**Name of Journal:** *World Journal of Nephrology*

**Manuscript NO:** 86919

**Manuscript Type:** ORIGINAL ARTICLE

***Retrospective Cohort Study***

**Bleeding complications after percutaneous kidney biopsies – nationwide experience from Brunei Darussalam**

Lim CY *et al.* Kidney biopsy bleeding risks in Brunei

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**Received:** July 20, 2023

**Revised:** September 11, 2023

**Accepted:** September 27, 2023

**Published online:**

**Abstract**

BACKGROUND

Kidney biopsy serves as a valuable method for both diagnosing and monitoring kidney conditions. Various studies have identified several risk factors associated with bleeding complications following the procedure, but these findings have shown inconsistency and variation.

AIM

To investigate the risk of bleeding complications following percutaneous kidney biopsy in Brunei Darussalam. We sought to explore the relevant clinical and pathological risk factors associated with these complications while also considering the findings within the broader international literature context.

METHODS

We conducted a retrospective study of all adult patients who underwent kidney biopsy in Brunei Darussalam from October 2013 to September 2020. The outcomes of interest were post-biopsy bleeding and the need for blood transfusions. Demographics, clinical, laboratory and procedural-related data were collected. Logistic regression analysis was used to identify predictors of outcomes.

RESULTS

A total of 255 kidney biopsies were included, with 11% being performed on transplanted kidneys. The majority of biopsies were done under ultrasound guidance (83.1%), with the rest under computer tomography guidance (16.9%). The most common indications for biopsy were chronic kidney disease of undefined cause (36.1%), nephrotic syndrome (24.3%) and acute kidney injury (11%). Rate of bleeding complication was 6.3% – 2% frank hematuria and 4.3% perinephric hematoma. Blood transfusion was required in 2.8% of patients. No patient lost a kidney or died because of the biopsy. Multivariate logistic regression identified baseline hemoglobin [odds ratio (OR): 4.11; 95% confidence interval (95%CI): 1.12-15.1; *P* = 0.03 for hemoglobin ≤ 11 g/dL *vs.* > 11 g/dL) and the presence of microscopic hematuria (OR: 5.24; 95%CI: 1.43-19.1; *P* = 0.01) as independent risk factors for post-biopsy bleeding. Furthermore, low baseline platelet count was identified as the dominant risk factor for requiring post-biopsy transfusions. Specifically, each 10 × 109/L decrease in baseline platelet count was associated with an 12% increase risk of needing transfusion (OR: 0.88; 95%CI: 0.79-0.98; *P* = 0.02).

CONCLUSION

Kidney biopsies were generally well-tolerated. The identified risk factors for bleeding and transfusion can help clinicians to better identify patients who may be at increased risk for these outcomes and to provide appropriate monitoring and management.

**Key Words:** Kidney biopsy; Bleeding complications; Logistic regression; Retrospective cohort study; Risk

Lim CY, Khay SL. Bleeding complications after percutaneous kidney biopsies – nationwide experience from Brunei Darussalam. *World J Nephrol* 2023; In press

**Core Tip:**

This retrospective study in Brunei Darussalam examined kidney biopsies from 2013 to 2020 and identified key risk factors for post-biopsy bleeding complications. Notably, it revealed that the presence of microscopic hematuria is a significant, previously unrecognized risk factor for such complications. Other findings included the impact of low baseline hemoglobin levels and platelet counts on bleeding and transfusion risk. These insights can assist clinicians in identifying high-risk patients and improving post-biopsy monitoring and care. Overall, the study enhances our understanding of kidney biopsy outcomes and patient safety.

**INTRODUCTION**

A kidney biopsy is a procedure used to diagnose and monitor kidney disease. However, it is not without risks, with bleeding being a major complication due to its invasive nature. Bleeding complications can range from self-limited hematuria and asymptomatic perinephric hematomas, to life-threatening hemorrhage that can lead to serious consequences such as hemodynamic instability, kidney loss, and even death. In current practice, kidney biopsies are commonly performed percutaneously using real-time ultrasound guidance, which has been shown to decrease the risk of complications[1,2]. Moreover, automated spring-loaded biopsy devices have been found to be more effective than hand-driven systems, resulting in a higher yield of glomeruli and a reduction in major complications[3-5].

The frequency of complications following percutaneous native kidney biopsies varies across studies, mainly due to differences in patient populations, procedural techniques, complication definitions, and post-procedural monitoring. Although several risk factors for bleeding complications have been identified in different studies, the findings have been inconsistent[6]. A recent systematic review and meta-analysis that included 118064 biopsies reported that hematomas occurred in 11% of cases, frank hematuria in 3.5%, bleeding requiring blood transfusions in 1.6%, and interventions to stop bleeding in 0.3%[7].

In this study, we aimed to further investigate the risk of bleeding complications after percutaneous kidney biopsy and explore the associated clinical and pathologic risk factors. The study focused on a cohort of patients who underwent biopsies in Brunei Darussalam. By analyzing this specific group, the researchers aimed to provide more insights into the local context and shed light on factors that may contribute to bleeding complications.

**MATERIALS AND METHODS**

***Study design and population***

In this retrospective study, medical records of adult patients aged 18 years and above were reviewed over a period of seven years, from October 1, 2013, to September 30, 2020. The objective was to identify major bleeding complications associated with kidney biopsies. The analysis included only the first biopsy for patients who had multiple procedures. Kidney biopsy requests made by renal physicians were included, while those requested by urologists for investigating kidney lesions were excluded. Prior to the biopsy, informed consent was obtained from each patient. All antiplatelet and anticoagulation medications were stopped at least five days before the procedure, following the guidelines of the Society of Interventional Radiology[8]. Coagulation tests were performed a day before the biopsy, and if required, they were corrected using fresh frozen plasma or vitamin K to normalize the results. Pre-biopsy desmopressin was not administered. The biopsies were carried out in an inpatient setting, under local anesthesia, and with the guidance of imaging techniques such as ultrasound or computed tomography (CT). In all cases, Bard Max-CoreTM disposable core biopsy instrument with 18-gauge needles were used, typically performing 2 or 3 passes in the lower left renal pole, with the patient in the prone position. The decision on the number of passes was made by the procedurist based on whether sufficient core samples were obtained. After the procedure, patients were prescribed strict bed rest in a supine position for at least 6 h and monitored for post-procedure hematuria. Imaging was conducted immediately after the biopsy to confirm hemostasis, but further imaging to detect perinephric hematoma was only performed if clinically necessary. Perinephric hematoma was defined as the presence of hematoma on imaging that was over 1 cm in any dimension. Full blood counts were routinely performed the next day, and blood transfusions were given if clinically indicated. The decision to resume antiplatelet medications for patients at high cardiovascular risk was made on an individual basis, considering the risks and benefits. The study adhered to the ethical standards outlined in the Declaration of Helsinki and received approval from the institutional review board. A waiver of consent was granted by the Medical and Health Research and Ethics Committee.

