



ORIGINAL ARTICLE

Trends and outcomes of the use of percutaneous native kidney biopsy in the United States: 5-year data analysis of the Nationwide Inpatient Sample

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Abstract

Background: Despite an inordinate share of health care resources being utilized by patients with kidney disease, morbidity and mortality in these patients remain high. Although renal biopsy is an intervention to identify potential treatment-modifiable causes of disease, large-scale data studying the safety and outcomes of percutaneous native kidney biopsy in hospitalized patients are lacking.

Methods: We queried the Nationwide Inpatient Sample database from 2008 to 2012 and identified all hospital admissions during which a percutaneous renal biopsy was performed. Patients <18 years of age or with a transplanted kidney were excluded. Data regarding associated renal pathology and procedure-related complications were collected and analyzed. Outcomes studied were length of stay, mortality and cost adjusted for inflation.

Results: A total of 118 064 hospital admissions were included in our analysis. The most common complications reported after percutaneous kidney biopsy were packed red blood cell transfusion (261/1000 cases), hematuria (129/1000 cases) and bleeding (78/1000 cases). Patients had an overall mortality of 1.8%. The mean length of stay for each hospitalization was 10.65 days, with a significant difference between elective and nonelective admissions (6.3 versus 11.7; $P < 0.01$). The average cost per hospitalization was US\$22 917 after adjusting for inflation, again with a significant difference between elective and nonelective admissions (15 168 versus 24 780; $P < 0.01$).

Conclusion: Overall, percutaneous renal biopsy is considered a safe procedure; however, our study based on a national database demonstrates a relatively higher complication rate as compared with the limited prior available studies.

Key words: acute kidney injury, chronic kidney disease, kidney biopsy, kidney failure, Nationwide Inpatient Sample (NIS)

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Introduction

The prevalence of chronic kidney disease (CKD) in the US adult general population has increased slightly over the past 17 years, reaching 14.8% according to data from the National Health and Nutrition Examination Survey (NHANES) database 2011–2014 [1]. In 2014, Medicare patients with CKD were twice as likely to be hospitalized and had an adjusted all-cause mortality rate that was twice as high as patients without CKD. In addition, Medicare expenditures on beneficiaries with CKD accounted for 44% of total expenditures on adults between 18 and 64 years of age and for 20% of expenditures on adults ≥ 65 years of age. In contrast, the incidence of end-stage renal disease (ESRD) is decreasing, though it remains as high as 1424 cases per million population in adults ≥ 65 years of age. Among patients on dialysis, the total number of deaths in 2014 was 172.8 per 1000 patient-years. Moreover, Medicare expenditures on beneficiaries with ESRD reached US\$32.8 billion during that period. Whereas it is estimated that $\sim 40\%$ of patients with CKD have diabetes, the incidence of ESRD due to diabetes was 2282 per million population. Given the significant cost and mortality associated with renal disease, accurate and timely diagnostic procedures are an essential part of the care of these patients. While renal biopsy has been used to identify the cause of renal disease since 1923, novel technologies involving proteomics are now being evaluated as noninvasive alternatives [2, 3]. Information from a renal tissue sample is not always conclusive, however, it remains helpful in certain clinical scenarios [4]. Although renal biopsy is performed to identify treatment modifiable causes of kidney disease, large-scale data studying the safety and outcome of percutaneous native kidney biopsy in hospitalized patients are lacking.

Percutaneous renal biopsy is the most commonly used method to obtain renal tissue, with an open surgical procedure reserved for patients with contraindications to a percutaneous approach [4, 5]. Novel ways of obtaining renal tissue include transjugular and laparoscopic approaches [6–8]. Studies on the benefit and safety of a renal biopsy are available for review. In a study by Kropp *et al.* [9], in 46 patients with CKD undergoing renal biopsy or nephrectomy, 9% of samples were inconclusive. Earlier studies [10, 11] concluded that a renal biopsy altered management in 19–42% of cases, but a recent study by Kitterer *et al.* [12] concluded that a disease responsive to treatment modification was identified in 74% of cases. Bleeding is a common complication occurring in 1.2% of cases of percutaneous native kidney biopsy and in 0.2% of cases of percutaneous biopsy of a transplanted kidney [13, 14]. In a meta-analysis published in 2012, 3.5% of patients had macroscopic hematuria and 0.9% of patients required erythrocyte transfusion after a percutaneous renal biopsy. Urinary tract obstruction, unilateral nephrectomy and death occurred in 0.3, 0.01 and 0.02% of those cases, respectively. Despite the number of studies available, a conclusive data on the use of inpatient percutaneous renal biopsy and the frequency of complications is still lacking at the national level. In this study we present data on the use of inpatient percutaneous native renal biopsy during inpatient hospitalization of US adults between 2008 and 2012. We describe baseline patient characteristics and medical comorbidities, identify the frequency of complications, report associated renal pathologies and discuss hospitalization outcomes.

