Research Square

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Bleeding Complications Following Image-Guided Kidney Biopsy: A Single-Center Experience

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Abstract

Purpose

Compare clinically significant bleeding rates across native, transplant, and renal mass image-guided biopsies; characterize bleeding timing to guide post-procedure monitoring; and identify associated patient and procedural factors.

Methods

A radiology information system search identified all image-guided renal biopsies by the abdominal imaging section from 01/01/2021 to 04/01/2025. Data included demographics, laboratory values, procedural parameters, and intra- and post-procedure bleeding findings. Clinically significant bleeding was defined by post-procedure CT showing active extravasation or moderate/large hematoma, or intervention to control bleeding.

Results

The cohort comprised 1,255 biopsies (508 native, 615 transplant, 132 renal mass), with clinically significant bleeding in 45 (3.6%). Native kidneys bled nearly three times more often than transplants (5.7% [29/508] vs. 2.0% [12/615]; OR, 3.04; p = .001) and required more interventions (4.1% [21/508] vs. 0.8% [5/615]; p < .001); the renal mass rate (3.0% [4/132]) did not differ significantly from either. Detection was temporally distributed: 42.2% of events occurred within 2 hours, 8.9% between 2–6 hours, 24.4% between 6–24 hours, and 24.4% beyond 24 hours. On multivariable analysis of pre-procedural factors, biopsy target (p = .02), platelet count (p = .003), and systolic blood pressure (p = .04) independently predicted bleeding; female sex showed a borderline association (p = .051).

Conclusion

Higher bleeding risk of native over transplant biopsy persisted after adjustment for baseline patient factors. Bleeding events clustered within 2 hours (42%) or beyond 24 hours (24%), and most events detected after leaving the biopsy suite were prompted by patient-reportable rather than monitoring-dependent symptoms.

Introduction

Percutaneous renal biopsy is an essential tool for the diagnosis and management of kidney disease, including evaluation of native parenchymal disease [1], surveillance of transplant allograft rejection [2–3], and characterization of renal masses [4–5]. Despite its overall safety profile, bleeding remains the major complication, due in part to the high vascularity of kidneys and their retroperitoneal location, which

precludes manual compression to aid hemostasis [6–7]. Post-procedure bleeding is most commonly asymptomatic and self-limited, presenting as transient hematuria or small perinephric hematoma [8–9]. However, a minority of bleeding complications can require significant intervention, including but not limited to blood transfusion, embolization, and surgical intervention; rarely, death can result [10].

Reported rates of bleeding complications vary widely across institutions [9]. Recent analyses suggest that up to 11% of renal biopsies are complicated by clinically significant bleeding events [2–3, 11–14]. Post-procedure monitoring strategies aim to balance safety and complication detection with resource stewardship. Literature has not established consensus on the optimal monitoring duration, which ranges from short observation periods to 24-hour admission [5–6, 15–16]. This challenge is compounded by meaningful differences in bleeding risk across biopsy targets [14]. Data consistently suggest that native biopsies carry up to twice the risk of bleeding compared to transplant biopsies [8, 14, 16]. Fewer data exist for renal masses, although a three-hospital study of 576 renal mass biopsies reported a complication rate of 4.3% [5].

Several studies have characterized risk factors for post-procedure bleeding following renal biopsy, which include female sex [17], needle size [8, 10, 16], non-coaxial technique [6], inpatient hospitalization [9, 12], and pre-procedure comorbidities [14, 16]. A small number of studies have also analyzed timing of post-procedure complications, though each focused on a single biopsy type [2, 5, 15, 18]. No study has systematically analyzed the presenting patient symptom in relation to timing of complication detection.

The present study sought to analyze bleeding complications for native, transplant, and renal mass biopsies conducted by radiologists between 2021–2025 at one large tertiary care institution employing a standard 23-hour post-procedure admission protocol for all biopsies. This policy provided an opportunity to investigate the temporal distribution of bleeding complications without the confounding effect of variable discharge. We aimed to identify and compare risk factors for complications across biopsy type and provide an analysis of complication rates, detection timing, and presenting symptoms. We hypothesized that complication detection is driven primarily by symptom evaluation rather than active inpatient surveillance (e.g. post-procedure hemoglobin checks), and that native, transplant, and renal mass biopsies have distinct risk profiles and temporal complication distributions—findings that would support the development of risk-stratified, symptom-based discharge protocols.

Methods

Study Design

This single-institution retrospective study was HIPAA-compliant and approved by institutional review board under a waiver of informed consent due to its minimal-risk, records-only design. The radiology information system (Montage; Nuance Communications) was queried by current procedural terminology code and procedure location to identify all image-guided percutaneous renal biopsies performed in adult patients (age > 18) by the abdominal radiology section between 1/1/21 and 4/1/25. The start of the

study corresponds with institution-wide adoption of a uniform post-procedure admission policy, described below. The unit of analysis was individual biopsy; patients undergoing more than one qualifying biopsy contributed a separate record for each procedure.

