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Trends in Radical Prostatectomy: Centralization, Robotics, and Access to Urologic Cancer Care

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Abstract

Background—Robotic surgery has been widely adopted for radical prostatectomy. We hypothesize that this change is rapidly shifting procedures away from hospitals that do not offer robotics and consequently increasing patient travel.

Methods—A population-based observational study of all prostatectomies for cancer in NY, NJ, and PA from 2000–2009 was performed using hospital discharge data. Hospital procedure volume was defined as the number of prostatectomies performed for cancer in a given year. Straight-line travel distance to treating hospital was calculated for each case. Hospitals were contacted to determine year of acquisition of first robot.

Results—From 2000–2009, the total number of prostatectomies performed annually increased substantially. The increase occurred almost entirely at the very high volume centers (≥106 prostatectomies/year). The number of hospitals performing prostatectomy fell 37% from 2000–2009. By 2009, the 9% (21/244) of hospitals that had very high volume performed 57% of all prostatectomies, and the 35% (86/244) of hospitals with a robot performed 85% of all prostatectomies. Median travel increased 54% from 2000–2009, p<0.001. The proportion of patients traveling ≥15 miles increased from 24% to 40%, p<0.001.

Conclusions—Over the past decade, the number of radical prostatectomies performed has risen substantially. These procedures have been increasingly centralized at high volume centers, leading to longer patient travel distances. Few prostatectomies are now performed at hospitals that do not offer robotic surgery. Future work should focus on the impact of these trends on cancer control, functional outcomes, access to care and cost.

In 2000, the Food and Drug Administration first approved a robotic surgery system for use for laparoscopic abdominal and pelvic procedures. Since then, robotic surgery has become increasingly widely adopted. According to the exclusive manufacturer, >1000 robots have been distributed in the US.[1] The first descriptions of robotic-assisted laparoscopic prostatectomy (RALP) were published in 2001.[2–4] Subsequent studies have detailed the safety and potential advantages of RALP, and preliminary data suggest that RALP has rapidly become the most common approach to prostatectomy.[5–11]

There has been a simultaneous trend toward centralization of complex cancer procedures at high volume centers.[12] In response to studies documenting an association between hospital procedure volume and clinical outcomes, many have advocated centralization of procedures, such as prostatectomy, at high volume centers.[13–24] Recent studies document that practice patterns for some oncologic procedures are changing in response to these findings.[12] This is particularly true for relatively uncommon cancers that require complex extirpative procedures, such as esophageal and pancreatic cancer. As these procedures have become centralized, the distances that patients travel for surgery have increased substantially.[25] The degree to which centralization has occurred for prostate cancer is unknown. While prostatectomy is a complex procedure, prostate cancer is far more common than esophageal or pancreatic cancer, so the extent and impact of centralization may be different.

This study evaluates how practice patterns have changed in the face of simultaneous trends toward increasing use of RALP and increasing centralization of cancer surgery. We hypothesize that over the past decade, prostatectomies have been centralized at higher volume centers that offer robotic surgery, resulting in a relevant increase in travel for patients seeking prostate cancer care.

Methods

A secondary data analysis was performed using inpatient discharge data from New Jersey (NJ), New York (NY), and Pennsylvania (PA). Each state mandates reporting of claims from all non-federal hospitals. Databay Resources (Warrendale, PA) acquires the de-identified data from individual state agencies (State of NJ Department of Health and Senior Services, State of NY Statewide Planning and Research Cooperative System, PA Healthcare Cost Containment Council) and produces a database suitable for secondary analysis. Available variables include demographic information, diagnosis codes (ICD-9), procedure codes (ICD-9), length of stay, disposition at discharge, and hospital charges. The study was exempted from full review and approved by the Institutional Review Boards of the University of North Carolina and Fox Chase Cancer Center.

Men ≥ 18 years of age undergoing radical prostatectomy in the study area from 2000–2009 were included. Patients residing in the study area who underwent surgery outside of the study area were not captured; however, patients residing outside the study area who had surgery in the study area (inward border crossers) were included. All admissions with an ICD-9 procedure code for radical prostatectomy (60.5) and a diagnosis code for prostate cancer (185) were captured. Since there are no ICD-9 procedure codes specific for RALP or laparoscopic prostatectomy, these procedures could not be differentiated from open prostatectomy.

Patients were geocoded to zip code centroid, which was available for every case, using a publicly available geocoding tool (Excel geocoding tool v2, Juice Analytics, Herndon, VA referencing Yahoo! Maps Web Services - Geocoding API, Yahoo, Sunnyvale, CA). Hospitals were geocoded to street address. Great-circle distance, a proven proxy for travel time, was calculated between cases and the hospitals where the procedures were performed [$d = \text{acos}(\sin(\text{lat1}).\sin(\text{lat2})+\cos(\text{lat1}).\cos(\text{lat2}).\cos(\text{long2}-\text{long1})).R$].[26–28] Inward border crossers were excluded from the distance analyses. The mean travel distance for this group (≈4% of total population) was >500 miles, and inclusion of this small, distinct group would have disproportionately influenced the results.

