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Limited Use of Surveillance Imaging Following Nephrectomy for Renal Cell Carcinoma

Eric H. Kim, Joel M. Vetter, Adrienne N. Kuxhausen, Joseph B. Song, Gurdarshan S. Sandhu, and Seth A. Strobe

Division of Urologic Surgery, Washington University School of Medicine, St. Louis, MO, USA

Abstract

OBJECTIVES—To evaluate the utilization of follow-up imaging after nephrectomy for renal cell carcinoma (RCC) in nationally representative data.

PATIENTS AND METHODS—Using Surveillance, Epidemiology, End Results (SEER) data linked to Medicare records, we identified patients with RCC who received nephrectomy from 1991 to 2007. Patients were stratified by tumor stage. Postoperative chest and abdominal imaging (including chest x-ray, CT scan, and MRI; abdominal ultrasound, CT scan, and MRI) was assessed. Observed surveillance imaging frequency was compared to published protocols. Predictors of initial and continued yearly surveillance imaging were identified.

RESULTS—Agreement between observed imaging frequency and evidence-based surveillance protocols was low, particularly for patients with T2-T4 disease. For patients who were not censored prior to 13 months, initial abdominal and chest surveillance imaging was obtained in 69% and 78% of patients, respectively. By year five, 28% and 39% of patients with high risk disease (T3 or T4), as compared to 21% and 25% of patients with low to moderate risk disease (T1 and T2), received yearly surveillance abdominal and chest imaging, respectively. High risk disease was predictive of initial chest (OR 1.38) and abdominal (OR 1.6) imaging, as well as continued yearly chest (HR 0.73) and abdominal (HR 0.74) imaging surveillance. For abdominal imaging, more contemporary year of surgery was predictive of initial (1997–2001, OR 1.6; 2002–2007, OR 2.4) and continued yearly surveillance (1997–2001, HR 0.82; 2002–2007; HR 0.67).

CONCLUSIONS—In the Medicare population, surveillance imaging is performed in a limited number of patients following nephrectomy for RCC. However, increasing tumor stage is predictive of both increased chest and abdominal imaging surveillance.

Corresponding Author: Seth A. Strobe, 4960 Children's Place, Campus Box 8242, St. Louis, MO 63110, 314-454-8049, strobes@wudosis.wustl.edu.

Conflict of Interest

Eric H. Kim - none

Joel M. Vetter - none

Adrienne N. Kuxhausen - none

Joseph B. Song - none

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Keywords

Renal Cell Carcinoma; Surveillance; Recurrence; Diagnostic Imaging

1. Introduction

In 2014 an estimated 64,000 new patients will be diagnosed with a renal malignancy [1]. Despite advances in both detection and treatment, patients diagnosed with renal cell carcinoma (RCC) have the lowest five-year survival rates among urologic cancers [2]. Traditionally, the importance placed on early detection of RCC local recurrence or metastases has been based on the assumption that outcomes are improved in the setting of lower disease burden. However, due to a lack of clear evidence that early detection of recurrence improves prognosis [3], opinions differ widely on how best to follow patients after nephrectomy. As a result, various surveillance protocols have been proposed, based on observed recurrences following nephrectomy [4–9].

Broadly speaking, some consensus among surveillance protocols exists—imaging frequency should be graduated on prognosis and the benefits of early detection should be weighed against the risks of radiation exposure. Patients with low risk disease should generally receive less frequent follow-up, while those with higher risk disease require imaging at shorter time intervals. The American Urologic Association (AUA) guideline recommendations for RCC surveillance after nephrectomy, published in 2013, differ for low (T1) versus moderate or high risk disease (>T2). For low risk disease, initial abdominal imaging followed by yearly chest x-ray (CXR) and optional yearly abdominal imaging is recommended for three years. For moderate or high risk disease, initial abdominal and chest imaging followed by semiannual abdominal and chest imaging for three years and annual imaging thereafter to five years is recommended [10].