Materials and methods

Data from the Nationwide Inpatient Sample (NIS) database, from 1 January 2008 to 31 December 2012, was studied. International

Classification of Disease, Revision 9 (ICD-9) procedure code 5523 was used to identify cases where percutaneous renal biopsy was performed. Data from patients ≥ 18 years of age were included, whereas those missing mortality or gender data elements were excluded. Patients with a transplanted kidney were identified and excluded using Diagnosis Related Group 24 (DRG24) code 302, ICD-9 diagnostic codes V420 and 99681 and ICD-9 procedure codes 5553, 5561 and 5569 (Appendix, Table A).

Mean age, number of chronic conditions and baseline medical comorbidities were described. Distribution of cases by gender, age groups, race, hospital region, hospital bed size, hospital academic status and primary coverage was reported. The prevalence of specific renal diseases and commonly associated diagnoses was determined.

The rate of occurrence of bleeding, transfusion, nephrectomy and other frequently reported procedure complications was identified. Outcomes studied include mortality, length of stay and total cost adjusted for inflation. Data processing and analysis was performed using Microsoft Excel 2013 and Statistical Package for the Social Sciences version 23 software (IBM, Armonk, NY, USA).

Categorical variables were expressed as frequency, rate and percentage while continuous variables were expressed as mean (standard deviation). An independent sample *t*-test was used for comparison between means at a 99% confidence level and a binary logistic regression was used for risk analysis.

Results

A total of 175 831 hospital admissions where percutaneous renal biopsy was performed were identified between 2008 and 2012. 11 190 hospitalizations involving patients < 18 years of age were excluded. One hundred and fifty-six cases missing data elements on gender or mortality were also excluded. After excluding patients with a transplanted kidney, a total of 118 064 cases were included in the subsequent analysis (Appendix, Table B).

The mean age was 55.36 years and the average number of chronic medical conditions was 6.27 (Appendix, Table C). Deficiency anemia, congestive heart failure, diabetes, hypertension and renal failure were reported, among others, as existing medical comorbidities (Table 1).

Patients undergoing percutaneous renal biopsy were 52.5% males. The majority of patients were between 38 and 77 years of age. Patients were 55.8% White, 22.9% Black and 13.7% Hispanic. More cases were encountered in the South (40.5%) and in large hospitals (71.3%). Cases from urban teaching hospitals comprised 57.2% compared with 42.8% from urban nonteaching or rural hospitals. Medicare or Medicaid were the primary payers in 54.4% of patients compared with 32.5% covered by private health insurance (Table 2).

ICD-9 diagnostic code 58089 (acute glomerulonephritis with other specified pathological lesion in kidney) was the most frequently reported diagnosis among acute glomerulonephritis, whereas 5821 (chronic glomerulonephritis with lesion of membranous glomerulonephritis) was the most frequently reported diagnosis among chronic glomerulonephritis. ICD-9 diagnostic code 5819 (nephrotic syndrome with unspecified pathological lesion in kidney) was the most frequently reported diagnosis among nephrotic group diagnoses, while 58381 (nephritis and nephropathy, not specified as acute or chronic, in diseases classified elsewhere) was the most frequently reported diagnosis among nephritis and nephropathy group. Code 5845 (acute kidney failure with lesion of tubular necrosis) was identified in