Biopsy Technique and Postprocedural Practice

Procedures were performed by board-certified abdominal radiologists, using ultrasound or CT guidance. Sampling was performed with spring-loaded cutting devices, with or without coaxial introducers, under local anesthesia (1% lidocaine) alone or with moderate procedural sedation (fentanyl and midazolam), according to operator preference and patient factors. Tract embolization, when performed, consisted of gelfoam slurry, gelfoam pledgets, or both; thrombin administration was recorded as a separate variable. All procedures were performed under a universal institutional policy of 23-hour monitored admission with telemetry. Serial vital signs and at least one post-procedure hemoglobin measurement were obtained as part of routine care, and cross-sectional imaging was obtained at the discretion of the treating team.

Data Collection

Clinical, procedural, and imaging data were obtained from the electronic medical record, the procedure and pathology reports, and the clinical PACS (Sectra) by two medical student reviewers, with ambiguous cases adjudicated by consensus of three board-certified abdominal radiologists. Study data were collected and managed using REDCap electronic data capture tools hosted at the author's institution and exported without identifying information for analysis.

Collected variables comprised patient demographics and inpatient versus outpatient status, pre-procedure vital signs and laboratory values, procedural parameters, diagnostic adequacy and glomerular yield, and all imaging, transfusions, interventions, and deaths within 30 days; the principal variables are summarized in Table 1. The procedure report was additionally reviewed for any documented suspicion for bleeding at the time of biopsy. Thirty-day follow-up was ascertained by review of all encounters, imaging, transfusions, and notes within the health system 30 days after biopsy.

Table 1
Patient and Procedural Characteristics by Biopsy Target

Characteristic	Native kidney (n = 508)	Transplant kidney (n = 615)	Renal mass (n = 132)	*p*
Patient characteristics				
Age (y)	56 (41–67)	53 (41–63)	67 (59–74)	< .001
Female sex	279 (54.9%)	229 (37.2%)	46 (34.8%)	< .001
Body mass index (kg/m²)	28.0 (23.9–33.4)	28.8 (25.0–33.9)	28.5 (23.4–32.0)	.08
Inpatient status	277 (54.5%)	218 (35.4%)	22 (16.8%)	< .001
Systolic blood pressure (mm Hg)	137 (125–153)	141 (130–152)	142 (125–156)	.14
Diastolic blood pressure (mm Hg)	78 (68–88)	82 (71–90)	80 (70–88)	.009
Pre-procedure laboratory values				
Hemoglobin (g/dL)	10.1 (8.9–11.8)	11.2 (9.7–13.0)	12.3 (10.9–13.9)	< .001
Platelet count (×10³/μL)	230 (179–305)	207 (163–252)	252 (197–308)	< .001
INR	1.00 (1.0–1.1)	1.02 (1.0–1.1)	1.04 (1.0–1.1)	.004
Serum creatinine (mg/dL)	2.3 (1.5–3.8)	2.2 (1.7–3.3)	1.1 (0.9–1.4)	< .001
Blood urea nitrogen (mg/dL)	33 (23–51)	31 (23–44)	17 (13–23)	< .001
Blood products within 24 h before biopsy	89 (17.5%)	58 (9.4%)	1 (0.8%)	< .001
Procedural characteristics				
Ultrasound guidance	491 (96.7%)	610 (99.2%)	49 (37.1%)	< .001
Procedural sedation	409 (80.5%)	519 (84.4%)	101 (78.3%)	.11

Note: Continuous data are medians, with IQRs in parentheses. Categorical data are numbers, with percentages of biopsies with available data in parentheses. *p* values test for a difference across all three biopsy targets and do not indicate which pairs differ. The tract embolization *p* value tests the distribution across all categories. For some variables (e.g., diastolic blood pressure, INR), the large sample size yielded statistically significant p values despite small absolute differences between groups that may not be clinically meaningful. An additional “other or not specified” embolization category (10 native, 26 transplant, 2 renal mass) is not listed but was included in the test. Three native, one transplant, and one renal mass biopsy used a needle other than the BioPince or Corvocet and are excluded from the needle-type denominators.

