ARTICLE

Clinical Research

Hospital volume and outcomes after radical prostatectomy: a national population-based study using patient-reported urinary continence and sexual function

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BACKGROUND: Improvements in short-term outcomes have been reported for hospitals with higher radical prostatectomy (RP) volumes. However, the association with longer-term functional outcomes is unknown.

METHODS: All patients diagnosed with non-metastatic prostate cancer in the English NHS between 2014 and 2016 who underwent RP ($N = 10,089$) were mailed a survey ≥18 months after diagnosis. Differences in patient-reported urinary continence and sexual function (EPIC-26 on scale from 0 to 100) by hospital volume group (≤60, 61–100, 101–140, >140 RPs/year) were estimated using multilevel linear regression.

RESULTS: Overall, 7702 men (76.3%) responded. There were no statistically significant differences in urinary continence ($p = 0.08$) or sexual function scores with increasing volume group ($p = 0.2$). When modelled as a linear function, we found a non-significant increase of 0.70 (95% CI −0.41 to 1.80; $p = 0.22$) in urinary continence and a significant increase of 1.54 (0.62–2.45; $p = 0.001$) in sexual function scores for a 100-procedure increase in hospital volume, which did not meet the threshold for a minimal clinically important difference (10–12 points). The results were similar for robotic-assisted RP (5529 men [71.8%]).

CONCLUSIONS: These results do not support further centralisation of RP services beyond levels in England where four in five hospitals perform >60 RPs/year.

Prostate Cancer and Prostatic Diseases (2023) 26:264–270; https://doi.org/10.1038/s41391-021-00443-z

INTRODUCTION

Men undergoing radical prostatectomy (RP) as primary treatment for prostate cancer (PCa) may experience treatment-related sexual dysfunction and urinary incontinence [1, 2]. These functional outcomes may be determined by the quality of surgical care [3].

In the United Kingdom, surgical services in the National Health Service (NHS) have been reorganised, concentrating RP to fewer centres following national guidance requiring that major urological pelvic cancer surgery is carried out in specialist centres performing more than 50 cases per year [4]. Centralisation has gathered pace since further guidance stipulated that robotic-assisted radical prostatectomy (RARP) is concentrated in centres performing at least 150 procedures per year [5].

There is evidence, mainly from the United States, that outcomes are better in hospitals with higher RP volumes [6, 7]. However, the effect of hospital volume is likely to depend on the outcome of interest as well as on the characteristics of the health system that provides the procedure [8].

In this study, we tested the hypothesis that two key measures of outcome post-prostatectomy, notably, long-term urinary incontinence and sexual function reported by the patients themselves at least 1 year after surgery, are better in hospitals with larger volumes, both for RP of any type and for RARP only. We used data from the National Prostate Cancer Audit (NPCA), a population-based study that evaluates the care and outcomes of all men diagnosed with PCa in the NHS in England and Wales [9].

METHODS

Study design and participants

All patients who were diagnosed with non-metastatic PCa between 1 April 2014 and 30 September 2016 (the study period) according to the English Cancer Registry and who subsequently underwent RP (OPCS-4 code 'M61') were eligible for inclusion in the study. The NPCA patient survey was designed to record their personal outcomes in a structured manner following surgery. Patients were identified using NPCA data, which includes English Cancer Registry data linked to Hospital Episode Statistics

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Received: 22 March 2021 Revised: 9 August 2021 Accepted: 11 August 2021
Published online: 8 September 2021

