Diffusion of Surgical Innovation Among Patients With Kidney Cancer

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BACKGROUND. Despite their potential benefits to patients with kidney cancer, the adoption of partial nephrectomy and laparoscopy has been gradual and asymmetric. To clarify whether this trend reflects differences in kidney cancer patients or differences in surgeon practice styles, the authors compared the magnitude of surgeon-attributable variance in the use of partial nephrectomy and laparoscopic radical nephrectomy with that attributable to patient and tumor characteristics.

METHODS. By using linked Surveillance, Epidemiology, and End Results-Medicare data, the authors identified a cohort of 5483 Medicare beneficiaries who underwent surgery for kidney cancer between 1997 and 2002. Two primary outcomes were defined: 1) the use of partial nephrectomy and (2) the use of laparoscopy among patients undergoing radical nephrectomy. By using multilevel models, surgeon- and patient-level contributions to observed variations in the use of partial nephrectomy and laparoscopic radical nephrectomy were estimated.

RESULTS. Of the 5483 cases identified, 611 (11.1%) underwent partial nephrectomy (43 performed laparoscopically), and 4872 (88.9%) underwent radical nephrectomy (515 performed laparoscopically). After adjusting for patient demographics, comorbidity, tumor size, and surgeon volume, the surgeon-attributable variance was 18.1% for partial nephrectomy and 37.4% for laparoscopy. For both outcomes, the percentage of total variance attributable to surgeon factors was consistently higher than that attributable to patient characteristics.

CONCLUSIONS. For many patients with kidney cancer, the surgery provided depends more on their surgeon's practice style than on the characteristics of the patient and his or her disease. Consequently, dismantling barriers to surgeon adoption of partial nephrectomy and laparoscopy is an important step toward improving the quality of care for patients with early-stage kidney cancer. ***Cancer* 2008;112:1708–17.** *© 2008 American Cancer Society.*

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Open radical nephrectomy is the traditional gold standard for treating patients with organ-confined or locally advanced renal cell carcinoma.[1] During the last 2 decades, however, the concurrent introduction of nephron-sparing (ie, partial nephrectomy) and

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minimally invasive (ie, renal laparoscopy) alternatives to open radical excision have modified therapeutic options appreciably.[2–6]

Easier convalescence[7–10] and equivalent cancer control[10] have established laparoscopy as an alternative standard of care for most patients who undergo radical nephrectomy.[1,2,4,11,12] In synchronicity with the gradual dissemination of laparoscopic radical nephrectomy,[2,4] multiple investigators reported that, for selected patients with smaller renal tumors, partial nephrectomy yields oncologic outcomes that are indistinguishable from the outcomes achieved by radical excision.[13–15] Partial nephrectomy also preserves long-term renal function[16,17] while reducing over-treatment of patients with benign[18] or clinically indolent[19] tumors.

Despite these potential benefits to patients, population-based data suggest that the adoption of partial nephrectomy and laparoscopy has been gradual and concentrated among select hospitals.[4,12] Consequently, open radical nephrectomy remains the predominant surgical therapy for Americans with kidney cancer.[3,4,12] Few data are available to clarify whether current practice patterns for partial nephrectomy and renal laparoscopy reflect differences in kidney cancer patients or differences in the practice styles of their surgeons.

We hypothesized that surgeon-level factors influence the use of nephron-sparing and/or minimally invasive surgery more than a patient's demographic or disease-related characteristics. We evaluated this hypothesis by using multilevel analyses to estimate the proportion of surgeon- and patient-attributable variance in the use of partial nephrectomy and laparoscopy while simultaneously accounting for clustering of patients with kidney cancer within a surgeons' practice.[20,21] By clarifying the relative contribution of surgeon factors and patient factors, we may be able to use these data to inform efforts to accelerate the adoption of partial nephrectomy and laparoscopy. Such adoption, in turn, could yield improved health outcomes among kidney cancer survivors.

MATERIALS AND METHODS

Data Source

We used linked data from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program and the Centers for Medicare and Medicaid Services (CMS) to identify and characterize a population-based cohort of older patients (aged ≥66 years) with incident kidney cancer diagnosed from 1997 through 2002. SEER is a population-based cancer registry that collects data regarding incidence, treatment, and mortality. The demographic composition, cancer incidence, and mortality trends in the SEER registries are representative of the entire United States population.[22]

From 1997 through 1999, 11 SEER-affiliated registries (San Francisco, San Jose, Los Angeles, Connecticut, Detroit, Hawaii, Iowa, New Mexico, Seattle, Utah, and Atlanta) provided incident cases for linkage with healthcare claims covered by the CMS. In 2000, the SEER-Medicare dataset was expanded to include cases from the Greater California, Louisiana, New Jersey, and Kentucky tumor registries. The Medicare Program provides primary health insurance for 97% of the United States population aged ≥65 years.[23] Successful linkage with CMS claims is achieved for >90% of Medicare patients whose cancer-specific data are tracked by SEER.[23]

Cohort Identification

We identified a preliminary cohort of 6515 Medicare beneficiaries who were diagnosed between 1997 and 2002 with localized/regional, nonurothelial kidney cancer. For each patient in the preliminary cohort, we then searched both inpatient (Medicare Provider Analysis and Review file; based on International Classification of Diseases, ninth revision, Clinical Modification [ICD-9] codes) and physician claims (Carrier Claims file; based on American Medical Association Current Procedural Terminology [CPT] and ICD-9 codes) for kidney cancer-specific diagnosis and procedure codes.

Of these beneficiaries, we excluded 1026 patients who lacked claims denoting surgical treatment for kidney cancer. We also excluded 3 patients (6 cases) who had claims that suggested the presence of bilateral tumors at diagnosis. This process yielded a final analytic cohort of 5483 cases (84.2% of the preliminary cohort).