Hospital procedure volume was calculated for each year individually. Since standard volume cutpoints do not exist for prostatectomy, previously defined methodology for defining hospital volume categories was used.[25, 29] Five equal-sized groups of patients treated in 2000 were created based on procedure volume of the treating hospital. These quintiles were designated very low, low, medium, high, and very high volume. These baseline 2000 volume cutpoints were then applied to each subsequent year to determine changes in the distribution of patients amongst volume categories over time.

Hospitals in the study area that owned a robot in 2009 were identified through communication with the exclusive vendor (Intuitive Surgical, Inc., Sunnyvale, CA). To add depth to the analysis, each hospital was contacted directly to determine the year of acquisition of the first robot at the facility. This information was successfully obtained for every hospital identified by the vendor as owning a robot in 2009. Lowess smoothers, fit separately for hospitals that eventually obtained robots and those that did not, were used.[30] For hospitals that eventually obtained robots, time was measured as years from robot acquisition. Negative values indicate years before acquisition and positive values indicate years after acquisition. For hospitals that never obtained robots, time was set as time from 2005, the midpoint of the study period. Multiple linear regression of procedure volume was used for hypothesis testing of time trends. To account for the correlation of observations within hospitals over time, we estimated the models using Generalized Estimating Equations assuming an autoregressive (order 1) working correlation structure.[31] The model included covariates for years from baseline, whether the hospital ever acquired a robot, whether the hospital had a robot in a given year, and interactions between the robot variables and years from baseline. STATA version 10 (StataCorp, College Station, TX) was used to create Figure 2 and for all statistical analyses. For Figure 4, all hospitals with robots in 2010 as reported by the vendor were geocoded to zip code centroid and mapped.[32]

Results

108,112 prostatectomies met inclusion criteria. The total number of prostatectomies performed annually increased substantially from 8,115 in 2000 to 10,241 in 2009. Figure 1a. There was no significant change in the age or racial distribution of patients undergoing prostatectomy over time. All of the increase in prostatectomy volume occurred at high volume centers. The odds of surgery at a very high volume center increased more than six-fold (OR 6.04; 95% CI 5.74, 6.37) over the study period. Both the total number and proportion of cases performed at hospitals in lower volume categories declined over time. At any given time, there were 590–600 non-federal acute care hospitals operating in the study area. Of these, 462 performed ≥1 eligible case during the study period, but the annual number of hospitals performing prostatectomy steadily decreased from 390 in 2000 to 244 in 2009 (37% decrease). Figure 1b. In 2000, the majority (242/390; 62%) of hospitals performing prostatectomy were very low volume (1–15/yr) and accounted for only 19% (1,567/8,115) of prostatectomies in the study area. Meanwhile only 8 of the 390 hospitals (2%) met criteria as very high volume centers (≥106/yr), accounting for 20% (1,631/8,115) of procedures. By 2009, the majority (145/244; 59%) of hospitals performing prostatectomy remained very low volume (1–15/yr) but accounted for only 8% (845/10,241) of all procedures The number of very high volume centers (≥106/yr) had grown to 21 out of 244 (9%), and these centers now performed the majority (5,828/10,241; 57%) of prostatectomies in the study area.

Only one of the 462 hospitals that performed a prostatectomy during the study period had a robot at the start of 2000, but by 2009, 18.6% of these hospitals had acquired a robot. In 2009, 11.0% of very low volume centers (1–15/yr), 37.0% of low volume centers (16–29/yr), 59.1% of medium volume centers (30–53/yr), 89.7% of high volume centers (54–105/yr), and 100.0% of very high volume centers (≥106/yr) owned a robot. In total, 35.3% (86/244) of the hospitals performing prostatectomy had a robot in 2009, and these centers performed 84.6% (8,662/10,241) of prostatectomies in the study area.

The mean prostatectomy volume for hospitals that never obtained a robot was 10.2/yr (SD 14.9) in 2000. For these hospitals, the mean volume decreased by 0.7/yr annually over the study period (95%CI −0.8 to −;0.5). Figure 2. In contrast, the mean procedure volume for hospitals that eventually obtained a robot was 48.4/yr (SD 59.8) in 2000. Prior to robot acquisition, there was a trend toward gradually increasing procedure volume at hospitals that eventually acquired a robot: mean 1.3/yr annual increase (95%CI −0.8 to 3.4). During the year of robot acquisition, there was a ramping up phase with average hospital volume increasing by 8.5/yr (95%CI 3.9–13.0) above historical trends. After robot acquisition, volume increased even more rapidly: mean 12.4/yr increase (95%CI 5.4–19.4) continuing annually.