Characteristic	Native kidney (n = 508)	Transplant kidney (n = 615)	Renal mass (n = 132)	*p*
Patient characteristics				
Sedation time (min)	28 (20–37)	25 (18–32)	36 (27–53)	< .001
BioPince needle	381 (75.4%)	470 (76.5%)	87 (68.0%)	.12
Introducer used	475 (93.5%)	608 (98.9%)	126 (96.9%)	< .001
No. of passes	2 (1–2)	2 (1–2)	4 (3–5)	< .001
Longest pass length (cm)	2.0 (2.0–2.5)	2.0 (2.0–3.0)	2.0 (1.0–2.0)	< .001
Cumulative pass length (cm)	4.0 (3.0–4.0)	4.0 (3.0–4.0)	6.0 (4.0–8.0)	< .001
Tract embolization				.001
None	137 (27.0%)	125 (20.3%)	21 (16.2%)	
Gelfoam slurry	115 (22.6%)	121 (19.7%)	43 (33.1%)	
Gelfoam pledgets	231 (45.5%)	330 (53.7%)	60 (46.2%)	
Both slurry and pledgets	15 (3.0%)	13 (2.1%)	4 (3.1%)	
Thrombin administered	22 (4.3%)	0	1 (0.8%)	< .001

Note: Continuous data are medians, with IQRs in parentheses. Categorical data are numbers, with percentages of biopsies with available data in parentheses. *p* values test for a difference across all three biopsy targets and do not indicate which pairs differ. The tract embolization *p* value tests the distribution across all categories. For some variables (e.g., diastolic blood pressure, INR), the large sample size yielded statistically significant p values despite small absolute differences between groups that may not be clinically meaningful. An additional “other or not specified” embolization category (10 native, 26 transplant, 2 renal mass) is not listed but was included in the test. Three native, one transplant, and one renal mass biopsy used a needle other than the BioPince or Corvocet and are excluded from the needle-type denominators.

Image Review

All post-procedure CT examinations performed within 30 days were reviewed by one of three board-certified, fellowship-trained abdominal radiologists (Reader 1, Reader 2, and Reader 3, with 6, 6, and 8 years of post-fellowship experience), who were blinded to the intraprocedural complications and the subsequent clinical course. Readers assessed each examination for a perinephric or retroperitoneal hematoma, active extravasation, hemoperitoneum, pseudoaneurysm, and arteriovenous fistula. Hematomas were graded as trace or small (< 1.5 cm in thickness, noncircumferential, and without mass effect on the kidney) versus moderate or large (≥ 1.5 cm in thickness or with mass effect).

Outcome Definitions

The primary outcome was clinically significant bleeding within 30 days, defined by imaging confirmation: a post-procedure CT demonstrating active extravasation or a moderate or large hematoma. Intervention for bleeding and death within 30 days from suspected biopsy-related hemorrhage were also qualifying events; in this cohort every such case had a positive CT and was therefore already captured by the imaging criterion. Biopsies with a post-procedure CT showing none of these findings, and biopsies with no post-procedure CT, were classified as not having clinically significant bleeding.

Timing and Indication of Detection

Time to detection was defined as the interval between completion of biopsy to the time at which the first post-procedure CT was ordered (not acquired), categorized as less than 2 hours, 2–4 hours, 4–6 hours, 6–24 hours, and > 24 hours. The indication for each CT was categorized as a finding arising in the biopsy suite, symptoms or vital sign or laboratory changes concerning for bleeding, or an unrelated clinical indication; when symptomatic, the presenting features were recorded. Presenting features were grouped post hoc as patient-reportable (pain or discomfort, hematuria, dizziness or light-headedness) or monitoring-dependent (worsening anemia, hypotension, tachycardia, cardiac arrest, rising serum creatinine), reflecting whether the complication could be recognized by the patient after discharge. Events prompted by a finding in the biopsy suite were classified as such even when a symptom was concurrently documented.

Statistical Analysis

Continuous variables are reported as medians with interquartile ranges and categorical variables as counts with percentages. Timing of detection is reported descriptively; the number of events per target was too small to support formal comparison. Associations between individual patient and procedural variables and clinically significant bleeding were assessed by univariable logistic regression. Odds ratios were expressed per one-unit increase for continuous predictors, except for body mass index (per 5 kg/m^2) and systolic blood pressure (per 10 mm Hg). A multivariable model was specified a priori using factors known before the biopsy began, with all variables retained regardless of significance. Intraprocedural variables such as thrombin administration and tract embolization were excluded because they may be applied in response to bleeding recognized during the case, and BUN was excluded because of correlation with creatinine ($r = 0.67$). Because events were few relative to model parameters, the model was fit by Firth penalized-likelihood logistic regression with profile-likelihood confidence intervals [19], among biopsies with complete data. All variance inflation factors were less than 2.0.