Surgical Procedures

Next, we defined and applied a claims-based algorithm to determine the type of surgical therapy received by each patient in the analytic cohort. Recognizing that specific CPT codes for laparoscopic radical nephrectomy (introduced in 2000) and laparoscopic partial nephrectomy (introduced in 2002) did not exist during the earlier years of the study, we identified laparoscopic cases using both direct (CPT) and indirect (ICD-9 and CPT) laparoscopy codes.[2,4,24] We also ascribed a laparoscopic approach to patients with a live discharge and length of stay ≤2 days after radical or partial nephrectomy.[2,4,24] By using this algorithm, we assigned each case to 1 of 4 mutually exclusive surgical categories: 1) open radical nephrectomy, 2) open partial nephrectomy, 3) laparoscopic radical nephrectomy, and 4) laparoscopic partial nephrectomy.

We assessed the level of concordance between our claims-based algorithm and the type of cancer-directed surgery specified for each patient in the SEER data file (Patient Entitlement and Diagnosis Summary File) as validation. Although SEER does not collect data regarding whether the surgical approach was open or laparoscopic, we observed 97% agreement for the assignment of partial versus radical nephrectomy ($\kappa = 0.83$). In addition, we identified relevant surgical pathology claims within 30 days of the index admission for > 95% of the cases analyzed, thus supporting the occurrence of cancer-directed surgery.

Patient-level Covariates

We used SEER variables to ascertain demographic and cancer-specific information (ie, age at surgery, sex, race/ethnicity, marital status, SEER registry, year of surgery, tumor size) for each patient in the analytic cohort. We collapsed tumor size into 2 clinically relevant groups based on a 4-cm threshold.[14] We assigned median Census-tract income and Census-tract percentage of nonhigh school graduates as patient-level measures of income and education, respectively.[25]

We measured pre-existing comorbidity by using a modification of the Charlson Index[26] to identify comorbid conditions (including diabetes, renal insufficiency, and cardiovascular disease) from inpatient and physician claims that were submitted during the 12 months before the index admission for kidney cancer surgery.[27] We also noted the presence or absence of hypertension, urolithiasis, and/or renovascular disease, given their relevance to surgical decision-making among patients with kidney cancer.

Primary Surgeon

To identify the primary surgeon for each patient, we used encrypted Unique Physician Identifier Numbers, which are submitted with Medicare physician claims. By using claims from 1991 through 2002, we also determined each surgeon's average annual nephrectomy (partial or radical) volume. We empirically defined high-volume surgeons as those who performed $\geq$3 annual cancer-related nephrectomies among the SEER-Medicare population (83rd percentile). This measure of case volume may not reflect the total number of nephrectomies performed by a provider: It fails to account for surgeries among younger (non-Medicare-eligible) patients, Medicare Health Maintenance Organization enrollees, and/or fee-for-service Medicare participants who reside outside of the SEER registries.

Statistical Analysis

Before fitting multilevel models, we performed several univariate analyses. We used chi-square tests to evaluate the level of association between surgical procedure and various patient-level covariates and to assess the statistical significance of temporal surgical trends.

For our multilevel analyses, we defined the following primary outcomes: 1) use of partial nephrectomy and 2) use of laparoscopy among patients who underwent radical nephrectomy. We hypothesized a priori that kidney cancer patients are nested within surgeons' practices. Within this conceptual framework, we fit multilevel models (also known as hierarchical generalized linear models) to estimate surgeon- and patient-level contributions to observed variations in the use of partial nephrectomy and laparoscopy for radical nephrectomy.[20,21] Each model included a unique surgeon identifier as a random-effects term.[20,21]

In a first set of models (ie, a model for partial nephrectomy and a model for laparoscopic radical nephrectomy), we estimated the surgeon-attributable residual intraclass correlation coefficient (ICC). The residual ICC estimates the proportion of the "leftover" or unexplained variance in the use of partial nephrectomy or laparoscopic radical nephrectomy attributable to unmeasured surgeon factors (rather than, for instance, unmeasured patient or hospital factors) after accounting for the variance explained by measured variables, such as patient demographics, prevalent comorbidity, tumor size, and surgeon case-volume classification. For the partial nephrectomy outcome, we fit an additional model based on a subsample of patients who were diagnosed in 2000 or later and had tumors that measured $\leq$4 cm (ie, the subsample of patients for whom partial nephrectomy may have been most appropriate).

Next, we fit a series of models that estimated the proportion of total variance (in the use of partial nephrectomy and laparoscopy for radical nephrectomy) that could be explained by surgeon factors and specific patient and tumor characteristics. For this step, the initial model (known as the "unconditional model") included only a surgeon-level random-effects term; From the unconditional models, we calculated the surgeon-attributable variance without adjustment for case volume, patient characteristics, or tumor characteristics. Then, we estimated the proportion of total variance explained by patient demographics, patient comorbidity, tumor size, and surgeon volume classification by fitting separate models (for each outcome) that included both a surgeon-level random-effects term and only 1 of the following fixed-effect covariate subsets: 1) surgeon case volume, 2) patient demographics, 3) medical comorbidity, and 4) tumor size.

For sensitivity analyses, we calculated the residual ICC attributable to surgeons based on procedure assignment without the length-of-stay assumption for laparoscopy and based on a subsample of patients (n = 3989) in which only direct CPT and ICD-9 codes were used to determine case assignment. We also repeated the primary analyses after limiting our sample to patients whose surgeons performed $\geq$3 nephrectomies during the study period. We were unable to fit models that also included surgeon-level covariates, such as year of medical school graduation and practice structure, because of computational limitations.

All statistical testing was 2-sided, completed by using computerized software (SAS version 9.1; SAS Institute, Cary, NC), and carried out at the 5% significance level. We obtained approval for this study from the Institutional Review Board at the University of California, Los Angeles.

RESULTS

Analytic Cohort

We identified a final analytic cohort comprising 5483 Medicare beneficiaries who underwent surgery for an incident kidney cancer diagnosed between 1997 and 2002. Table 1 presents demographic and clinical characteristics for patients in the analytic sample. During the study interval, 611 patients (11.1%) underwent partial nephrectomy (43 performed laparoscopically), and 4872 patients (88.9%) underwent radical nephrectomy (515 performed laparoscopically). We observed differences in treatment patterns according to sex, marital status, SEER registry, income, tumor size, and prevalent hypertension diagnosis (all *P* values <.05) (Table 1).

