UROLOGIC ONCOLOGY

Urologic Oncology: Seminars and Original Investigations 34 (2016) 431.e17–431.e24

Original article

# Determinants of radical cystectomy operative time

Christopher P. Filson, M.D., M.S.[a,b,c], Hung-Jui Tan, M.D.[a], Karim Chamie, M.D., M.S.[a], Aaron A. Laviana, M.D.[a], Jim C. Hu, M.D., M.P.H.[d,*]

[a] *Department of Urology, David Geffen School of Medicine at UCLA, Los Angeles, CA*
[b] *Department of Urology, Emory University, Atlanta, GA*
[c] *Department of Urology, Atlanta Veterans Affairs Medical Center, Decatur, GA*
[d] *Department of Urology, Weill Cornell Medical College, New York, NY*

Received 20 January 2016; received in revised form 13 March 2016; accepted 3 May 2016

**Abstract**

**Objective:** To examine factors associated with radical cystectomy operative time among Medicare beneficiaries.

**Material and methods:** Using linked Surveillance, Epidemiology, and End Results-Medicare data, we identified 4,975 patients who underwent a radical cystectomy during 1991 to 2007. Using a validated method of using anesthesia administrative data to quantify operative time, we used generalized estimating equations to examine the association of patient, provider, and hospital factors on radical cystectomy operative time.

**Results:** We found that mean operative time decreased by 5 minutes per year ($\Delta = -5.3$ min/y, $P < 0.001$). Longer operative times were found in academic centers ($\Delta = +39.0$ min vs. nonacademic), continent diversion ($\Delta = +34.9$ min vs. ileal conduit), surgical excision of $\geq 11$ lymph nodes ($\Delta = +24.9$ min vs. 1–5), female ($\Delta = +32.3$ min vs. male sex), and perioperative anesthesia procedures such as placement of central venous catheters or arterial lines ($\Delta = +47.2$ min vs. no procedures), respectively (all $P < 0.01$). In adjusted analysis, higher surgeon volume ($\Delta = -22.0$ min vs. lowest volume) was associated with shorter operative times ($P = 0.002$).

**Conclusions:** Operative times for cystectomy have been steadily decreasing annually. There is notable variation based on academic affiliation, diversion type and extent of lymphadenectomy, surgeon and hospital volumes, as well as use of anesthetic procedures. Efforts to improve operative time by selective referral to high-volume surgeons or hospitals or both, or judicious use of perioperative procedures may have a positive effect on health care costs and overall quality of care for patients undergoing radical cystectomy for bladder cancer. © 2016 Published by Elsevier Inc.

*Keywords:* Bladder cancer; Operative time; Radical cystectomy; SEER-Medicare

## 1. Introduction

Radical cystectomy remains the gold standard treatment for patients with muscle-invasive bladder cancer. The procedure is time-consuming, as it requires extirpation of the bladder and the surrounding organs, pelvic lymphadenectomy, bowel resection, and urinary diversion. Prolonged operative time has been linked to more frequent complications and higher perioperative mortality among patients undergoing reconstructive and orthopedic procedures [1–3], Using National Surgical Quality Improvement Program data, Lavallée et al. [4] demonstrated that cystectomy operative times over 6 hours were associated with a higher incidence of perioperative complications. Moreover, longer operative times are associated with increased expenditures—a 1 hour increment in operative suite time increases overall hospital charges by $1,000 [5].

Most urologists perform this operation infrequently, with half of radical cystectomies in the United States performed by urologists doing only one of these operations annually [6]. With increasing pressure from policymakers and payers to reduce complications and minimize health care costs, a greater understanding of the association between patient, surgeon, and hospital factors with radical cystectomy operative times is important and timely. This is particularly

* Corresponding author. Tel.: +1-212-746-4600.
*E-mail address:* jch9011@med.cornell.edu (J.C. Hu).

http://dx.doi.org/10.1016/j.urolonc.2016.05.006
1078-1439/

relevant as we transition from fee-for-service payment structures to accountable care organizations. However, there is a dearth of information as to mutable factors that contribute to radical cystectomy operative times. To this end, we performed a population-based study to better discern the various patient, provider, and clinical factors that affect radical cystectomy operative time. We hypothesized that operative time would be decreasing over time and operative time would vary significantly based on selected patient, surgeon, and hospital factors.

