**Impact of patient choice and hospital competition on patient outcomes following prostate cancer surgery: a national population-based study**

**Ajay Aggarwal MD PhD,1,2\* Arun Sujenthiran MD,3 Daniel Lewis PhD4, Kate Walker PhD,1,3 Paul Cathcart MD5 Noel Clarke MD PhD,6 Richard Sullivan MD PhD,7 Jan van der Meulen PhD1,3**

1. Department of Health Services Research & Policy, London School of Hygiene and Tropical Medicine, London, UK
2. Department of Clinical Oncology, Guy’s & St Thomas’ NHS Trust, London, UK
3. Clinical Effectiveness Unit, Royal College of Surgeons of England, London, UK
4. Department of Social and Environment Health Research, London School of Hygiene and Tropical Medicine, London, UK
5. Department of Urology, Guy’s & St Thomas’ NHS Trust, London, UK
6. Department of Urology, The Christie and Salford Royal NHS Foundation Trust, Manchester, UK
7. Institute of Cancer Policy, King’s College London, London, UK

**\*Correspondence**

Dr Ajay Aggarwal

Department of Health Services Research & Policy

London School of Hygiene and Tropical Medicine

15-17 Tavistock Place

London

WC1H 9SH

Email: [ajay.aggarwal@lshtm.ac.uk](mailto:ajay.aggarwal@lshtm.ac.uk) Tel: 02079272135

**Running Title:** Hospital competition and cancer outcomes

**Key Words:** Hospital competition, Patient choice, Healthcare markets, Cancer surgery, Patient outcomes, Quality improvement

**Text Pages:** 21

**References:** 37

**Tables: 4**

**Figure:** 1

**Appendices:** 3

**Funding:** AA was funded by a Doctoral Research Fellowship from the National Institute for Health Research <https://www.nihr.ac.uk/> . Grant Number: DRF-2014-07-064.

JvdM was partly supported by the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care North Thames at Bart’s Health NHS Trust.

**Author Contributions:** Conceptualization (AA, JvdM), data curation (AA, AS) formal analysis (AA, DL, AS, KW, JVdM), funding acquisition (AA), methodology (AA, DL, KW, JvdM), project administration (AA), supervision (JvdM, NC, RS, PC), writing - original draft (AA, JvdM), and writing - review and editing (All authors)

**Conflict of interest statement:** The authors declare no conflicts of interest

**Acknowledgements:** The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NHS National Institute for Health Research, or the Department of Health.

Hospital Episode Statistics were made available by the NHS Health and Social Care Information Centre (© 2012, Re-used with the permission of NHS Digital. All rights reserved.)

Data for this study is based on patient-level information collected by the NHS, as part of the care and support of cancer patients. The data is collated, maintained and quality assured by the National Cancer Registration and Analysis Service, which is part of Public Health England (PHE). Access to the data was facilitated by the Public Health England’s Office for Data Release.

AA, AS, NC, PC and JvdM are members of the Project Team of the National Prostate Cancer Audit ([www.npca.org.uk](http://www.npca.org.uk)) funded by the Healthcare Quality Improvement Partnership (<http://www.hqip.org.uk/>).

**ABSTRACT**

**Introduction**

Policies encouraging patient choice and hospital competition have been introduced across several countries with the aim of improving the quality of healthcare services. This national cohort study aimed to analyse the relationship between choice and competition on cancer surgery outcomes using prostate cancer as a case study.

**Methods**

We included all men who underwent prostate cancer surgery in England (UK) between 2008 and 2011 (*n*=12,925). Multi-level logistic regression was used to assess the effect of a radical prostatectomy centre being located in a “competitive environment” (based on number of centres within a threshold distance) and being a “successful competitor” (based on ability to attract patients from other hospitals) on three patient level outcomes: post-operative length of hospital stay > 3days, 30-day emergency readmissions, and 2-year urinary complications.

**Results**

With adjustment for patient characteristics, men who received surgery in centres located in a stronger competitive environment were less likely to have a 30-day emergency readmission, irrespective of type or volume of procedures performed at each centre (odds ratio 0.46, 95%CI 0.36-0.60, p=0.005). Men treated at centres that were successful competitors were less likely to have a length of stay >3 days (odds ratio 0.49, 95%CI 0.25-0.94, p=0.02).

**Conclusions**

Our results suggest for the first time that hospital competition improves short-term outcomes after prostate cancer surgery. Further evaluation of the potential role of patient choice and hospital competition is required to inform health service design in contrast to role of top-down driven approaches which have focused on centralisation of services.

**INTRODUCTION**

Policies encouraging patient choice and hospital competition have been introduced across several countries with the aim of improving the efficiency and quality of healthcare services 1-4. At the same time, specialist services are reconfigured into fewer, larger units guided by evidence that demonstrates improved outcomes of care for patients treated by hospitals that carry out a high volume of procedures 5,6.

In contrast to the impact of hospital volume, there has been no published study to date that has investigated the impact of hospital competition on outcomes of cancer treatment. In addition, it is unknown whether cancer centres that are more successful competitors (i.e. centres attracting patients from the local catchment areas of other hospitals) deliver better outcomes than centres that are less successful.