Renal biopsy diagnoses were categorized from the free-text pathology reports using Microsoft 365 Copilot under clinician supervision. Reports were analyzed to identify recurring diagnostic patterns and develop a limited set of mutually exclusive categories. Copilot was instructed not to make assumptions about ambiguous cases. A radiologist examined unresolved cases to establish generalizable classification rules, which Copilot then applied systematically, yielding 10 categories. For statistical analysis, native kidney diagnoses were grouped as lupus nephritis, other inflammatory or proliferative glomerulonephritis, podocytopathy or membranous nephropathy, or chronic, metabolic, vascular, or

other, and bleeding rates across groups were compared with the Pearson chi-square test. Because lupus nephritis is more common in women, post hoc analyses compared bleeding between lupus nephritis and other native diagnoses (Fisher exact test) and examined the association of sex with bleeding within each target after adjustment for age, hemoglobin, and platelet count, and after excluding lupus nephritis.

Analyses were performed using SAS version 9.4 for Windows and R statistical software for MacOS (v4.5.3; R Core Team 2026). Missing data were handled by pairwise deletion, such that the denominator for a given analysis reflected the number of records with non-missing data for that variable; the multivariable model included biopsies with complete data for all model variables.

Results

Patient and Procedure Characteristics

The final cohort comprised 1255 biopsies: 508 native, 615 transplant, and 132 renal masses. Patient and procedural characteristics are summarized in **Table 1**. Baseline indices of health differed across targets ($p < .001$ for hemoglobin, platelet count, creatinine, and BUN): patients undergoing native and transplant biopsy were more anemic and had comparatively impaired renal function, with the lowest hemoglobin values in the native group, whereas renal mass patients had near-normal creatinine and BUN and the highest hemoglobin values.

Nearly all biopsies used an 18-gauge BioPince (Argon Medical Devices) or 18-gauge Corvocet (Merit Medical) needle. Renal mass biopsies involved more passes and greater cumulative tissue length, although individual passes tended to be shorter. Tract embolization was performed in the majority of all biopsies (73.0% native, 79.7% transplant, 83.8% renal mass), most often with gelfoam pledgets. Thrombin was administered almost exclusively during native biopsies (22/508 [4.3%]) and only when procedural or immediate post-procedural ultrasound showed active bleeding.

Incidence of Clinically Significant Bleeding

Clinically significant bleeding within 30 days occurred after 45/1255 biopsies (3.6%): 29/508 native (5.7%), 12/615 transplant (2.0%), and 4/132 renal mass biopsies (3.0%) ($p = .003$). Native kidney biopsy was associated with higher odds of clinically significant bleeding than transplant biopsy (OR, 3.04; 95% CI, 1.54–6.03; $p = .001$). Renal mass biopsy did not differ significantly from either native or transplant biopsy.

Component outcomes are shown in **Table 2**. Interventions for bleeding were required after 21/508 native (4.1%), 5/615 transplant (0.8%), and 0/132 renal mass biopsies (0%) ($p < .001$); native biopsy carried higher odds of intervention than transplant biopsy (OR, 5.26; 95% CI, 1.97–14.05; $p < .001$). All 21 angiograms and all 16 embolizations were performed for native kidney biopsies; all 5 transplant interventions were surgical (i.e., hematoma evacuation). One death (1/1255 [0.1%]), after a native kidney biopsy, was classified as related to bleeding.

TABLE 2: Bleeding Outcomes Within 30 Days by Biopsy Target

Outcome	Native kidney (n = 508)	Transplant kidney (n = 615)	Renal mass (n = 132)	Total (n = 1255)	*p*
Primary outcome					
Clinically significant bleeding (CT-confirmed)	29 (5.7%)	12 (2.0%)	4 (3.0%)	45 (3.6%)	.003
Component and related outcomes					
Post-procedure CT within 30 d	92 (18.1%)	90 (14.6%)	20 (15.2%)	202 (16.1%)	.27
Moderate or large perinephric hematoma	26 (5.1%)	11 (1.8%)	4 (3.0%)	41 (3.3%)	.006
Active extravasation	17 (3.3%)	0	0	17 (1.4%)	< .001
Hemoperitoneum	4 (0.8%)	0	0	4 (0.3%)	.08
Pseudoaneurysm	4 (0.8%)	0	0	4 (0.3%)	.08
Angiography	21 (4.1%)	0	0	21 (1.7%)	< .001
Embolization	16 (3.1%)	0	0	16 (1.3%)	< .001
Surgery or other invasive procedure	1 (0.2%)	5 (0.8%)	0	6 (0.5%)	.31
Any intervention for bleeding	21 (4.1%)	5 (0.8%)	0	26 (2.1%)	< .001
Death related to bleeding	1 (0.2%)	0	0	1 (0.1%)	.51

Pairwise Comparisons

Comparison	Clinically significant bleeding	Any intervention for bleeding
Native vs transplant	3.04 (1.54–6.03); p = .001	5.26 (1.97–14.05); p < .001
Renal mass vs native	0.52 (0.18–1.49); p = .22	--
Renal mass vs transplant	1.57 (0.50–4.95); p = .44	--

Note: *p* values in the main table test for a difference across all three biopsy targets (chi-square or Fisher exact test) and do not indicate which pairs differ. Pairwise comparisons are reported as odds ratios.