## 2. Material and methods

### *2.1. Data source and analytic cohort*

We used Surveillance, Epidemiology, and End Results (SEER) cancer registry data linked to Medicare claims for our analyses. The data were drawn from 18 SEER registries, which comprised approximately 26% of the United States population [7]. In our initial step, we identified 86,606 patients over 65 years of age who were diagnosed with bladder cancer from 1991 through 2007. Next, we restricted this group to 62,746 patients who had both Medicare part A and B coverage without additional health maintenance organization coverage. Among this group, 5,124 patients had claims for radical cystectomy with an appropriate length of stay (i.e., $\geq$2 days) and operative time ($\geq$120 min). Finally, we excluded 149 patients without 12 months of available claims data before diagnosis, leaving a final analytic cohort of 4,975 patients with bladder cancer patients who were treated with a radical cystectomy.

### *2.2. Exposures and covariates of interest*

Patient age and sex were abstracted from the Medicare file. SEER registry data were used to define tumor stage, tumor grade, race, geographic region, and marital status. We used ZIP code of residence and SEER data to define socioeconomic covariates (e.g., median household income, percentage with high school education, and rural/urban status). Patient comorbidity was defined using the Klabunde et al. [8] method of administrative claims from 12 months before diagnosis.

Surgeon characteristics were assessed using American Medical Association Masterfile data, which were linked to physician identifiers available in Medicare data. Surgeon age, employment type (e.g., solo/2-person, group practice, and medical school), and annual cystectomy volume were included. Surgeon and hospital volume was calculated by aggregating all radical cystectomy cases by each unique surgeon or hospital identifier over the course of the study time frame. We split surgeon and hospital volume variables into evenly divided quartiles. Other hospital factors of interest included ownership status, academic affiliation, hospital size, and annual cystectomy volume. Additional anesthesia procedures were identified using the following Current Procedural Terminology (CPT)-4 codes: placement of epidural (62318, 62319, 62310, 62311, and 62350); arterial line (36620); and central venous catheter (93593).

### *2.3. Outcomes*

We used administrative claims by anesthesiologists to define operative time, consistent with our prior work [9] and reported elsewhere [10]. We assumed that the anesthesiologist claims encompass the time from induction to reversal of general anesthesia. We evaluated operative time as a continuous variable in minutes.

### *2.4. Statistical analysis*

For unadjusted analyses, we employed Wilcoxon rank-sum, chi-square, Fisher exact, and *t* tests to evaluate the association between operative time and pertinent covariates of interest. We fit our multivariate linear regression model and estimated the change in operative time based on significant factors identified with stepwise selection using cutoffs of 0.15 for both significance level to enter and significance level to stay. Generalized estimating equations were used to adjust for clustering at the surgeon level [11]. After fitting this model, we generated predicted mean operative time based on quartiles of surgeon and hospital case volume.

All analyses were performed using SAS (version 9.2; Cary, NC) and STATA software (version 13.1; College Station, TX). All statistical tests were 2-tailed, and the probability of a type I error was set at $<$0.05. The institutional review board at the University of California, Los Angeles, exempted our study protocol.

## 3. Results

Across the time frame of interest, we noted a gradual decrease in operative times for patients treated with radical cystectomy, where the shortest operative times were noted among patients treated with cystectomy from 2004 through 2007. Patient characteristics of the analytic cohort are seen in Table 1. Table 2 demonstrates the other unadjusted associations between surgeon and hospital factors and operative time. The shortest operative time was noted among solo/2-person (median: 376 min) and group practices (median: 385 min) ($P < 0.001$). Regarding hospital factors, the longest operative times were noted among hospitals with NCI Cancer Center affiliation, government hospitals, large hospitals (i.e., 669+ beds), and those with academic affiliation (all $P < 0.01$). Regarding operative factors, performance of radical cystectomy with continent diversion took 65 minutes longer than radical cystectomy with an ileal conduit diversion (449 vs. 384 min, $P < 0.001$) (Table 3).

Table 1
Characteristic of patients with bladder cancer treated with radical cystectomy