The English National Health Service (NHS) is an example of a publicly funded healthcare system covering the whole population in which patients are able to choose any hospital that best meet their needs. Care is free at the point of use and not based on ability to pay for insurance or treatment. With tariffs for services fixed nationally, hospitals are therefore encouraged to compete for “market share” on measures of quality rather than price and receive financial rewards accordingly as money follows the patients 7. This in turn is expected to drive improvements in quality.

A study of the outcomes of prostate cancer surgery in the English NHS therefore provides an ideal environment to investigate these associations with hospital competition. We have already demonstrated that patient choice and hospital competition are occurring for prostate cancer services in the English NHS. One in three men receiving a radical prostatectomy are prepared to bypass their nearest radical prostatectomy centre to receive surgery at another more distant hospital 8. It is likely that this mobility of substantial numbers of patients to centres other than their nearest, contributed to the large-scale investment in robotic surgical equipment in some prostate cancer surgery centres as they sought to attract new patients and retain their local patients. Some centres that lost patients to alternative centres, closed as they were no longer able to meet minimum surgical volume thresholds 9.

In this analysis, the first of its kind, we used national patient-level data on all men undergoing a radical prostatectomy in the English NHS between 2008 and 2011 to analyse if radical prostatectomy centres that are located in a “competitive environment” and those that are “successful competitors” have better patient-level outcomes, including post-operative length of stay, 30-day emergency readmissions, and 2-year urinary complications.

**METHODS**

Patient population

Hospital-level data was obtained on all patients diagnosed with prostate cancer who underwent a radical prostatectomy between 1st January 2008 and 31st December 2011 from the Hospital Episode statistics (HES) database linked at the patient-level to English cancer registry data.

The HES dataset was used to determine patient-level characteristics, including age, Royal College of Surgeons (RCS) Charlson comorbidity score 10, socioeconomic deprivation status 11, treating hospital, date of procedure, and radical prostatectomy type (i.e. robot-assisted, laparoscopic or open based on the UK Office for Population Census and Surveys Classification of Interventions and Procedures – 4th revision (OPCS4)). Reason for emergency re-admission following a radical prostatectomy was coded using the International Classification of Diseases, 10th revision (ICD-10). National cancer registry data was used as the data source for cancer stage, which was categorised according to a modified D’Amico classification system 12,13.

Hospital characteristics

Two hospital-level factors were considered in this analysis. The first was the hospitals’ “competitive environment” which is related to the geographical configuration of services and the demand for services by patients. The second is the extent to which hospitals are “successful competitors” derived from their ability to attract patients from other hospitals.

*Competitive environment*

For each surgical centre, we calculated a spatial competition index (SCI)9,14 based on both the number of eligible patients within a 60-minute drive by car and the number of alternative surgical centres within 60-minute drive for each eligible patient:

where surgical centre i has n eligible patients within a 60-minute drive and patient j in centre i has k alternative surgical centres within a 60-minute drive. Drive times were calculated using Geographic Information System (GIS) software and is considered the standard for this type of choice and competition analysis.

The SCI ranges theoretically from 0 for centres in a monopoly environment to a value close to 1 for centres in the most competitive environment. Centres were stratified into two more or less equally-sized groups according to whether or not they were located in areas with “high” or “low” levels of environmental competition. The date range 1st January 2008 and 31st December 2011 was used for this analysis as the number of prostate cancer surgical centres remained fixed during this time (n=65). From 2012 the number of operational centres decreased annually, which would subsequently have influenced the spatial competition index value and the analysis of competitive environment on outcomes.

*Successful competition*

Using established methods 8, we first estimated the drive times for patients in our cohort to each of the 65 radical prostatectomy (RP) centres operational in the NHS during the study period using GIS methods. For each RP centre, we identified the number of patients for whom that centre was nearest but who had their treatment elsewhere, termed “leavers”, and those patients for whom another RP centre was nearest but who had their surgery at that centre, termed “arrivers”. Prostate cancer surgical centres were subsequently stratified into three groups based on whether they were successful (having a statistically significantly higher number of arrivers than leavers) or unsuccessful competitors (having a statistically significantly higher number of leavers than arrivers) or third those centres that could not be included in either category. We used the conditional methods for testing a difference between two Poisson means to determine whether the differences between arrivers and leavers were statistically significant 15.

Patient outcomes

To date there remains a paucity of patient-level outcomes available at the national level which accurately reflect the quality of cancer treatment delivered at individual centres. For prostate cancer, given the relatively good prognosis of localised disease, measures of survival are not considered a sensitive indicator of quality given the length of time needed (up to 10 years) before differences may become manifest. In this study we used three patient-level measures derived from the National Prostate Cancer Audit, which is collecting data on the processes and outcomes of all men diagnosed with prostate cancer in England (www.npca.org.uk). These remain the most relevant patient-level outcome measures of treatment quality and efficiency that are available during the study time period for all patients treated in the English NHS.

*Severe urinary complications*

We have previously developed and validated a tool to identify urinary complications (e.g. stricture, bleeding and incontinence) severe enough to require an intervention within 2 years of a radical prostatectomy using OPCS-4 procedure codes within HES readmission records 16. All men included in the study were assessed for the occurrence of urinary complications within 2 years after their radical prostatectomy.