***Outcomes and covariates***

Data on biopsy-associated bleeding events were collected by review of patient records. Outcomes of interest were post-biopsy bleeding (frank hematuria and/or perinephric hematoma), the need for blood transfusions, angiographic or open surgical interventions to control bleeding, nephrectomy and death. The timings of these bleeding events in relation to the procedure were also recorded.

Covariates examined included demographics (age, gender, ethnicity, height, weight), clinical (presence of hypertension, diabetes, whether dialysis was required before biopsy, biopsy indication), pre-biopsy laboratory (hemoglobin, platelet, serum creatinine, urea, albumin, total cholesterol, urine red blood cell, urine protein:creatinine ratio) and procedural-related (native or graft kidney, right or left kidney, procedurist, ultrasound or CT guided, number of passes, number of cores obtained) data.

***Statistical analysis***

Mean ± SD were calculated for continuous parametric data, and medians and interquartile ranges for non-parametric data. Categorical data were reported using frequencies. For group comparisons, we used the Student *t*-test, Mann-Whitney test, chi-square test or Fisher exact test, as appropriate.

Logistic regression analysis was used to identify risk factors associated with the outcomes. Univariate analysis was done for each variable, using the Wald test. Any variable with a significant univariate test at *P* value < 0.1 was then selected as a candidate for the multivariate model along with all variables of known biologic importance. We chose this *P* value cut-off point as more traditional levels such as 0.05 can fail in identifying variables known to be important.

Following the fit of the multivariable model, iterative process of variable selection was done where covariates were removed from the model if they were non-significant and not a confounder. Significant was evaluated at the 0.05 alpha level and confounding as a change in any remaining parameter estimate greater than 15% as compared to the full model. At the end of this iterative process, the model contains significant covariates and confounders. Any variable not selected for the original multivariate model is added back one at a time, with significant covariates and confounders retained earlier. Any that are significant at the 0.05 level are put in the model, and the model is iteratively reduced as before but only for the variables that were additionally added.

All statistical analyses were performed using STATA software application version 17.

**RESULTS**

Over the 7-year period, 255 kidney biopsies were performed (Tables 1 and 2). The mean age of the patients were 35.5 years old, with mean weight of 72.3 kg. Out of the total, 28 procedures (11%) were conducted on transplanted kidneys. Notably, those performed with CT-guidance (16.9%) tended to involve patients with a higher average weight compared to those guided by ultrasound scan (83.1%) – with mean weights of 92 kg *vs.* 68 kg, respectively (*P* < 0.001). Forty-six percent of the patients had history of hypertension and 21% had history of diabetes. The primary reasons for performing biopsies were as follows: Chronic kidney disease of unspecified cause (36%), nephrotic syndrome (24%), and acute kidney injury (AKI) (11%). 10.2% of patients needed dialysis pre-biopsy. This decision was left at the discretion of the attending nephrologists. The median pre-biopsy serum creatinine was 158 [interquartile range (IQR): 80 to 381] µmol/L, hemoglobin 11.5 ± 2.6 g/dL and platelet count 300 ± 108.3 × 109/L. Out of the 255 kidney biopsies performed, only 5 patients exhibited minor abnormalities in their coagulation tests prior to the procedure. This 2% incidence was deemed statistically insignificant. Importantly, none of these 5 patients experienced any bleeding complications post-biopsy. Consequently, our team decided not to incorporate coagulation tests as predictive factors. Moreover, it is worth noting that the occurrence of post-biopsy bleeding could not be linked to abnormal coagulation test results, as all patients involved in this study displayed normal coagulation results or had their abnormalities corrected before the biopsy. The mean size of the biopsied kidney was 11 ± 1.4 cm. Majority (92.4%) needed two passes.

Bleeding complications were observed in 16 (6.3%) patients, with 4.3% developing a perinephric hematoma and 2% experiencing frank hematuria. These bleeding complications happened at a median of 1-hour (IQR: 1-15 h) post-biopsy. The maximum duration was a 48 h delay. Blood transfusion was needed in a total of 7 (2.8%) patients. As shown in Tables 3 and 4, both bleeding complications and need for blood transfusion were associated with very similar risk factors in the univariate analysis – the presence of microscopic hematuria, 4 needle passes (compared to 2 passes), lower baseline hemoglobin, platelet, complements, higher serum creatinine, urea, as well as anti-double stranded DNA and antinuclear antibodies positivity.

Multivariable logistic regressions were performed to assess factors associated with an increased risk of bleeding complications and the need for blood transfusion after kidney biopsy. As indicated in Table 3, there is a significant association between pre-biopsy hemoglobin levels [with an odds ratio (OR) of 4.11; 95% confidence interval (95%CI): 1.12-15.1; P = 0.03 for hemoglobin ≤ 11 g/dL *vs.* >11 g/dL) and the presence of microscopic hematuria (with an OR of 5.24; 95% CI: 1.43 – 19.1; P = 0.01), both linked to the occurrence of post-biopsy bleeding.

After adjustment for other variables, it was solely the pre-biopsy platelet level that emerged as the primary factor influencing the need for post-biopsy blood transfusions. For every decrease of 10000/µL in the initial platelet count, there was a corresponding 12% rise in the likelihood of requiring a blood transfusion (with an OR of 0.88; 95%CI: 0.79-0.98; P = 0.02). There was no death, nephrectomy or angiographic or open surgical interventions needed to control bleeding. No differences in outcomes were found regarding the biopsy time period, first period from 2013 to 2016 years and second period from 2017 to 2020 (data not shown).