Surgical Practice Patterns

From 1997 through 2002, the proportion of patients who underwent partial nephrectomy increased from 7.1% to 14.6% ($P < .01$); for patients who had tumors that measured $\leq$4 cm, the proportion rose from 8.9% to 23.5% ($P < .01$) (Fig. 1A). Among patients who had tumors that measured $\leq$4 cm, laparoscopic radical nephrectomy increased from 1.2% to 20.3%; for patients with larger tumors, laparoscopic radical nephrectomy increased from 0.8% to 16.2% (*P* values < .01) (Fig. 1B).

In Table 2, we compare the use of surgical procedures, stratified by comorbidity, from 1997 through 1999 and from 2000 through 2002. During both periods, laparoscopic radical nephrectomy decreased among patients with greater comorbidity. The proportion of partial nephrectomies (open or laparoscopic) remained similar across comorbidity strata.

Multilevel Models

We identified 1632 primary surgeons who performed 5025 kidney cancer surgeries (92% of all cases in the analytic cohort) during the study interval. Among the cases with identifiable primary surgeons, 364 different surgeons performed 556 open or laparoscopic partial nephrectomies (median, 1 procedure; range, 1–15 procedures). During the same interval, 4469 patients underwent open or laparoscopic radical nephrectomy by 1570 different surgeons (median, 2 procedures; range, 1–27 procedures). Among the latter group, we distinguished 262 surgeons who performed 495 laparoscopic procedures during the study period (median, 1 procedure; range, 1–12 procedures). In comparison, we identified 1485 different primary surgeons for the 3974 open radical nephrectomies (median, 2 procedures; range, 1–21 procedures).

We failed to identify a primary surgeon for 458 cases. On the basis of our empirical definition, we classified 138 providers (8.4%) as high-volume surgeons; and 936 patients (18.6%) received treatment by a high-volume surgeon.

In addition to the 458 cases for whom we could not identify the primary surgeon, cases missing data for 1 or more independent variables were also excluded from the multivariate analyses. Thus, our final partial nephrectomy and laparoscopy models included 3995 cases (73% of the analytic sample) and 3565 cases (80% of radical nephrectomies in the analytic sample), respectively (Table 3).

Table 3 presents findings from our multilevel analyses. For both the partial nephrectomy and laparoscopy outcomes, we report the surgeon-attributable residual ICC, that is, the percentage of ‘‘left-over’’ or unexplained variance in the use of the procedure associated with the surgeon after adjusting for available patient demographics, comorbidity, tumor size, and surgeon volume. Table 3 also presents the proportions of total variance in procedure use attributable to unmeasured surgeon factors, surgeon case volume, patient demographics, comorbidity, and tumor size.

For our primary models, the proportions of variance that were explained by measured variables (patient demographics, comorbidity, tumor size, and surgeon volume) were 22.5% and 23.2% for partial nephrectomy and laparoscopy, respectively. With respect to the remaining or ‘‘left-over’’ variance, the

TABLE 1
Distribution of Patient Characteristics by Procedural Strata (1997–2002)

Patient-level covariate	No. of patients (%)			
	LPN	OPN	LRN	ORN
Total	43 (0.8)	568 (10.4)	515 (9.4)	4357 (79.5)
Age at surgery. y				
66–69	12 (1.1)	142 (12.6)	92 (8.2)	880 (78.1)
70–74	11 (0.7)	183 (10.8)	143 (8.4)	1359 (80.1)
74–79	7 (0.5)	156 (10.6)	149 (10.1)	1164 (78.8)
80–84	9 (1)	68 (7.8)	95 (10.9)	698 (80.3)
≥85	<5 (1.3)	19 (6)	36 (11.4)	256 (81.3)
Sex*				
Men	13 (0.6)	216 (9.5)	234 (10.3)	1801 (79.6)
Women	30 (0.9)	352 (10.9)	281 (8.8)	2556 (79.4)
Race/ethnicity				
White, non-Hispanic	39 (0.8)	468 (10.3)	441 (9.7)	3615 (79.2)
White, Hispanic	<5 (0.3)	33 (9.8)	22 (6.6)	279 (83.3)
Black	<5 (0.8)	46 (11.6)	32 (8.1)	315 (79.5)
Other or unknown	<5 (0)	21 (11.1)	20 (10.6)	148 (78.3)
Marital status*,†				
Married	31 (0.9)	362 (10.8)	312 (9.3)	2648 (79)
Not married	10 (0.5)	184 (9.6)	186 (9.7)	1539 (80.2)
SEER registry*				
Atlanta	<5 (1.8)	12 (7.1)	15 (8.8)	140 (82.4)
Connecticut	<5 (0.6)	48 (9.6)	50 (10)	400 (79.8)
Detroit	6 (0.9)	82 (12.3)	57 (8.5)	522 (78.3)
Greater California	<5 (0.5)	50 (8.5)	62 (10.5)	476 (80.5)
Hawaii	<5 (0)	<5 (4.7)	<5 (4.7)	58 (90.6)
Iowa	<5 (0.2)	48 (9)	25 (4.7)	460 (86.1)
Kentucky	<5 (0.8)	34 (9.4)	42 (11.5)	285 (78.3)
Los Angeles	8 (1.5)	79 (14.4)	43 (7.8)	419 (76.3)
Louisiana	5 (1.5)	29 (9)	43 (13.4)	245 (76.1)
New Jersey	7 (1)	78 (10.8)	91 (12.5)	549 (75.7)
New Mexico	<5 (0)	12 (7.1)	10 (6)	146 (86.9)
Rural Georgia	<5 (0)	<5 (5.9)	<5 (17.7)	13 (76.5)
San Francisco	<5 (0.5)	30 (15.4)	25 (12.8)	139 (71.3)
San Jose	<5 (0)	15 (11)	7 (5.1)	115 (83.9)
Seattle	<5 (0.6)	28 (8.4)	28 (8.4)	276 (82.6)
Utah	<5 (0.7)	19 (13.1)	11 (7.6)	114 (78.6)
Median census tract income‡,§				
<$35,000	9 (0.7)	120 (9.3)	112 (8.7)	1050 (81.3)
$35,000–44,999	8 (0.6)	132 (10.4)	101 (7.9)	1033 (81.1)
$45,000–59,999	13 (0.9)	148 (10.2)	154 (10.7)	1128 (78.2)
≥$60,000	12 (0.9)	147 (11.3)	132 (10.2)	1005 (77.6)
Percentage of residents in Census tract with less than a high school education‖				
>25	8 (0.7)	124 (10.5)	101 (8.6)	944 (80.2)
15.1–25	11 (0.9)	108 (8.9)	114 (9.4)	979 (80.8)
10–15	8 (0.8)	98 (9.9)	107 (10.9)	774 (78.4)
<10	12 (0.8)	175 (12.1)	148 (10.2)	1116 (76.9)
Tumor size, cm*,¶				
≤4	34 (1.5)	415 (17.7)	260 (11.1)	1631 (69.7)
>4	6 (0.2)	112 (3.8)	238 (8)	2604 (88)
Charlson Index score				
0	22 (0.7)	337 (10.4)	319 (9.8)	2573 (79.1)
1	11 (0.8)	137 (10.2)	120 (9)	1074 (80)
≥2	10 (1.1)	94 (10.6)	76 (8.5)	710 (79.8)
Hypertension*				
Yes	25 (0.9)	305 (11.5)	235 (8.8)	2092 (78.8)
No	18 (0.6)	263 (9.3)	280 (9.9)	2265 (80.2)