| Covariate | *n* | Median operative time, min (IQR) | *P* |
|---|---|---|---|
| Age at diagnosis, y | | | |
| 66–70 | 1,654 | 406 (324–509) | **<0.001** |
| 71–75 | 1,513 | 405 (320–509) | |
| 76–80 | 1,144 | 384 (303–475) | |
| 81+ | 664 | 379 (307–483) | |
| Sex | | | |
| Female | 899 | 415 (328–512) | **<0.001** |
| Male | 4,076 | 393 (314–495) | |
| Race | | | |
| White | 4,630 | 397 (315–496) | 0.429 |
| Black | 180 | 405 (326–495) | |
| Other | 165 | 406 (321–539) | |
| Marital status | | | |
| No | 1,510 | 385 (312–494) | **<0.001** |
| Yes | 3,465 | 403 (319–503) | |
| Percentage with high school education[a] | | | |
| 90+ | 1,664 | 404 (321–497) | **0.014** |
| 85–89.9 | 992 | 404 (319–503) | |
| 75–84.9 | 1,328 | 388 (315–490) | |
| <75 | 940 | 389 (304–494) | |
| Median income[a] | | | |
| <$35,000 | 1,705 | 385 (304–490) | **0.002** |
| $35,000–<$45,000 | 1,221 | 394 (315–494) | |
| $45,000–<$60,000 | 1,115 | 406 (327–505) | |
| $60,000+ | 883 | 409 (330–498) | |
| Geographic region | | | |
| Northeast | 1,147 | 391 (320–479) | **<0.001** |
| South | 698 | 359 (280–492) | |
| Midwest | 1,047 | 381 (305–465) | |
| West | 2,083 | 418 (334–535) | |
| Comorbidity | | | |
| 0 | 3,507 | 398 (316–496) | 0.424 |
| 1 | 1,059 | 397 (318–498) | |
| 2 | 247 | 384 (302–506) | |
| 3+ | 162 | 407 (308–501) | |
| Rural/urban status | | | |
| Rural | 504 | 369 (295–480) | **0.002** |
| Urban | 4,471 | 400 (319–499) | |
| AJCC stage[b] | | | |
| Stage I or in situ | 1,658 | 396 (315–502) | 0.181 |
| Stage II | 1,132 | 391 (314–483) | |
| Stage III | 1,092 | 396 (309–495) | |
| Stage IV | 996 | 406 (323–521) | |
| TNM: N stage | | | |
| Nx | 536 | 406 (323–521) | **<0.001** |
| N0 | 2,624 | 389 (311–481) | |
| N+ | 1,815 | 322 (409–516) | |
| TNM: T stage | | | |
| Ta | 512 | 392 (306–506) | 0.839 |
| Tis | 177 | 399 (344–506) | |
| T1 | 1,000 | 396 (316–497) | |
| T2 | 1,520 | 399 (318–496) | |
| T3 | 1,010 | 393 (310–489) | |
| T4 | 651 | 404 (322–502) | |
| Unknown | 105 | 411 (335–535) | |
| TNM: M stage | | | |
| M0/Mx | 4,239 | 394 (314–494) | **0.005** |
| M+ | 736 | 415 (330–529) | |

Bold values signifies p<0.05.
AJCC = American Joint Committee on Cancer; IQR = interquartile range.
[a]Missing in 51 cases.
[b]Missing in 97 cases.

Table 2
Surgeon and hospital factors among patients with bladder cancer treated with radical cystectomy

| Covariate | *n* | Median operative time, min (IQR) | *P* |
|---|---|---|---|
| Quartiles of surgeon volume (annual cases) | | | |
| Lowest (1–3) | 1,137 | 404 (314–525) | **0.012** |
| Moderate (4–8) | 1,381 | 390 (309–490) | |
| High (9–24) | 1,212 | 380 (301–479) | |
| Highest (25+) | 1,245 | 412 (340–505) | |
| Surgeon age | | | |
| <50 y | 1,698 | 388 (304–480) | 0.210 |
| 50+ years | 2,143 | 399 (322–498) | |
| Unknown | 1,134 | 407 (321–524) | |
| Surgeon employment | | | |
| 1–2 Physicians | 562 | 376 (299–475) | **<0.001** |
| Group | 2,266 | 385 (304–479) | |
| Medical school | 399 | 437 (357–563) | |
| Nongovernment | 151 | 437 (359–530) | |
| Government | 160 | 407 (342–482) | |
| Not classified | 1,437 | 405 (329–525) | |
| Quartiles of hospital volume (annual cases) | | | |
| Lowest (1–8) | 1,233 | 375 (299–484) | **<0.001** |
| Moderate (9–18) | 1,273 | 379 (303–480) | |
| High (18–54) | 1,274 | 399 (318–499) | |
| Highest (55+) | 1,195 | 428 (355–523) | |
| NCI Cancer Center affiliation | | | |
| No | 3,774 | 385 (305–487) | **<0.001** |
| Yes | 1,201 | 427 (355–534) | |
| Hospital setting | | | |
| Nonprofit | 3,724 | 389 (310–484) | **<0.001** |
| Proprietary | 399 | 419 (344–536) | |
| Government | 852 | 429 (330–539) | |
| Hospital size (beds) | | | |
| Lowest (1–269) | 1,261 | 388 (317–479) | **0.005** |
| Moderate (270–450) | 1,280 | 385 (304–494) | |
| High (451–668) | 1,254 | 402 (316–517) | |
| Highest (669+) | 1,180 | 415 (332–509) | |
| Academic affiliation | | | |
| No | 1,798 | 378 (304–475) | **<0.001** |
| Yes | 3,177 | 406 (324–510) | |

Bold values signifies p<0.05.
IQR = interquartile range; NCI = National Cancer Institute.