Timing of Detection

Nineteen clinically significant bleeding events (42.2%) were detected within 2 hours of biopsy, 1 (2.2%) between 2-4 hours, 3 (6.7%) between 4-6 hours, 11 (24.4%) between 6-24 hours, and 11 (24.4%) > 24 hours after biopsy (**Table 3** and **Fig. 1**). Native and renal mass events were concentrated early, whereas 9/12 transplant events (75.0%) were detected at 6 hours or later. Detection beyond 24 hours occurred in 8/29 native (27.6%), 3/12 transplant (25.0%), and 0/4 renal mass events (0%).

Among the 26 events requiring intervention, detection occurred within 2 hours in 12 (46.2%, all native), between 2 and 6 hours in 2 (7.7%), between 6 and 24 hours in 5 (19.2%), and more than 24 hours in 7 (26.9%). No transplant biopsy requiring intervention was detected within 6 hours (0/5), whereas 14/21 native biopsies requiring intervention (66.7%) were detected within 6 hours and 12/21 (57.1%) within 2 hours.

TABLE 3: Timing of Detection of Clinically Significant Bleeding by Biopsy Target

Time to detection	Native kidney	Transplant kidney	Renal mass	Total
All CT-detected bleeding events	n = 29	n = 12	n = 4	n = 45
< 2 h	14 (48.3%)	2 (16.7%)	3 (75%)	19 (42.2%)
2–4 h	0	1 (8.3%)	0	1 (2.2%)
4–6 h	2 (6.9%)	0	1 (25%)	3 (6.7%)
6–24 h	5 (17.2%)	6 (50%)	0	11 (24.4%)
> 24 h	8 (27.6%)	3 (25%)	0	11 (24.4%)
Events requiring intervention for bleeding	n = 21	n = 5	n = 0	n = 26
< 2 h	12 (57.1%)	0	—	12 (46.2%)
2–4 h	0	0	—	0
4–6 h	2 (9.5%)	0	—	2 (7.7%)
6–24 h	2 (9.5%)	3 (60%)	—	5 (19.2%)
> 24 h	5 (23.8%)	2 (40%)	—	7 (26.9%)

Indication for CT, by Detection Interval

Indication for CT	≤ 6 h (n = 23)	6–24 h (n = 11)	> 24 h (n = 11)	Total (n = 45)
Findings identified in the biopsy suite	17 (73.9%)	0	0	17 (37.8%)
Findings identified after leaving the biopsy suite	6 (26.1%)	11 (100%)	11 (100%)	28 (62.2%)
Patient-reportable symptom	5 (21.7%)	6 (54.5%)	8 (72.7%)	19 (42.2%)
Monitoring-dependent finding	1 (4.3%)	4 (36.4%)	1 (9.1%)	6 (13.3%)
Suspected hematoma, no symptom specified	0	1 (9.1%)	1 (9.1%)	2 (4.4%)
Unrelated indication	0	0	1 (9.1%)	1 (2.2%)

Note: Time to detection is the interval between completion of the biopsy and the time the first post-procedure CT was ordered. Indented rows are subcategories of findings identified after leaving the biopsy suite.

Indication for CT and Presenting Features

The most frequently recorded presenting feature among patients with clinically significant bleeding was pain or discomfort (24/45 [53.3%]), followed by worsening anemia (8/45 [17.8%]), hypotension (5/45 [11.1%]), tachycardia (2/45 [4.4%]), and hematuria (1/45 [2.2%]). Detection in the biopsy suite differed by biopsy target, accounting for 13/29 native (44.8%), 1/12 transplant (8.3%), and 3/4 renal mass events (75.0%). Among the 28 events identified after the biopsy suite, 19 (67.9%) were prompted by a patient-reportable symptom and 6 (21.4%) by a monitoring-dependent finding alone.

Risk Factors for Clinically Significant Bleeding

Univariable associations are shown in **Table 4**. In the multivariable model (n = 1202; 41 events), biopsy target (p = .02), platelet count (OR, 0.994; p = .003), and systolic blood pressure (OR, 1.18 per 10 mm Hg; p = .04) were independently associated with bleeding. Native kidneys carried higher odds of bleeding than transplants (OR, 2.67; p = .006), with renal masses not differing significantly (OR, 2.14; p = .28). Female sex was of borderline significance (OR, 1.94; p = .051). In post hoc analyses, women bled more often than men within each target (native 6.8% vs 4.4%; transplant 3.1% vs 1.3%; renal mass 4.3% vs 2.3%), with a similar effect after adjustment for age, hemoglobin, and platelet count. Bleeding did not differ across the four native kidney diagnostic groups (n = 497; p = .61) or for lupus nephritis versus other diagnoses (3/46 vs 26/462; p = .74).