LPN indicates laparoscopic partial nephrectomy; OPN, open partial nephrectomy; LRN, laparoscopic radical nephrectomy; ORN, open radical nephrectomy; SEER, Surveillance, Epidemiology, and End Results Program.
* P <.05 (general chi-square test).
† Marital status was unknown for 211 patients.
‡ Information on income was missing for 179 patients.
§ P <.05 (chi-square test for linear trend).
‖ Information on education was missing for 656 patients.
¶ Information on tumor size was missing for 183 patients.

corresponding surgeon-attributable residual ICCs were 18.1% and 37.4%, respectively. When we fit the partial nephrectomy model for a subsample of patients with small tumors (≤4 cm) diagnosed between 2000 and 2002, the residual ICC for surgeons was 21.6% (Table 3).

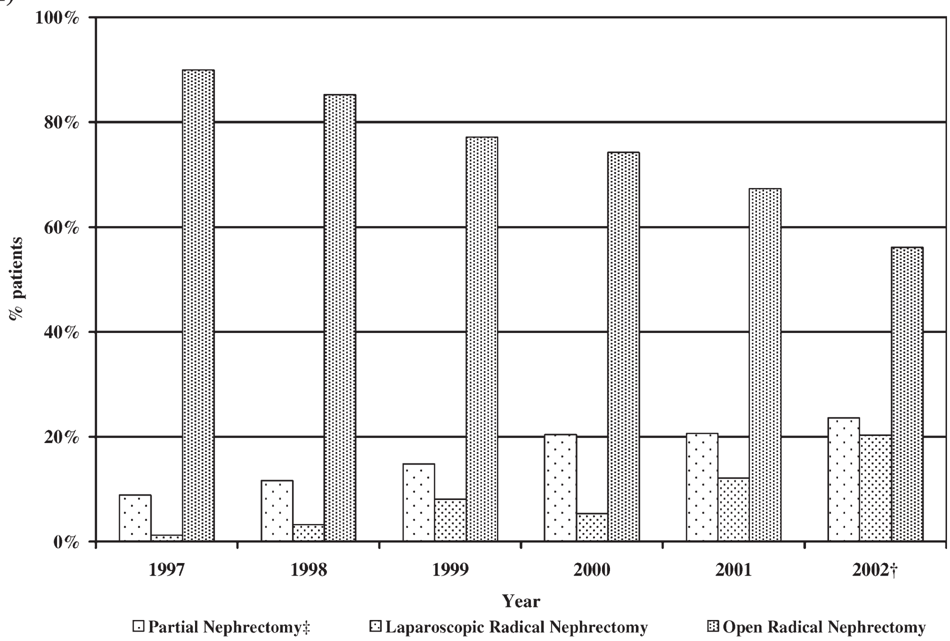
With respect to partial nephrectomy, only the proportion of total variance attributable to tumor size (19.6%) exceeded that attributable to unmeasured surgeon factors (17.5%). Neither comorbidity nor surgeon volume explained >5% of the total variance in use of partial nephrectomy. The relative contribution of surgeon factors and patient factors was similar in analyses limited to patients with smaller tumors (≤4 cm) diagnosed between 2000 and 2002 (Table 3).

For our laparoscopy outcome, the percentage of total variance attributable to unmeasured surgeon factors (37.5%) was substantially greater than that attributable to surgeon case volume (13.9%), tumor size (14.6%), comorbidity (13.4%), or patient demographics (20.7%) (Table 3). The partitioned variances and residual ICC attributable to surgeons did not change substantively in sensitivity analyses.