**DISCUSSION**

Our study has provided further evidence of the safety of kidney biopsy. We did not observe any nephrectomy or death after kidney biopsies performed in these 7 years. In a large meta-analysis, the rate of nephrectomy and death were 0.01% and 0.02% respectively[9].

The incidence of bleeding complications, specifically perinephric hematoma and frank hematuria, was found to be similar to that reported in other studies such as by Pombas *et al*[10] (5.44% hematoma, 2.57% frank hematuria) and Xu *et al*[11] (5.8% hematoma, 4.8% frank hematuria). However, two meta-analyses conducted by Poggio *et al*[7] and Corapi *et al*[9] have reported a higher incidence of hematoma at 11% and 11.6% respectively, while the incidence of frank hematuria was found to be comparable at 3.5% in both meta-analyses.

In our study, the 2.8% incidence of blood transfusion after kidney biopsy is consistent with the findings of other studies such as Shidham *et al*[12] (2.48%). However, our rate is lower compared to some population-based studies from other countries such as United States (26%)[13], Canada (9%)[14], France (5%)[15], Boston (4.3%)[16] and Australia (4%)[17]. Some of these population-based studies overestimated the risks of blood transfusion as not all of the events were attributable to kidney biopsies, particularly if the cohort had high co-morbidities such as anemia and heart failure. On the other hand, our rate of blood transfusion is higher than some other studies, such as Poggio *et al*[7] (1.6%), Pombas *et al*[10] (1.2%), Andrulli *et al*[18] (1.1%), Corapi *et al*[9] (0.9%), Tøndel *et al*[19] (0.9%) and Kawaguchi *et al*[20] (0.8%).

Our study found that patients with low baseline hemoglobin were more likely to experience bleeding complications, while those with low baseline platelet counts had an increased risk of requiring blood transfusion. This is consistent with findings from other studies, such as Pombas *et al*[10] and Xu *et al*[11]. Specifically, we observed that with every decrease of 10000/µL in the initial platelet count, there was a corresponding 12% rise in the likelihood of necessitating a blood transfusion. This is comparable to the 11% increase reported in the Xu *et al*[11] study.

To our knowledge, our study is the first to show that the presence of microscopic hematuria is associated with bleeding complication following kidney biopsy. The reasons for this association are unclear, and it is possible that unmeasured confounding factors may contribute to both hematuria from glomerular bleeding and bleeding post-biopsy. Therefore, further evaluation in larger, prospective studies is needed before changes are made to clinical practice. Interestingly, a recent study by Andrulli *et al*[18] found that high proteinuria levels may actually protect against bleeding complications after biopsy. It is therefore important that variables including urinalysis (hematuria and/or proteinuria) be included in the regression models in future studies, to better elucidate this association.

Numerous studies have reported increased bleeding complications and the need for blood transfusions to be associated with factors such as presence of hypertension[12,21], presence of diabetes[22], poor kidney function[9,18,23,24], female[17,25,26], elderly[9,27], larger biopsy needle[9,28], higher number of needle passes[18], AKI as indication for biopsy[7,9,11,26]. We have not found these variables to be significant risk factors in our cohort. It is important to note that different studies may use different definitions of bleeding complications, have variation in patient selection, procedural technique or monitoring protocols, leading to variability in findings. Analyses of predictors of complications associated with kidney biopsy also vary across studies.

Our study found that majority of bleeding complications were identified within the first 1-15 h of the biopsy, but a significant proportion (2%-10%) occurred after 24 h[12,14,29]. Specifically, we observed that 6% of patients with bleeding complications experienced them after 24 h. Therefore, it is crucial to consider the appropriate post-biopsy observation period based on individual patient risk.

A strength of our study is the nationwide investigation that allowed for an extensive and in-depth analysis of risk factors for post-biopsy bleeding complications in the current era. However, our study has some limitations that should be considered. Our findings are limited by the relatively small sample size which may limit the power to detect significant associations. Residual confounding is also likely to be present in the retrospective study design. Additionally, we did not collect data on certain potential predictors, such as blood pressure and coagulation tests. We also did not evaluate the impact of antiplatelet use as it is already standard practice to withhold. Furthermore, a recent meta-analysis found no significantly increased risk for major bleeding complications in patients on aspirin[30]. Another limitation is that repeat imaging post-biopsy was not routinely performed, unless prompted by patient symptoms or hemodynamic instability. This may have led to ascertainment bias and potential underestimation of hematoma events.

Notwithstanding these limitations, the identified risk factors can still be utilized in clinical practice to effectively risk stratify patients and inform shared-decision making. Counseling patients on these known risks is imperative to achieving patient-centered care. We strongly suggest that modifiable risk factors be managed aggressively to lower the risk of bleeding.

**CONCLUSION**

In conclusion, our study shows that the risk of bleeding after kidney biopsy performed by radiologists is generally low. However, we found that bleeding complications were more frequent in patients with lower pre-biopsy hemoglobin level and those with microscopic hematuria. Patients with lower platelet counts also had a higher likelihood of requiring blood transfusion after kidney biopsy. While our findings support the safety of kidney biopsy, it is important to carefully evaluate patients in order to minimize the risks associated with the procedure.

**ARTICLE HIGHLIGHTS**

***Research background***

Kidney biopsy serves as a valuable method for both diagnosing and monitoring kidney conditions. However, various studies have identified several risk factors associated with bleeding complications following the procedure, but these findings have shown inconsistency and variation.

***Research motivation***

Identifying key factors that significantly predict complications following a kidney biopsy is valuable in providing patients with essential information when seeking their consent for the procedure.

***Research objectives***

Our primary objective was to investigate the risk of bleeding complications following percutaneous kidney biopsy in Brunei Darussalam. We sought to explore the relevant clinical and pathological risk factors associated with these complications while also considering the findings within the broader international literature context.

***Research methods***

We performed a retrospective review of records of patients who underwent percutaneous kidney biopsies in Brunei Darussalam from October 1, 2013 to September 30, 2020. The demographic, clinical, laboratory and procedural-related characteristics of the patients were reviewed.