The estimates from our multivariable analysis are shown in Table 4. Over time, we observed a 5-minute decrease in operative time per year ($P < 0.001$). Regarding patient factors, longer operative time was noted with female sex (adjusted $\Delta = +32.3$ minutes, $P < 0.001$) and increasing patient comorbidity (adjusted $\Delta = +7.8$ min per point of Charlson Comorbidity Score, $P < 0.001$). Shorter operative time was seen with patients of increasing age (adjusted $\Delta = -2.0$ min/y, $P<0.001$) and those who were unmarried (vs. married patients, adjusted $\Delta = -15.9$ min, $P < 0.001$). We also noted significant geographic variation,

Table 3
Operative factors among patients with bladder cancer treated with radical cystectomy

| Covariate | *n* | Median operative time, min (IQR) | *P* |
|---|---|---|---|
| Lymphadenectomy | | | |
| No | 1,583 | 409 (320–524) | **<0.001** |
| Yes | 3,392 | 390 (314–488) | |
| Lymph nodes examined | | | |
| 0 | 2,454 | 396 (315–494) | **<0.001** |
| 1–5 | 704 | 369 (297–475) | |
| 6–10 | 577 | 404 (324–506) | |
| 11+ | 909 | 420 (340–517) | |
| Unknown | 331 | 381 (295–503) | |
| Type of urinary diversion | | | |
| Continent | 869 | 449 (369–565) | **<0.001** |
| Ileal conduit | 3,968 | 384 (307–480) | |
| Ureterosigmoidostomy | 50 | 405 (320–537) | |
| Unknown | 88 | 434 (362–480) | |
| Epidural placement | | | |
| No | 3,534 | 402 (315–510) | 0.061 |
| Yes | 1,441 | 388 (317–472) | |
| Arterial line placement | | | |
| No | 1,871 | 359 (284–454) | **<0.001** |
| Yes | 3,104 | 420 (340–524) | |
| Central venous catheter placement | | | |
| No | 3,586 | 390 (309–495) | **<0.001** |
| Yes | 1,389 | 412 (334–505) | |
| Any perioperative procedure | | | |
| No | 1,238 | 363 (284–465) | **<0.001** |
| Yes | 3,737 | 408 (329–509) | |

Bold values signifies p<0.05.
IQR = interquartile range.

with cases in the South (adjusted $\Delta = -50.6$ min, $P < 0.001$) and Midwest (adjusted $\Delta = -56.7$ min, $P < 0.001$) approximately 1 hour shorter, than those in the West.

Operative factors had arguably the most significant effect on operative times. Performance of a continent diversion added an estimated 35 minutes to a case ($P < 0.001$), compared with cases involving an ileal conduit diversion. When patients had 1 or more perioperative anesthetic procedure (e.g., epidural or arterial line placement or both), the estimated case duration was over 47 minutes longer than patients who did not receive any ($P < 0.001$). Finally, we noted a stepwise increase in operative times associated with extent of lymph node dissection. Compared with patients with 1 to 5 nodes removed, patients with 6 to 10 nodes (adjusted $\Delta = +14.8$ min, $P < 0.001$), and $\geq 11$ nodes (adjusted $\Delta = +24.9$ min, $P < 0.001$) excised experienced longer cystectomy operative times.

After adjustment for other covariates, the only surgeon factor associated with change in operative time was non-government practice type (adjusted $\Delta = +32.3$ min/case, 0.02) (Table 4). Hospital factors associated with increased operative time included hospital ownership status (e.g., for profit vs. nonprofit), with proprietary (adjusted $\Delta = +33.6$ min/case, $P = 0.003$) and government hospitals (adjusted $\Delta = +33.5$ min/case, $P = 0.002$) being associated with increased operative time compared with nonprofit hospitals. Furthermore, cases performed at hospitals without an academic affiliation had operative times that were nearly 40 minutes shorter ($P < 0.001$) than academic hospitals. Fig., shows the relationship between cystectomy operative time and quartiles of surgeon and hospital case volume—where the highest volume surgeons ($P = 0.002$) and hospitals ($P = 0.06$) had the shortest mean operative times.

## 4. Discussion

Among Medicare-eligible patients with bladder cancer treated with a radical cystectomy, we found 4 important findings. First, potentially modifiable operative factors (e.g., perioperative procedures, lymph node dissections, and diversion type) had the greatest effect on time in the operating room. Second, nonmodifiable patient factors such as age and sex were associated with significant variation in operative time. Third, we noted longer operative times in academic settings. Finally, there was a significant surgeon volume-operative time relationship, whereby higher-volume surgeons had shorter operative times.