Median travel distance was proportional to hospital prostatectomy volume. Figure 3. This relationship persisted throughout the study period. As a result, median travel for prostatectomy increased 54% from 6.9 miles in 2000 to 10.6 miles in 2009. The proportion of patients traveling ≥15 miles increased from 24% in 2000 to 40% in 2009, $p<0.001$.

Discussion

Two major forces have altered patterns of care for prostate cancer surgery over the past decade. Since high surgical volumes have been associated with improved cancer control and lower rates of morbidity and mortality following radical prostatectomy, many have advocated centralization of prostatectomies at higher volume centers.[15–22, 24, 29] During the same time period, there has been rapid diffusion of RALP. First described about a decade ago, RALP has quickly emerged as the most common technique for radical prostatectomy.[33] Between 2003 and 2006–7, the use of RALP increased almost fivefold in the Medicare population (9.2% vs. 43% of all prostatectomies).[34] This study highlights how these changes are impacting prostate cancer care on the patient, hospital, and population level.

The number of radical prostatectomies performed annually has increased over the past decade and in particular over the past five years. Meanwhile, prostatectomies have been progressively centralized at high volume centers. Unlike other cancers for which centralization of extirpative procedures has occurred steadily over time, there was little centralization of prostatectomy evident until the publication of the first major studies advocating RALP. [25, 35–37] Beginning in 2004–2005, a rapid shift to higher volume centers ensued. Within 3 years, few prostatectomies were performed at centers without robotic surgery capabilities. The overall result has been sudden, population-wide, technology-driven centralization of procedures that is without precedent.

The interplay of these trends is supported by the fact that acquisition of a robot led to a rapid increase in the number of prostatectomies performed at a given hospital and that hospitals that did not acquire a robot performed fewer prostatectomies over time. Still, a few hospitals remain in the low volume categories for prostatectomy despite robot acquisition, suggesting that volume is a dynamic influenced by the complex interplay between hospitals and professional staff, where uptake of robotic techniques requires both hospital investment in technology and the presence of surgeons able to perform the procedures.

On a population-level, rapid centralization has been an unintended, but potentially beneficial, consequence of the introduction of robotics. Still, the full impact of the introduction and uptake of RALP on the triad of quality, cost, and access needs to be explored. Since publication of initial studies, RALP has been heavily marketed to patients, surgeons, and hospitals as an attractive alternative to traditional open prostatectomy with the promise of shorter hospitalization, faster recovery and minimal blood loss. However, observational studies have also suggested that patients may have higher rates of complications, such as incontinence and erectile dysfunction, following minimally invasive prostatectomies.[34, 38] One study found patients undergoing RALP had greater dissatisfaction and regret with their treatment decision compared to patients who underwent open prostatectomy, likely due to heightened expectations and subsequent disappointment with this “innovative” technology.[39] In addition, there is a steep learning curve for surgeons who had been trained to perform traditional open procedures.[40–41] The impact of the early end of this learning curve on population-level cancer control and functional outcomes is not known.

It is possible that the improvements in quality resultant from centralization could be offset, at least in part, by the higher complication rate associated with RALP, particularly early in the learning curve. The reported experience of surgeons at large referral centers supports the theory that outcomes improve with increased surgical experience.[15, 40–43] Ultimately, however, no studies to date demonstrate that RALP, even in experienced hands, leads to *improved* overall cancer control or functional outcomes compared to open prostatectomy.

The economic impact of the rapid diffusion of RALP also deserves consideration. The high upfront capital investment associated with robot acquisition ($1.2–1.7+ million), annual maintenance contracts ($150,000+/robot), and disposable instruments results in much greater direct costs compared to open prostatectomy.[44–46] Given diagnosis-based reimbursement in the U.S., most hospitals receive little or no additional payment to offset these added costs. Many hospitals have marketed robotic surgery heavily to patients, likely in an effort to recoup the fixed capital investment costs of robot acquisition and maintenance, which may be amortized over a given volume of cases. This revenue shift places an additional burden on the health care system in exchange for potential yet incalculable societal benefits of more rapid convalescence and centralized care.

Many investigators have attempted to quantify the additional costs of this technology. In an early study, Lotan et al. optimistically assumed a utilization rate of 300 cases/year (far in excess of our upper quintile) and estimated the cost of RALP to be ≈$2500 more per case than open prostatectomy ($857/case for the robot + $1705/case for disposable instruments).[46] Another analysis found the “break even” point for RALP versus open prostatectomy was between 10 and 15 cases/week, again well above hospital volumes in this study where only 2.9% of hospitals (7/244) performed >300 prostatectomies in 2009.[45] Another group of investigators estimated an increase of $2315 in median direct costs for RALP compared to open prostatectomy due to additional surgical supply and OR costs. After adding the additional fixed costs of the robot, the total additional cost burden of RALP increased to $4713/case assuming an average of 126 cases/year.[46] There is additional cost associated with the learning curve but this is difficult to quantify since the number of RALP each surgeon must complete to be competent varies widely.[41] Based on eight published series, one group estimated the average learning curve was 77 cases, resulting in $217,034 additional operating room and anesthesia costs.[47] Given that published studies have not demonstrated superior oncologic and functional outcomes for RALP over an open approach, many hospitals, insurers and federal agencies question both the comparative effectiveness and the cost effectiveness of this new technology.[38, 46, 48] Understanding the extent to which individual and societal benefits may offset the indisputable direct cost disadvantages of RALP requires additional study. With >1000 robotic surgical systems installed in the past decade in the U.S., the scale of these economic considerations is considerable.