***Research results***

A total of 255 kidney biopsies were included. The incidence of bleeding (including hematuria and perinephric hematoma) stood at 6.3%. Blood transfusions were deemed necessary for 2.8% of patients, and fortunately, no patient suffered kidney loss or mortality due to the biopsy procedure. In a multivariable logistic regression analysis, two factors emerged as independent risk contributors for post-biopsy bleeding: baseline hemoglobin levels and the presence of microscopic hematuria. Additionally, a lower baseline platelet count emerged as the primary risk factor associated with the need for post-biopsy transfusions.

***Research conclusions***

Our findings align with existing research regarding the predictive risk factors for post-kidney biopsy bleeding complications. Nevertheless, our study uniquely highlights that the presence of pre-biopsy microscopic hematuria represents a notable and previously unreported risk factor for these complications.

***Research perspectives***

While our findings support the safety of kidney biopsy, it is important to carefully evaluate patients in order to minimize the risks associated with the procedure.

**REFERENCES**

1 **Burstein DM**, Schwartz MM, Korbet SM. Percutaneous renal biopsy with the use of real-time ultrasound. *Am J Nephrol* 1991; **11**: 195-200 [PMID: 1962666 DOI: 10.1159/000168303]

2 **Birnholz JC**, Kasinath BS, Corwin HL. An improved technique for ultrasound guided percutaneous renal biopsy. *Kidney Int* 1985; **27**: 80-82 [PMID: 3981874 DOI: 10.1038/ki.1985.13]

3 **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* 1994; **23**: 498-503 [PMID: 8154484 DOI: 10.1016/s0272-6386(12)80370-2]

4 **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* 1994; **9**: 1568-1574 [PMID: 7870344]

5 **Burstein DM**, Korbet SM, Schwartz MM. The use of the automatic core biopsy system in percutaneous renal biopsies: a comparative study. *Am J Kidney Dis* 1993; **22**: 545-552 [PMID: 8213794 DOI: 10.1016/s0272-6386(12)80927-9]

6 **Whittier WL**. Complications of the percutaneous kidney biopsy. *Adv Chronic Kidney Dis* 2012; **19**: 179-187 [PMID: 22578678 DOI: 10.1053/j.ackd.2012.04.003]

7 **Poggio ED**, McClelland RL, Blank KN, Hansen S, Bansal S, Bomback AS, Canetta PA, Khairallah P, Kiryluk K, Lecker SH, McMahon GM, Palevsky PM, Parikh S, Rosas SE, Tuttle K, Vazquez MA, Vijayan A, Rovin BH; Kidney Precision Medicine Project. Systematic Review and Meta-Analysis of Native Kidney Biopsy Complications. *Clin J Am Soc Nephrol* 2020; **15**: 1595-1602 [PMID: 33060160 DOI: 10.2215/CJN.04710420]

8 **Patel IJ**, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, Saad WA; Standards of Practice Committee, with Cardiovascular and Interventional Radiological Society of Europe (CIRSE) Endorsement. Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. *J Vasc Interv Radiol* 2012; **23**: 727-736 [PMID: 22513394 DOI: 10.1016/j.jvir.2012.02.012]

9 **Corapi KM**, Chen JL, Balk EM, Gordon CE. Bleeding complications of native kidney biopsy: a systematic review and meta-analysis. *Am J Kidney Dis* 2012; **60**: 62-73 [PMID: 22537423 DOI: 10.1053/j.ajkd.2012.02.330]

10 **Pombas B**, Rodríguez E, Sánchez J, Radosevic A, Gimeno J, Busto M, Barrios C, Sans L, Pascual J, Soler MJ. Risk Factors Associated with Major Complications after Ultrasound-Guided Percutaneous Renal Biopsy of Native Kidneys. *Kidney Blood Press Res* 2020; **45**: 122-130 [PMID: 31822004 DOI: 10.1159/000504544]

11 **Xu J**, Wu X, Xu Y, Ren H, Wang W, Chen W, Shen P, Li X, Shi H, Xie J, Chen X, Zhang W, Pan X. Acute Kidney Disease Increases the Risk of Post-Kidney Biopsy Bleeding Complications. *Kidney Blood Press Res* 2020; **45**: 873-882 [PMID: 33105145 DOI: 10.1159/000509443]

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)* 2005; **10**: 305-310 [PMID: 15958047 DOI: 10.1111/j.1440-1797.2005.00394.x]

13 **Al Turk AA**, Estiverne C, Agrawal PR, Michaud JM. Trends and outcomes of the use of percutaneous native kidney biopsy in the United States: 5-year data analysis of the Nationwide Inpatient Sample. *Clin Kidney J* 2018; **11**: 330-336 [PMID: 29988286 DOI: 10.1093/ckj/sfx102]

14 **Simard-Meilleur MC**, Troyanov S, Roy L, Dalaire E, Brachemi S. Risk factors and timing of native kidney biopsy complications. *Nephron Extra* 2014; **4**: 42-49 [PMID: 24803920 DOI: 10.1159/000360087]

15 **Halimi JM**, Gatault P, Longuet H, Barbet C, Bisson A, Sautenet B, Herbert J, Buchler M, Grammatico-Guillon L, Fauchier L. Major Bleeding and Risk of Death after Percutaneous Native Kidney Biopsies: A French Nationwide Cohort Study. *Clin J Am Soc Nephrol* 2020; **15**: 1587-1594 [PMID: 33060158 DOI: 10.2215/CJN.14721219]

16 **Palsson R**, Short SAP, Kibbelaar ZA, Amodu A, Stillman IE, Rennke HG, McMahon GM, Waikar SS. Bleeding Complications After Percutaneous Native Kidney Biopsy: Results From the Boston Kidney Biopsy Cohort. *Kidney Int Rep* 2020; **5**: 511-518 [PMID: 32274455 DOI: 10.1016/j.ekir.2020.01.012]

17 **Anpalahan A**, Malacova E, Hegerty K, Malett A, Ranganathan D, Healy HG, Gois PHF. Bleeding Complications of Percutaneous Kidney Biopsy: Does Gender Matter? *Kidney360* 2021; **2**: 1308-1312 [PMID: 35369661 DOI: 10.34067/KID.0002432021]