Congruent with other analyses, we noted longer operative times with continent neobladder diversion [12]. We noted an excess of 30 to 45 minutes of operative time associated with more extensive lymphadenectomies and with additional perioperative anesthesia procedures (e.g., central venous catheter placement). We acknowledge that there are cases where performance of extended lymph node dissection or central venous catheter placement is absolutely indicated, and not modifiable. However, our findings emphasize the importance of understanding the true value and potential benefit of these components of the performance of radical cystectomy. For instance, in a patient with a borderline indication for central venous catheter placement, the marginal benefit of this procedure must be weighed against the potential detriment of prolonged operative time, in cost and risk of postoperative complications. Further, data from the S1011 study on the marginal benefit of an extended pelvic lymphadenectomy, compared with a standard lymphadenectomy, would shed additional light on the morbidity and cost of extending the lymphadenectomy [13].

Nonmodifiable patient factors were associated with considerable variation in operative times. First, at a patient-level, performance of cystectomy was 20 minutes shorter for every decade of increasing patient age. This finding may be related to surgeons' impetus to get older patients "off the table" because of a theoretical risk of complications from prolonged general anesthesia. On the contrary, we noted increased operative time for radical cystectomy performed for sicker bladder patient with cancer, which may suggest that surgeons are considering a patient's age much more strongly when trying to optimize operative time. This relationship is similar

Table 4
Multivariable analysis for radical cystectomy operative time

| Covariate | Reference group | Estimated difference in operative time, min (95% CI) | *P* |
|---|---|---|---|
| *Patient and tumor factors* | | | |
| Year of surgery | N/A | **−5.32 (−6.78** to **3.86)** | **<0.001** |
| Age at cystectomy (per year) | N/A | **−1.98 (−2.86** to **1.09)** | **<0.001** |
| Female sex | Male | **32.27 (20.32–44.23)** | **<0.001** |
| Patient race | | | |
| Black | White | 7.57 (−16.16 to **31.31)** | 0.532 |
| Other | | **−33.49 (−54.68** to **12.3)** | **0.002** |
| Not married | Married | **−15.85 (−25.08** to **6.62)** | **<0.001** |
| Charlson comorbidity score (per point) | N/A | **7.83 (2.14 –13.52)** | **0.007** |
| Region | | | |
| Northeast | West | −15.36 (−34.05 to **3.33)** | 0.107 |
| South | | **−50.55 (−69.97** to **31.13)** | **<0.001** |
| Midwest | | **−56.73 (−75.62** to **37.84)** | **<0.001** |
| Rural residence | Urban | −3.63 (−24.94 to **17.68)** | 0.739 |
| High school education | | | |
| 1:<75 | 90+ | −3.13 (−20.29 to 14.03) | 0.721 |
| 2:75–84.99 | | −2.11 (−14.32 to 10.11) | 0.735 |
| 3:85–89.99 | | 4.23 (−8.73 to 17.19) | 0.522 |
| Median income | | | |
| 1 = <$35,000 | $60,000+ | 10.47 (−5.48 to 26.42) | 0.198 |
| 2 = $35,000–<$45,000 | | 13.38 (−1.77 to 28.54) | 0.084 |
| 3 = $45,000–<$60,000 | | 6.12 (−6.07 to 18.31) | 0.325 |
| AJCC tumor stage | | | |
| Stage I or in situ | Stage IV | 2.63 (−18.35 to 23.61) | 0.806 |
| Stage II | | 3.41 (−18.8 to 25.62) | 0.763 |
| Stage III | | 5.07 (−14.7 to 24.83) | 0.615 |
| TNM: N stage | | | |
| Nx | N+ | −15.23 (−35.83 to 5.37) | 0.147 |
| N0 | | **−21.47 (−36.08** to **6.85)** | **0.004** |
| TNM: M+ stage | Mx/M0 | 13.03 (−8.42 to 34.48) | 0.234 |
| Tumor grade | | | |
| Well/moderately differentiated | Poorly or un-differentiated | −9.4 (−21.63 to 2.82) | 0.132 |
| Other | | −3.65 (−11.49 to 4.19) | 0.361 |
| *Surgeon factors* | | | |
| Surgeon age (per year) | N/A | −0.71 (−1.48 to 0.06) | 0.070 |
| Practice type | | | |
| 1–2 Physicians | Group | 0.31 (−21.28 to 21.91) | 0.978 |
| Medical school | | 14.91 (−14 to 43.82) | 0.312 |
| Nongovernment | | **32.29 (5.32–59.26)** | **0.019** |
| Government | | 5.94 (−30.91 to 42.78) | 0.752 |
| Not classified | | 18.02 (−2.6 to 38.64) | 0.087 |
| Hospital factors | | | |
| Hospital bed count | N/A | 0.00 (−0.02 to 0.02) | 0.709 |
| No academic affiliation | Academic affiliation | **−38.98 (−53.09** to **24.86)** | **<0.001** |
| Hospital ownership | | | |
| Proprietary | Nonprofit | **33.56 (11.8–55.31)** | **0.003** |
| Government | | **33.52 (12.87–54.17)** | **0.002** |
| NCI Cancer Center affiliation | No cancer center | 16.85 (−5.79 to 39.50) | 0.145 |
| *Operative factors* | | | |
| Diversion | | | |
| Continent | Ileal conduit | **34.86 (21.62–48.10)** | **<0.001** |
| Ureterosigmoidostomy | | 39.85 (−34.23 to 113.93) | 0.292 |
| Unknown | | 16.92 (−8.7 to 42.54) | 0.196 |
| No perioperative procedures | Any perioperative procedure | **−47.23 (−58.47** to **35.99)** | **<0.001** |
| Lymph nodes examined | | | |
| 0 | 1–5 | **24.68 (9.6–39.76)** | **0.001** |
| 6–10 | | **14.79 (0.05–29.52)** | **0.049** |
| 11+ | | **24.94 (8.67–41.21)** | **0.003** |
| Unknown | | 10.14 (−9.72 to 30.00) | 0.317 |