TABLE 4: Univariable and Multivariable Associations With Clinically Significant Bleeding Within 30 Days After Renal Biopsy

Predictor	Univariable		Multivariable	
	OR (95% CI)	p	OR (95% CI)	p
Patient characteristics				
Age (per 1 y)	1.00 (0.99, 1.02)	.61	1.00 (0.98, 1.02)	.71
Female sex (vs male)	2.14 (1.16, 3.96)	**.01**	1.94 (1.00, 3.91)	.051
Body mass index (per 5 kg/m²)	0.97 (0.78, 1.21)	.78	0.97 (0.77, 1.19)	.79
Inpatient status (vs outpatient)	1.65 (0.91, 3.00)	.10	1.05 (0.48, 2.28)	.90
Systolic blood pressure (per 10 mm Hg)	1.16 (0.99, 1.35)	.06	1.18 (1.01, 1.39)	**.04**
Pre-procedure laboratory values				
Hemoglobin (per 1 g/dL)	0.78 (0.67, 0.92)	**.003**		
Hemoglobin category		**.02**		.48
< 8 g/dL	2.10 (0.25, 17.50)	.49	1.61 (0.15, 9.50)	.65
8–9.9 g/dL	3.28 (1.46, 7.39)	**.004**	2.06 (0.77, 5.87)	.15
10–11.9 g/dL	1.58 (0.63, 3.97)	.33	1.26 (0.47, 3.55)	.65
≥ 12 g/dL	Reference		Reference	
Platelet count (per 1 × 10³/μL)	0.995 (0.991, 0.999)	**.01**	0.994 (0.990, 0.998)	**.003**
INR (per 1.0)	3.41 (0.45, 25.79)	.24	3.31 (0.39, 22.26)	.26
Serum creatinine (per 1 mg/dL)	1.04 (0.90, 1.19)	.60	0.95 (0.80, 1.11)	.56
Blood urea nitrogen (per 1 mg/dL)	1.00 (0.99, 1.02)	.56		
Procedural characteristics				
Biopsy target		**.005**		**.02**
Native kidney vs transplant kidney	3.04 (1.54, 6.03)	**.001**	2.67 (1.32, 5.68)	**.006**
Renal mass vs transplant kidney	1.57 (0.50, 4.95)	.44	2.14 (0.50, 7.22)	.28
CT vs US guidance	1.07 (0.38, 3.06)	.89		
BioPince vs Corvocet needle	0.70 (0.36, 1.33)	.27		
Introducer not used (vs used)	2.03 (0.60, 6.83)	.25		
Local anesthesia (vs procedural sedation)	0.84 (0.37, 1.92)	.69		

Sedation time (per 1 min)	1.04 (1.02, 1.05)	**< .001**
No. of passes (per 1 pass)	1.10 (0.90, 1.35)	.36
Longest pass length (per 1 cm)	0.49 (0.29, 0.82)	**.007**
Cumulative pass length (per 1 cm)	0.97 (0.83, 1.13)	.67
Tract embolization material		**.006**
Gelfoam pledgets vs gelfoam slurry	0.33 (0.16, 0.68)	**.003**
Both vs gelfoam slurry	1.50 (0.42, 5.40)	.54
Thrombin not administered (vs administered)	0.06 (0.02, 0.15)	**< .001**
Performing radiologist	—	.93

Note: Univariable odds ratios are from separate models for each predictor. Multivariable odds ratios are from a single Firth penalized logistic regression model including all variables shown in that column (n = 1202; 41 events). Blank cells indicate variables not included.

Discussion

In this single-center retrospective study of over 1,200 image-guided native, transplant, and renal mass biopsies, we compared rates and timing of clinically significant bleeding across targets and identified associated variables. Clinically significant bleeding was uncommon across all three biopsy targets. Consistent with prior literature, our data demonstrated that native kidneys had the highest rate of clinically significant bleeding, and that women had higher rates of bleeding complications.

No prior study has compared complication rates across all three biopsy types within a single practice. Native kidneys bled more often than transplant kidneys, and notably, this elevated risk persisted after adjustment for baseline patient factors (age, sex, pre-procedure hemoglobin and platelet count, systolic blood pressure, INR, creatinine, body mass index, and inpatient status). This suggests that the difference is not fully explained by the healthier baseline physiology and predominantly outpatient setting often attributed to transplant biopsy populations [20, 21], and that an anatomic explanation may more likely account for the disparity [6, 8].