DISCUSSION

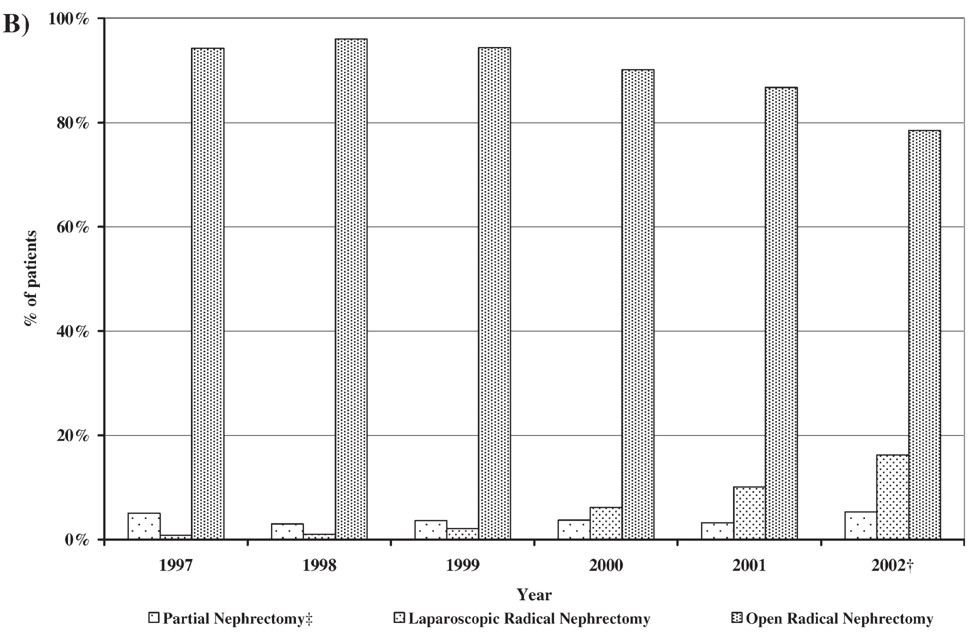
This study has 2 principal findings. First, and consistent with prior population-based studies,[2–4,12] the use of both open partial nephrectomy and laparoscopic radical nephrectomy increased gradually between 1997 and 2002; these trends notwithstanding, through 2002, open radical nephrectomy remained the predominant surgical therapy for older Americans with kidney cancer. Second, for both pro-

A) n = 2340



† Includes a small number of cases treated in 2003.
‡ Includes 34 laparoscopic partial nephrectomies.

B)



† Includes a small number of cases treated in 2003.
‡ Includes 6 laparoscopic partial nephrectomies.

FIGURE 1. (A) Distribution of surgical therapies for patients with tumors $\leq$4 cm (1997–2002). (B) Distribution of surgical therapies for patients with tumors $>$4 cm (1997–2002).

TABLE 2
Surgical Therapies for Early-stage Kidney Cancer by Year of Diagnosis and Charlson Index Strata*

	No. of patients (%)							
	1997–1999				2000–2002†			
CI	LPN	OPN	LRN	ORN	LPN	OPN	LRN	ORN
0	<5	78 (8)	27 (2.8)	871 (89.2)	22 (1)	259 (11.4)	292 (12.8)	1702 (74.8)
1	<5	23 (6.5)	8 (2.3)	320 (90.9)	10 (1)	114 (11.5)	112 (11.3)	754 (76.2)
≥2	<5	17 (7.5)	4 (1.8)	206 (90.7)	10 (1.5)	77 (11.6)	72 (10.9)	504 (76)

CI indicates Charlson Index; LPN, laparoscopic partial nephrectomy; OPN, open partial nephrectomy; LRN, laparoscopic radical nephrectomy; ORN, open radical nephrectomy.

* $P > .20$ (Cochran-Mantel-Haenszel chi-square test).

† Includes a small number of patients who were diagnosed in late 2002 who did not undergo surgery until 2003.

cedures, the proportion of total variance attributable to surgeon factors exceeded that for almost all patient and tumor characteristics, including tumor size and comorbidity. The ensuing inference is that a minority of elderly patients with kidney cancer undergoes nephron-sparing or minimally invasive surgery; moreover, surgeon-level determinants appear to influence the likelihood of undergoing a partial nephrectomy or a laparoscopic approach for radical nephrectomy as much as or greater than a patient's tumor size, demographic characteristics, or general medical health.

Our findings are consequential clinically insofar as the benefits of partial nephrectomy[16,28] and laparoscopy[7–9] support the application of 1 or both of these techniques for a majority (rather than a minority) of patients with organ-confined renal tumors. Evidence for the feasibility of this paradigm comes from multiple contemporary case series in which >50% of patients with tumors ≤4 cm underwent a partial nephrectomy (or another kidney-sparing technique); at these centers, most of the patients who did not undergo kidney-sparing treatment underwent laparoscopic radical nephrectomy.[5,6,29] The finding that, even in 2002, 2 of 3 Medicare beneficiaries with kidney cancer underwent an open radical nephrectomy highlights an opportunity for population-level improvements in the quality of surgical care. In fact, it is elderly patients who may benefit most from treatments that preserve renal function and/or ease postoperative convalescence.

Reducing clinical uncertainty is a necessary step toward the goal of optimizing surgical practice patterns. The debut of (and progressively broadening indications for) partial nephrectomy and laparoscopy fragmented professional consensus regarding the

TABLE 3
Surgeon and Patient Contributions to Variance in the Use of Partial Nephrectomy and Laparoscopy (1997–2002)

	1997–2002 (All patients)		2000–2002 (Tumor size ≤ 4 cm)
Characteristic	Partial nephrectomy	Laparoscopy*	Partial nephrectomy
No. of patients	3995	3565	1364
No. of urologists	1487	1426	820
Proportion of variance attributable to surgeon (residual intraclass correlation coefficient), %†	18.1%	37.4%	21.6%
Partitioned variances, %‡			
Unmeasured surgeon factors	17.5	37.5	21.7
Surgeon nephrectomy case volume	4.5	13.9	6.4
Patient demographics	7.4	20.7	9.4
Comorbidity	4.7	13.4	6.7
Tumor size	19.6	14.6	—

* The multilevel model for use of laparoscopy was based on the subsample of patients who underwent radical nephrectomy.

† This row presents the percentage of variance attributable to the surgeon after adjusting for patient and tumor characteristics as well as surgeon nephrectomy case volume (the residual intraclass correlation coefficient). The denominator for calculation of this proportion includes the residual variance attributable to the surgeon random effect (after adjustment for patient demographics, comorbidity, tumor size, and surgeon case volume) and the variance attributable to unmeasured patient or tumor variables plus error.