*30-day emergency readmissions*

HES records were analysed to identify men readmitted as an emergency at any NHS hospital within 30 days of the date of discharge following a radical prostatectomy. Readmission rates have been used extensively as an outcome indicator for acute and elective surgical admissions 17-20. In this analysis, we also used the ICD-10 codes available within HES to carry out an additional analysis of the *primary reason* for emergency hospital admission.

*Length of stay*

HES records were analysed to identify the duration of inpatient stay following a radical prostatectomy. We identified each man who was in hospital more than 3 days from the date of surgery. This outcome indicator is being used as a performance measure in the National Prostate Cancer Audit for England and Wales 21 to assess the quality and efficiency of surgical care.

Statistical analysis

Multi-level logistic regression modelling with a random intercept was used to assess the effect of being located in a competitive environment and being a successful competitor on the three patient outcome indicators with adjustment for the patient-level variables (age, comorbidity status, socioeconomic status, and year of treatment). In this [statistical model](https://en.wikipedia.org/wiki/Statistical_model), outcomes vary at the level of both the hospital and the patients . Further exploratory analyses were undertaken to assess whether adjustment for radical prostatectomy type affected the results. All statistical analyses were undertaken in Stata version 14.

**RESULTS**

*Patient population*

We identified 14,044 men who underwent radical prostatectomy between 1st Jan 2008 and 31st December 2011 (4 years) in the English NHS (**Figure 1**). 840 men were excluded because they had an additional diagnosis of bladder cancer which, would affect our assessment of the occurrence of urinary complications following a radical prostatectomy. A further 279 patients were excluded as they could not be assigned to an NHS hospital recognised as a radical prostatectomy centre. The final study cohort comprised 12,925 men and patient characteristics are presented in **Table 1**.

*Length of stay >3 days*

35.4% of all patients in the study were admitted for longer than three days from the date of surgery. The proportion varied between centres from 3.2% to 86.4%.

*30-day emergency readmissions*

5.4% of all patients in the study were re-admitted as an emergency within 30 days of the discharge date. The proportion of 30-day emergency readmissions varied between hospitals from 0% to 18.3%. **Table 2** lists the 20 most frequent causes of emergency readmission based on ICD-10 diagnostic codes, which accounted for approximately 75% of all emergency admissions. Nearly all are directly related to a complication related to the radical prostatectomy.

*Severe urinary complications*

16.0% of all patients in the study developed at least one severe urinary complication within 2 years of their radical prostatectomy. The proportion of patients experiencing a urinary complication varied between hospitals from 3.3% to 45.1%.

Competitive environment

**Table 3** presents the results of the multi-level regression model as both unadjusted and adjusted odds ratios for the impact of a hospital being located in a competitive environment on patient outcomes. With adjustment for patient characteristics, men who received a radical prostatectomy in centres located in areas with a stronger competitive environment were less likely to be readmitted as an emergency within 30-days of surgery compared to men receiving care at centres located in areas with a weaker competitive environment (odds ratio 0.46 (95% CI 0.36-0.60, p=0.005)) irrespective of the type or volume of procedures performed at each centre. The strength of the competitive environment did not have a significant impact on length of stay or the risk of developing a severe urinary complication.

Successful competition

19 radical prostatectomy centres were identified as being a successful competitor and 33 as a being an unsuccessful competitor based on the difference between arrivers and leavers (see Methods). For 13 centres, the difference between arrivers and leavers was not statistically significant and these were excluded from the analysis. **Table 4** presents the results of the

multi-level regression model. With adjustment for patient characteristics, men treated at centres that were successful competitors were less likely to have a prolonged length of stay compared to centres that were unsuccessful competitors (odds ratio 0.49 (95% CI 0.25-0.94, p=0.02)). With respect to our other two outcome indicators, being a successful competitor or not did not have an impact on the 30-day emergency readmission rate or the risk of developing a severe urinary complication.

*Further exploratory analyses*

Additional multivariable regression analyses were performed to assess whether further adjustment for radical prostatectomy type and procedure volume affected the results.

With respect to volume, we were able to determine the total number of procedures performed by each prostate cancer surgical centre (n=65) during the four-year study period. This ranged from 13 procedures a year to 154 procedures a year. Hospitals were stratified into two groups based on the distribution of the number of procedures performed across all centres nationally and volume thresholds used in the empirical literature to define a high volume centre for prostate cancer surgery.22 In this analysis, centres performing greater than 50 procedures a year were defined as “high volume” (n=22 centres).

The inclusion of hospital volume weakened the association between a successful competitor and length of stay, which was no longer statistically significant (odds ratio 0.63 (95% CI 0.30-1.34, p=0.08). The inclusion of annual procedure volume did not have any appreciable impact on any of the other associations for being a successful competitor or being located in a competitive environment (Appendix 1 and Appendix 2). These results are in line with a secondary analysis (Appendix 3) that demonstrated that there was no statistically significant difference in mean procedure volume for centres located in a stronger (50 procedures per year) or weaker competitive environment (48 procedures per year). However, the mean volume of procedures undertaken was significantly higher in successful competitors (73 procedures per year) versus unsuccessful competitors (43 procedures per year).