Despite these general recommendations, it is unknown whether any practice patterns for post-nephrectomy surveillance imaging exists in the United States. We utilize Surveillance, Epidemiology, End Results (SEER) data linked to Medicare records to examine stage stratified patterns of chest and abdominal imaging following radical or partial nephrectomy.

2. Patients and Methods

2.1 Study Population

Using linked SEER—Medicare data, we identified a cohort of patients with non-metastatic RCC who underwent nephrectomy from 1991 to 2007. To ensure that billing records were complete, we limited the cohort to patients enrolled in both Medicare parts A and B, and with no Health Maintenance Organization (HMO) enrollment for one year prior to their surgery. Patients were between 65 and 90 years of age, had non-metastatic disease based on SEER coding, and did not have transitional cell carcinoma identified on pathology. Only patients with kidney cancer (ICD-03 code 649) as their first malignancy and with no other subsequent non-kidney primary cancer diagnoses were included. Cases diagnosed at autopsy or by death certificate were also excluded. To ensure continuity of assessment in a

geographically stable area within our analysis, we limited the cohort to the 12 SEER regions that had continuous data collection during our study period. Using a validated algorithm [11], we identified patients who received either partial (n=923) or radical nephrectomy (n=5420), leaving a total of 6343 patients available for analysis.

2.2 Ascertainment of Imaging

We searched the Medicare National Claims History for physician and outpatient claims for the following imaging tests performed after surgery: chest computed tomography (CT) scan, chest x-ray (CXR), chest magnetic resonance imaging (MRI) scan, abdominal or pelvic CT scan, abdominal or pelvic MRI scan, and abdominal or retroperitoneal ultrasound (US) (Appendix 1). We included all scans patients received, rather than only scans coded for kidney cancer as the diagnosis, because the diagnosis listed might not reflect the true indication for the scan. During a two-month interval where both chest CT and CXR or abdominal CT, MRI, and US were performed, the CT scan was kept as the scan of interest. Assessment of imaging was censored at patient death, loss of Medicare eligibility, or enrollment in a Medicare HMO. Given the high fidelity of Medicare claims for imaging, our analysis likely represents an overestimate of postoperative surveillance as imaging for indications other than RCC surveillance is captured.

2.3 Statistical Analysis

2.3.1 Comparison to contemporary published surveillance protocols—We compared stage-stratified postoperative imaging frequency to published postoperative surveillance protocols for non-metastatic RCC. Patients with less than two month survival following surgery (n=13) were excluded from this analysis, leaving 6330 patients for this analysis. Patients were stratified by pathologic tumor stage [12] based on Patient Entitlement and Diagnosis Summary File information (T1, n = 3668 and T2–T4, n = 2662). As the largest studies to date and with similar study periods as our cohort, the studies by Lam et al. [8] (n=559, years 1988–2003) and Antonelli et al. [9] (n=814, years 1983–2005) were selected for comparison. For these protocols, the low risk schedule was applied to T1 disease, the intermediate risk schedule was applied to T2 and T3 disease, and the high risk schedule was applied to T4 disease, as tumor histology was not available from SEER-Medicare data. This approach would likely overestimate the agreement with these protocols, as the least strict surveillance schedule would be applied to each disease stage. Additionally, imaging frequency was compared to recently published AUA guidelines for follow-up for clinically localized RCC [10] for both low risk (T1) and moderate to high risk (>T2) patients. Agreement with a particular protocol required appropriate chest and/or abdominal imaging between two months prior and two months after the recommended time for imaging following surgery. Schedule appropriate chest or abdominal MRI were considered in agreement with the protocols in lieu of chest or abdominal CT. Also, schedule appropriate chest CT or MRI were considered in agreement with protocol recommended CXR.

2.3.2 Assessment of initial surveillance imaging—We examined predictors of obtaining initial surveillance imaging, within 13 months of surgery. Patients who were censored prior to 13 months (n=442) were excluded, leaving 5901 patients for this analysis. Multivariate logistic regression was performed to identify predictors of obtaining at least one

surveillance abdominal or chest scan within 13 months of surgery. Patient comorbidity was quantified with the Charlson comorbidity index (CCI) [13]. For surgeon and hospital volume the distribution of values were divided into tertiles for analysis. Our study period was separated into three roughly equivalent segments (1991–1996, 1997–2001, and 2002–2007) for surgical year.