The impact of RALP and centralization on geographic access to care for prostate cancer has not been previously examined. In this study, the distance patients traveled to reach the treating hospital increased > 50% over the study period. This is consistent with previous work demonstrating that informal centralization results in increased patient travel.[25] With market-driven centralization in the U.S., universal patient access is only a minor determinant of the geographic location of high volume centers. Consequently, the geographic distribution of high volume centers and robots is not necessarily optimized for patient travel and access to care. Figure 4. While the absolute increase in median straight-line travel distance was only 3.7 miles, it is important to remember that straight-line distance underestimates actual road mileage by 20–40%.[25, 28, 49] This increase in travel is particularly remarkable considering the study area is a densely populated region with extensive healthcare resources and relatively few rural counties. As a result, findings from this region likely underestimate the impact of centralization on patient travel burden nationwide.

Limitations

In previous studies, we have demonstrated that patterns of centralization occurring in this region are similar to those seen nationwide.[12, 25] Similarly, the uptake of robotics is not unique to this region, but is occurring nationally. Figure 4. Still, trends in this region may not completely represent practice patterns across the country. For example, <10% of our study population lived in rural counties, so this study may underestimate the impact of centralization on travel distance and overestimate the availability of prostate cancer care for patients from more rural areas of the country.

Another major limitation of hospital discharge data is the lack of detailed case information. For example, while we examine the influence of robot acquisition, we do not know the proportion of prostatectomies at a hospital with a robot that are actually performed robotically. Additional information about the hospitals (i.e. teaching status, ownership, etc.) and the patients (i.e. comorbidity, cancer staging, etc.) would greatly enhance our analysis but were not available. In particular, without information on tumor stage, Gleason score, PSA, and other factors used to risk stratify cancer patients, we were not able to determine if the disease severity of patients treated with prostatectomy changed over time.

Similarly, we were not able to examine how centralization, the introduction of robotics, and travel influenced the relative frequency with which surgery, active surveillance, and radiation therapy were used to treat localized disease. Prostate cancer differs from other cancers to the extent that surgical therapy is not the clear “gold standard,” but rather one among several equivalently appropriate treatment options. The vast majority of men diagnosed with prostate cancer in the U.S. during the study period had clinically localized disease.[50] For these men, surgery, radiation therapy and, in some cases, active surveillance are all considered acceptable treatment options.[51] The perception that RALP was associated with quicker recovery or fewer side effects may have led patients with indolent disease, who previously would have chosen active surveillance, to proceed with surgery. These behavioral economics issues are important and deserve attention in future studies.

Conclusions

Over the past decade, there has been widespread adoption of RALP and increasing centralization of prostate cancer surgery at high volume centers. These changes have had a major impact on patterns of care for prostate cancer. On a population-level, the number of radical prostatectomies performed has risen substantially, but the true impact on patient level outcomes is unknown. Future studies should focus on the impact of these trends on access to care and cost, in addition to cancer control and functional outcomes.

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References

1. [last upated: Accessed: May 25, 2010] Intuitive Surgical Frequently Asked Questions. http://www.intuitivesurgical.com/products/faq/index.aspx
2. Abbou, CC.; Hoznek, A.; Salomon, L.; Olsson, LE.; Lobontiu, A.; Saint, F., et al. Laparoscopic radical prostatectomy with a remote controlled robot; J Urol. 2001. p. 1964-6.Available from