Bold values signifies $p<0.05$.
AJCC = American Joint Committee on Cancer; NCI = National Cancer Institute.

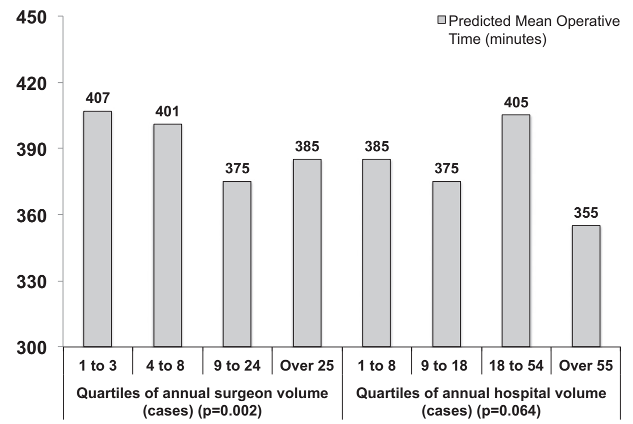


Fig. Relationship between surgeon and hospital volume and radical cystectomy operative time. This figure depicts the predicted mean operative times for individual quartiles of surgeon and hospital volume based on estimates from our multivariable regression models. The 4 columns on the left are quartiles of annual surgeon volume and the 4 columns on the right represent quartiles of annual hospital volume. Quartiles of volume increase from left to right. The *y*-axis represents the mean operative time in minutes. There was a notable and statistically downtrend in operative time as surgeon volume increased across the 4 quartiles ($P = 0.002$). Though there was a similar trend for hospital volume, this did not reach statistical significance ($P = 0.064$).

to what we see when urologists weigh age and comorbidity during decision-making for prostate cancer, where comorbid disease burden falls far short of the effect that patient age confers [14]. However, as our operating time algorithm also included induction time, sicker patients (particularly those with cardiovascular and pulmonary disease) may have required more attention during initiation of general anesthesia. Second, female patients required longer operative times (possibly because of performance of hysterectomy and vaginal reconstruction), which stands in contrast to the results from prior institutional cohort studies showing no significant difference in operative time based on patient sex [15].

In addition, at a hospital level, we noted that patients with bladder cancer treated with radical cystectomy at academic centers had procedures that were nearly 40 minutes longer compared with those treated at nonacademic centers. Hospitals associated with academic centers typically involve postgraduate trainees (i.e., residents and fellows in anesthesia and urology) to assist during both anesthesia and surgery. Broadly, prior reports looking at the association between resident involvement and operative time are conflicting; though single institution studies did not show any differences in operative time [16], other population-based reports have demonstrated increased operative time for procedures with resident participation [17,18]. We acknowledge that some of the differences between hospitals could reflect differences in operational efficiency or workplace culture that are beyond the scope of our dataset.