2.3.3 Assessment of continued yearly surveillance imaging—As our initial analysis demonstrated that intensive imaging frequency was undertaken infrequently in our study population, we assessed continued yearly surveillance imaging for our cohort. Although some guidelines do not recommend continued yearly abdominal surveillance for low risk disease [10], we believe yearly surveillance imaging to be a low clinical threshold for comparison. Additionally, yearly surveillance imaging for low risk disease comparable to higher risk disease would provide an indication of inappropriate risk stratified imaging. Patients who did not receive any abdominal imaging (n=1686) or chest imaging (n=1180) within 13 months of surgery were excluded from this analysis, leaving 4657 patients for the abdominal imaging analysis and 5163 patients for the chest imaging analysis. Stage-stratified Kaplan-Meier curves depicting the estimated probability of continued yearly imaging were generated and multivariate cox proportional hazards analyses were performed to identify predictors of discontinuation of yearly imaging.

All analysis was performed with SAS version 9.3 and R version 2.15.1. P-values of < 0.05 were considered statistically significant.

3. Results

The comparison of observed surveillance imaging to contemporary published protocols is summarized in Table 1. For reference the published surveillance protocols are summarized by risk category in Figure 1.

For patients who were not censored prior to 13 months, 31% (1829/5901) received no initial abdominal imaging surveillance and 22% (1323/5901) received no initial chest imaging surveillance. Predictors of initial surveillance imaging are summarized in Table 2. Receipt of abdominal imaging within 13 months of surgery was not predictive of overall survival (HR 0.96, p=0.26), while receipt of chest imaging within 13 months of surgery was predictive of overall survival (HR 1.22, p<0.01), when controlling for all baseline clinical variables.

For abdominal imaging, yearly surveillance was discontinued for 59% (2755/4657) of patients. For chest imaging, yearly surveillance was discontinued for 57% (2925/5163) of patients. Median follow-up was 4.9 years for patients with T1 and T2 disease, and 3.5 years for patients with T3 and T4 disease. Of the entire study cohort, 49.4% of patients with T1, 48.7% of patients with T2, and 34.1% of patients with T3 or T4 tumors were uncensored at five years. Stage-stratified Kaplan-Meier curves illustrating the proportion of patients with continued yearly surveillance imaging is provided in Figure 2a (abdominal imaging) and Figure 2b (chest imaging). At three years, 46% and 53% of patients with T3 or T4 disease, as compared to 36% and 42% of patients with T1 and T2 disease, received yearly surveillance abdominal and chest imaging, respectively. At five years, 28% and 39% of

patients with T3 or T4 disease, as compared to 21% and 25% of patients with T1 and T2 disease, received yearly surveillance abdominal and chest imaging, respectively.

Significant predictors for continuing yearly surveillance imaging are summarized in Table 3. Of note, for this analysis hazard ratios (HR) represent risk of discontinuation of yearly surveillance, thus increasing HR is associated with decreased likelihood of yearly surveillance while decreasing HR is associated with increased likelihood of yearly surveillance. Patients with increasing age were significantly more likely to discontinue both abdominal and chest yearly surveillance.

4. Discussion

Our analysis of SEER-Medicare data finds that both chest and abdominal imaging surveillance are performed in a limited number of patients following radical or partial nephrectomy for RCC. Overall, few patients received surveillance imaging that would have been in agreement with more contemporary evidence-based surveillance imaging protocols. More importantly, a sizeable proportion of patients received no initial postoperative imaging within the first 13 months (31% with no abdominal imaging and 22% with no chest imaging). Predictors of obtaining initial postoperative surveillance included gender, age, tumor stage, and surgical approach for both abdominal and chest imaging. The majority of patients discontinued yearly surveillance imaging by year five. Increasing age was a significant predictor of discontinuation. Conversely, increasing tumor stage and more recent year of surgery protected against discontinuation of surveillance.