The rate of clinically significant bleeding for renal mass biopsies was higher than transplants but lower than natives. This intermediate position is notable given how few comparative data exist for renal mass biopsy: most series report renal mass biopsy in isolation. Our clinically significant bleeding rate of 3.0% (4/132) sits at the lower end of reported ranges, in line with the 4.3% complication rate reported by a prior multicenter series [5]. None of the renal mass bleeds required intervention.

The strongest predictors of clinically significant bleeding on multivariable analysis were biopsy target, low pre-procedure platelet count, and higher systolic blood pressure, with female sex significant univariably and borderline after adjustment. Women bled more than men within every target even after accounting for age, hemoglobin, and platelet count, suggesting a component of bleeding risk unexplained by these factors alone. In a post hoc analysis, pathology did not explain the difference either: bleeding rates did not differ by diagnosis, and the sex difference persisted after excluding lupus, a diagnosis more common in women.

Pre-procedure low hemoglobin was also associated with bleeding on univariable analysis. Examined by clinical band, risk was concentrated at 8–9.9 g/dL, which differed significantly from a hemoglobin of at least 12 g/dL, whereas 10–11.9 g/dL did not. This accords with the Boston Kidney Biopsy Cohort, in which anemia was the dominant risk factor for post-biopsy transfusion and a pre-biopsy hemoglobin below 10 g/dL was associated with a markedly higher transfusion rate [7]. These findings highlight the importance of pre-procedure optimization of platelet count and hemoglobin through transfusion when necessary, and of critically evaluating the clinical utility of biopsies in higher risk patients.

Beyond patient-level factors, our data highlight potentially modifiable procedural factors. On univariable analysis, gelfoam pledgets were associated with lower odds of bleeding than gelfoam slurry. This association may be confounded: pledgets are harder to advance through the introducer when there is substantial backflow, and radiologists may preferentially choose slurry when concern for bleeding is already higher. Longer individual passes were likewise associated with lower odds of bleeding, which may reflect fewer total passes for a given cumulative length, better visualization, a more tangential approach relative to the renal cortex, or other technical or operator-related factors.

This study is uniquely positioned to scrutinize utility of post-procedure monitoring because the 23-hour observation after all renal biopsies. Prior studies addressing this question examined a single biopsy type and reached different conclusions—a 24-hour observation window for native biopsies [15], 30 minutes to 4 hours for transplant biopsies [2, 22], and 1 hour for renal mass biopsies [18]. These studies also found that although 89–97% of complications are identified within 24 hours, subacute presentations can occur up to 14–18 days post-procedure [2, 5]. Of note, in our study 17/45 instances of clinically significant bleeds were identified in the biopsy suite or immediately after the procedure, and the case for abbreviated observation differs by target.

For native kidneys, extended 23-hour observation (using a 2-hour window as reference) captured roughly one additional intervention per 125 biopsies; for transplant kidneys, one per 200. Renal mass biopsies did not incur any interventions. Native kidneys are the least clear-cut case, presenting with both the highest bleeding rate and the largest absolute number of bleeding events. However, the distribution of these events does not favor prolonged inpatient monitoring: more native interventions occurred after 24 hours, beyond any commonly utilized observation period, than were captured during hours 2 through 23. The same pattern held for transplants—40% of interventions occurred after 24 hours. Transplant bleeds did cluster later than native bleeds, with most interventions occurring between 6 and 23 hours post-

biopsy, which on timing alone would argue against early discharge. However, all transplant interventions within this interval were prompted by pain, a patient-reportable symptom. Moreover, transplant biopsies have consistently been found to be low risk for bleeding [22], as our data support. Renal masses are the least ambiguous: 3/4 bleeds were detected within two hours, and all within six. None required intervention.

Two methodological choices influence this timing analysis: whether events are compared as absolute numbers or as percentages of each target's bleeding cohort, and whether all clinically significant bleeds are considered or only those requiring intervention. By absolute numbers, a uniform 2-hour observation window is defensible across all three targets; by percentage of events captured, longer observation would be favored for native biopsies given their higher bleeding rate. Restricting the analysis to interventions alone, rather than all clinically significant bleeds, raises the proportion detected within 2 hours for native biopsies (48% to 57%) but lowers it for transplant biopsies (17% to 0%).

Despite this variability, the marginal yield of extended monitoring must be weighed against the cost of admitting every patient. Although this is not a cost-effectiveness analysis, these findings may inform shortening the 23-hour observation to 2 hours, paired with patient education on symptoms that should prompt return to the hospital. Distance from the treating institution or nearest tertiary care center should also inform this decision, with a lower threshold for admission in patients with limited access to care. Patients with intraprocedural bleeding or clinical concern during observation could reasonably be admitted, with a low threshold for CT. A structured direct-admission protocol or direct referral to interventional radiology may further support timely intervention.