Table 1. Baseline patient comorbidities

| Comorbidities | Percentage |
|--|------------|
| Acquired immune deficiency syndrome | 0.8 |
| Alcohol abuse | 3.9 |
| Chronic blood loss anemia | 2.6 |
| Chronic pulmonary disease | 15.4 |
| Coagulopathy | 11.2 |
| Collagen vascular disease/rheumatoid arthritis | 6.4 |
| Congestive heart failure | 14.1 |
| Deficiency anemia | 49.1 |
| Depression | 8.3 |
| Diabetes, uncomplicated | 15.8 |
| Diabetes with chronic complications | 12.6 |
| Drug abuse | 3.9 |
| Fluid and electrolyte disorders | 49.7 |
| Hypertension | 44.6 |
| Hypothyroidism | 10.7 |
| Liver disease | 5.2 |
| Lymphoma | 2.4 |
| Metastatic cancer | 2.2 |
| Obesity | 12.8 |
| Other neurological disorders | 4.9 |
| Paralysis | 1.6 |
| Peripheral vascular disorders | 4.9 |
| Psychosis | 3.5 |
| Pulmonary circulation disorders | 4.1 |
| Renal failure | 26.5 |
| Solid tumor without metastasis | 2.9 |
| Valvular disease | 4.7 |
| Weight loss | 9.7 |

15.2% of the cases. As a reported diagnosis, 1% of cases had renal sclerosis (587—renal sclerosis, unspecified) (Table 3).

In CKD, more cases were classified into Stages 3 and 4, with 8.7% and 6.5%, respectively. As a reported diagnosis, 13.3% of cases had ESRD (Appendix, Table D). Among kidney-related neoplasm, 9.6% were malignant, 0.8% were benign and 0.7% were secondary metastatic (Appendix, Table E).

Among DRG 24 codes, 316 (renal failure) was the most frequent at 29.9%, followed by 331 (other kidney and urinary tract diagnoses with major complications or comorbidities) at 8%. Connective tissue disorders with major complications or comorbidities (code 240) was next at 7.6%, followed by 315 (other kidney and urinary tract procedure) at 4.1%. Table 4 lists all the DRG 24 codes with a rate of occurrence $\geq 1\%$.

The need for packed red blood cell (PRBC) transfusion was the most frequently reported complication (261/1000). This was followed by hematuria, bleeding and hypotension (129/1000, 78/1000 and 40/1000, respectively). Death occurred in 18 of 1000 hospital admissions. Ileus was reported at a rate of 15/1000. Kidney laceration and the need for nephrectomy occurred less frequently (1/1000 and 0.4/1000, respectively). During the course of hospitalization, a repeat percutaneous renal biopsy was needed in 14 of 1000 cases, whereas an open renal biopsy was performed in 0.2 of 1000 cases (Table 5).

While neither gender nor hospital academic status had an impact on inpatient mortality, patients admitted electively had significantly lower mortality rates when compared with non-electively admitted patients (0.99 versus 2.01%; $P < 0.01$) (Table 6).

The average length of stay was 10.65 hospital days (Appendix, Table C). Females had a slightly higher but statistically significant length of stay compared with males (10.9 versus 10.5 days; $P < 0.01$). A similar effect was observed when

Table 2. Distribution of cases by gender, age group, race, hospital region, hospital bed size, hospital academic status and primary coverage

| Characteristic | Percentage |
|-------------------------------|------------|
| Gender | |
| Male | 52.5 |
| Female | 47.5 |
| Age group (years) | |
| 18–37 | 19.8 |
| 38–57 | 31.6 |
| 58–77 | 37.8 |
| ≥ 78 | 10.8 |
| Race | |
| White | 55.8 |
| Black | 22.9 |
| Hispanic | 13.7 |
| Asian or Pacific Islander | 3.2 |
| Native American | 0.7 |
| Other | 3.7 |
| Hospital region | |
| Northeast | 17.8 |
| Midwest or North Central | 22.2 |
| South | 40.5 |
| West | 19.5 |
| Hospital bed size | |
| Small | 7.1 |
| Medium | 21.6 |
| Large | 71.3 |
| Hospital academic status | |
| Rural or urban nonteaching | 42.8 |
| Urban teaching | 57.2 |
| Primary coverage | |
| Medicare or Medicaid | 54.4 |
| Private | 32.5 |
| Self-pay, no charge, or other | 13.1 |

comparing the length of stay between teaching and nonteaching hospitals. Patients admitted electively were discharged an average of 5.4 days earlier ($P < 0.01$) (Table 6).