‡ The denominator for the calculation of partitioned-variance proportions is the total. The total variance includes 3 components: 1) the variance attributable to the surgeon (after adjustment for the corresponding fixed-effect covariate[s] in a given model); 2) the variance attributable to the corresponding measured covariate(s) (ie, the fixed effects); and 3) the variance attributable to unmeasured patient or tumor variables plus error. The partitioned variance attributable to the surgeon is estimated using an "unconditional" model, which includes a surgeon-level random-effects term as the only independent variable; accordingly, the denominator for calculation of this percentage includes only 2 components: 1) the variance attributable to the surgeon unadjusted for any other covariates and 2) the variance attributable to unmeasured patient or tumor variables plus error.

standard therapy for patients with small, organ-confined renal masses.[11,30–32] Emblematic of this concern is the finding that both open partial nephrectomy and laparoscopic radical nephrectomy are used most frequently among patients with small tumors (≤4 cm) and little comorbidity. Likewise, the persistently high proportion of surgeon-attributable variance among patients with tumors ≤4 cm (ie, those for whom partial nephrectomy may have been most feasible) further underscores the extant uncertainty regarding the relative benefits of kidney-sparing and minimally invasive surgery.

In the setting of such uncertainty, individual surgeons may have developed distinctive approaches to the treatment of otherwise similar patients with kidney cancer (so-called surgical signatures).[33,34] The finding that the percentage of provider-attributable variance in our analysis was higher than that reported in other clinical studies[35,36] using multilevel modeling techniques supports the validity of this hypothesis and highlights the need for additional studies and/or consensus-based clinical guidelines that clarify optimal surgical treatment algorithms for patients with kidney cancer (including the appropriate integration of ablative therapies[37] and surveillance protocols[38]).

Although these data are consistent with the proposition that a surgeon's kidney cancer case volume is associated with the use of partial nephrectomy and laparoscopy,[4,12] the relatively greater percentage of variance attributable to nonvolume-related surgeon factors underscores the potential leverage of other provider-adoption barriers related to technical complexity,[39,40] practice setting,[41,42] and informational resources.[42] For instance, during the years that we studied, few practicing urologists received formal training in laparoscopy; moreover, relatively small kidney cancer caseloads further deterred uptake of this technique.[40,43] In view of these barriers, several mentored and simulator-based training programs consequently emerged to facilitate skill transfer from experienced to laparoscopy-naive urologists.[44–46]

The high percentage of provider-attributable variance also may reflect unmeasured differences in practice setting (and consequent access to information) among surgeons in our sample. That is, most providers make conclusive decisions about innovations based on interactions with local peer adopters rather than on scientific research or mass-media channels.[40,42] For the use of partial nephrectomy and laparoscopy, therefore, the high proportion of surgeon-attributable variance may signify an asymmetric distribution of local surgical colleagues who assess the procedure, refine its application, and then use informal communication channels to facilitate propagation among other potential adopters in their community.[5,40,42] Recognizing that social connections and local informational resources facilitate the diffusion of new surgical therapies,[39,40,42,47] we see innovative collaborations between urologists—informed by established practice-based surgical research models[48–51]—as representing a potential mechanism for accelerating the adoption of partial nephrectomy and renal laparoscopy.

Alternatively, it is possible that payer-initiated referral policies could emerge that circumvent adoption barriers by promoting the concentration of surgical care among providers with established proficiency in the spectrum of surgical treatment options for patients with kidney cancer (the "centers-of-excellence" model).[48] This potential policy lever has several limitations, including its reliance on imperfect methods for identifying "excellent" providers,[48] its indifference to patient preferences for where they receive care,[52] its potential to yield delays in care as a result of saturation of designated providers,[53] its failure to address the obstacles encountered by surgeons endeavoring to adopt beneficial innovations,[40,51] and its assumption that variations in convalescence and morbidity (as opposed to mortality) sufficiently motivate a policy-based intervention. Ultimately, the development of specific interventions to increase the use of partial nephrectomy and laparoscopy will be informed by future studies that further characterize surgeon-level (eg, attitudes, practice structure and setting) and hospital-level (eg, technology, ancillary staff) determinants of adoption as well as patient preferences.

Our study had several limitations. First, current SEER-Medicare data reflect the earlier years after urologists' acceptance of partial nephrectomy and laparoscopy; more recent data may reveal expanded use of these techniques with a smaller percentage of provider-attributable variance.[54] There is evidence, however, that the use of these techniques remained stable in 2003 and 2004.[2,55] Second, the generalizability of our results was restricted by a sample that was limited to patients aged $\geq$66 years who had traditional fee-for-service Medicare coverage. Nonetheless, linked SEER-Medicare data provided a unique opportunity to evaluate variations in kidney cancer care in the context of clinically important case-mix variables, including tumor size and medical comorbidity. Third, we could not explicitly measure all clinical variables that were relevant to surgical decision making. Consequently, we were unable to distinguish reliably which patients had recognized contraindications to nephron-sparing and/or minimally invasive surgery. Fourth, we defined high-volume surgeons empirically rather than based on existing criteria; alternative volume thresholds may have changed the proportion of variance explained by surgeon case volume.

Fifth, although we posit that the expanded use of partial nephrectomy and laparoscopy is a desirable objective, we also recognize that clarifying the optimal use of these procedures will require a better understanding of patient preferences. This is particularly relevant given the potentially dissimilar nononcologic outcomes (eg, intensity of convalescence, short-term complications) after different surgical therapies. Sixth, our algorithm for assigning surgical procedure necessarily assigns a single treatment for the small number of cases with a discrepancy in surgical procedure classification based on inpatient claims versus physician claims. Thus, our primary outcome is susceptible to some degree of misclassification; however, sensitivity analyses confirmed our principal findings. Finally, our findings are subject to potential selection bias based on observed differences (eg, sex, race, income) between patients who were excluded and patients who were included in our multivariable models. The observed differences, however, were small in magnitude and lacked clinical significance. In addition, excluded and included patients did not differ in tumor size, education, or marital status, and the 2 groups were similar with respect to the distribution of surgical therapies.