Several limitations apply. This is a retrospective, single-institution study, and the experience of a tertiary care academic medical center may differ from other institutions. Clinically significant bleeding is rare, and the small number of events limited multivariable models, whose estimates should be read as adjusted associations rather than a risk prediction tool. We did not compile co-morbid conditions, limiting risk prediction and stratification. Our definition of clinically significant bleeding is subject to potential verification bias, as the clinical significance of what we defined as moderate hematoma is unclear, and patients with moderate hematomas who were discharged without post-procedure CT imaging would not have been captured. We also excluded transfusion from the definition of the primary outcome: only two patients were transfused without a CT demonstrating bleeding, and it was nearly impossible to ascertain whether a transfusion reflected a borderline pre-procedure hemoglobin or an acute biopsy-related drop. The CT indication was ascertained from ordering-provider notes, which were not always detailed or exhaustive. Finally, complications managed outside our regional healthcare network or systems connected through Epic Care Everywhere may not have been captured.

In this large retrospective cohort of more than 1,200 image-guided renal biopsies, clinically significant bleeding was uncommon, and biopsy target and select patient factors independently predicted bleeding risk. Because post-biopsy monitoring varies widely and largely reflects local experience, these detailed data on the timing of bleeding detection offer a framework for institutions to reconsider their protocols,

and the data on CT indications can inform patient education and discharge instructions. Together, these findings may improve preprocedural counseling, patient selection, biopsy technical factors, and post-biopsy monitoring protocols.

Declarations

Author Contribution

A.A. and S.M. contributed equally as co-first authors. D.L. and B.S. conceptualized the study and developed the study methodology. A.A. and S.M. collected and cleaned the data, performed portions of the analysis, prepared the figures and tables, and wrote the main manuscript text. J.H. served as the study statistician and contributed to the analysis. D.L., B.S., and M.I. handled project administration and provided supervision and resources. All authors reviewed the manuscript.

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Data Availability

The datasets generated and analyzed during this study contain protected patient health information and are not publicly available because of patient privacy and institutional restrictions. De-identified data may be made available from the corresponding author on reasonable request, subject to institutional and ethical approval.

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Figures

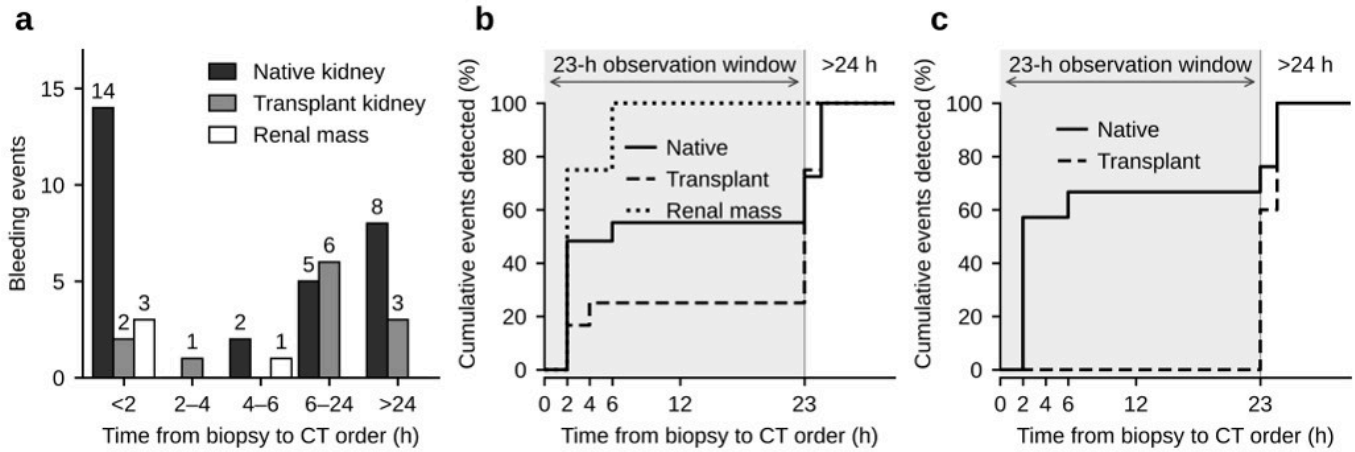


Figure 1

Timing of detection of clinically significant bleeding after renal biopsy. A: Bar graph shows the number of bleeding events by detection interval. B: Graph shows the cumulative percentage of all 45 bleeding events detected over time, by biopsy target. C: Graph shows the cumulative percentage of the 26 bleeding events that required intervention, by biopsy target; no renal mass biopsy required intervention, so that group is not plotted.