We found that the inclusion of procedure type (e.g. open, laparoscopic or robotic-assisted radical prostatectomy) weakened the association between being a successful or unsuccessful competitor and length of stay, which was no longer statistically significant (odds ratio 0.82 (95% CI 0.48-1.38, p= 0.13)). The addition of procedure type had no appreciable impact on any of the other associations for being a successful competitor or being located in a competitive environment (Appendix 1 and Appendix 2).

**DISCUSSION**

This is the first study to explore the relationship between patient choice and hospital competition on outcomes following surgical cancer treatment. Our analysis demonstrates that men who had a radical prostatectomy in a hospital located in a region with a high concentration of other radical prostatectomy centres (thus creating an environment with strong competition between hospitals) were less likely to be re-admitted within 30 days following a radical prostatectomy irrespective of the type of procedure (e.g open, laparoscopic or robot-assisted radical prostatectomy). In addition, men treated at successful competitors (centres that attracted more patients from elsewhere) were less likely to have a prolonged length of stay compared to those treated at centres that were unsuccessful competitors.

It is not clear what the drivers for improved quality are for centres located in the most competitive areas, where there is a higher concentration of alternative hospitals from which patients can choose to have elective treatment. Studies demonstrating similar associations 23-25 have suggested that the reduction in length of stay may be a consequence of hospitals’ responses to the threat of losing patients to alternative centres 7. As a result, they seek to retain and attract new patients, to prevent the loss of income from patients travelling elsewhere for care (given money follows the patient in the NHS) and preserve their reputation 23,26,27. We have previously demonstrated that men are responsive to perceived differences in the quality of prostate cancer surgery and are prepared to “bypass” their nearest surgical centre 8. This movement of patients is more marked in more competitive areas 9, in keeping with the greater choice of available centres within 60 minutes drive time and therefore competition for local patients may have acted as a quality improvement driver.

One consideration is that centres located in competitive environments achieve better outcomes as they are also higher volume centres. However, our analysis in Appendix 3, demonstrates that no appreciable difference in mean procedure volume is demonstrated between centres in a strongly competitive or weaker competitive environment. Both high and low volume centres exist which is compatible with the notion of having a competitive environment where centres gain and lose patients.

A further hypothesis, based on findings from a study by Bloom et al 2015, is that hospitals located in areas with a stronger competitive environment have enhanced system and management practices, which may have an impact on improving quality across disease domains 28. As a result, our findings may not be limited to prostate cancer surgery alone and further evaluation is required to see the impact of hospital competition in other tumour types 29,30.

The association between being a “successful competitor” and a reduction in length of stay is likely to be explained by two main factors. First these centres were more likely to be higher volume centres compared with unsuccessful competitors (Appendix 3). Second, successful competitors had more rapidly adopted robot-assisted radical prostatectomy during the time-period of analysis9. This explains why the addition of mean annual procedure volume and prostatectomy type separately in the regression model weakened the association between being a successful competitor and length of stay. This is in line with the existing evidence that robotic-assisted prostatectomy and procedure volume are associated with reduced lengths of stay 31,32 33.

Both radical prostatectomy procedure type and procedure volume were not included in the original regression model, as both these factors are potentially in the causal pathway explaining why hospitals classified as more successful competitors may demonstrate superior patient-level outcomes. Furthermore, there is a long-standing debate as to the direction of effect with respect to the volume outcome relationship 34. Do larger centres have better outcomes because they treat a greater volume of patients and gain more experience and expertise in the delivery of a particular intervention or are centres with better outcomes larger because of selective referral patterns. In this health care context, there is evidence to suggest that patients were preferentially attracted to centres that were early adopters of robotic surgery (in the absence of publicly reported outcomes) who in turn were more likely to be classified as “successful competitors” 8,9 It remains unknown whether the integration of robotics or the larger volume of the centre is the major contributing factor to reduced length of stay.

In addition, the more rapid adoption of robotic-assisted prostatectomy procedure in itself by successful competitors could be considered as an argument in support of competition given that it may have facilitated clinical integration of an innovative surgical technique associated with better outcomes 9.

Policy Implications

Our study highlights that enhancing hospital competition may stimulate improvements in cancer treatment quality. To date the evidence internationally has been both limited and mixed with respect to understanding the direction of the associations between competition and patient outcomes for medical and surgical care 35.

Given the evidence that choice and competition is occurring, the provision of objective and accurate indicators of treatment quality (where possible) is critical in order to guide patient choice towards providers that provide a better quality of care. In the absence of these indicators, patients are reliant on informal and potentially untrustworthy proxy measures for quality 36, such as a hospital’s reputation, which do influence patient mobility but may not necessarily translate to improvements in outcome 8. By publishing at the hospital level process indicators (for which we have evidence that they are linked to better outcome) or outcome indicators, prostate cancer patients will have more relevant information to inform their choices. This, in turn could provide the necessary incentives for hospitals to demonstrate improved quality to attract new and retain local patients.

In the UK, public reporting of cancer outcomes has recently commenced. For example, the National Prostate Cancer Audit published in 2017 risk-adjusted outcomes following prostate cancer surgery with the plan to publish patient-reported outcome measures at the individual hospital level 21.

