Trends in Percutaneous Renal Mass Biopsy Utilization in the United States: A Contemporary Analysis of an All-Payer Discharge Database

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Trends in Percutaneous Renal Mass Biopsy Utilization in the United States: A Contemporary Analysis Of An All-Payer Discharge Database

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Abstract

Purpose: Despite its theoretical benefit, it is unknown for which indications percutaneous renal mass biopsy (RMB) is actually used in clinical practice. This study aims to characterize trends in RMB utilization using data from a contemporary population-based cohort.

Methods: Using ICD-9 codes, we captured data from the Premier Hospital Database of patients who underwent a RMB for a renal mass between 2004 and 2012. Based on an estimate of renal mass incidence, we determined utilization rate (annual RMB / annual patients with renal masses), 30-day RMB complication rate, and subsequent interventions within 90 days.

Results: We identified 39,421 patients who underwent RMB; the annual number of RMB procedures in the U.S. ranged from 4000-5000. The RMB utilization rate for renal masses decreased from 9.5% in 2004 to 4.9% in 2012. Patients who underwent RMB tended to be older (71% >60 years old) and less healthy (43% Charlson Comorbidity Index ≥2); 20% had a concurrent metastatic disease and 17.2% had ablation as the subsequent intervention.

Conclusions: Despite its safety and utility for guiding the management of renal masses, the utilization of percutaneous RMB is declining in the U.S.. Additional studies are needed to determine the barriers to adoption and to clarify the indications.

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GLOSSARY OF ABBREVIATIONS

CCI: Charlson Co-morbidity Index

PN: Partial nephrectomy

RMB: Renal mass biopsy

SRM: Small renal mass

RCC: Renal cell carcinoma

SEER: Surveillance, Epidemiology, and End Results

INTRODUCTION

A widely established treatment paradigm across many diseases involves biopsy of a suspected cancer to establish a diagnosis prior to definitive therapy. A notable exception is kidney cancer for which renal mass biopsy (RMB) has historically been limited to diagnosing cancer in patients with unresectable disease, discriminating between metastases and kidney cancer in patients with a renal mass and an extra-renal malignancy, and diagnosing suspected infections (1). Consequently, most patients with a renal mass concerning for kidney cancer frequently proceeded with extirpative surgery without a pre-operative tissue diagnosis confirming malignancy. Since the turn of the century, it has been recognized that a substantial proportion of solid renal masses (SRMs) represent benign tumors or indolent cancers (2,3). Although some benign etiologies (e.g., angiomyolipomas with imageable fat) can be distinguished from malignant ones using imaging, most cannot (4). As a result, there has been a growing body of literature supporting an expanded role for RMB (5–8). Multiple studies have shown that RMB can be used to diagnose benign tumors, discriminate benign from malignant ones, and prevent unnecessary surgeries (6,8,9). Despite this, very little is currently known about the rate of usage of RMB in the United States or the clinical situations in which it is utilized.

To ascertain the correct role of RMB, it is important to understand both its evolution and potential. Contrast-enhancing renal lesions represent a heterogenous group of potential diseases. While renal cell carcinoma (RCC) is the most common, and increases in likelihood with the size of the lesion, several non-malignant tumors may also be present. A landmark study by Frank et al. (2), looked retrospectively at 30 years of pathological specimens and demonstrated that a relatively large number of the removed kidney cancers were in fact benign, and the odds of a benign tumor were directly related to the size of the lesion. Overall, oncocytomas make up approximately 7% of all renal tumors. Most notably, greater than 20% of tumors less than 4 cm in diameter, as identified by imaging, are benign, and do not need to be removed. Additionally, these smaller masses, if they are RCC, have less metastatic potential than larger RCC's, and there have been recent studies suggesting that even these malignant lesions do not need to be removed, particularly in older or sicker patients (10). In an

effort to avoid any unnecessary surgeries and their accompanying morbidity and mortality, ultrasound and CT guided RMB's have been developed to identify the nature of the lesion before surgery.

The evolution of the RMB has focused on the type of needle used, number of biopsies taken, and the imaging modality. There has also been discussion surrounding the merits of fine needle aspiration versus the use of core biopsies, with studies demonstrating that core biopsies are more likely to produce a true diagnosis (8). Surveys of urologists and interventional radiologists have shown that while needle sizes can range widely, contemporary physicians generally use 16 or 18-gauge needles. Similarly, there is significant variability of the number of biopsy specimens taken, with the most recent consensus being that two is sufficient. Finally, CT coaxial techniques are generally recognized as the most likely to be successful, though a radiation-sparing ultrasound is still commonly used. The advancement of these technologies, particularly of CT guidance, has increased the chances of retrieving an adequate specimen for diagnosis (6).

