. Mattiazzi, R.J. Patil, P. Ruiz, J.T. Salsamendi, and M. Sedki were responsible for data curation; F.H. Cabeza Rivera, K.G. Carias Martinez, C.A. Cortesi, A.D. Mattiazzi, and M. Sedki were responsible for the formal analysis; F.H. Cabeza Rivera, C.A. Cortesi, A.D. Mattiazzi, and M. Sedki wrote the original draft of the manuscript; F.H. Cabeza Rivera, G. Guerra, and A.D. Mattiazzi were responsible for supervision; F.H. Cabeza Rivera, G. Guerra, A.D. Mattiazzi, and R.J. Patil reviewed and edited the manuscript; A.D. Mattiazzi was responsible for conceptualization, project administration, and visualization; A.D. Mattiazzi, P. Ruiz, and J.T. Salsamendi were responsible for resources; R.J. Patil and M. Sedki were responsible for the software; and M. Sedki was responsible for validation.

Data Sharing Statement
All data are included in the manuscript and/or supporting information.

Supplemental Material
This article contains the following supplemental material online at http://kidney360.asnjournals.orglookup/suppdoitt/10.3407/KID.000033022/DCSupplemental.

Supplemental Table 1. Demographics by sex.
Supplemental Figure 1. Prebiopsy mean Hb and Hct by sex.
Supplemental Figure 2. Mean Hb change by sex.
Supplemental Figure 3. ΔHb and ΔHct pre- and postbiopsy.
Supplemental Figure 4. Postbiopsy transfusions by sex.

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