Our study adds to the long-standing debate around the optimum design of health systems to improve quality. The policy focus regarding the organisation of cancer services continues to be based on the premise that the eradication of low-volume surgical units through centralisation will deliver improvements in outcome as patients are re-directed towards higher-volume centres 37. However, this potentially limits the role of hospital competition as a driver of quality improvement by reducing the availability of hospitals from which patients can choose.

As well as the impact on outcomes, one also needs to consider how patient choice and provider competition will impact on equity in access to surgery and the efficiency of delivering healthcare services. For example, closures of units that are found to be unsuccessful competitors may require some patients to travel further to receive care which may have an impact on access to cancer surgery for patients that are less able to travel for treatment due to physical or financial constraints 8,36. At the same time, competition, in the absence of publically available information on the quality of surgery, can create perverse incentives for hospitals to invest in unproven technology in order to attract patients and to prevent closures, potentially escalating the cost of treatment without improving care quality 9.

Conversely, competition may create inefficiencies as unsuccessful competitors will lose patients to other centres and not utilise their available surgical capacity 9. In this respect, closures of surgical units may optimise the use of available specialist services, especially if the remaining centres have sufficient capacity. A key question, which is rarely been addressed explicitly is thus whether *patients* should decide which centres should close through the choices they make as a “bottom-up” driver of service reconfiguration or whether these decisions are better made by *policymakers and healthcare insurers* through “top-down” policies.

Going forward, current policy directives designed to reconfigure services need to be subject to rigorous evaluation. By using a robust empirical approach and the rich national patient-level datasets that are currently available, we have demonstrated how aspects of the impact that competition has on the organisation and delivery of prostate cancer services can be analysed. This type of analysis, can be broadened so that it can consider a wider range of tumour types and interventions.

Limitations

There are a number of study limitations. Our analysis only considers three outcome measures related to radical prostatectomy. The effect of choice and competition on a number of key outcomes, such as urinary continence and sexual function, remains unknown due to the lack of data available at national level. In addition, we were not able to adjust for cancer stage due to incomplete staging data. Our findings are also likely to be underpowered statistically due to the use of a hierarchical model, which provided an analysis effectively comparing 65 hospitals. Therefore, small differences in outcome may not be manifest as statistically significant results.

**CONCLUSIONS**

This is the first national level study to assess the impact of patient choice and hospital competition on the outcomes of cancer surgery. Using prostate cancer surgery as a case study, we observed that there is evidence that competition improves short-term outcomes. Men treated in hospitals located in a more competitive environment were less likely to be readmitted as an emergency within 30 days of discharge and men treated at centres that are successful competitors were less likely to have prolonged lengths of stay. Further evaluation of the role of competition on patient outcomes is required using a wider set of outcome measures across other cancer types. This will help to inform the design of health services which to date has focussed predominantly on centralisation of services.

**REFERENCES**

1. Vrangbaek K, Ostergren K, Birk HO, Winblad U. Patient reactions to hospital choice in Norway, Denmark, and Sweden. *Health Economics, Policy and Law.* 2007;2(2):125-152.

2. Balia S, Brau R, Marrocu E. What drives patient mobility across Italian regions? Evidence from hospital discharge data. *Developments in health economics and public policy.* 2014;12:133-154.

3. Siciliani L, Chalkley M, Gravelle H. Policies towards hospital and GP competition in five European countries. *Health Policy.* 2017;121(2):103-110.

4. Pope DG. Reacting to rankings: Evidence from "America's Best Hospitals". *Journal of Health Economics.* 2009;28(6):1154-1165.

5. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *New England Journal of Medicine.* 2002;346(15):1128-1137.

6. Gruen RL, Pitt V, Green S, Parkhill A, Campbell D, Jolley D. The effect of provider case volume on cancer mortality: systematic review and meta-analysis. *CA: a cancer journal for clinicians.* 2009;59(3):192-211.

7. Le Grand J. *The other invisible hand: Delivering public services through choice and competition.* Princeton University Press; 2009.

8. Aggarwal A, Lewis D, Charman SC, et al. Determinants of patient mobility for prostate cancer surgery: a population-based study of choice and competition. *European urology.* 2018;73(6):822-825.

9. Aggarwal A, Lewis D, Mason M, Purushotham A, Sullivan R, van der Meulen J. Effect of patient choice and hospital competition on service configuration and technology adoption within cancer surgery: a national, population-based study. *The Lancet Oncology.* 2017;18(11):1445-1453.

10. Armitage JN, van der Meulen JH, Royal College of Surgeons Co-morbidity Consensus G. Identifying co-morbidity in surgical patients using administrative data with the Royal College of Surgeons Charlson Score. *The British journal of surgery.* 2010;97(5):772-781.

11. Department of Communities and Local Government. The English Indices of Deprivation 2010. In:2011.

12. D'Amico AV, Whittington R, Malkowicz SB, et al. Biochemical outcome after radical prostatectomy, external beam radiation therapy, or interstitial radiation therapy for clinically localized prostate cancer. *Jama.* 1998;280(11):969-974.