As our study period (1991–2007) predates the publication date for the evidence-based protocols, comparison to these protocols was performed in order to provide context for the observed surveillance imaging frequency. The low rate of agreement found between observed surveillance and the proposed protocol by Lam et al. [8] is likely related to the requirement of chest CT scan as the chest imaging modality used, coupled with the semiannual frequency of chest imaging recommended for both intermediate and high risk disease for the first three postoperative years. Even after publication of the study by Lam et al., it is unlikely that the practicing urologist will order semiannual chest CT scans particularly in the era of cost containment in healthcare. Although the AUA guideline for RCC surveillance [10] was published more recently than that proposed by both Lam et al. and Antonelli et al., the AUA guideline has higher agreement with observed surveillance imaging, suggesting that the AUA guideline is more indicative of actual clinical practice patterns.

As more intensive imaging frequency was undertaken infrequently in our study population, yearly surveillance imaging was assessed for our cohort. Both initial surveillance imaging and continued yearly surveillance, for those patients who had received initial imaging, were examined. The majority of patients received both initial postoperative abdominal and chest imaging (69% and 78%, respectively). However, yearly surveillance imaging dropped off rapidly (Figure 2). With multiple studies demonstrating that lungs are the most common site for non-local recurrence following nephrectomy (estimates from 3–16% of patients) [4–7, 14], the majority of pulmonary recurrence occurring without symptoms [16], and the

accessibility of obtaining a yearly CXR in the Medicare population that not infrequently require a CXR for non-cancer related complaints, the overall number of patients receiving yearly chest imaging is both surprisingly and inappropriately low. Less than half (42%) of the patients with T1 disease in our study received yearly chest surveillance imaging for the first three years, which is the minimum recommendation by the AUA.

Underscoring the relative importance of chest imaging during surveillance, many studies recommend CXR as the only imaging modality for surveillance after nephrectomy for lower risk patients [4,6,7]. Although overall rates of chest surveillance were low, we found that both initial and continued yearly chest surveillance imaging was significantly more likely to be obtained for patients with higher tumor stage. Additionally, obtaining chest imaging within 13 months of surgery was an independent and significant predictor of overall survival. Although statistically independent, this may still be related to more frequent chest imaging obtained in patients with complications, significant comorbidities, and higher risk RCC. Continued yearly chest surveillance was also significantly more likely for patients who underwent surgery between 2002 and 2007 (HR 0.88, $p=0.01$), which is reflective of the number of studies recommending stage-based imaging surveillance protocols that were published prior to and during this time period (publication dates for references 4–8: 1995 to 2005). Increasing comorbidity was also seemingly predictive of initial and continued yearly chest imaging. However, this may be due to confounding from cardiopulmonary medical conditions that drive CCI and require yearly CXR, as there was no corresponding association between increasing comorbidity and surveillance abdominal imaging. Age > 80 years was predictive of no initial chest or abdominal surveillance and age > 70 years was predictive of no continued yearly chest or abdominal surveillance, which—independent of tumor stage and comorbidity—may be a result of clinical discretion on the part of the ordering physician as older patients likely derive less benefit with surveillance imaging.

Abdominal surveillance imaging was performed at a lower rate than chest imaging in our study cohort, with more patients with no initial postoperative abdominal imaging and greater proportion of patients with no yearly abdominal surveillance imaging by year three. This is not surprising for patients with low risk disease (T1a), as studies have demonstrated very low rates of local recurrence for these patients following radical or partial nephrectomy [6,14]. In fact, multiple studies have recommended no abdominal imaging surveillance for patients with T1 disease [4–7]. For patients with high risk disease, one would anticipate a higher proportion of patients receiving yearly abdominal surveillance, given high rates of local recurrence for stage T3 or T4 disease (20% reported in the study by Antonelli et al. [9]). We do find patients with higher tumor stage are significantly more likely to receive both initial and yearly surveillance abdominal imaging. However, overall numbers are surprisingly low, with approximately 28% of patients with T3 or T4 disease continuing yearly surveillance through year five, which is the minimum AUA recommendation for abdominal surveillance [10].