While the advancement of technology has improved the true utility of the RMB, part of its disuse was cultural as well. In the past, the usage of RMB was limited due to its low success rate, as defined by the ability to accurately diagnose a benign tumor and avoid surgery. In particular, a high number of biopsies (>20-30% in most studies) (11) were non-diagnostic, meaning that an inadequate amount of tissue was retrieved in order to make a pathological diagnosis. This "failure" rate had an unintended consequence. As noted by Lane et al. and Samplaski et al. (11,12), the biopsy "failure" rate was often conflated with having a low negative predictive value or an incorrect negative diagnosis--a reputation and miswording that exists throughout much of the urology literature. Believing that extirpative surgery would be necessary regardless of biopsy outcome due to an untrustworthy test, RMB's were not the standard of care and were even discouraged. Only in recent years have more rigorous studies of biopsy results been conducted, demonstrating a negative predictive value nearing 100% in multiple studies (6,8), while the non-diagnostic rate has remained around 90%, arguably due to inadequate specimen retrieval. Notably, a non-diagnostic biopsy now allows the

surgeon to decide between surgery and a repeat biopsy, while, in light of these new data, a negative biopsy allows the patient to avoid treatment altogether.

Though the presumed low negative predictive value played an important role in the low usage of RMB, concerns about its safety also contributed substantially. Several case reports before the turn of the century suggested evidence of tumor seeding along the tract of the biopsy needle, essentially introducing local metastasis through the procedure. Fear of this rare complication, combined with the suspected low clinical decision making assistance of the biopsy result, were two of the most common reasons that biopsies were not used (13). Modern biopsy techniques address this risk, using an inner sheath in which to perform the biopsy, and there have been no reports of needle tract seeding since 2001. Notably though, there has been a single case report of retroperitoneal seeding following a retroperitoneal hematoma caused by a RMB (8).

The RMB procedure does carry inherent risks. The penetration of the renal capsule by the biopsy needle can often lead to bleeding, which may manifest as a retroperitoneal hematoma or hematuria, though both are usually self-limited and benign. Similarly, while achieving access to the kidney, the needle may cause a pneumothorax in very rare cases. Overall, the modern day RMB is a safe procedure and its risks, while not negligible, are far outweighed by the potential morbidity and mortality of an avoidable partial or radical nephrectomy. A nephrectomy not only carries the risks of the procedure itself but the subsequent introduction of renal deficiency, with patients seeing, on average, a 15% reduction in renal function following the procedure (14). In particular, this loss of renal function can have devastating effects on patients with underlying renal dysfunction, such as those with diabetes. In these cases, the justification for a diagnostic RMB is even greater.

Despite evidence demonstrating the clinical benefit and safety of RMB (8), it is unclear to what extent the medical community has incorporated RMB into practice. Previous questionnaires have demonstrated very low usage among respondents, while few nationally representative studies have been performed. The most recent previous attempt to characterize the recent utilization of RMB on a national level was performed by Leppert et al. and concluded that in the most recent year with available data (2007) approximately 30% of patients with renal masses underwent a biopsy. Unfortunately,

this study was limited because the study population was restricted by age, insurance status, and pathology (15). Because Leppert et al. utilized the SEER-Medicare database, their patient cohort, by definition, all had positive biopsies, excluding all patients with negative biopsies. In addition, because of Medicare's age restrictions, younger patients with RCC were excluded from the study. These restrictions offered an incomplete picture of the usage of the RMB, and did not answer whether RMB is now being utilized appropriately. In light of these limitations, our study aimed to characterize the contemporary utilization of RMB in the management of renal masses using a contemporary, population-based cohort.

STUDENT ROLE

I worked closely with Dr. Steve Chang and Dr. Tudor Borza to examine the contemporary usage of renal mass biopsies. When I joined the project, the project had been through a preliminary stage, with an abstract of the preliminary results having been presented at the American Urological Association conference in 2015. After joining, we revamped the project together, examining new variables and outcomes in order to better fully describe the usage of renal mass biopsy. In addition, we augmented the methodology by which we examined the rate of usage, as well as the way in which we identified which patients had undergone a biopsy. The targets, variables, and types of patients chosen were identified through a collaborative process between myself, Dr. Chang, and Dr. Borza, while the programming and statistical analysis was performed by Dr. Chang. I performed the complete literature review and wrote the first draft of the manuscript, which was then reviewed with Dr. Borza, who worked with me on revisions. Dr. Chang then revised the manuscript, which we sent out to co-authors, including Dr. Jeffrey Leow, Dr. Ye Wang, Dr. Francisco Gelpi-Hammerschmidt, Dr. Adam Feldman, Dr. Stuart Silverman, and Dr. Benjamin Chung, for review. These co-authors all contributed helpful revisions and, where warranted, led to our examination of new variables and outcomes. The manuscript, of which I am a co-first author, is now being submitted to the Journal of Clinical Oncology for publication.