13. Royal College of Surgeons of England. National Prostate Cancer Audit - First Year Annual Report - Organisation of Services and Analysis of Existing Clinical Data. 2014.

14. Gravelle H, Santos R, Siciliani L, Goudie R. *Hospital quality competition under fixed prices.* The University of York;2012.

15. Rothman KJ, Greenland S, Lash TL. *Modern epidemiology.* Lippincott Williams & Wilkins; 2008.

16. Sujenthiran A, Charman SC, Parry M, et al. Quantifying severe urinary complications after radical prostatectomy: the development and validation of a surgical performance indicator using hospital administrative data. *BJU international.* 2017;120(2):219-225.

17. Fischer C, Lingsma HF, Marang-van de Mheen PJ, Kringos DS, Klazinga NS, Steyerberg EW. Is the Readmission Rate a Valid Quality Indicator? A Review of the Evidence. *PloS one.* 2014;9(11):e112282.

18. Wick EC, Shore AD, Hirose K, et al. Readmission rates and cost following colorectal surgery. *Diseases of the colon and rectum.* 2011;54(12):1475-1479.

19. Gandaglia G, Sammon JD, Chang SL, et al. Comparative Effectiveness of Robot-Assisted and Open Radical Prostatectomy in the Postdissemination Era. *Journal of Clinical Oncology.* 2014;32(14):1419-1426.

20. Jacobs BL, Zhang Y, Tan HJ, Ye Z, Skolarus TA, Hollenbeck BK. Hospitalization trends after prostate and bladder surgery: implications of potential payment reforms. *J Urol.* 2013;189(1):59-65.

21. Royal College of Surgeons of England. National Prostate Cancer Audit - Third Year Annual Report - Results of the NPCA Prospective Audit and Patient Survey. 2016.

22. Trinh QD, Bjartell A, Freedland SJ, et al. A systematic review of the volume-outcome relationship for radical prostatectomy. *Eur Urol.* 2013;64(5):786-798.

23. Chou S-Y, Deily ME, Li S, Lu Y. Competition and the impact of online hospital report cards. *Journal of health economics.* 2014;34:42-58.

24. Cooper Z, Gibbons S, Jones S, McGuire A. Does Hospital Competition Save Lives? Evidence from the English NHS Patient Choice Reforms. *Economic journal (London, England).* 2011;121(554):F228-f260.

25. Diller G-P, Kempny A, Piorkowski A, et al. Choice and Competition Between Adult Congenital Heart Disease Centers Evidence of Considerable Geographical Disparities and Association With Clinical or Academic Results. *Circulation: Cardiovascular Quality and Outcomes.* 2014;7(2):285-291.

26. Cutler DM, Huckman RS, Landrum MB. The Role of Information in Medical Markets: An Analysis of Publicly Reported Outcomes in Cardiac Surgery. *American Economic Review.* 2004;94(2):342-346.

27. Hibbard JH, Stockard J, Tusler M. Hospital performance reports: impact on quality, market share, and reputation. *Health Affairs.* 2005;24(4):1150-1160.

28. Bloom N, Propper C, Seiler S, Van Reenen J. The Impact of Competition on Management Quality: Evidence from Public Hospitals. *The Review of Economic Studies.* 2015;82:457-489.

29. Royal College of Surgeons of England. *National Bowel Cancer Audit - Annual report 2016.* 2016.

30. Royal College of Surgeons of England. *National Oesophago-Gastric Cancer Audit.* 2016.

31. Kelly M, Sharp L, Dwane F, Kelleher T, Drummond FJ, Comber H. Factors predicting hospital length-of-stay after radical prostatectomy: a population-based study. *BMC Health Services Research.* 2013;13:244-244.

32. Barocas DA, Mitchell R, Chang SS, Cookson MS. Impact of surgeon and hospital volume on outcomes of radical prostatectomy. *Urol Oncol.* 2010;28(3):243-250.

33. 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. *Reviews in Urology.* 2010;12(1):35-43.

34. Luft HS, Hunt SS, Maerki SC. The volume-outcome relationship: practice-makes-perfect or selective-referral patterns? *Health Serv Res.* 1987;22(2):157-182.

35. Bevan G, Skellern M. Does competition between hospitals improve clinical quality? A review of evidence from two eras of competition in the English NHS. *BMJ.* 2011;343:1-7.

36. Aggarwal A, Lewis D, Mason M, Sullivan R, van der Meulen J. Patient Mobility for Elective Secondary Health Care Services in Response to Patient Choice Policies: A Systematic Review. *Medical Care Research and Review.* 2016;74(4):379-403.