Initial postoperative surveillance abdominal scan was significantly greater for patients who received partial nephrectomy (OR 2.5 for open and OR 2.4 for laparoscopic) and to a lesser extent laparoscopic radical nephrectomy (OR 1.4). Laparoscopic partial nephrectomy was also a predictor of continued yearly abdominal surveillance imaging. The association

between increased use of surveillance abdominal CT scans and both open and minimally-invasive partial nephrectomy has been reported in the past [15,16]. With a concomitant increase in performance of partial nephrectomy, population-based estimates of 15.3% in 2002 and 24.7% in 2008 [17], and accessibility of CT scans during our study period, the increasing performance of abdominal surveillance imaging may not be completely independent. The likelihood of initial postoperative abdominal scan (OR 1.6 for 1997–2001 and OR 2.4 for 2002–2007) and continued yearly abdominal surveillance (HR 0.82 for 1997–2001 and HR 0.67 for 2002–2007) increases with each time period within our study.

This study is not without limitations. The observational database study design restricts the level of detail that may be obtained in a single or multi-center retrospective study. Nephrometry score was not able to be ascertained through SEER-Medicare data for this study. Given that nephrometry score has been linked to pathologic outcomes in addition to perioperative outcomes [18], we would anticipate that nephrometry score may have influenced surveillance imaging. Additionally, as different RCC subtypes are known to behave more or less aggressively and pathologic characteristics have been demonstrated to associated with tumor recurrence [19], the pathologic data would likely influence surveillance imaging as well. With more detail regarding tumor characteristics as well as final pathology, a more detailed analysis for predictors of appropriate surveillance imaging could be performed. Confounding due to unaccounted variables may have introduced bias. As patients were censored only for death, loss of Medicare eligibility, or enrollment in a Medicare HMO, we anticipate that the imaging data captured is an over rather than under estimate of routine surveillance imaging, as imaging for metastatic or recurrent disease as well as other diagnoses would be included. However, with no validated algorithm to capture postoperative surveillance imaging, there may be codes that were not included or discrepancies in coding between similar studies that would have limited our ascertainment of imaging. Although comparison to literature proposed surveillance protocols are made to illustrate the relatively limited use of postoperative surveillance imaging, our study likely does not reflect contemporary practice as our study period (1991 to 2007), predates the AUA guidelines for postoperative RCC surveillance (2013) and has small overlap with other literature recommended schedules (Stephenson et al. 2004, Lam et al. 2005, Antonelli et al. 2007). Future studies comparing surveillance imaging frequency before and after publication of the AUA guidelines may be informative. Finally, as SEER-Medicare data were used for this study, our results cannot be applied to patients younger than 65 years of age.

5. Conclusions

Analysis of nationally representative data demonstrates that there is limited use of both chest and abdominal surveillance imaging following nephrectomy. Although overall rates of surveillance imaging were low, increasing tumor stage was a significant predictor of initial and continued yearly surveillance abdominal and chest imaging. Abdominal surveillance imaging is increasingly utilized after partial nephrectomy and during the more contemporary portion of our study period.