After adjusting for inflation, the average cost per hospitalization was US\$22 917 (Appendix, Table C). Males had a slightly lower but significant difference in the total cost compared with females (22 639 versus US\$23 224; $P < 0.01$). A nonelective nature of an admission and an admission to an urban teaching hospital were associated with a higher total cost. A nonelective admission was ~US\$9500 more expensive than an elective admission, while the difference between teaching and non-teaching hospitals approached US\$3000 (Table 6). Hematuria was associated with a lower admission cost, however, the need for PRBC transfusion, occurrence of bleeding and hypotension were associated with a higher cost. Interestingly, performing a nephrectomy or an open renal biopsy had no significant impact on the mean cost of an admission (Appendix, Table F).

In an attempt to identify predictors of increased mortality in patients admitted for a percutaneous renal biopsy, a binary logistic regression analysis was performed using a forward likelihood ratio model. Advanced age was found to be associated with the highest predicted mortality, with an odds ratio (OR) of 18.8. Patients with metastatic cancer, acute kidney injury, coagulopathy or liver disease at baseline had a higher predicted mortality as well (OR 6.2, 3.9, 2.7 and 2.1, respectively). Among the studied complications, the need for PRBC transfusion was the best predictor for increased mortality, followed by

Table 3. Frequency of reported pathology among patients undergoing percutaneous native kidney biopsy

| ICD-9 diagnosis code | ICD-9 diagnostic code description | Percentage |
|-----------------------------------|---|------------|
| Acute glomerulonephritis | | |
| 5800 | Acute glomerulonephritis with lesion of proliferative glomerulonephritis | 0.4 |
| 5804 | Acute glomerulonephritis with lesion of rapidly progressive glomerulonephritis | 0.8 |
| 58081 | Acute glomerulonephritis in diseases classified elsewhere | 1.2 |
| 58089 | Acute glomerulonephritis with specified pathological lesion in kidney | 3.9 |
| 5809 | Acute glomerulonephritis with unspecified pathological lesion in kidney | 1.4 |
| Nephrotic syndrome | | |
| 5810 | Nephrotic syndrome with lesion of proliferative glomerulonephritis | 0.1 |
| 5811 | Nephrotic syndrome with lesion of membranous glomerulonephritis | 1.9 |
| 5812 | Nephrotic syndrome with lesion of membranoproliferative glomerulonephritis | 0.4 |
| 5813 | Nephrotic syndrome with lesion of minimal change glomerulonephritis | 0.4 |
| 58181 | Nephrotic syndrome in diseases classified elsewhere | 4.1 |
| 58189 | Nephrotic syndrome with specified pathological lesion in kidney | 0.4 |
| 5819 | Nephrotic syndrome with unspecified pathological lesion in kidney | 7.6 |
| Chronic glomerulonephritis | | |
| 5820 | Chronic glomerulonephritis with lesion of proliferative glomerulonephritis | N |
| 5821 | Chronic glomerulonephritis with lesion of membranous glomerulonephritis | 1.2 |
| 5822 | Chronic glomerulonephritis with lesion of membranoproliferative glomerulonephritis | 0.1 |
| 5824 | Chronic glomerulonephritis with lesion of rapidly progressive glomerulonephritis | 0.1 |
| 58281 | Chronic glomerulonephritis in diseases classified elsewhere | 0.9 |
| 58289 | Chronic glomerulonephritis with specified pathological lesion in kidney | 0.5 |
| 5829 | Chronic glomerulonephritis with unspecified pathological lesion in kidney | 0.3 |
| Nephritis and nephropathy | | |
| 5830 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of proliferative glomerulonephritis | 0.3 |
| 5831 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of membranous glomerulonephritis | 0.6 |
| 5832 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of membranoproliferative glomerulonephritis | 0.7 |
| 5834 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of rapidly progressive glomerulonephritis | 1.2 |
| 5836 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of renal cortical necrosis | N |
| 5837 | Nephritis and nephropathy, not specified as acute or chronic, with lesion of renal medullary necrosis | N |
| 58381 | Nephritis and nephropathy, not specified as acute or chronic, in diseases classified elsewhere | 10.9 |
| 58389 | Nephritis and nephropathy, not specified as acute or chronic, with specified pathological lesion in kidney | 3.2 |
| 5839 | Nephritis and nephropathy, not specified as acute or chronic, with unspecified pathological lesion in kidney | 4.7 |
| Acute renal failure | | |
| 5845 | Acute kidney failure with lesion of tubular necrosis | 15.2 |
| 5846 | Acute kidney failure with lesion of renal cortical necrosis | N |
| 5847 | Acute kidney failure with lesion of renal medullary [papillary] necrosis | N |
| 5848 | Acute kidney failure with specified pathological lesion in kidney | 1.7 |
| 5849 | Acute kidney failure, unspecified | 48.6 |
| Renal sclerosis | | |
| 587 | Renal sclerosis, unspecified | 1 |

N, negligible.