37. Urbach DR. Pledging to Eliminate Low-Volume Surgery. *New England Journal of Medicine.* 2015;373(15):1388-1390.

|  |  |  |
| --- | --- | --- |
| **Table 1.** Characteristics of 12,925 men undergoing radical prostatectomy between 2008 and 2011 in the English National Health Service. | | |
|  | **Number** | **%** |
|
|  |  |  |
| **Year** |  |  |
| 2008 | 1902 | 14.7 |
| 2009 | 3427 | 26.5 |
| 2010 | 3637 | 28.1 |
| 2011 | 3959 | 30.6 |
|  |  |  |
| **Age (years)** |  |  |
| <50 | 489 | 3.8 |
| 50-59 | 3478 | 26.9 |
| 60-64 | 3826 | 29.6 |
| 65-69 | 3772 | 29.2 |
| ≥70 | 1360 | 10.5 |
|  |  |  |
| **Cancer severity** |  |  |
| Advanced | 64 | 0.9 |
| Locally advanced | 3149 | 43.9 |
| Intermediate localised | 3514 | 49 |
| Low-risk localised | 445 | 6.2 |
| Insufficient staging information (n=5753) |  |  |
|  |  |  |
| **Number of comorbidities** |  |  |
| 0 | 10,838 | 83.9 |
| ≥1 | 2087 | 16.1 |
|  |  |  |
| **Index of Multiple Deprivation** |  |  |
| **(national quintiles)** |
| 1 (least deprived) | 3273 | 25.3 |
| 2 | 3159 | 24.4 |
| 3 | 2674 | 20.7 |
| 4 | 2189 | 16.9 |
| 5 (most deprived) | 1630 | 12.6 |
|  |  |  |
| **Procedure Type** |  |  |
| Open | 5510 | 42.6 |
| Laparoscopic | 4138 | 32 |
| Robotic | 3277 | 25.4 |
|  |  |  |
|  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 2.** 20 most frequent causes for 30-day emergency readmissions following discharge after a radical prostatectomy using ICD-10 diagnostic codes. | | | |
| **Reason for Admission** | **Frequency** | **(%) of all readmissions** | **Cumulative frequency (%)** |
| **Fitting and adjustment of urinary device** | 102 | 14.6 | 14.6 |
| **Mechanical complication of urinary (indwelling) catheter** | 94 | 13.5 | 28.1 |
| **Urinary tract infection, site not specified** | 54 | 7.8 | 35.9 |
| **Infection following a procedure, not elsewhere classified** | 40 | 5.7 | 41.6 |
| **Urinary retention** | 39 | 5.6 | 47.2 |
| **Unspecified haematuria** | 31 | 4.5 | 51.7 |
| **Haemorrhage and haematoma complicating a procedure** | 22 | 3.2 | 54.8 |
| **Constipation** | 16 | 2.3 | 57.1 |
| **Disruption of operation wound, not elsewhere classified** | 15 | 2.2 | 59.3 |
| **Other complications of procedures, not elsewhere classified** | 13 | 1.9 | 61.1 |
| **Other genitourinary complications prosthetic devices, implants & grafts** | 12 | 1.7 | 62.8 |
| **Other specified soft tissue disorders** | 11 | 1.6 | 64.4 |
| **Pain localized to other parts of lower abdomen** | 11 | 1.6 | 66 |
| **Other and unspecified abdominal pain** | 10 | 1.4 | 67.4 |
| **Pulmonary embolism without mention of acute cor pulmonale** | 9 | 1.3 | 68.7 |
| **Other specified disorders of bladder** | 9 | 1.3 | 70 |
| **Orchitis epididymitis and epididymo-orchitis without abscess** | 9 | 1.3 | 71.3 |
| **Other specified disorders of male genital organs** | 9 | 1.3 | 72.6 |
| **Other postprocedural disorders of the genitourinary system** | 8 | 1.2 | 73.7 |
| **Pelvic and perineal pain** | 6 | 0.9 | 74.6 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 3.** Results of a multi-level model exploring the impact of hospital competition (measured with the spatial competition index) on urinary complications, 30-day emergency readmissions and length of stay following a radical prostatectomy | | | | | |
|  | **COMPETITIVE ENVIRONMENT** | |  |  |  |
| **Outcome** | **Weakest Competition**  **6439 men**  **33 centres** | **Strongest Competition**  **6486 men**  **32 centres** | **Unadjusted odds ratio**  **(95% CIs)** | **Adjusted odds ratio1**  **(95% CIs)** | **P value** |
| **Severe urinary complication** | 1114 (17.3%) | 959 (14.8%) | 0.86 (0.67-1.12) | 0.85 (0.66-1.10) | 0.21 |
| **30-day readmissions** | 475 (7.4%) | 220 (3.4%) | 0.44 (0.29-0.67) | 0.44 (0.29-0.67) | 0.0002 |
| **Length of stay >3 days** | 2449 (38.0%) | 2132 (32.9%) | 0.77 (0.43-1.37) | 0.75 (0.42-1.33) | 0.32 |
|  |  |  |  |  |  |

**Notes**

1. Adjusted odds ratio for the impact of competition on each outcome measure includes the effect of age, comorbidity, socioeconomic status and year of treatment in the multivariate regression analysis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4.** Results of a multi-level model exploring the impact of patient choice on urinary complications, 30-day emergency readmissions and length of stay following a radical prostatectomy | | | | | |
|  | **SUCCESSFUL COMPETITION1** | |  |  |  |
| **Outcome** | **Centres losing patients**  **5101 men**  **33 centres** | **Centres gaining patients**  **5553 men**  **19 centres** | **Unadjusted odds ratio**  **(95% CIs)** | **Adjusted odds ratio2**  **(95% CIs)** | **P value** |
| **Severe urinary complication** | 1866 (17.0%) | 749 (13.5 %) | 0.86 (0.64-1.15) | 0.89 (0.67-1.19) | 0.18 |
| **30-day readmissions** | 271 (5.3%) | 287 (5.2%) | 1.19 (0.70-2.01) | 1.21 (0.71-2.05) | 0.69 |
| **Length of Stay >3 days** | 2020 (39.6%) | 1375 (24.8%) | 0.48 (0.25-0.90) | 0.49 (0.25-0.94) | 0.02 |
|  |  |  |  |  |  |