MATERIALS AND METHODS

Data Source

Data were obtained retrospectively from the Premier Hospital Database (Premier, Inc, Charlotte, NC), which is a de-identified Health Insurance Portability and Accountability Act (HIPPA)-compliant, all payer, population-based hospital discharge database, comprised of data from over 600 hospitals and 20% of the hospital discharges in the United States. The dataset provides patient demographics, hospital characteristics, and primary and secondary diagnoses, as well as patient-level administrative data containing all billed items for medications, interventions, and diagnostic procedures. We received Institutional Review Board exemption for this study.

Study Cohort

Using the International Classification of Diseases, Ninth Revision (ICD-9) codes, we identified all patients who underwent a percutaneous RMB (ICD-9 55.23) between January 1, 2004 and December 31, 2012. To exclude percutaneous biopsies performed for the evaluation of renal parenchymal diseases, we limited inclusion to patients with an ICD-9 code for renal mass or renal cancer (189.0, 189.8, 189.9, 223.0, 223.1, 236.91, 593.2, 593.9,753.10, 753.11, 753.19), and excluded patients who underwent a RMB by a physician with a specialty designation of nephrology, internal medicine, or transplant medicine.

Cohort Characteristics

We examined patient characteristics that potentially influenced the decision to receive a RMB, including age, gender, race, and insurance status, as well as hospital characteristics, including number of beds, type of hospital (teaching vs. non-teaching), location (urban vs. rural), and geographic region (Mid-West, Northeast, South, and West). To account for baseline health status, we calculated the Charlson Comorbidity Index (CCI) with Deyo modification for each patient (16). Although tumor characteristics data (e.g., size, location) were not available in this dataset, we determined the presence of metastatic disease based on associated diagnostic codes (196.x, 197.x, 198.x).

The cohort was divided into patients who underwent thermal ablation (55.3x), extirpative surgery (i.e., partial nephrectomy [55.4] or radical nephrectomy [55.5x]) or no documented treatment within 90 days of the biopsy. Among patients who underwent subsequent intervention, we assessed whether the RMB was performed on a day prior to intervention ("pre-intervention RMB"), which we assumed was used to guide therapy, or the day of intervention ("same-day RMB"), which we assumed did not influence the decision for therapy.

RMB Complications

We identified 30-day post-RMB complications based on the following ICD-9 codes: hematuria (599.7x), subcapsular hematoma (866.01), retroperitoneal hematoma (568.81), fistula (447.0, 747.62), colonic injury (863.4x), splenic injury (865.01), liver injury (865.01), adrenal injury (868.01), and pneumothorax (512.1, 512.89). Post-RMB mortality was determined by discharge codes. As the retrospective nature of our analysis may be associated with a selection bias that could potentially influence the probability of complications, we performed a secondary analysis restricted to patients who were younger (<60 years old), healthy (CCI=0), and without metastatic disease.

RMB Utilization Rate

We calculated the annual RMB utilization rate based on the following equation:

$$RMB\ Rate\ = \frac{Annual\ Number\ of\ RMB}{Estimated\ Annual\ Number\ of\ Patients\ with\ Renal\ Masses}$$

The "Annual Number of RMB" was obtained from the Premier Hospital Database as described above. Because there are no contemporary published reports on the combined incidence of benign and malignant renal masses, we estimated the "Annual Number of Patients with Renal Masses" from data published by the American Cancer Society, tumor stage information from the Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute, and from previously published estimates of probabilities of benign and malignant tumors based on tumor size (see Appendix/Supplement).

Statistical Analysis

Descriptive statistics were used for clinicodemographic and hospital characteristics. Pearson's chi-square test was used for categorical variables. We constructed logistic regression models to evaluate the odds for complications. We applied the sampling weights and adjusted for hospital clustering to achieve a nationally representative analysis as has been previously described (17). Data analysis was performed using Stata 14.1 (College Station, TX). All tests were two-sided and a p-value of <0.05 was considered statistically significant.

RESULTS

Study Cohort

We identified 310,682 patients who underwent a renal biopsy during the 9-year study period (**Figure 1**). After applying our inclusion and exclusion criteria, the final study cohort was comprised of 39,421 patients. We found that the majority of patients (71%) did not undergo an intervention within 90 days of RMB. Among those who received intervention, thermal ablation was the most common treatment (17%) followed by radical nephrectomy (10%) and then partial nephrectomy (2%).

Patient and Hospital Characteristics

The clinicodemographic and hospital characteristics are shown in **Table 1**. Patients tended to be relatively older (63% over 60 years old, 40% over 70 years old) and less healthy (43% with CCI ≥2), with 19% of patients having metastatic disease. The majority of biopsies were done in urban (97%), non-teaching hospitals (72%), with the greatest proportion performed in the southern region of the U.S. (40%).

RMB Utilization

Our analysis demonstrates that approximately 4,000 to 5,000 RMB were performed annually (**Figure 2**). When factoring in the rising incidence of renal masses, we estimate that RMB rate decreased from 9.5% to 4.9% from 2004 to 2012 (see Supplement). There were no appreciable trends in patient and hospital characteristics associated with RMB.