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11371890

3. Pasticier, G.; Rietbergen, JB.; Guillonneau, B.; Fromont, G.; Menon, M.; Vallancien, G. Robotically assisted laparoscopic radical prostatectomy: feasibility study in men; Eur Urol. 2001. p. 70-4.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11528179
4. Rassweiler, J.; Frede, T.; Seemann, O.; Stock, C.; Sentker, L. Telesurgical laparoscopic radical prostatectomy. Initial experience; Eur Urol. 2001. p. 75-83.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11528180
5. Kawachi, MH. Counterpoint: robot-assisted laparoscopic prostatectomy: perhaps the surgical gold standard for prostate cancer care; J Natl Compr Canc Netw. 2007. p. 689-92.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17692172
6. Patel, VR.; Palmer, KJ.; Coughlin, G.; Samavedi, S. Robot-assisted laparoscopic radical prostatectomy: perioperative outcomes of 1500 cases; J Endourol. 2008. p. 2299-305.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18837657
7. Krambeck, AE.; DiMarco, DS.; Rangel, LJ.; Bergstralh, EJ.; Myers, RP.; Blute, ML., et al. Radical prostatectomy for prostatic adenocarcinoma: a matched comparison of open retropubic and robot-assisted techniques; BJU Int. 2009. p. 448-53.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18778350
8. Casey, JT.; Meeks, JJ.; Greco, KA.; Wu, SD.; Nadler, RB. Outcomes of locally advanced (T3 or greater) prostate cancer in men undergoing robot-assisted laparoscopic prostatectomy; J Endourol. 2009. p. 1519-22.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19694528
9. Barocas, DA.; Salem, S.; Kordan, Y.; Herrell, SD.; Chang, SS.; Clark, PE., et al. Robotic assisted laparoscopic prostatectomy versus radical retropubic prostatectomy for clinically localized prostate cancer: comparison of short-term biochemical recurrence-free survival; J Urol. 2010. p. 990-6.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=20083261
10. Finkelstein, J.; Eckersberger, E.; Sadri, H.; Taneja, SS.; Lepor, H.; Djavan, B. Open Versus Laparoscopic Versus Robot-Assisted Laparoscopic Prostatectomy: The European and US Experience; Rev Urol. 2010. p. 35-43.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=20428292
11. Wexner, SD.; Bergamaschi, R.; Lacy, A.; Udo, J.; Brolmann, H.; Kennedy, RH., et al. The current status of robotic pelvic surgery: results of a multinational interdisciplinary consensus conference; Surg Endosc. 2009. p. 438-43.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19037694
12. Stitzenberg KB, Meropol NJ. Trends in centralization of cancer surgery. Ann Surg Oncol. 2010
13. Barocas, DA.; Mitchell, R.; Chang, SS.; Cookson, MS. Impact of surgeon and hospital volume on outcomes of radical prostatectomy; Urol Oncol. 2010. p. 243-50.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19395287
14. Mitchell, RE.; Lee, BT.; Cookson, MS.; Barocas, DA.; Herrell, SD.; Clark, PE., et al. Immediate surgical outcomes for radical prostatectomy in the University HealthSystem Consortium Clinical Data Base: the impact of hospital case volume, hospital size and geographical region on 48,000 patients; BJUInt. 2009. p. 1442-5.Available from

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19681895

15. Eastham, JA. Do high-volume hospitals and surgeons provide better care in urologic oncology?; Urol Oncol. 2009. p. 417-21.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19573772
16. Wilt, TJ.; Shamliyan, TA.; Taylor, BC.; MacDonald, R.; Kane, RL. Association between hospital and surgeon radical prostatectomy volume and patient outcomes: a systematic review; J Urol. 2008. p. 820-8.discussion 28–9. Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18635233
17. Yao, SL.; Lu-Yao, G. Population-based study of relationships between hospital volume of prostatectomies, patient outcomes, and length of hospital stay; J Natl Cancer Inst. 1999. p. 1950-6.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10564679
18. Potosky, AL.; Warren, JL. Radical prostatectomy: does higher volume lead to better quality?; J Natl Cancer Inst. 1999. p. 1906-7.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10564667
19. Ellison, LM.; Heaney, JA.; Birkmeyer, JD. The effect of hospital volume on mortality and resource use after radical prostatectomy; J Urol. 2000. p. 867-9.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10687994
20. Joudi, FN.; Konety, BR. The volume/outcome relationship in urologic cancer surgery; Support Cancer Ther. 2004. p. 42-6.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18628157
21. Nuttall, M.; van der Meulen, J.; Phillips, N.; Sharpin, C.; Gillatt, D.; McIntosh, G., et al. A systematic review and critique of the literature relating hospital or surgeon volume to health outcomes for 3 urological cancer procedures; J Urol. 2004. p. 2145-52.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15538220
22. Ellison, LM.; Trock, BJ.; Poe, NR.; Partin, AW. The effect of hospital volume on cancer control after radical prostatectomy; J Urol. 2005. p. 2094-8.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15879850
23. Hollenbeck, BK.; Dunn, RL.; Miller, DC.; Daignault, S.; Taub, DA.; Wei, JT. Volume-based referral for cancer surgery: informing the debate; J Clin Oncol. 2007. p. 91-6.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17194909
24. Siu, W.; Daignault, S.; Miller, DC.; Dunn, RL.; Gilbert, S.; Weizer, AZ., et al. Understanding differences between high and low volume hospitals for radical prostatectomy; Urol Oncol. 2008. p. 260-5.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18452816
25. Stitzenberg, KB.; Sigurdson, ER.; Egleston, BL.; Starkey, RB.; Meropol, NJ. Centralization of cancer surgery: implications for patient access to optimal care; J Clin Oncol. 2009. p. 4671-8.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19720926
26. Phibbs, CS.; Luft, HS. Correlation of travel time on roads versus straight line distance; Med Care Res Rev. 1995. p. 532-42.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=10153313

27. McGuirk, MA.; Porell, FW. Spatial patterns of hospital utilization: the impact of distance and time; Inquiry. 1984. p. 84-95.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=6232220

28. Fortney J, Rost K, Warren J. Comparing alternative methods of measuring geographic access to health services. Health Services Research and Outcomes Methodology. 2000; 1(2):173–84.