We also observed a significant decrease in operative time associated with increasing surgeon volume—as has been noted elsewhere with performance of hysterectomy among gynecologic surgeons and laparoscopic/robotic-assisted procedures in other specialties (including radical prostatectomy performed by urologists) [19,20]. Radical cystectomy is one of the most complex procedures in urologic oncology and—like its correlate in surgical oncology, pancreaticoduodenectomy—requires extirpation, lymph node dissection, and a complex reconstruction (biliary vs. urinary diversion). Single institution reports suggest that the "learning curve" for pancreaticoduodenectomy requires 60 cases before improvements in operative time are observed [21]. If radical cystectomy has a similar learning curve, this cutoff may be difficult to reach for most urologists practicing in the United States, where the median cystectomy volume is estimated at 2 cases per year [6]. Studies assessing the radical cystectomy learning curve are limited to those performed from a minimally invasive approach, where 21 robotic-assisted laparoscopic radical cystectomies were required to reach operative times less than 6.5 hours [22]. Of note, dividing this complex operation between 2 providers (i.e., 1 performing extirpation and 1 completing diversion) has been considered. In fact, small studies suggest that this approach can result in decreasing operative time by as much as 2 hours, on average [23].

Furthermore, we also noted that, after adjusting for other potential confounders, the highest volume hospitals had the shortest operative times for patients undergoing radical cystectomy. This may reflect clustering of high-volume surgeons to high-volume hospitals, or streamlining of intraoperative pathways to optimize performance in the operating room. Taken collectively, these findings highlight potential cost savings and improving quality of care (by decreasing postoperative complications) with referral to high-volume individuals and centers. However, regionalization of patients requiring complex care may have associated costs, such as delayed access to care [24] or impaired recovery from complications after readmission to secondary hospitals [25]. Alternatively, lower-volume surgeons may be able to find means to elevate their skills through mentoring or other educational mechanisms.

Our findings must be interpreted within the context of the study design. First, we restricted our analysis to Medicare beneficiaries, and results may not be generalizable to other populations (e.g., age less than 65 years, those with Health Maintenance Organization benefits). Nevertheless, SEER-Medicare analyses are representative of the United States population, Moreover, the age distribution of a diagnosis of muscle-invasive bladder cancer highlights the potential importance of these findings for the Medicare-eligible population in the United States. Second, we did not assess the association between surgical approach (i.e., laparoscopic/robotic-assisted vs. open radical cystectomy) and operative times. However, the introduction and pursuant diffusion of minimally invasive approaches in performing radical cystectomy were incorporated were far later than our current cohort and incorporating those factors is unlikely to change our overall findings. Furthermore, we would have found that the introduction of robotic surgery in the recent era would likely be associated with longer operative times, not shorter times. Third, there are unmeasured factors outside the scope of the SEER-Medicare dataset that we could not adjust for in our analysis. However, this issue of confounding is present in any nonrandomized study, and allows for additional investigation in the future. In particular, there has been increased focus on surgeons "double booking" multiple rooms at the same time; it remains unknown how long patients remain under anesthesia whereas urologists tend to cases starting concurrently in another room. Fourth, we cannot evaluate the clinical effect of the incremental change in operative time with this analysis. Further research would have to assess to what degree absolute differences in operative time influence outcomes. Finally, though validated previously [10], our measurement of operative time also includes induction time for general anesthesia, and would likely be influenced by a number of factors specific to the anesthesiologists associated with each case (e.g., provider age and experience.) that we could not measure. Furthermore, actual operative time "under the knife" would likely be shorter than our claims-based operative time, based on the validation study by Silber et al. [10].

In summary, we demonstrate the first population-based analyses to explore factors associated with operative time for radical cystectomy, which has relevance in the era of value-based care. A clearer sense of how patient, surgeon, and hospital factors are related to operative time is crucial for 2 reasons. On the contrary, prolonged operative times are directly associated with increased health care costs, where each minute in the operating room, on average, adds $15 to overall charges [5]. On the contrary, outside of underlying comorbidity and more advanced disease, extended operative times may put patients at risk for postoperative complications and has been shown to be associated with wound infections or venous thromboembolic events [1–4].

## 5. Conclusion

Operative times for cystectomy have been steadily decreasing annually. There is notable variation based on academic affiliation, diversion type and extent of lymphadenectomy, surgeon and hospital volumes, as well as use of anesthetic procedures. Efforts to improve operative time by selective referral to high-volume surgeons or hospitals, or judicious use of perioperative procedures may have a positive effect on health care costs and overall quality of care for patients undergoing radical cystectomy for bladder cancer.

## Acknowledgments

The authors acknowledge the American Cancer Society, United States for their funding support for Dr. Filson through Grant PF-14-161-01 and the NIH, United States Loan Repayment Program (L30 CA154326) to Dr. Chamie. This study used the linked SEER-Medicare database. The interpretation and reporting of these data are the sole responsibility of the authors. The authors acknowledge the efforts of the Applied Research Program, NCI; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Program tumor registries in the creation of the SEER-Medicare database.