18 **Andrulli S**, Rossini M, Gigliotti G, La Manna G, Feriozzi S, Aucella F, Granata A, Moggia E, Santoro D, Manenti L, Infante B, Ferrantelli A, Cianci R, Giordano M, Giannese D, Seminara G, Di Luca M, Bonomini M, Spatola L, Bruno F, Baraldi O, Micarelli D, Piemontese M, Distefano G, Mattozzi F, De Giovanni P, Penna D, Garozzo M, Vernaglione L, Abaterusso C, Zanchelli F, Brugnano R, Gintoli E, Sottini L, Quaglia M, Cavoli GL, De Fabritiis M, Conte MM, Manes M, Battaglia Y, Fontana F, Gesualdo L; ITA-KID-BIO-Group. The risks associated with percutaneous native kidney biopsies: a prospective study. *Nephrol Dial Transplant* 2023; **38**: 655-663 [PMID: 35587882 DOI: 10.1093/ndt/gfac177]

19 **Tøndel C**, Vikse BE, Bostad L, Svarstad E. Safety and complications of percutaneous kidney biopsies in 715 children and 8573 adults in Norway 1988-2010. *Clin J Am Soc Nephrol* 2012; **7**: 1591-1597 [PMID: 22837269 DOI: 10.2215/CJN.02150212]

20 **Kawaguchi T**, Nagasawsa T, Tsuruya K, Miura K, Katsuno T, Morikawa T, Ishikawa E, Ogura M, Matsumura H, Kurayama R, Matsumoto S, Marui Y, Hara S, Maruyama S, Narita I, Okada H, Ubara Y; Committee of Practical Guide for Kidney Biopsy 2019. A nationwide survey on clinical practice patterns and bleeding complications of percutaneous native kidney biopsy in Japan. *Clin Exp Nephrol* 2020; **24**: 389-401 [PMID: 32189101 DOI: 10.1007/s10157-020-01869-w]

21 **Kriegshauser JS**, Patel MD, Young SW, Chen F, Eversman WG, Chang YH. Risk of bleeding after native renal biopsy as a function of preprocedural systolic and diastolic blood pressure. *J Vasc Interv Radiol* 2015; **26**: 206-212 [PMID: 25533452 DOI: 10.1016/j.jvir.2014.10.020]

22 **Hasegawa S**, Okada A, Aso S, Kumazawa R, Matsui H, Fushimi K, Yasunaga H, Nangaku M. Association Between Diabetes and Major Bleeding Complications of Renal Biopsy. *Kidney Int Rep* 2022; **7**: 232-240 [PMID: 35155862 DOI: 10.1016/j.ekir.2021.11.013]

23 **Korbet SM**, Volpini KC, Whittier WL. Percutaneous renal biopsy of native kidneys: a single-center experience of 1,055 biopsies. *Am J Nephrol* 2014; **39**: 153-162 [PMID: 24526094 DOI: 10.1159/000358334]

24 **Xu DM**, Chen M, Zhou FD, Zhao MH. Risk Factors for Severe Bleeding Complications in Percutaneous Renal Biopsy. *Am J Med Sci* 2017; **353**: 230-235 [PMID: 28262208 DOI: 10.1016/j.amjms.2016.12.019]

25 **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* 2004; **66**: 1570-1577 [PMID: 15458453 DOI: 10.1111/j.1523-1755.2004.00922.x]

26 **Moledina DG**, Luciano RL, Kukova L, Chan L, Saha A, Nadkarni G, Alfano S, Wilson FP, Perazella MA, Parikh CR. Kidney Biopsy-Related Complications in Hospitalized Patients with Acute Kidney Disease. *Clin J Am Soc Nephrol* 2018; **13**: 1633-1640 [PMID: 30348813 DOI: 10.2215/CJN.04910418]

27 **Lees JS**, McQuarrie EP, Mordi N, Geddes CC, Fox JG, Mackinnon B. Risk factors for bleeding complications after nephrologist-performed native renal biopsy. *Clin Kidney J* 2017; **10**: 573-577 [PMID: 28852497 DOI: 10.1093/ckj/sfx012]

28 **Waldo B**, Korbet SM, Freimanis MG, Lewis EJ. The value of post-biopsy ultrasound in predicting complications after percutaneous renal biopsy of native kidneys. *Nephrol Dial Transplant* 2009; **24**: 2433-2439 [PMID: 19246472 DOI: 10.1093/ndt/gfp073]

29 **Prasad N**, Kumar S, Manjunath R, Bhadauria D, Kaul A, Sharma RK, Gupta A, Lal H, Jain M, Agrawal V. Real-time ultrasound-guided percutaneous renal biopsy with needle guide by nephrologists decreases post-biopsy complications. *Clin Kidney J* 2015; **8**: 151-156 [PMID: 25815170 DOI: 10.1093/ckj/sfv012]

30 **Relvas M**, Gonçalves J, Castro I, Diniz H, Mendonça L, Coentrão L. Effects of Aspirin on Kidney Biopsy Bleeding Complications: A Systematic Review and Meta-Analysis (PROSPERO 2021 CRD42021261005). *Kidney360* 2023; **4**: 700-710 [PMID: 36951435 DOI: 10.34067/KID.0000000000000091]

**Footnotes**

**Institutional review board statement:** This study has been approved by the Medical and Health Research and Ethics Committee, Ministry of Health, Brunei Darussalam. The reference number is MHREC/MOH/2023/1(1).

**Conflict-of-interest statement:** The authors have nothing to disclose.

**Data sharing statement:** All data is included in the manuscript and/or supporting information. The data supporting this study are available from the corresponding author on reasonable request.

**STROBE statement:** The authors have read the STROBE statement – checklist of items, and the manuscript was prepared and revised according to the STROBE statement – checklist of items.