Of the minority of patients (29.4%) who had a subsequent therapy, over half (58.5%) underwent thermal ablation. We also noted that the timing of RMB varied based on treatment (**Figure 3**): a same-day RMB was performed for 96% of patients undergoing thermal ablation, 54% of patients undergoing partial nephrectomy, and 8% of patients undergoing radical nephrectomy.

30-day RMB Complications

The most common complication was hematuria, which occurred in less than 10% of cases. All other non-fatal complications occurred in less than 1% of cases in both the overall cohort and the subgroup analysis of healthy individuals (**Table 2**). The probability of 30-day mortality was substantially higher for the total cohort (2.91%) compared to the subset of healthy patients (0.42%); the risk of mortality was associated with metastatic disease (adjusted odds ratio [AOR]: 4.4, 95% confidence interval [CI]: 3.6-5.4, $p<0.001$), and comorbidities (CCI≥1 vs CCI=0; AOR: 1.8, 95% CI: 1.4-2.3, $p<0.001$).

DISCUSSION

Our analysis of a contemporary, population-based cohort reveals that RMB remains infrequently utilized in the current management of renal masses with the absolute annual number of RMB relatively stable between 4,000 and 5,000. Despite the rise in the detection of renal masses (18,19), we found a decrease in the RMB rate from 9.5% in 2004 to 4.9% in 2012. RMB was preferentially used for patients who were older or had multiple comorbidities that may have made them suboptimal surgical candidates, for patients for whom thermal ablation was chosen, or for patients for whom no subsequent intervention was needed. In the latter-most, it is possible that the biopsy yielded a diagnosis of a benign neoplasm or process or a cancer that was not sufficiently aggressive to warrant therapy.

The current findings contrast with those of a recent study by Leppert et al., which reported an upward trend in the RMB rate to 30% by 2007 (15). This difference most likely reflects the prior study's use of data from the SEER-Medicine linked dataset, which is comprised of Medicare beneficiaries with a diagnosis of kidney cancer who are primarily 65 years old or older (15). In contrast, our study used the Premier Hospital Database, which is nationally representative and not constrained by age, insurance status, or cancer diagnosis, thus permitting a more generalizable description of RMB utilization across the U.S. population.

A number of factors likely contributed to our finding of low RMB utilization. One of the most common reasons for forgoing a RMB learned from surveys of clinical urologists is the concern for a false-negative result (13,20,21). Clinicians may mistakenly equate a non-diagnostic biopsy, in which the tumor was not appropriately sampled (22) with a false-negative biopsy, where the pathology suggests a benign tumor when in fact the tumor is malignant. Non-diagnostic biopsies occur in approximately 8% of the cases (6) and can be managed effectively with a repeat biopsy, which yields a definitive diagnosis in 83-100% of cases (11,22), or by proceeding to definitive management. In contrast, an actual false-negative biopsy occurs in less than 1% of cases in contemporary series (6). While some clinicians may consider any appreciable false-negative rate unacceptable, it is important to consider that false-

negative biopsies are recognized for other diseases that use biopsies, including pancreatic cancer (1.3%) (23), breast cancer (1.7%) (24), prostate cancer (20%) (25), and biliary cancer (20%) (26). Newer molecular studies have shown promising results, with the identification of several post-nephrectomy molecular predictors that could raise the accuracy of RMB to diagnose a clear cell renal cell carcinoma to nearly 100% (27) while also reducing the challenges of determining Fuhrman grade (28) or sarcomatoid features (29). These advances in RMB accuracy further bolster the argument to expand the role for RMB (6–8,30).

Alternatively, some clinicians argue that RMB will not change the decision for surgical intervention (13,20,21). Though this may be true of large, symptomatic renal masses, there has been a well described stage migration towards asymptomatic small (≤4 cm) renal masses over the past 20-30 years (18,19). As many as 25% of small solid renal masses are benign and do not warrant surgery or ablation. Furthermore, only 20% represent aggressive kidney cancer (10); the remainder may be indolent and, if known, would prompt active surveillance in selected patients (2). Consequently, current treatment paradigms for the management of small renal masses call for considering less aggressive alternatives to surgery such as thermal ablation or active surveillance and to consider using RMB to help with the decision (1). Indeed, studies now estimate that utilizing RMB can avoid surgery in 16-50% of patients with SRM (9,31–34).