Table 4. Most frequently associated DRG 24 code in patients undergoing percutaneous native kidney biopsy

| DRG 24 code | DRG 24 code description | Percentage |
|-------------|--|------------|
| 316 | Renal failure | 29.9 |
| 331 | Other kidney and urinary tract diagnoses with major complications or comorbidities | 8.0 |
| 240 | Connective tissue disorders with major complications or comorbidities | 7.6 |
| 315 | Other kidney and urinary tract procedures | 4.1 |
| 303 | Kidney and ureter procedures for neoplasm | 3.9 |
| 318 | kidney and urinary tract neoplasm with major complications or comorbidities | 3.3 |
| 332 | Other kidney and urinary tract diagnoses | 2.5 |
| 127 | Heart failure and shock | 2.4 |
| 576 | Septicemia without mechanical ventilation >96 h | 1.9 |
| 403 | Lymphoma and nonacute leukemia with major complications or comorbidities | 1.8 |
| 239 | Pathological fractures and musculoskeletal and connective tissue malignancy | 1.5 |
| 468 | Extensive operating room procedure unrelated to principal diagnosis | 1.4 |
| 304 | Kidney and ureter procedures for nonneoplasm with major complications or comorbidities | 1.0 |
| 452 | Complications of treatment with major complications or comorbidities | 1.0 |

Table 5. Frequency of reported complications of percutaneous native kidney biopsy

| Complication | ICD-9 code | Rate per 1000 cases |
|----------------------------------|---|---------------------|
| PRBC transfusion | 9904 ^a | 261 |
| Hematuria | 5997, 59970, 59971, 59972 ^b | 129 |
| Bleeding | 4590, 99811, 99812 ^b | 78 |
| Hypotension | 4580, 45829, 4588, 4589 ^b | 40 |
| Death | | 18 |
| İleus | 5601 ^b | 15 |
| Repeat percutaneous renal biopsy | 5523 ^a | 14 |
| Kidney laceration | 86600, 86601, 86602, 86603, 86610, 86611, 86612, 86613 ^b | 1 |
| Nephrectomy | 554, 5551, 5552, 5554 ^a | 0.4 |
| Open renal biopsy | 5524 ^a | 0.2 |

^aICD-9 procedure code.^bICD-9 diagnostic code.

Table 6. Variation in inpatient mortality, length of hospital stay and cost by gender, hospital academic status and admission urgency

| | Gender | | | Hospital academic status | | | Admission urgency | | |
|-----------------------|--------|--------|---------|----------------------------|----------------|---------|-------------------|----------|---------|
| | Male | Female | P-value | Rural or urban nonteaching | Urban teaching | P-value | Nonelective | Elective | P-value |
| Mortality (%) | 1.90 | 1.71 | 0.13 | 1.80 | 1.83 | 0.67 | 2.01 | 0.99 | <0.01 |
| Length of stay (days) | 10.5 | 10.9 | <0.01 | 10.2 | 10.9 | <0.01 | 11.7 | 6.3 | <0.01 |
| Cost (US\$) | 22 639 | 23 224 | <0.01 | 21 173 | 24 135 | <0.01 | 24 780 | 15 168 | <0.01 |

hypotension (OR 2.0 and 1.7, respectively). The Nagelkerke R²-value of this regression model was 0.158.

Discussion

The prevalence of CKD in the USA was 14.8% as recently as 2014. While CKD Stage 2 decreased in prevalence, CKD Stage 3 has increased over the period 1999–2014 and is currently present in >6% of the US adult population [1]. In our data search, renal failure was identified as the primary diagnosis in hospitalized patients undergoing kidney biopsy. A study performed by Liaño et al. [15] found that acute tubular necrosis (ATN) was the most common cause of acute kidney injury treated by nephrologists. Typically ATN is a clinical diagnosis and is treated with supportive care. In our study, ATN was identified in ~15.2% of biopsies. As discussed by Haas et al. [16], in patients whose clinical presentations are not consistent with ATN, obstructive or prerenal causes, prebiopsy and postbiopsy diagnoses differed in up to one-third of cases. We feel that this highlights the utility and significance of renal biopsy to diagnose renal dysfunction when the clinical presentation is not conclusive.