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References

1. American Cancer Society. Cancer Facts & Figures 2014. Atlanta: American Cancer Society; 2014.
2. Howlader, N.; Noone, AM.; Krapcho, M., et al. SEER Cancer Statistics Review, 1975–2011. National Cancer Institute; Bethesda, MD: Apr. 2014 http://seer.cancer.gov/csr/1975_2011/, based on November 2013 SEER data submission, posted to the SEER web site
3. Ljungberg B, Bensalah K, Bex A, et al. EAU guidelines on renal cell carcinoma: March 2013 update. European Association of Urology. 2013
4. Sandom DS, Seftel AD, Resnick MI. A new protocol for the follow-up of renal cell carcinoma based on pathological stage. J Urol. 1995; 154:28–31. [PubMed: 7776446]
5. Levy DA, Slaton JW, Swanson DA, Dinney CP. Stage-specific guidelines for surveillance after radical nephrectomy for local renal cell carcinoma. J Urol. 1998; 159:1163–1167. [PubMed: 9507823]
6. Ljungberg B, Alamdari FI, Rasmuson T, Roos G. Follow-up guidelines for nonmetastatic renal cell carcinoma based on the occurrence of metastases after radical nephrectomy. BJU Int. 1999; 84:405–411. [PubMed: 10468753]
7. Stephenson AJ, Chetner MP, Rourke K, et al. Guidelines for the surveillance of localized renal cell carcinoma based on the patterns of relapse after nephrectomy. J Urol. 2004; 172:58–62. [PubMed: 15201737]
8. Lam JS, Shvarts O, Leppert JT, et al. Postoperative surveillance protocol for patients with localized and locally advanced renal cell carcinoma based on a validated prognostic nomogram and risk group stratification system. J Urol. 2005; 174:466–472. [PubMed: 16006866]
9. Antonelli A, Cozzoli A, Zani D, et al. The follow-up management of non-metastatic renal cell carcinoma: definition of a surveillance protocol. BJU Int. 2007; 99:296–300. [PubMed: 17326263]
10. Donat SM, Diaz M, Bishoff JT, et al. Follow-up for clinically localized renal neoplasms: AUA guideline. J Urol. 2013; 190:407–416. [PubMed: 23665399]
11. Miller DC, Saigal CS, Warren JL, et al. External validation of a claims-based algorithm for classifying kidney-cancer surgeries. BMC Health Serv Res. 2009; 9:92. [PubMed: 19500395]
12. Edge, SB.; Byrd, DR.; Compton, CC., et al., editors. AJCC Cancer Staging Manual. 7. New York, NY: Springer; 2010. p. 479-89.
13. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol. 1994; 47:1245–1251. [PubMed: 7722560]
14. Hafez KS, Novick AC, Campbell SC. Patterns of tumor recurrence and guidelines for follow-up after nephron-sparing surgery for sporadic renal cell carcinoma. J Urol. 1997; 157:2067–2070. [PubMed: 9146581]
15. Lam JS, Leppert JT, Figlin RA, Belldegrun AS. Surveillance following radical or partial nephrectomy for renal cell carcinoma. Cur Urol Rep. 2005; 6:7–18.
16. Kowalczyk KJ, Harbin AC, Choueiri TK, et al. Use of surveillance imaging following treatment of small renal masses. J Urol. 2013; 190:1680–1685. [PubMed: 23764074]

17. Patel SG, Penson DF, Pabla B, et al. National trends in the use of partial nephrectomy: a rising tide that has not lifted all boats. *J Urol.* 2012; 187:816–821. [PubMed: 22248514]
18. Kutikov A, Smaldone MC, Egleston BL, et al. Anatomic features of enhancing renal masses predict malignant and high-grade pathology: a preoperative nomogram using the RENAL nephrometry score. *Eur Urol.* 2011; 60:241–248. [PubMed: 21458155]
19. Frank I, Blute ML, Cheville JC, et al. A multifactorial postoperative surveillance model for patients with surgically treated clear cell renal cell carcinoma. *J Urol.* 2003; 170:2225–2232. [PubMed: 14634384]

6. Appendix

Appendix 1: Codes Used to Define Imaging Tests

HCPCS	Procedure
71010 71015 71020 71021 71022 71023 71030 71034 71035	Chest x-ray
71250 71260 71270 71275	CT scan Chest
74150 74151 74152 74153 74154 74155 74156 74157 74158 74159 74160 74161 74162 74163 74164 74165 74166 74167 74168 74169 74170 76497	CT scan Abdomen
72191 72192 72193 72194	CT scan Pelvis
72146 72147 72157 71550 71551 71552	MRI scan Chest
74181 74182 74183	MRI scan Abdomen
72195 72196 72197	MRI scan Pelvis
76700 76770 76705 76775 76778	Abdominal/Renal ultrasound
ICD-9 Codes	Procedure
87.3, 87.44, 87.49	Chest x-ray
87.41	CT scan Chest
87.71, 88.01	CT Scan Abdomen
88.38	CT Scan Pelvis
88.92	MRI scan Chest
88.97	MRI scan Abdomen
88.95	MRI scan Pelvis
88.7, 88.74, 88.75, 88.76, 88.79	Abdominal/Renal ultrasound