While the purpose of a biopsy is generally to determine if treatment of a mass is necessary, we found that nearly one in five RMB (18.5%) was performed on the same day as the intervention, and thus was unlikely to have guided the decision for therapy. For thermal ablation, in particular, the vast majority (96%) were same day RMB, a finding consistent with previously reported survey data (35). When used in this setting, RMB does not assist in the decision for treatment; rather, it serves to obtain a histologic diagnosis and possibly influence the subsequent surveillance protocol. In contrast, for extirpative surgery, which inherently results in a histologic diagnosis, a same day RMB may represent intraoperative evaluation of multiple renal masses or miscoded frozen section analysis. In the case of both thermal ablation and surgery, a same day RMB could have led to the unnecessary treatment of a benign neoplasm. The definitive

reason for a same day RMB rather than a pre-intervention RMB is not clear based on the available data but warrants further evaluation.

Consistent with previous findings (6,8), our study suggests that RMB has a low rate of procedural complications (**Table 2**) with the notable exception of hematuria, which was present in 7.6% to 9.25% of cases. In our cohort, the median length of hospital stay was not prolonged among patients with hematuria (data not shown), suggesting that this may not be a clinically significant event. While the 30-day mortality rate seems high at 2.91% in our study cohort, we found that this could be explained by the fact that RMB is frequently performed in patients with advanced disease or those with limited life expectancy. Additionally, our inclusion algorithm captures a RMB performed for medical renal disease in a patient who also had a diagnosis of renal mass. We chose this inclusion approach in order to avoid under-reporting the RMB rate. Given the generally poorer state of health among ESRD patients, a higher mortality rate is not surprising. In fact, among our subgroup of "healthy" patients, the 30-day mortality rate was markedly lower at 0.42%, but still higher than previous studies (6,12), raising the possibility that the limitations of the administrative data failed to identify important comorbidities.

The low utilization rate suggests that RMB may be considered a "missed opportunity" in the current management of renal masses. Given the increasing incidence of renal masses and widespread dissemination of costly treatments (e.g., robotic surgery) over the past decade, the economic burden of renal masses on the health care system is undoubtedly higher today than the estimated annual expenditure of $4.4 billion based on data prior to 2000 (36). More frequent use of RMB may potentially avoid costly and invasive treatments. While not all renal masses necessarily warrant evaluation with RMB, we believe that this diagnostic test is useful in more than 4.9% of cases, which was the RMB rate at the end of our study. The need for a greater utilization of RMB is perhaps best emphasized by a recent study by Johnson et al. that showed that the prevalence of benign renal mass resections in the U.S. remains high, and is increasing (3). Our data, showing low utilization of RMB and therefore low avoidance of unnecessary benign resections, are consistent with these data. Additional

studies are necessary to determine the specific patient and tumor characteristics that make RMB cost-effective and to identify barriers to RMB adoption.

Our study has several limitations. First, although the Premier Hospital database offers a wealth of granular clinical data, it does not provide information of the size and location of renal masses, and therefore it was not possible to control for stage or the potential difficulty of intervention. Similarly, the database does not capture the number of renal masses diagnosed. For this reason, we relied on an estimated incidence compiled from additional external sources. Since the Premier Hospital database provides a nationally representative sample of patients, we felt that using additional sources of nationally representative data to generate the estimated incidence of renal masses would serve as a reasonable comparison. Furthermore, we could not focus our analysis on SRMs only; it is possible that the RMB utilization rate for SRM is decidedly higher than larger tumors. However, we do not believe this to be the case given the stable absolute number of RMB in the face of a rising incidence of SRM over the course of the study. Second, if patients received post-RMB care at a hospital not represented in the database, we may have erroneously classified patients as having no subsequent treatment or failed to capture post-procedural complications. Finally, we determined the annual RMB rate based on a denominator of number of total renal masses. Because the data for the incidence of total renal masses is not reported in the literature, we estimated this value based on a combination of several sources, as explained further in the supplement, and thus there may be some degree of inaccuracy in our calculated RMB rate.

Conclusions

This study demonstrates that while the incidence of renal masses is rising, the utilization of RMB in their management is declining. Despite data showing the safety of RMB and utility in identifying patients who can forgo costly and invasive interventions, the RMB rate has been decreasing with less than 5% of patients with a renal mass undergoing this evaluation by the end of the study. Because RMB represents an opportunity to reduce the number of renal masses unnecessarily treated, strategies to overcome the barriers to RMB adoption are warranted.

Suggestions for Future Work

The expansion of the field of RMB has and will continue to take multiple paths. In the field of interventional radiology, there is need for improvement in the ability of a RMB to retrieve tissue for diagnosis. The failure rate stands as one of the main impediments to widespread adaptation. Second, the rate of hematuria, though not life threatening, still plays a prominent role in the morbidity of the procedure, and efforts to improve the safety of the procedure are needed.

On a national scale, efforts should be made to encourage the usage of RMB, stressing both its safety and clinical utility, as well as its benefits to the patient in terms of cost and decreased morbidity. Finally, in order to strengthen the foundation on which these arguments are presented, further research should be conducted in a prospective manner to bolster the argument for RMB's decreased morbidity and cost compared to extirpative surgery.

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Table I. Clinicodemographic and hospital characteristics of patients who underwent a renal mass biopsy in the United States, 2004-2012.