Indications for percutaneous renal biopsy are largely driven by clinical presentation and expert opinion [17, 18]. Some common indications include acute kidney injury lasting >3 weeks, proteinuria >1g/day, renal involvement of systemic disease and hematuria presumed to be of renal origin. Diabetes mellitus is the most common cause of CKD and ESRD, with most patients not requiring biopsy for diagnosis. Our search revealed that 28.4% of biopsied patients carried a diagnosis of diabetes, which is consistent with the 25% figure proposed in a study performed by Sharma et al. [19]. Indications for renal biopsy in diabetic patients are nephrotic-range proteinuria or significant decline in renal function that exceeds the patient's natural history of their disease [18]. While initial evaluation can suggest diabetic nephropathy, up to 60% of diabetic patients may have kidney findings other than diabetic nephropathy [19]. Several other

diseases were present, with focal segmental glomerulosclerosis (FSGS) and ATN being two of the top disorders found in diabetics. While FSGS can be explained by hypertension and obesity being more prevalent in the diabetes population, the mechanism for the increased incidence of ATN has not been elucidated to date. Perhaps more importantly, up to 36% of patients did not have signs of diabetic kidney disease at all, carrying alternative diagnoses such as membranous nephropathy and pauci-immune glomerulonephritis. Some of these causes are potentially amenable to immunosuppressive therapy, which can lead to increased renal survival.

Our study, while quantifying the number of renal biopsies performed, relied on ICD-9 and DRG coding for diagnostic information. Glomerulonephritides together composed nearly 10% of renal biopsies performed, however, identifying the specific etiologies of glomerulonephritis was beyond the scope of this study due to the nature of the database and the ICD-9 and DRG coding systems. About 15% of renal biopsies were performed for nephrotic syndrome; membranous nephropathy was diagnosed in ~2% of cases. Renal malignancy was identified in nearly 10% of patients.

Previous data on percutaneous renal biopsy concluded that it is a safe procedure, with several studies showing a significant complication rate of ~1% [20, 21]. It was also shown to be highly sensitive and specific in diagnosing primary renal malignancy, with close to 100% accuracy [22]. In contrast to a study by Tondel et al. [23] where gross hematuria was the most frequently reported complication (1.9%), hematuria was reported in 12.9% of our patients while the rate of occurrence of PRBC transfusion was 26.1%. Bleeding without the need for PRBC transfusion was less frequently reported. This may be due to underreporting of bleeding as a complication or due to the use of PRBC transfusion for indications other than acute blood loss. Of note, the frequency of PRBC transfusion, hematuria and bleeding were much higher in our study than in previous studies. Given that our study included a national database, we think that our study reveals the true incidence of the aforementioned

complications in the USA. Prior studies reporting lower complication rates may be related to the selection of centers where renal biopsies were performed and perhaps is also related to a selection bias, with patients enrolled in these studies being less sick. For example, 11.2% of patients in our study had preexisting coagulopathy while, such patients were excluded in other biopsy series [24]. The difference in complication rates observed between our data and the data from the national registry for renal biopsy in Norway may be partly related to the higher mean age of patients analyzed in our study (55.36 years compared with 50.6 years) [23]. The Norwegian data included patients with renal biopsies performed both in outpatient and inpatient settings; the data from the NIS database pertains to patients who are only admitted to the hospital, hence a sicker population. Identifying the true incidence of reported complications is an aid for clinicians when weighing the risks and benefits of a percutaneous renal biopsy and in obtaining true informed consent.

Due to the nature of the database used, several elements were missing in our analysis. These elements include the use of real-time ultrasound technology, the needle size used for biopsy, the number of passes performed and the number of cores obtained and the level of experience and specialty of the operator. In a prior study, however, the needle size used, the number of needle passes, and the specialty of the operator had no influence on the rate of major complications of a percutaneous renal biopsy [23]. Also not included were the number of patients on antiplatelet or anticoagulation therapy and the number of patients who underwent arterial embolization therapy in an attempt to control bleeding after a renal biopsy.