Highlights

- Agreement between observed imaging frequency and evidence-based surveillance protocols was low, particularly for patients with T2–T4 disease.
- High risk disease was predictive of initial chest (OR 1.38) and abdominal (OR 1.6) imaging, and of decreased risk of discontinuation of yearly chest (HR 0.73) and abdominal (HR 0.74) imaging surveillance.
- The majority of patients discontinued yearly surveillance imaging by year five.
- Abdominal surveillance imaging is increasingly utilized after partial nephrectomy and during the more contemporary portion of our study period.

	Months of Follow-up													
	3	6	12	18	24	30	36	48	60	72	84	96	108	120
Low risk														
Lam et al. (2005) [8]														
Chest CT			x		x		x	x	x					
Abdominal CT					x			x						
Antonelli et al. (2007) [9]														
Chest CT or CXR						x			x			x		x
Abdominal CT or US			x		x				x			x		x
AUA guideline (2013) [10]														
Chest CXR			x		x		x							
Abdominal CT, MRI, or US			x*		x**		x**							
Intermediate risk														
Lam et al. (2005) [8]														
Chest CT		x	x	x	x	x	x	x	x		x		x	
Abdominal CT			x				x		x		x		x	
Antonelli et al. (2007) [9]														
Chest CT or CXR		x	x	x	x	x	x	x	x			x		x
Abdominal CT or US		x	x	x	x	x	x	x	x			x		x
AUA guideline (2013) [10]														
Chest CT, MRI, or CXR		x*	x	x	x	x	x	x	x					
Abdominal CT, MRI, or US		x*	x	x	x	x	x	x	x					
High risk														
Lam et al. (2005) [8]														
Chest CT		x	x	x	x	x	x	x	x		x		x	
Abdominal CT		x	x	x	x		x	x	x		x		x	
Antonelli et al. (2007) [9]														
Chest CT or CXR		x	x	x	x	x	x	x	x	x	x	x	x	x
Abdominal CT or US		x	x	x	x	x	x	x	x	x	x	x	x	x
AUA guideline (2013) [10]														
Chest CT, MRI, or CXR		x*	x	x	x	x	x	x	x					
Abdominal CT, MRI, or US		x*	x	x	x	x	x	x	x					

Figure 1.

Summary of published surveillance schedule by risk category

* = Baseline imaging must be CT or MRI

** = For patients receiving partial nephrectomy

Figure 2.
Kaplan-Meier curves for continued yearly surveillance abdominal (a) and chest (b) imaging

Table 1

Comparison to published surveillance imaging protocols

	Stage T1		Stage T2–T4	
	#	%	#	%
Total number of patients	3668	2662		
Lam et al. (2005) [8]	47	1.3%	x	<1%
Antonelli et al. (2007) [9]	72	2.0%	39	1.5%
AUA guideline (2013) [10]	272	7.4%	46	1.7%
No follow-up imaging	90	2.5%	50	1.9%

*As per data use agreement requirements, cell sizes less than 11 were suppressed in the table.