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**Provenance and peer review:** Invited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** July 20, 2023

**First decision:** September 4, 2023

**Article in press:**

**Specialty type:** Urology and nephrology

**Country/Territory of origin:** Brunei Darussalam

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): 0

Grade C (Good): C, C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Klimontov VV, Russia **S-Editor:** Lin C **L-Editor: P-Editor:**

**Table 1 Characteristics of study cohort (continuous variables)**

|  |  |  |
| --- | --- | --- |
| **Variables** | ***N* = 255** | **Missing** |
| Mean age in years | 35.5 ± 14.3 |  |
| Mean weight (kg) | 72.3 ± 20.1 | 21 |
| Mean hemoglobin (g/dL) | 11.5 ± 2.6 | 1 |
| Mean platelet (× 109/L) | 300 ± 108.3 | 1 |
| Median creatinine (µmol/L) | 158 (80-381) |  |
| Median urea (mmol/L) | 9.4 (5.5-15.8) |  |
| Mean albumin (g/L) | 30.1 ± 9.1 |  |
| Median cholesterol (mmol/L) | 5.6 (4.6-8.2) | 13 |
| Median urine protein: Creatinine ratio (mg/mmol) | 598 (239-1119) | 20 |
| Median 24hr urine total protein (g/day) | 4.2 (1.7-7.8) | 103 |
| Mean complement C3 (g/L) | 1 ± 0.4 | 43 |
| Mean complement C4 (g/L) | 0.28 ± 0.14 | 44 |
| Mean size of biopsied kidney (cm) | 11 ± 1.4 | 40 |

**Table 2 Characteristics of study cohort (categorical variables)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables** | **Classifications** | ***N* = 255** | **Missing** |
| Male gender |  | 120 (47%) |  |
| Ethnicity | Malay | 207 (81.2%) |  |
|  | Chinese | 6 (2.4%) |  |
|  | Indian | 1 (0.4%) |  |
|  | Other | 41 (16%) |  |
| Presence of hypertension |  | 116 (45.5%) |  |
| Presence of diabetes |  | 53 (20.8%) |  |
| Dialysis before biopsy |  | 26 (10.2%) |  |
| Clinical syndrome | Isolated hematuria | 4 (1.6%) |  |
|  | Isolated non-nephrotic proteinuria | 25 (9.8%) |  |
|  | Hemo-proteinuria | 26 (10.2%) |  |
|  | Nephritic syndrome | 2 (0.8%) |  |
|  | RPGN | 1 (0.4%) |  |
|  | Nephrotic syndrome | 62 (24.3%) |  |
|  | Nephritic-nephrotic syndrome | 10 (3.9%) |  |
|  | AKI | 28 (11%) |  |
|  | CKD of undefined cause | 92 (36.1%) |  |
|  | Other | 5 (2%) |  |
| Presence of urine RBC |  | 108 (43.9%) | 9 |
| Presence of ANA |  | 69 (29.5%) | 31 |
| Presence of anti-dsDNA |  | 28 (15.5%) | 74 |
| Presence of ENA |  | 28 (15.6%) | 76 |
| Presence of ANCA |  | 8 (4.2%) | 63 |
| Presence of HBV |  | 6 (2.6%) | 27 |
| Presence of HCV |  | 2 (0.9%) | 34 |
| Presence of HIV |  | 2 (1%) | 45 |
| Transplanted (*vs.* native) kidney |  | 28 (11%) |  |
| If native, right (*vs.* left) kidney |  | 3 (1.3%) |  |
| Procedurist | Radiologist 1 | 82 (34%) | 15 |
|  | Radiologist 2 | 28 (11.6%) |  |
|  | Radiologist 3 | 68 (28.2%) |  |
|  | Radiologist 4 | 13 (5.4%) |  |
|  | Radiologist 5 | 49 (20.3%) |  |
|  | Radiologist 6 | 1 (0.4%) |  |
| CT (*vs.* USS) guidance |  | 43 (16.9%) |  |
| Number of passes | 1 | 1 (0.5%) | 57 |
|  | 2 | 183 (92.4%) |  |
|  | 3 | 11 (5.6%) |  |
|  | 4 | 3 (1.5%) |  |
| Number of cores | 1 | 3 (1.5%) | 48 |
|  | 2 | 188 (90.8%) |  |
|  | 3 | 12 (5.8%) |  |
|  | 4 | 4 (1.9%) |  |

RPGN: Rapidly progressive glomerulonephritis; AKI: Acute kidney injury; CKD: Chronic kidney disease; RBC: Red blood cell; ANA: Antinuclear antibody; Anti-dsDNA: Anti-double stranded DNA; ENA: Extractable nuclear antigen antibodies; ANCA: Antineutrophil cytoplasmic antibodies; HBV: Hepatitis B virus; HCV: Hepatitis C virus; HIV: Human Immunodeficiency virus; CT: Computer tomography; USS: Ultrasound scan.