This report describes patterns of surgical care for elderly Americans with kidney cancer. Specifically, despite their potential advantages relative to open radical nephrectomy, partial nephrectomy and laparoscopy are used relatively infrequently in this population; moreover, much of the variance in their use is attributable to surgeon-specific factors rather than patient- or tumor-specific factors. Thus, for many older patients with kidney cancer, the surgery provided may depend more on their surgeon's practice style than on the characteristics of the patient and his or her disease. Consequently, the timely dismantling of residual barriers to surgeons' adoption of partial nephrectomy and laparoscopy is an important step toward improving the quality of care provided to patients with kidney cancer.

REFERENCES

1. Novick AC. Laparoscopic and partial nephrectomy. *Clin Cancer Res*. 2004;10(18 pt 2):6322S–6327S.
2. Miller DC, Wei JT, Dunn RL, Hollenbeck BK. Trends in the diffusion of laparoscopic nephrectomy. *JAMA*. 2006; 295:2480–2482.
3. Miller DC, Hollingsworth JM, Hafez KS, Daignault S, Hollenbeck BK. Partial nephrectomy for small renal masses: an emerging quality of care concern? *J Urol*. 2006;175:853–857.
4. Miller DC, Taub DA, Dunn RL, Wei JT, Hollenbeck BK. Laparoscopy for renal cell carcinoma: diffusion versus regionalization? *J Urol*. 2006;176:1102–1106.
5. Permpongkosol S, Bagga HS, Romero FR, Solomon SB, Kavoussi LR. Trends in the operative management of renal tumors over a 14-year period. *BJU Int*. 2006;98:751–755.
6. Bhayani SB, Belani JS, Hidalgo J, et al. Trends in nephron-sparing surgery for renal neoplasia. *Urology*. 2006;68:732–736.
7. Wolf JS, Merion RM, Leichtman AB, et al. Randomized controlled trial of hand-assisted laparoscopic versus open surgical live donor nephrectomy. *Transplantation*. 2001;72: 284–290.
8. Simforoosh N, Basiri A, Tabibi A, Shakhssalim N, Hosseini Moghaddam SM. Comparison of laparoscopic and open donor nephrectomy: a randomized controlled trial. *BJU Int*. 2005;95:851–855.
9. Oyen O, Andersen M, Mathisen L, et al. Laparoscopic versus open living-donor nephrectomy: experiences from a prospective, randomized, single-center study focusing on donor safety. *Transplantation*. 2005;79:1236–1240.
10. Dunn MD, Portis AJ, Shalhav AL, et al. Laparoscopic versus open radical nephrectomy: a 9-year experience. *J Urol*. 2000; 164:1153–1159.
11. Best S, Ercole B, Lee C, Fallon E, Skenazy J, Monga M. Minimally invasive therapy for renal cell carcinoma: is there a new community standard? *Urology*. 2004;64:22–25.
12. Hollenbeck BK, Taub DA, Miller DC, Dunn RL, Wei JT. National utilization trends of partial nephrectomy for renal cell carcinoma: a case of underutilization? *Urology*. 2006;67:254–259.
13. Fergany AF, Hafez KS, Novick AC. Long-term results of nephron sparing surgery for localized renal cell carcinoma: 10-year follow-up. *J Urol*. 2000;163:442–445.
14. Hafez KS, Fergany AF, Novick AC. Nephron sparing surgery for localized renal cell carcinoma: impact of tumor size on patient survival, tumor recurrence and TNM staging. *J Urol*. 1999;162:1930–1933.
15. Lee CT, Katz J, Shi W, Thaler HT, Reuter VE, Russo P. Surgical management of renal tumors 4 cm or less in a contemporary cohort. *J Urol*. 2000;163:730–736.
16. Huang WC, Levey AS, Serio AM, et al. Chronic kidney disease after nephrectomy in patients with renal cortical tumours: a retrospective cohort study. *Lancet Oncol*. 2006; 7:735–740.
17. Go AS, Chertow GM, Fan D, McCullogc CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. *N Engl J Med*. 2004;351: 1296–1305.
18. Kutikov A, Fossett LK, Ramchandani P. Incidence of benign pathologic findings at partial nephrectomy for solitary renal mass presumed to be renal cell carcinoma on preoperative imaging. *Urology*. 2006;68:737–740.
19. Hollingsworth JM, Miller DC, Daignault S, Hollenbeck BK. Rising incidence of small renal masses: a need to reassess treatment effect. *J Natl Cancer Inst*. 2006;98:1331–1334.
20. Subramanian S, Jones K, Duncan C. Multilevel methods for public health research. In: Kawachi I, Berkman L, eds. Neighborhoods and Health. New York, NY: Oxford University Press; 2003:65–111.
21. Snijders T, Bosker R. Multilevel Analysis. Thousand Oaks, Calif: SAGE Publications; 1999.
22. Hankey BF, Ries LA, Edwards BK. The Surveillance, Epidemiology, and End Results Program: a national resource. *Cancer Epidemiol Biomarkers Prev*. 1999;8:1117–1121.
23. Warren JL, Klabunde CN, Schrag D, Bach PB, Riley GF. Overview of the SEER-Medicare data: content, research applications, and generalizability to the United States elderly population. *Med Care*. 2002;40(8 suppl):3–18.
24. Finlayson SR, Laycock WS, Birkmeyer JD. National trends in utilization and outcomes of antireflux surgery. *Surg Endosc*. 2003;17:864–867.
25. Bach PB, Guadagnoli E, Schrag D, Schussler N, Warren JL. Patient demographic and socioeconomic characteristics in the SEER-Medicare database applications and limitations. *Med Care*. 2002;40(8 suppl):IV-19–IV-25.
26. Klabunde CN, Potosky AL, Legler JM, Warren JL. Development of a comorbidity index using physician claims data. *J Clin Epidemiol*. 2000;53:1258–1267.
27. Klabunde CN, Harlan LC, Warren JL. Data sources for measuring comorbidity: a comparison of hospital records and Medicare claims for cancer patients. *Med Care*. 2006; 44:921–928.