## References

[1] Peersman G, Laskin R, Davis J, et al. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. HSS J 2006;2:70–2.
[2] Singh B, Cordeiro PG, Santamaria E, et al. Factors associated with complications in microvascular reconstruction of head and neck defects. Plastic Reconstr Surg 1999;103:403.
[3] Ball CG, Pitt HA, Kilbane ME, et al. Peri-operative blood transfusion and operative time are quality indicators for pancreatoduodenectomy. HPB (Oxford) 2010;12:465–71.
[4] Lavallée LT, Schramm D, Witiuk K, et al. Perioperative morbidity associated with radical cystectomy in a multicenter database of community and academic hospitals. PLoS One 2014;9:e111281.
[5] Macario A. What does one minute of operating room time cost? J Clin Anesth 2010;22:233–6.
[6] Flum A, Oberlin D, Bachrach L, et al. PD18-05 characteristics of certifying urologists performing cystectomies in the United States. J Urol 2014;191:e536–7.
[7] National Cancer Institute. SEER cancer statistics review 1975-2011: an introduction. Bethesda, MD. Available at: http://seer.cancer.gov/csr/1975_2011/results_figure/sect_01_intro1_7pgs.pdf [accessed 16.03.15].
[8] Klabunde CN, Potosky AL, Legler JM, et al. Development of a comorbidity index using physician claims data. J Clin Epidemiol 2000;53:1258–67.
[9] Carter SC, Lipsitz S, Shih YCT, et al. Population-based determinants of radical prostatectomy operative time. BJU Int 2014;113:E112–8.
[10] Silber JH, Rosenbaum PR, Even-Shoshan O, et al. Estimating anesthesia time using the Medicare claim: a validation study. Anesthesiology 2011;115:322–33.
[11] Hanley JA, Negassa A, Edwardes MDD, et al. Statistical analysis of correlated data using generalized estimating equations: an orientation. Am J Epidemiol 2003;157:364–75.
[12] Lowrance WT, Rumohr JA, Chang SS, et al. Contemporary open radical cystectomy: analysis of perioperative outcomes. J Urol 2008;179:1313–8.
[13] National Institutes of Health. S1101 standard or extended pelvic lymphadenectomy in treatment patients undergoing surgery for invasive bladder cancer. Available at: https://clinicaltrials.gov/ct2/show/NCT01224665 [accessed 22.10.15].
[14] Daskivich TJ, Lai J, Dick AW, et al. Variation in treatment associated with life expectancy in a population-based cohort of men with early-stage prostate cancer. Cancer 2014;120:3642–50.
[15] Lee KL, Freiha F, Presti JC Jr, et al. Gender differences in radical cystectomy: complications and blood loss. Urology 2004;63:1095–9.
[16] Uecker J, Luftman K, Ali S, et al. Comparable operative times with and without surgery resident participation. J Surg Educ 2013;70:696–9.
[17] Kiran RP, Ahmed Ali U, Coffey JC, et al. Impact of resident participation in surgical operations on postoperative outcomes. Ann Surg 2012;256:469–75.
[18] Matulewicz RS, Pilecki M, Rambachan A, et al. Impact of resident involvement on urological surgery outcomes: an analysis of 40,000 patients from the ACS NSQIP database. J Urol 2014;192:885–90.
[19] Rogo-Gupta LJ, Lewin SN, Kim JH, et al. The effect of surgeon volume on outcomes and resource use for vaginal hysterectomy. Obstet Gynecol 2010;116:1341–7.

[20] Pierorazio PM, Patel HD, Feng T, et al. Robotic-assisted versus traditional laparoscopic partial nephrectomy: comparison of outcomes and evaluation of learning curve. Urology 2011;78:813–9.
[21] Tseng JF, Pisters PWT, Lee JE, et al. The learning curve in pancreatic surgery. Surgery 2007;141:694–701.
[22] Hayn MH, Hussain A, Mansour AM, et al. The learning curve of robot-assisted radical cystectomy: results from the international robotic cystectomy consortium. Eur Urol 2010;58:197–202.
[23] Ludwig AT, Inampudi L, O'Donnell MA, et al. Two-surgeon versus single-surgeon radical cystectomy and urinary diversion: impact on patient outcomes and costs. Urology 2005;65:488–92.
[24] Gore JL, Saigal CS, Handley JM, Litwin MS. Variations in reconstruction after radical cystectomy. Cancer 2006;107:729–37.
[25] Nayak J, Holt S, Wright J, Dash A, Gore J. MP24-18 The impact of readmissions to secondary hospitals on failure-to-rescue rates following major urologic cancer surgery. J Urol 2015;193:e283–4.