Table 2
Baseline demographic data and predictors of initial surveillance imaging (within 13 months of surgery)

Clinical Variables	Demographic Data		Abdominal Imaging		Chest Imaging	
	Number (%)	female	Odds Ratio	p-value	Odds Ratio	p-value
Gender (female vs. male)	2724 (46%)	female	1.24	<0.01	1.15	0.04
Race (Caucasian as referent)	5110 (87%)					
African-American	464 (8%)		1.04	0.75	0.68	<0.01
Other	327 (6%)		0.85	0.22	0.76	0.03
Age (65–70 years as referent)	1845 (31%)					
70–75 years	1813 (31%)		0.96	0.60	1.07	0.44
75–80 years	1402 (24%)		0.87	0.07	0.92	0.36
> 80 years	841 (14%)		0.66	<0.01	0.77	<0.01
Comorbidity (CCI = 0 as referent)	2778 (47%)					
CCI = 1	1680 (28%)		1.11	0.14	1.13	0.12
CCI = 2	688 (12%)		1.11	0.28	1.17	0.13
CCI > 3	755 (13%)		0.99	0.87	1.35	<0.01
Marital status (married vs. all non-married)	3602 (61%)	married	1.16	0.02	1.070.36	
Tumor stage (T1 as referent)	3518 (60%)					
T2	1007 (17%)		1.19	0.03	1.40	<0.01
T3 or T4	1376 (23%)		1.60	<0.01	1.38	<0.01
Surgery year (1991–1996 as referent)	1337 (23%)					
1997–2001	2964 (50%)		1.62	<0.01	0.90	0.27
2002–2007	1600 (27%)		2.35	<0.01	1.01	0.94
Surgery type (open radical nephrectomy as referent)	3965 (67%)					
Open partial nephrectomy	666 (11%)		2.46	<0.01	0.69	<0.01
Laparoscopic radical nephrectomy	1053 (18%)		1.44	<0.01	1.06	0.54
Laparoscopic partial nephrectomy	217 (4%)		2.37	<0.01	0.66	0.01
Surgeon Volume (lowest tertile as referent)	1920 (33%)					
Middle tertile	2107 (36%)		0.89	0.10	1.05	0.51
Highest tertile	1874 (32%)		1.05	0.56	0.99	0.93
Hospital Volume (lowest tertile as referent)	1907 (32%)					

Clinical Variables	Demographic Data Number (%)	Abdominal Imaging		Chest Imaging	
		Odds Ratio	p-value	Odds Ratio	p-value
Middle tertile	2113 (36%)	1.07	0.35	0.97	0.74
Highest tertile	1881 (32%)	1.23	0.01	1.10	0.29

CCI = Charlson comorbidity index

Table 3

Predictors of continued yearly surveillance imaging

Clinical Variables	Abdominal Imaging		Chest Imaging	
	Hazard Ratio	p-value	Hazard Ratio	p-value
Gender (female vs. male)	1.00	0.97	1.00	0.92
Race (Caucasian as referent)				
African-American	1.05	0.56	1.16	0.06
Other	0.99	0.89	0.89	0.19
Age (65–70 years as referent)				
70–75 years	1.12	0.02	1.10	0.04
75–80 years	1.15	<0.01	1.14	0.01
> 80 years	1.46	<0.01	1.18	<0.01
Comorbidity (CCI = 0 as referent)				
CCI = 1	0.99	0.89	0.96	0.38
CCI = 2	0.92	0.18	0.83	<0.01
CCI > 3	0.97	0.68	0.75	<0.01
Marital status (married vs. all non-married)	0.95	0.28	0.97	0.51
Tumor stage (T1 as referent)				
T2	0.94	0.28	0.95	0.32
T3 or T4	0.74	<0.01	0.73	<0.01
Surgery year (1991–1996 as referent)				
1997–2001	0.82	<0.01	0.99	0.82
2002–2007	0.67	<0.01	0.88	0.01
Surgery type (open radical nephrectomy as referent)				
Open partial nephrectomy	0.91	0.12	1.18	<0.01
Laparoscopic radical nephrectomy	1.01	0.81	1.09	0.14
Laparoscopic partial nephrectomy	0.76	0.01	1.12	0.33
Surgeon Volume (lowest tertile as referent)				
Middle tertile	0.98	0.62	0.98	0.67
Highest tertile	0.85	<0.01	0.95	0.35
Hospital Volume (lowest tertile as referent)				
Middle tertile	1.06	0.21	0.90	0.02
Highest tertile	1.06	0.27	0.88	0.02

CCI = Charlson comorbidity index