Clinicodemographic Characteristics	**%**
Age (years)	
< 50	19.3
50 to 59	17.6
60 to 69	23.0
≥ 70	40.1
Gender	
Male	56.1
Female	43.9
Race	
White	61.3
Non-White	38.7
Marital Status	
Married	45.1
Not Married	54.9
Health Care Payer	
Medicare	54.7
Medicaid	7.8
Managed Care	23.9
Commercial	4.8
Unknown	8.8
Charlson Comorbidity Index	
0	35.0
1	22.1
2 or more	42.9
Metastatic disease	
Yes	19.0
No	81.0
Hospital Characteristics	**%**
Size (Number of beds)	
< 200	8.7
200 to 399	38.8
400 to 599	31.4
≥ 600	21.0
Type	
Teaching	27.9
Non-Teaching	72.1
Location	
Urban	97.3

Rural	2.7
Region	
Midwest	18.9
Northeast	22.0
South	40.2
West	18.9

Table 2. 30-day complications of renal mass biopsy

	n (%)	
Complications	**Total Cohort** (n = 39,421)	**Healthy Cohort** (n = 4,930)
Mortality	1147 (2.91)	21 (0.42)
Hematuria	2996 (7.60)	456 (9.25)
Subcapsular Hematoma	27 (0.07)	8 (0.17)
Retroperitoneal Hematoma	33 (0.08)	8 (0.16)
Fistula	59 (0.15)	7 (0.15)
Colonic Injury	0 (0.00)	0 (0.00)
Splenic Injury	18 (0.05)	0 (0.00)
Adrenal Injury	10 (0.03)	0 (0.00)
Pneumothorax	307 (0.78)	37 (0.75)