29. Begg, CB.; Riedel, ER.; Bach, PB.; Kattan, MW.; Schrag, D.; Warren, JL., et al. Variations in morbidity after radical prostatectomy; N Engl J Med. 2002. p. 1138-44.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11948274

30. Cleveland WS. Robust locally weighted regression and smoothing scatterplots. J Am Stat Assoc. 1979; 74:829–36.

31. Shutts J, Ratcliffe SJ, Leonard M. Improved generalized estimating equation analysis via xtqls for quasi-least squares in STATA. STATA Journal. 2007; 7(2):147–66.

32. Intuitive Surgical Hospital & Surgeon Locator. [last upated: Accessed: July 6, 2010] http://www.intuitivesurgical.com/patientresources/hospitals_doctors/index.aspx

33. Box, GN.; Ahlering, TE. Robotic radical prostatectomy: long-term outcomes; Curr Opin Urol. 2008. p. 173-9.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18303539

34. Hu, JC.; Gu, X.; Lipsitz, SR.; Barry, MJ.; D'Amico, AV.; Weinberg, AC., et al. Comparative effectiveness of minimally invasive vs open radical prostatectomy; JAMA. 2009. p. 1557-64.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19826025

35. Menon, M.; Tewari, A.; Baize, B.; Guillonneau, B.; Vallancien, G. Prospective comparison of radical retropubic prostatectomy and robot-assisted anatomic prostatectomy: the Vattikuti Urology Institute experience; Urology. 2002. p. 864-8.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12429317

36. Menon, M.; Tewari, A.; Peabody, JO.; Shrivastava, A.; Kaul, S.; Bhandari, A., et al. Vattikuti Institute prostatectomy, a technique of robotic radical prostatectomy for management of localized carcinoma of the prostate: experience of over 1100 cases; Urol Clin North Am. 2004. p. 701-17.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15474597

37. Smith, JA, Jr. Robotically assisted laparoscopic prostatectomy: an assessment of its contemporary role in the surgical management of localized prostate cancer; Am J Surg. 2004. p. 63S-67S.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15476654

38. Ficarra, V.; Novara, G.; Artibani, W.; Cestari, A.; Galfano, A.; Graefen, M., et al. Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a systematic review and cumulative analysis of comparative studies; Eur Urol. 2009. p. 1037-63.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19185977

39. Schroeck, FR.; Krupski, TL.; Sun, L.; Albala, DM.; Price, MM.; Polascik, TJ., et al. Satisfaction and regret after open retropubic or robot-assisted laparoscopic radical prostatectomy; Eur Urol. 2008. p. 785-93.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18585849

40. Weizer, AZ.; Ye, Z.; Hollingsworth, JM.; Dunn, RL.; Shah, RB.; Wolf, JS., Jr, et al. Adoption of new technology and healthcare quality: surgical margins after robotic prostatectomy; Urology. 2007. p. 96-100.Available from

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17656216

41. Herrell, SD.; Smith, JA, Jr. Robotic-assisted laparoscopic prostatectomy: what is the learning curve?; Urology. 2005. p. 105-7.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16194715
42. Vickers, AJ.; Bianco, FJ.; Serio, AM.; Eastham, JA.; Schrag, D.; Klein, EA., et al. The surgical learning curve for prostate cancer control after radical prostatectomy; J Natl Cancer Inst. 2007. p. 1171-7.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17652279
43. Hollenbeck, BK.; Daignault, S.; Dunn, RL.; Gilbert, S.; Weizer, AZ.; Miller, DC. Getting under the hood of the volume-outcome relationship for radical cystectomy; J Urol. 2007. p. 2095-9.discussion 99. Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17509295
44. Bolenz, C.; Gupta, A.; Hotze, T.; Ho, R.; Cadeddu, JA.; Roehrborn, CG., et al. Cost comparison of robotic, laparoscopic, and open radical prostatectomy for prostate cancer; Eur Urol. 2010. p. 453-8.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19931979
45. Scales, CD., Jr; Jones, PJ.; Eisenstein, EL.; Preminger, GM.; Albala, DM. Local cost structures and the economics of robot assisted radical prostatectomy; J Urol. 2005. p. 2323-9.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16280833
46. Lotan, Y.; Cadeddu, JA.; Gettman, MT. The new economics of radical prostatectomy: cost comparison of open, laparoscopic and robot assisted techniques; J Urol. 2004. p. 1431-5.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15371862
47. Steinberg, PL.; Merguerian, PA.; Bihrle, W., 3rd; Seigne, JD. The cost of learning robotic-assisted prostatectomy; Urology. 2008. p. 1068-72.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18313121
48. Bhayani, SB.; Pavlovich, CP.; Hsu, TS.; Sullivan, W.; Su, LM. Prospective comparison of short-term convalescence: laparoscopic radical prostatectomy versus open radical retropubic prostatectomy; Urology. 2003. p. 612-6.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12639657
49. Williams, AP.; Schwartz, WB.; Newhouse, JP.; Bennett, BW. How many miles to the doctor?; N Engl J Med. 1983. p. 958-63.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=6621624
50. Jemal, A.; Siegel, R.; Ward, E.; Hao, Y.; Xu, J.; Thun, MJ. Cancer statistics, 2009; CA Cancer J Clin. 2009. p. 225-49.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19474385
51. Mohler, J.; Bahnson, RR.; Boston, B.; Busby, JE.; D'Amico, A.; Eastham, JA., et al. NCCN clinical practice guidelines in oncology: prostate cancer; J Natl Compr Canc Netw. 2010. p. 162-200.Available from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=20141676