**Notes**

1. See Methods for definitions

Adjusted odds ratio for the impact of patient choice on each outcome measure includes the effect of age, comorbidity, socioeconomic status and year of treatment in the multivariate regression analysis.

**Appendix 1 - Results of a multi-level model exploring the impact of hospital competition (measured with the spatial competition index) on urinary complications, 30-day emergency readmissions and length of stay following a radical prostatectomy**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **COMPETITIVE ENVIRONMENT** | |  | | | |
| **Outcome** | **Weakest Competition** | **Strongest Competition** | **Unadjusted odds**  **ratio** | **Adjusted odds**  **ratio1** | **Adjusted odds ratio2** | **Adjusted odds ratio3** |
| **6439 men** | **6486 men** | **(95% CIs)** | **(95% CIs)** | **(95% CIs)** | **(95% CIs)** |
| **33 centres** | **32 centres** |  |  |  |  |
| **Severe urinary complication** | 1114 (17.3%) | 959 (14.8%) | 0.86 (0.67-1.12) | 0.85 (0.66-1.10)  p-value 0.21 | 0.85 (0.66-1.10)  p-value 0.22 | 0.91 (0.72-1.16)  p-value 0.46 |
| **30-day readmissions** | 475 (7.4%) | 220 (3.4%) | 0.44 (0.29-0.67) | 0.44 (0.29-0.67)  p-value 0.0002 | 0.44 (0.29-0.68)  p-value 0.0003 | 0.46 (0.30-0.70)  p-value 0.0005 |
| **Length of stay >3 days** | 2449 (38.0%) | 2132 (32.9%) | 0.77 (0.43-1.37) | 0.75 (0.42-1.33)  p-value 0.32 | 0.79 (0.33-1.40)  p-value 0.42 | 1.03 (0.64-1.64)  p-value 0.91 |

**Notes**

1. Adjusted odds ratio for the impact of competition on each outcome measure includes the effect of age, comorbidity, socioeconomic status and year of treatment in the multivariate regression analysis
2. Addition of annual procedure volume to multivariate regression analysis
3. Addition of procedure type to multivariate regression analysis

**Appendix 2 – Results of a multi-level model exploring the impact of patient choice on urinary complications, 30-day emergency readmissions and length of stay following a radical prostatectomy**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **SUCCESSFUL COMPETITION** | |  | | | |
| **Outcome** | **Centres losing patients** | **Centres gaining patients** | **Unadjusted**  **odds**  **ratio1** | **Adjusted odds**  **ratio** | **Adjusted odds ratio2** | **Adjusted odds ratio3** |
| **5101 men** | **5553 men** | **(95% CIs)** | **(95% CIs)** | **(95% CIs)** | **(95% CIs)** |
| **33 centres** | **19 centres** |  |  |  |  |
| **Severe urinary complication** | 1866 (17.0%) | 749 (13.5 %) | 0.86 (0.64-1.15) | 0.89 (0.67-1.19)  p-value 0.18 | 0.93 (0.67-1.30)  p-value 0.22 | 1.01 (0.76-1.32)  p- value 0.29 |
| **30-day readmissions** | 271 (5.3%) | 287 (5.2%) | 1.19 (0.70-2.01) | 1.21 (0.71-2.05)  p-value 0.69 | 1.37 (0.75-2.51)  p-value 0.51 | 1.31 (0.77-2.21)  p-value 0.54 |
| **Length of Stay >3 days** | 2020 (39.6%) | 1375 (24.8%) | 0.48 (0.25-0.90) | 0.49 (0.25-0.94)  p-value 0.02 | 0.63 (0.30-1.34)  p-value 0.08 | 0.82 (0.48-1.38)  p-value 0.13 |

1. Adjusted odds ratio for the impact of patient choice on each outcome measure includes the effect of age, comorbidity, socioeconomic status and year of treatment in the multivariate regression analysis.
2. Addition of annual procedure volume to multivariate regression analysis
3. Addition of procedure type to multivariate regression analysis

**Appendix 3** - **Analysis of the average procedure volume for all centres in each competition category: Competitive environment and Successful competition.**

|  |  |  |
| --- | --- | --- |
| **COMPETITIVE ENVIRONMENT** | **Average annual volume** | **P value** |
| Weakest (n=33) | 48 | 0.60 |
| Strongest (n=32) | 50 |  |
| **SUCCESSFUL COMPETITION** | **Average annual volume** | **P value** |
| Centres losing patients (n=33) | 43 | 0.0000 |
| Centres gaining patients (n=19) | 73 |  |
| In between (n=13) | 38 |  |