28. Russo P. Partial nephrectomy achieves local tumor control and prevents chronic kidney disease. *Expert Rev Anticancer Ther.* 2006;6:1745–1751.
29. Hollingsworth JM, Miller DC, Dunn RL, et al. Surgical management of low-stage renal cell carcinoma: technology does not supersede biology. *Urology.* 2006;67:1175–1180.
30. Bhayani SB, Clayman RV, Sundaram CP, et al. Surgical treatment of renal neoplasia: evolving toward a laparoscopic standard of care. *Urology.* 2003;62:821–826.
31. Scherr DS, Ng C, Munver R, Sosa RE, Vaughan ED, Del Pizzo J. Practice patterns among urologic surgeons treating localized renal cell carcinoma in the laparoscopic age: technology versus oncology. *Urology.* 2003;62:1007–1111.
32. Lotan Y, Duchene DA, Cadeddu JA, Sagalowsky AI, Koeneman KS. Changing management of organ-confined renal masses. *J Endourol.* 2004;18:263–268.
33. Baicker K, Chandra A, Skinner JS, Wennberg JE. Who you are and where you live: how race and geography affect the treatment of Medicare beneficiaries [supplemental Web exclusive]. *Health Aff (Millwood).* 2004;VAR:33–44.
34. Weinstein JN, Bronner KK, Morgan TS, Wennberg JE. Trends and geographic variations in major surgery for degenerative diseases of the hip, knee, and spine [supplemental Web exclusive]. *Health Aff (Millwood).* 2004; VAR: 81–89.
35. Shahinian VB, Kuo YF, Freeman JL, Goodwin JS. Determinants of androgen deprivation therapy use for prostate cancer: role of the urologist. *J Natl Cancer Inst.* 2006;98: 839–845.
36. Hawley ST, Hofer TP, Janz NK, et al. Correlates of between-surgeon variation in breast cancer treatments. *Med Care.* 2006;44:609–616.
37. Aron M, Gill IS. Minimally invasive nephron-sparing surgery (MINSS) for renal tumours part II: probe ablative therapy. *Eur Urol.* 2007;51:348–357.
38. Kunkle DA, Crispen PL, Chen DY, Greenberg RE, Uzzo RG. Enhancing renal masses with zero net growth during active surveillance. *J Urol.* 2007;177:849–854.
39. Sachdeva AK. Acquiring skills in new procedures and technology: the challenge and the opportunity. *Arch Surg.* 2005; 140:387–389.
40. Rogers EM. Diffusion of Innovations. New York, NY: Free Press; 2003.
41. McFall SL, Warnecke RB, Kaluzny AD, Ford SL. Practice setting and physician influences on judgments of colon cancer treatment by community physicians. *Health Serv Res.* 1996;31:5–19.
42. Escarce JJ. Externalities in hospitals and physician adoption of a new surgical technology: an exploratory analysis. *J Health Econ.* 1996;15:715–734.
43. Carroll PR, Albertsen PC, Smith JA, Howards SS. Volume of major surgeries performed by recent and more senior graduates from North American urology training programs. *J Urol.* 2006;175(suppl):1. Abstract 2.
44. Corica FA, Boker JR, Chou DS, et al. Short-term impact of a laparoscopic "mini-residency" experience on postgraduate urologists' practice patterns. *J Am Coll Surg.* 2006; 203:692–698.
45. McDougall EM, Corica FA, Boker JR, et al. Construct validity testing of a laparoscopic surgical simulator. *J Am Coll Surg.* 2006;202:779–787.
46. Shalhav AL, Dabagia MD, Wagner TT, Koch MO, Lingeman JE. Training postgraduate urologists in laparoscopic surgery: the current challenge. *J Urol.* 2002;167:2135–2137.
47. Myers JA, Doolas A. How to teach an old dog new tricks and how to teach a new dog old tricks: bridging the generation gap to push the envelope of advanced laparoscopy. *Surg Endosc.* 2006;20:1177–1178.
48. Birkmeyer NJ, Birkmeyer JD. Strategies for improving surgical quality—should payers reward excellence or effort? *N Engl J Med.* 2006;354:864–870.
49. Gagliardi A, Ashbury FD, George R, Irish J, Stern HS. Improving cancer surgery in Ontario: recommendations from a strategic planning retreat. *Can J Surg.* 2004;47:270–276.
50. Wibe A, Moller B, Norstein J, et al. A national strategic change in treatment policy for rectal cancer—implementation of total mesorectal excision as routine treatment in Norway. A national audit. *Dis Colon Rectum.* 2002;45:857–866.
51. Westfall JM, Mold J, Fagnan L. Practice-based research—"Blue Highways" on the NIH roadmap. *JAMA.* 2007;297: 403–406.
52. Finlayson SR. Delivering quality to patients. *JAMA.* 2006; 296:2026–2027.
53. Dimick JB, Finlayson SR, Birkmeyer JD. Regional availability of high-volume hospitals for major surgery [supplemental Web exclusive]. *Health Aff (Millwood).* 2004;VAR: 45–53.
54. Katz SJ, Hawley ST. From policy to patients and back: surgical treatment decision making for patients with breast cancer. *Health Aff.* 2007;26:761–769.
55. American College of Surgeons Commission on Cancer National Cancer Database. Public Access to Cancer Data: NCDB Public Benchmark Reports: diagnosis year, 2004; primary site, kidney/renal pelvis; variable 1, surgical procedure. Available at: http://web.facs.org/ncdbbmr/frames/public7/TABLES/Y04S49XaTa_20000000_tb_B.html Accessed May 25, 2007.