**Table 3 Odds ratios for bleeding complications**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Classifications** | **Univariate logistic regression** | | | **Multivariate logistic regression1** | | | |
| **OR** | **95%CI** | ***P* value** | | **OR** | **95%CI** | ***P* value** | |
| Age (yr) |  | 1.02 | 0.99-1.06 | 0.254 | |  |  |  | |
| Gender | Female | Reference |  |  | |  |  |  | |
|  | Male | 0.49 | 0.17-1.47 | 0.204 | |  |  |  | |
| Ethnicity | Malay | Reference |  |  | |  |  |  | |
|  | Chinese | 2.55 | 0.28-23.2 | 0.407 | |  |  |  | |
|  | Indian | NA | NA | NA | |  |  |  | |
|  | Other | NA | NA | NA | |  |  |  | |
| Mean weight (kg) |  | 1.01 | 0.98-1.04 | 0.428 | |  |  |  | |
| Hypertension | No | Reference |  |  | |  |  |  | |
|  | Yes | 1.2 | 0.44-3.31 | 0.720 | |  |  |  | |
| Diabetes | No | Reference |  |  | |  |  |  | |
|  | Yes | 1.8 | 0.60-5.42 | 0.297 | |  |  |  | |
| Dialysis before biopsy | No | Reference |  |  | |  |  |  | |
|  | Yes | 2.16 | 0.57-8.13 | 0.256 | |  |  |  | |
| Clinical syndrome | AKI | Reference |  |  | |  |  |  | |
|  | Isolated hematuria | NA | NA | NA | |  |  |  | |
|  | Isolated non-nephrotic proteinuria | NA | NA | NA | |  |  |  | |
|  | Hemo-proteinuria | 0.33 | 0.03-3.43 | 0.355 | |  |  |  | |
|  | Nephritic syndrome | NA | NA | NA | |  |  |  | |
|  | RPGN | NA | NA | NA | |  |  |  | |
|  | Nephrotic syndrome | 0.28 | 0.04-1.80 | 0.180 | |  |  |  | |
|  | Nephritic-nephrotic syndrome | NA | NA | NA | |  |  |  | |
|  | CKD of undefined cause | 1.02 | 0.26-3.98 | 0.982 | |  |  |  | |
|  | Other | NA | NA | NA | |  |  |  | |
| Mean hemoglobin (g/dL) | > 11 | Reference |  |  | | Reference |  |  | |
|  | ≤ 11 | 5.04 | 1.40-18.15 | 0.0132 | | 4.11 | 1.12-15.1 | 0.033 | |
| Mean platelet (× 109/L) | > 250 | Reference |  |  | |  |  |  | |
|  | ≤ 250 | 3.23 | 1.13-9.20 | 0.0282 | |  |  |  | |
| Median creatinine (µmol/L) | < 265 | Reference |  |  | |  |  |  | |
|  | ≥ 265 | 3.62 | 1.27-10.3 | 0.0162 | |  |  |  | |
| Median urea (mmol/L) | < 10 | Reference |  |  | |  |  |  | |
|  | ≥ 10 | 3.8 | 1.19-12.12 | 0.0242 | |  |  |  | |
| Mean albumin (g/L) |  | 0.95 | 0.90-1.01 | 0.0802 | |  |  |  | |
| Median cholesterol (mmol/L) |  | 0.91 | 0.75-1.11 | 0.346 | |  |  |  | |
| Presence of urine RBC | No | Reference |  |  | | Reference |  |  | |
|  | Yes | 6.1 | 1.7-22 | 0.0062 | | 5.24 | 1.43-19.1 | 0.012 | |
| Median urine protein:creatinine ratio (mg/mmol) |  | 1 | 0.9996-1.0005 | 0.787 | |  |  |  | |
| Median 24 h urine total protein (g/day) |  | 0.92 | 0.78-1.09 | 0.351 | |  |  |  | |
| Mean complement C3 (g/L) | ≥ 0.8 | Reference |  |  | |  |  |  | |
|  | < 0.8 | 3.35 | 1.20-9.36 | 0.0212 | |  |  |  | |
| Mean complement C4 (g/L) | ≥ 0.15 | Reference |  |  | |  |  |  | |
|  | < 0.15 | 3.41 | 1.10-10.5 | 0.0332 | |  |  |  | |
| Presence of ANA | No | Reference |  |  | |  |  |  | |
|  | Yes | 2.98 | 1.03-8.58 | 0.0442 | |  |  |  | |
| Presence of anti-dsDNA | No | Reference |  |  | |  |  |  | |
|  | Yes | 3.94 | 1.19-13.1 | 0.0252 | |  |  |  | |
| Presence of ENA | No | Reference |  |  | |  |  |  | |
|  | Yes | 1.89 | 0.48-7.48 | 0.363 | |  |  |  | |
| Presence of ANCA |  | NA | NA | NA | |  |  |  | |
| Presence of HBV |  | NA | NA | NA | |  |  |  | |
| Presence of HCV |  | NA | NA | NA | |  |  |  | |
| Presence of HIV |  | NA | NA | NA | |  |  |  | |
| Kidney type | Native | Reference |  |  | |  |  |  | |
|  | Transplanted | 0.52 | 0.07-4.10 | 0.536 | |  |  |  | |
| Site of kidney |  | NA | NA | NA | |  |  |  | |
| Mean size of biopsied kidney (cm) | > 12 | Reference |  |  | |  |  |  | |
|  | ≤ 12 | 2.11 | 0.58-7.63 | 0.254 | |  |  |  | |
| Procedurist | Radiologist 1 | Reference |  |  | |  |  |  | |
|  | Radiologist 2 | 0.30 | 0.04-2.48 | 0.265 | |  |  |  | |
|  | Radiologist 3 | 0.51 | 0.15-1.73 | 0.277 | |  |  |  | |
|  | Radiologist 4 | 0.68 | 0.08-5.83 | 0.722 | |  |  |  | |
|  | Radiologist 5 | 0.17 | 0.02-1.38 | 0.101 | |  |  |  | |
|  | Radiologist 6 | NA | NA | NA | |  |  |  | |
| Guidance | Ultrasound | Reference |  |  | |  |  |  | |
|  | CT | 2.39 | 0.79-7.28 | 0.124 | |  |  |  | |
| Number of passes | 1 | NA | NA | NA | |  |  |  | |
|  | 2 | Reference |  |  | |  |  |  | |
|  | 3 | NA | NA | NA | |  |  |  | |
|  | 4 | 8.65 | 0.72-103.7 | 0.0892 | |  |  |  | |
| Number of cores | 1 | 35.6 | 2.97-426.6 | 0.0052 | |  |  |  | |
|  | 2 | Reference |  |  | |  |  |  | |
|  | 3 | NA | NA | NA | |  |  |  | |
|  | 4 | 5.93 | 0.57-62.3 | 0.138 | |  |  |  | |

1Only *P* value < 0.05 in the multivariate analysis is shown.

2*P* value < 0.1.

OR: Odds ratio; 95%CI: 95% confidence interval; NA: Not applicable (as zero cell count); AKI: Acute kidney injury; RPGN: Rapidly progressive glomerulonephritis; CKD: Chronic kidney disease; RBC: Red blood cell; ANA: Antinuclear antibody; Anti-dsDNA: Anti-double stranded DNA; ENA: Extractable nuclear antigen antibodies; ANCA: Antineutrophil cytoplasmic antibodies; HBV: Hepatitis B virus; HCV: Hepatitis C virus; HIV: Human Immunodeficiency virus; CT: Computer tomography.