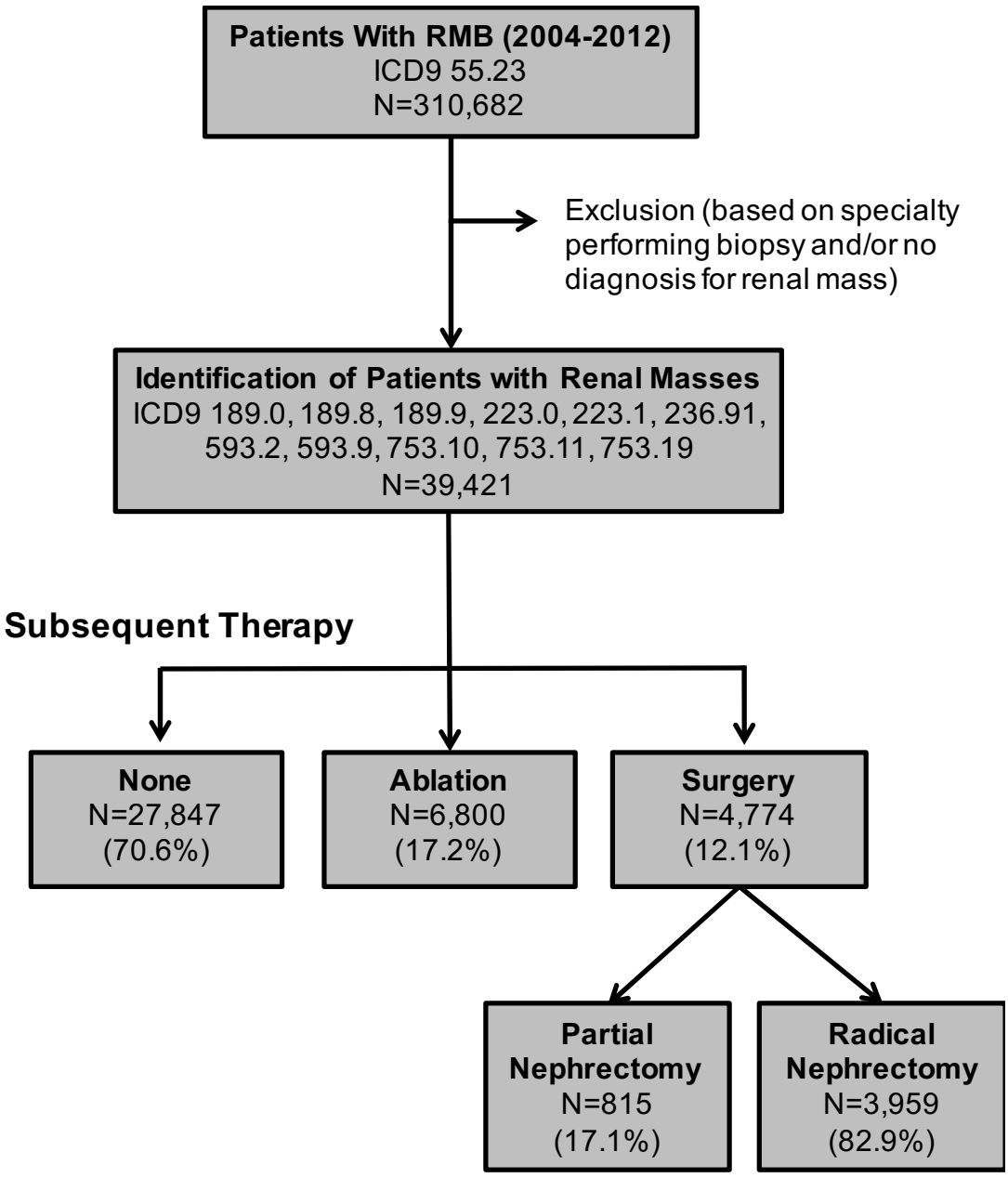

Figure 1. Identification of patients undergoing renal mass biopsy (RMB) for the management of renal masses in the United States, 2004-2012.

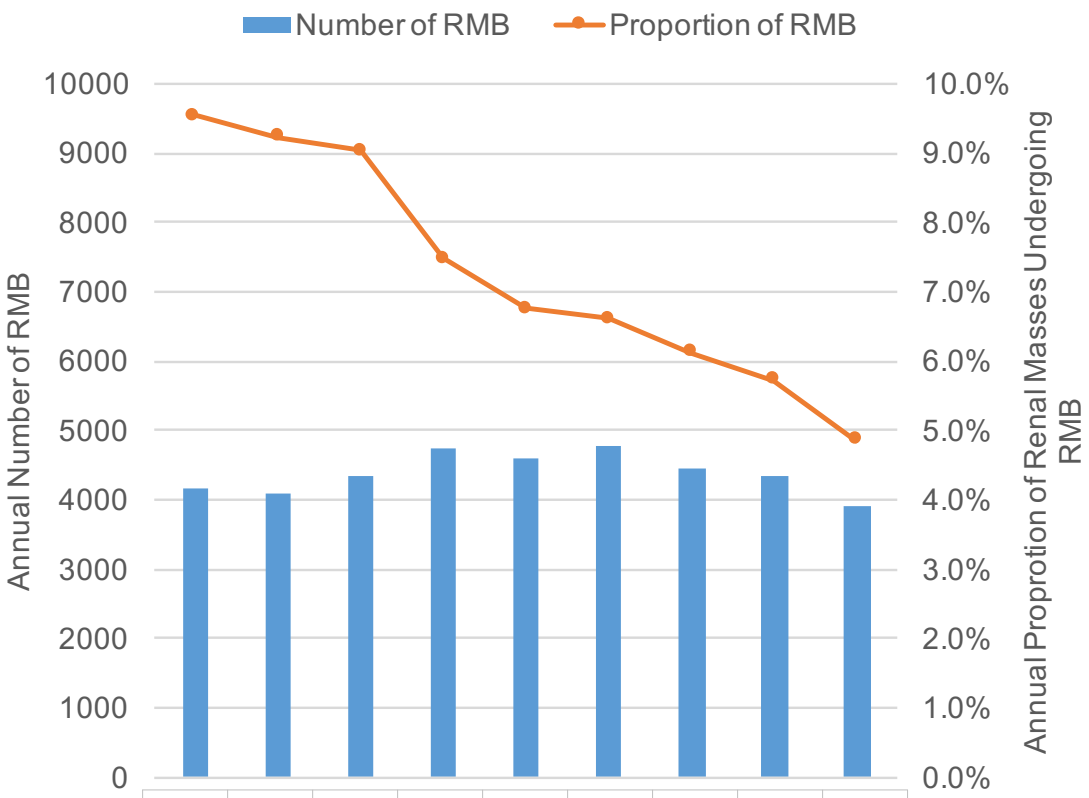

Figure 2. The annual number of renal mass biopsy (RMB) and annual proportion of renal masses undergoing RMB in the United States, 2004-2012.