Our database search showed an overall mortality of 1.8%. While this value could be directly related to the renal biopsy performed, it is more likely due to the nature of the acute disease leading to hospitalization and related complications. This is further supported when comparing the mortality rate of elective admissions (0.99%) with nonelective admissions (2.01%). Again we see the discrepancy in mortality rate between our study and prior work, thus solidifying the idea of bias existing towards a lower rate of complications in previous studies. Interestingly, there was no difference in mortality rate between teaching and nonteaching hospitals.

The appropriate observation period following a percutaneous renal biopsy is still undefined. The practice varies from 4–8 h of observation to an overnight admission. According to a large biopsy series, up to 7.4% of major complications occur 12–24 h after biopsy [24]. Studies that advocate the safety of outpatient observation typically include doing a Doppler ultrasound postprocedure, frequent vital checks and serial hemoglobin level monitoring [21]. However, this is labor intensive and costly, thus negating the cost benefit of preventing a hospitalization. Patients who have an increased mortality risk after renal biopsy may benefit from a prolonged observation period. Our study identified advanced age, the presence of metastatic cancer, acute kidney injury, liver disease and coagulopathy as predictors of higher mortality. However, the Nagelkerker R-squared value of our model was low, 0.158. We also found that academic institutions perform renal biopsies at a rate 1.3 times that of nonacademic hospital institutions, likely due to a large referral base.

A nonelective admission was found to be a major contributor to an increased length of stay, likely secondary to the nature of acute illness requiring hospitalization and a prolonged treatment duration. Furthermore, patients who did not survive the admission had a statistically significant longer length of stay

compared with other patients (23.6 versus 10.4 days; $P < 0.01$). In elective admissions, the average length of stay was 6.3 days, which decreased to 6.1 days when excluding deaths. This length of stay is longer than expected considering the trend towards outpatient observation after biopsy. Since the NIS database includes information on hospitalized patients only, patients who underwent a percutaneous renal biopsy under observation status were not studied. This is a potential source of bias toward the longer length of stay reported in our study.

Due to advances in CKD and ESRD care, the life expectancy of patients with renal disease is increasing [1]. As a result, the expenditures for ESRD have doubled during the 2003–2014 period, from 16 billion to US\$32 billion. It is difficult to properly assess the economic burden of CKD, but a study by Wang et al. [25] revealed a linear increase in health care utilization and economic burden as patients advance from early to advanced-stage CKD. In our study, a higher cost was observed both in patients with nonelective admissions and with admissions to urban teaching hospitals. Whereas a shorter length of stay can explain the lower cost observed in elective admissions, a slightly longer length of stay cannot fully account for the higher cost observed in teaching hospitals. One explanation could be the variation in disease severity among hospitals, along with more advanced diagnostic testing and procedures done at academic centers, resulting in higher hospital bills. With the exception of hematuria, complications from a percutaneous renal biopsy resulted in an increase in admission cost. The lack of significance in cases where a nephrectomy or an open renal biopsy was performed is likely due to the small number of patients in these groups.

In this analysis of percutaneous renal biopsies in hospitalized patients we found that PRBC transfusion and hematuria occurred at a rate of 26.1% and 12.9% respectively, and that occurrence of bleeding, ileus or PRBC transfusion was associated with an increased hospitalization cost. Renal biopsy remains the gold standard for diagnostic, prognostic and therapeutic purposes in many renal diseases; however, other techniques, such as proteomics, are being increasingly studied as noninvasive alternatives [3, 24]. The use of these technologies may eventually replace renal biopsy as a primary means of determining individual renal pathology. Developing a comprehensive national registry of renal biopsy findings would serve the dual purpose of being able to directly compare tissue diagnosis to noninvasive techniques and to clearly identify those at highest risk for progression of renal disease. By revealing complication rates of percutaneous renal biopsy and identifying underlying renal disease in hospitalized patients while also providing an in-depth analysis of hospitalization outcomes, we believe that our study helps to emphasize both the financial and scientific aspects of kidney disease in the USA.

Supplementary data

Supplementary data are available online at <http://ckj.oxfordjournals.org>.

Conflicts of interest statement

None declared.

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