**Table 4 Odds ratios for blood transfusion**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Classifications** | **Univariate logistic regression** | | | **Multivariate logistic regression1** | | | |
| **OR** | **95%CI** | ***P* value** | | **OR** | **95%CI** | ***P* value** | |
| Age (yr) |  | 1.00 | 0.95-1.05 | 0.951 | |  |  |  | |
| Gender | Female | Reference |  |  | |  |  |  | |
|  | Male | 0.44 | 0.08-2.33 | 0.338 | |  |  |  | |
| Ethnicity | Malay | Reference |  |  | |  |  |  | |
|  | Chinese | NA | NA | NA | |  |  |  | |
|  | Indian | NA | NA | NA | |  |  |  | |
|  | Other | NA | NA | NA | |  |  |  | |
| Mean weight (kg) |  | 0.99 | 0.95-1.04 | 0.809 | |  |  |  | |
| Hypertension | No | Reference |  |  | |  |  |  | |
|  | Yes | 0.89 | 0.19-4.06 | 0.880 | |  |  |  | |
| Diabetes | No | Reference |  |  | |  |  |  | |
|  | Yes | 0.63 | 0.07-5.31 | 0.667 | |  |  |  | |
| Dialysis before biopsy | No | Reference |  |  | |  |  |  | |
|  | Yes | NA | NA | NA | |  |  |  | |
| Clinical syndrome | AKI | Reference |  |  | |  |  |  | |
|  | Isolated hematuria | NA | NA | NA | |  |  |  | |
|  | Isolated non-nephrotic proteinuria | NA | NA | NA | |  |  |  | |
|  | Hemo-proteinuria | NA | NA | NA | |  |  |  | |
|  | Nephritic syndrome | NA | NA | NA | |  |  |  | |
|  | RPGN | NA | NA | NA | |  |  |  | |
|  | Nephrotic syndrome | 0.45 | 0.03-7.47 | 0.577 | |  |  |  | |
|  | Nephritic-nephrotic syndrome | NA | NA | NA | |  |  |  | |
|  | CKD of undefined cause | 1.55 | 0.17-13.9 | 0.694 | |  |  |  | |
|  | Other | NA | NA | NA | |  |  |  | |
| Mean hemoglobin (g/dL) | > 11 | Reference |  |  | |  |  |  | |
|  | ≤ 11 | 6.67 | 0.79-56.2 | 0.0812 | |  |  |  | |
| Mean platelet (10 × 109/L) |  | 0.88 | 0.79-0.98 | 0.0212 | | 0.88 | 0.79-0.98 | 0.021 | |
| Median creatinine (µmol/L) |  | 1.001 | 0.999-1.003 | 0.105 | |  |  |  | |
| Median urea (mmol/L) |  | 1.068 | 0.999-1.141 | 0.0522 | |  |  |  | |
| Mean albumin (g/L) |  | 0.93 | 0.86-1.01 | 0.105 | |  |  |  | |
| Median cholesterol (mmol/L) |  | 0.94 | 0.71-1.24 | 0.654 | |  |  |  | |
| Presence of urine RBC | No | Reference |  |  | |  |  |  | |
|  | Yes | 8 | 0.95-67.5 | 0.0562 | |  |  |  | |
| Median urine protein:creatinine ratio (mg/mmol) |  | 1 | 0.9997-1.0006 | 0.415 | |  |  |  | |
| Median 24 h urine total protein (g/day) |  | 0.88 | 0.66-1.18 | 0.389 | |  |  |  | |
| Mean complement C3 (g/L) | ≥ 0.8 | Reference |  |  | |  |  |  | |
|  | < 0.8 | 6.32 | 1.20-33.3 | 0.0302 | |  |  |  | |
| Mean complement C4 (g/L) | ≥ 0.15 | Reference |  |  | |  |  |  | |
|  | < 0.15 | 5.43 | 1.16-25.4 | 0.0322 | |  |  |  | |
| Presence of ANA | No | Reference |  |  | |  |  |  | |
|  | Yes | 6.39 | 1.21-33.8 | 0.0292 | |  |  |  | |
| Presence of anti-dsDNA | No | Reference |  |  | |  |  |  | |
|  | Yes | 12.6 | 2.18-72.5 | 0.0052 | |  |  |  | |
| Presence of ENA | No | Reference |  |  | |  |  |  | |
|  | Yes | 2.83 | 0.49-16.2 | 0.244 | |  |  |  | |
| Presence of ANCA |  | NA | NA | NA | |  |  |  | |
| Presence of HBV |  | NA | NA | NA | |  |  |  | |
| Presence of HCV |  | NA | NA | NA | |  |  |  | |
| Presence of HIV |  | NA | NA | NA | |  |  |  | |
| Kidney type | Native | Reference |  |  | |  |  |  | |
|  | Transplanted | 1.36 | 0.16-11.7 | 0.781 | |  |  |  | |
| Site of kidney |  | NA | NA | NA | |  |  |  | |
| Mean size of biopsied kidney (cm) | > 12 | Reference |  |  | |  |  |  | |
|  | ≤ 12 | 1.18 | 0.22-6.19 | 0.849 | |  |  |  | |
| Procedurist | Radiologist 1 | Reference |  |  | |  |  |  | |
|  | Radiologist 2 | NA | NA | NA | |  |  |  | |
|  | Radiologist 3 | 0.79 | 0.13-4.86 | 0.797 | |  |  |  | |
|  | Radiologist 4 | 2.17 | 0.21-22.6 | 0.518 | |  |  |  | |
|  | Radiologist 5 | 0.54 | 0.05-5.36 | 0.600 | |  |  |  | |
|  | Radiologist 6 | NA | NA | NA | |  |  |  | |
| Guidance | Ultrasound | Reference |  |  | |  |  |  | |
|  | CT | 0.81 | 0.10-6.93 | 0.850 | |  |  |  | |
| Number of passes | 1 | NA | NA | NA | |  |  |  | |
|  | 2 | Reference |  |  | |  |  |  | |
|  | 3 | NA | NA | NA | |  |  |  | |
|  | 4 | 22.4 | 1.67-300.3 | 0.0192 | |  |  |  | |
| Number of cores | 1 | 23 | 1.71-308.7 | 0.0182 | |  |  |  | |
|  | 2 | Reference |  |  | |  |  |  | |
|  | 3 | NA | NA | NA | |  |  |  | |
|  | 4 | 15.3 | 1.30-181.4 | 0.0302 | |  |  |  | |

1Only p-value < 0.05 in the multivariate analysis is shown.

2*p*-value < 0.1.

OR: Odds ratio; 95%CI: 95%confidence interval; NA: Not applicable (as zero cell count); AKI: Acute kidney injury; RPGN: Rapidly progressive glomerulonephritis; CKD: Chronic kidney disease; RBC: Red blood cell; ANA: Antinuclear antibody; Anti-dsDNA: Anti-double stranded DNA; ENA: Extractable nuclear antigen antibodies; ANCA: Antineutrophil cytoplasmic antibodies; HBV: Hepatitis B virus; HCV: Hepatitis C virus; HIV: Human Immunodeficiency virus; CT: Computer tomography.