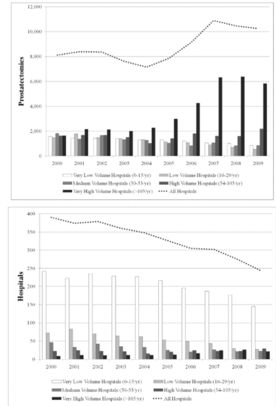

Figure 1.

Figure 1a. Total number of prostatectomies performed annually in NJ, NY, and PA, 2000–2009.

Figure 1b. Total number of hospitals performing prostatectomy each year in NJ, NY, and PA, 2000–2009. During this time period, there were roughly 590–600 acute care hospitals in the study area.

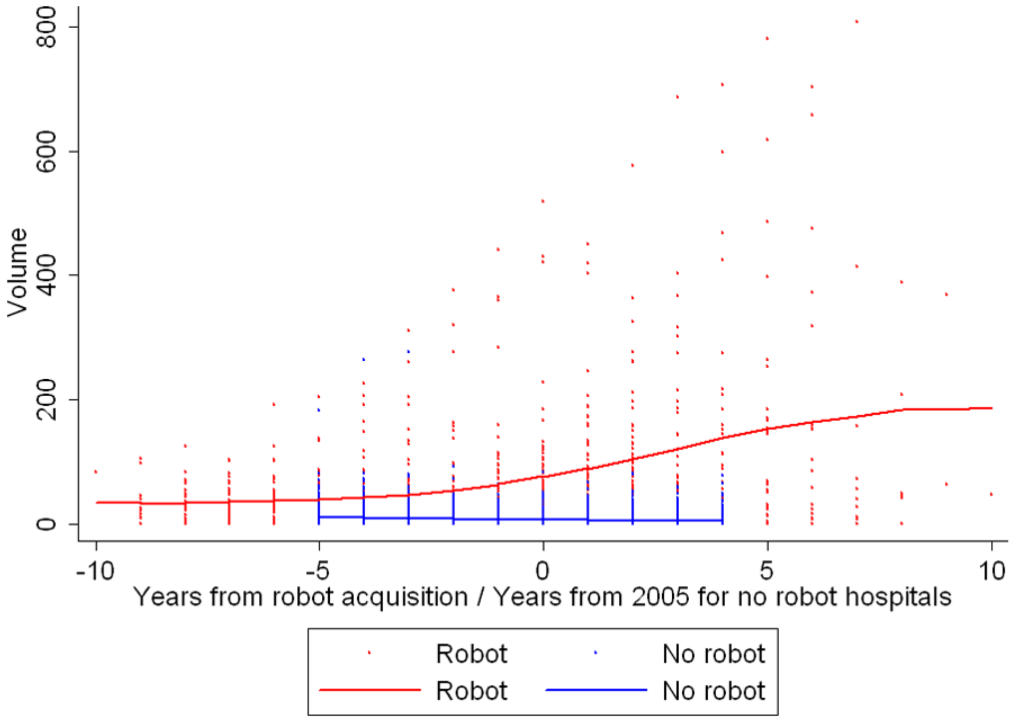

Figure 2.

Relationship between hospital prostatectomy volume and robot acquisition.

Each dot represents a single hospital in a single year. Hospitals that acquired a robot during the study period are red. Those that never obtained a robot are blue. For the hospitals that acquired a robot, year 0 is the year that the robot was acquired. For the hospitals that never acquired a robot, year 2005 (midway through the study period) was designated as year 0. The fitted curves show the trends in prostatectomy volume.