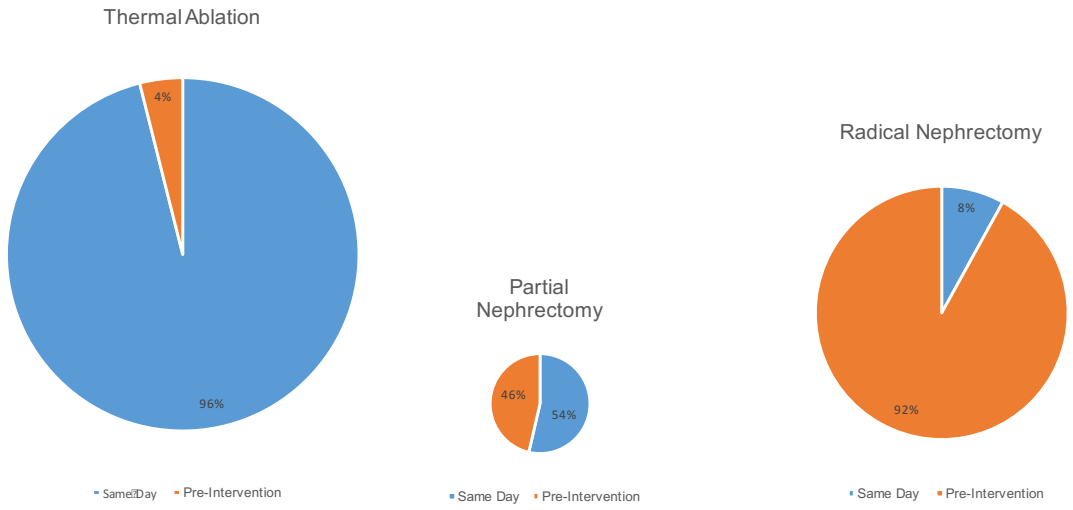

Figure 3. The subsequent intervention following renal mass biopsy (RMB) stratified by timing of the biopsy (same-day RMB vs pre-intervention RMB). The frequency of RMB is represented by relative size of the pie charts.

Appendix:
RMB Rate Calculation Supplement:

Table I. Annual Number and Percentage of Renal Cancer by Pathological Stage

(a) Annual Number of Renal Cancer by Pathological Stage [a]

Year	T1a	T1b	T2	T3	T4	Total
2004	3,526	1,962	1,173	1,896	352	8,909
2005	3,723	2,092	1,145	1,864	337	9,161
2006	4,292	2,318	1,236	1,902	290	10,038
2007	4,697	2,384	1,319	2,002	301	10,703
2008	5,210	2,574	1,328	2,076	300	11,488
2009	5,441	2,579	1,327	2,205	298	11,850
2010	5,217	2,609	1,318	2,153	327	11,624
2011	5,477	2,559	1,369	2,200	352	11,957
2012	5,665	2,695	1,406	2,419	344	12,529

[a] Data source: the Surveillance, Epidemiology, and End Results (SEER) Program (2004-2012).

(b) Annual Percentage of Renal Cancer by Pathological Stage [a, b]

Year	T1a (%)	T1b (%)	T2-T4 (%)
2004	39.58	22.02	38.40
2005	40.64	22.84	36.52
2006	42.76	23.09	34.15
2007	43.88	22.27	33.84
2008	45.35	22.41	32.24
2009	45.92	21.76	32.32
2010	44.88	22.44	32.67
2011	45.81	21.40	32.79
2012	45.22	21.51	33.27

[a] Annual Percentage of renal cancer in each stage = Number of renal cancer in the stage / Total number of renal cancer in the year.
[b] Data source: Table Ia.

Table II. Annual Incidence of Renal Cancer by Pathological Stage [a, b]

Year	T1a	T1b	T2-T4	Total
2004	14,134	7,863	13,713	35,710
2005	14,695	8,259	13,206	36,160
2006	16,629	8,980	13,281	38,890
2007	22,462	11,400	17,323	51,190
2008	24,666	12,189	17,535	54,390
2009	26,523	12,569	18,668	57,760
2010	26,138	13,069	19,027	58,240
2011	27,907	13,037	19,976	60,920
2012	29,289	13,932	21,549	64,770

[a] Annual incidence of renal cancer in each stage = Annual proportion of renal cancer in each stage * Total incidence of renal cancer in the year.
[b] Data sources: The annual proportion of renal cancer in each stage was obtained from Table Ib. The total incidence of renal caner by year was obtained from the American Cancer Society (ACS).

Table III. Annual Incidence of Benign and Malignant Renal Masses

(a) Percentage of Benign and Malignant Renal Masses by Pathological Stage [a]

	Benign (%)	Malignant (%)
T1a	30.4	69.6
T1b	10.5	89.5
T2-T4	6.3	93.7

[a] Data source: (Frank, Blute et al. 2003).

$$\frac{\textbf{ACS + SEER data (Figure II)}}{\textbf{\% Malignant}} = \textbf{Total Renal Masses}$$

(b) Annual Incidence of Benign and Malignant Renal Masses by Pathological Stage [a, b]

Year	T1a	T1b	T2-T4	Total Renal Masses
2004	20,319	8,789	14,635	43,743
2005	21,126	9,232	14,094	44,452
2006	23,906	10,038	14,174	48,118
2007	32,292	12,743	18,488	63,523
2008	35,460	13,625	18,714	67,799
2009	38,130	14,050	19,923	72,103
2010	37,577	14,609	20,306	72,492
2011	40,120	14,573	21,319	76,012
2012	42,107	15,573	22,998	80,678

[a] Annual number of renal masses (i.e., benign and malignant) = Annual incidence of renal cancer / Percentage of malignant renal masses.
[b] Data sources: Annual incidence of renal cancer was obtained from Table II. Percentage of malignant renal masses was obtained from Table IIIa.