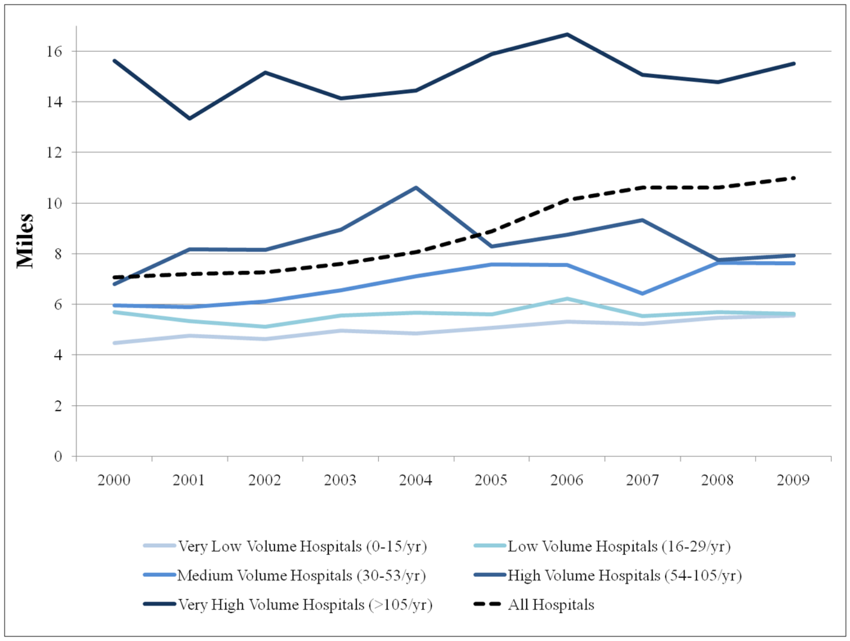

Figure 3.
Median distance traveled in miles from patient home to hospital where prostatectomy was performed.

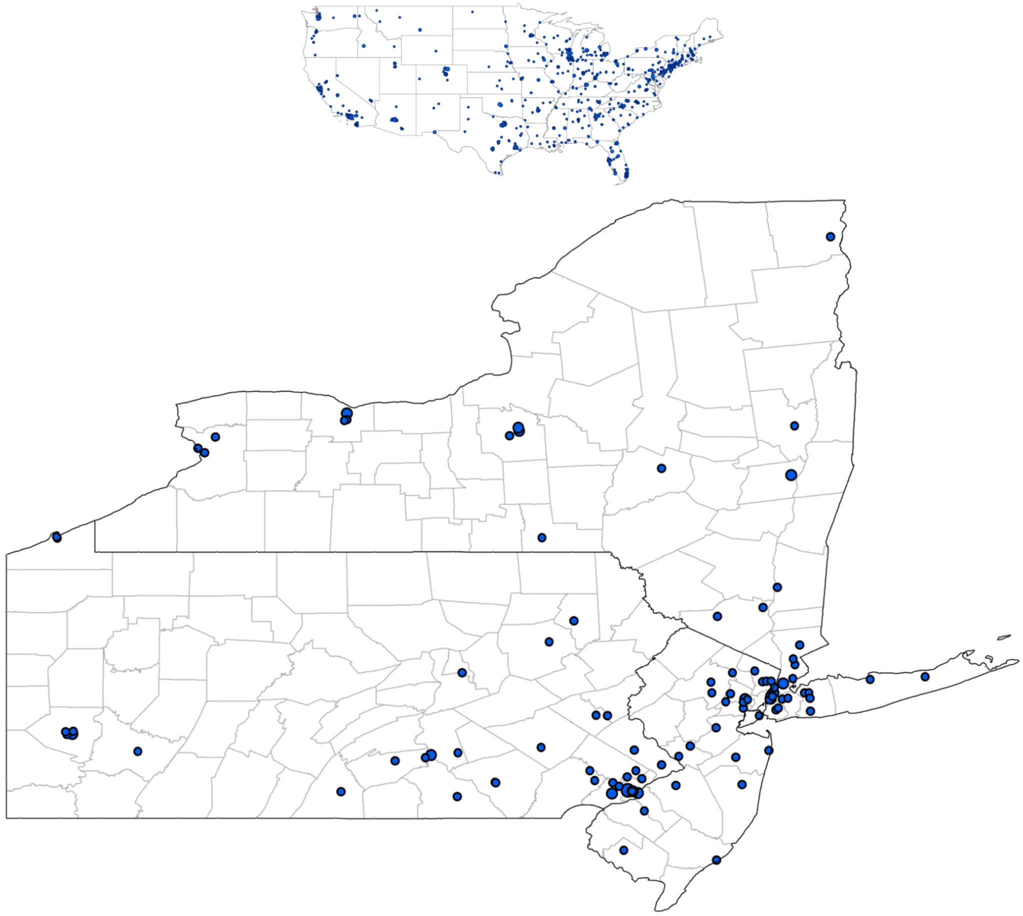

Figure 4.

Figure 4a. Geographic location, by zip code, of US hospitals with robots in 2010. (Not shown: There are two hospitals with robots in Alaska, both in the same zip code in Anchorage. There are two hospitals with robots in Hawaii, both in Honolulu but in different zip codes.)

Figure 4b. Geographic location, by zip code of hospitals with robots in NJ, NY, and PA in 2010.