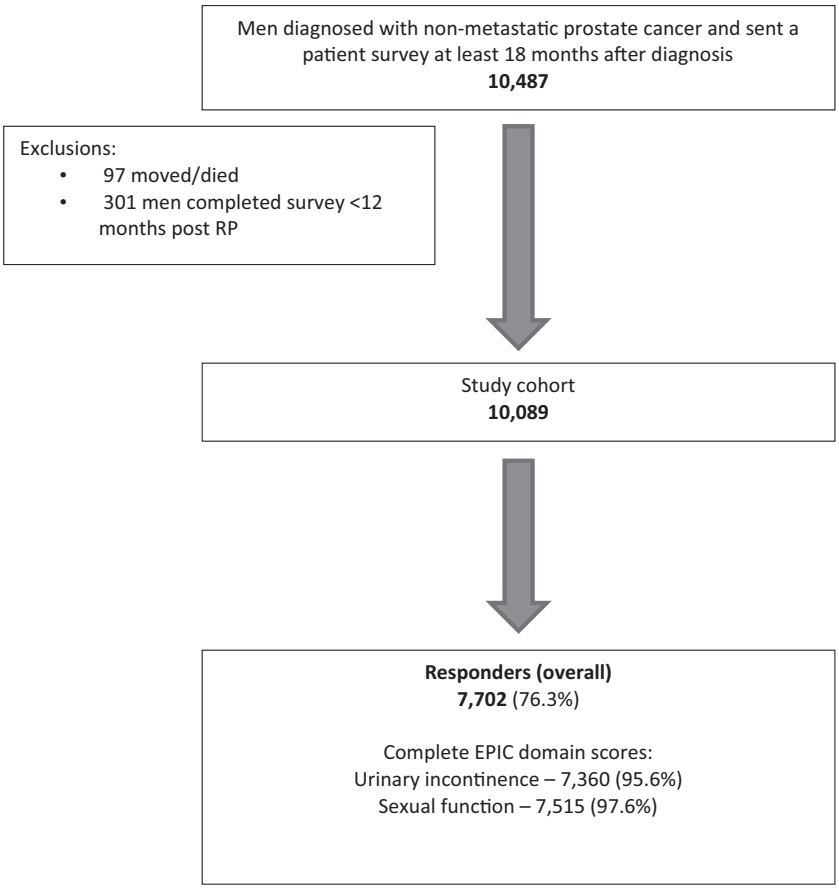

Fig. 1 Patient flow diagram illustrating the cohort selection of men undergoing radical prostatectomy (RP) in the study.

(HES) at patient level [10, 11]. The NPCA patient survey methods are described in detail elsewhere [2].

Outcome measures

Men were invited to complete a questionnaire at least 18 months after diagnosis (Appendix 1). Time from surgery to completion of the questionnaires was at least 12 months. The patient-reported outcome (PRO) questionnaire comprised items from EPIC-26, a validated instrument to measure function following radical PCa treatment across five domains including sexual function and urinary incontinence. The validated summary score for each domain ranges from 0–100, with higher scores representing better function [12]. Thresholds for a minimal clinically important difference (MCID) have been estimated for each domain, representing changes considered to be meaningful for patients [13].

The questionnaire also included two adapted EPIC-26 questions: "Overall, how big a problem was your urinary incontinence function or lack of sexual function for you immediately before you were diagnosed with PCa?"

Hospital-level characteristics

Hospital RP volume was derived from the number of patients diagnosed during the study period according to the Cancer Registry data who subsequently underwent a RP according to HES data. For each hospital RP volume was calculated as the average annual number of procedures.

For this study, a 'hospital' is defined as an NHS Hospital Trust, the organisational unit that provides secondary care in the English NHS in a local area [14]. Overall, 52 hospitals performing at least 10 RPs in each year of the study period were included. Two hospitals not meeting this minimum number of RPs each year, in total treating 50 patients, were excluded. Hospital volume was modelled in 'volume groups' (up to 60 RPs per year, from 61 to 100 RPs, from 101 to 140 RPs, and 141 RPs or more). The volume groups were chosen in order to create, as much as possible, categories that are equal in terms of both the number of hospitals and the number of patients. Hospital volume was also modelled as a continuous variable.

Patient-level characteristics

10,487 men were sent a survey questionnaire and 10,089 men were eligible for inclusion in the final analysis in the study cohort after exclusions (Fig. 1). Questionnaire responses were linked to the NPCA database. Cancer Registry records provided information on age at diagnosis, tumour characteristics according to the TNM classification [15], Gleason biopsy score, and pre-treatment serum prostate-specific antigen. A modified D'Amico risk stratification algorithm [16] categorised each patient's cancer into low, intermediate or high risk/locally advanced disease.

HES records of hospital admissions provided information on each patient's ethnicity, socioeconomic status (measured in quintiles by the Index of Multiple Deprivation) and number of comorbidities in the year preceding diagnosis according to the RCS Charlson score [17, 18]. Patients who had a code for a robot-assisted procedure (OPCS-4 Y753, Y765) in their HES records were classified as having had a RARP.

Statistical analysis

We used multilevel multivariable linear regression to model EPIC-26 domain scores as a function of hospital volume, included as 'volume groups' or as a continuous variable. RP volume was included as a hospital-level characteristic. We modelled the volume-outcome relationship including all men undergoing a RP of any type as well as those undergoing a RARP. The models were adjusted for patient-level characteristics (age, number of comorbidities, ethnicity, cancer risk group, and socioeconomic status) and hospital-level characteristics (radiotherapy centre, university hospital). *P* values were derived from Wald tests.

When modelling hospital volume as a continuous variable, we tested whether the relationships between hospital volume and the outcomes were linear by adding a quadratic term for hospital volume in the model. Missing patient-reported data to individual questions were handled in accordance with guidelines for EPIC-26 [19]. Multiple imputation accounted for missing values of the patient-level characteristics and the PROs so that regression models included all patients [20]. Missing values

Table 1. Hospital characteristics stratified by annual hospital RP volume per year.

	Hospital volume (%)									
	≤60	%	61–100	%	101–140	%	≥141	%	Total	%
Total (patients)	1049 (8.6%)		3716 (30.3%)		3911 (31.9%)		3582 (29.2%)		12,258	
Total (hospitals)	11 (21.2%)		19 (36.5%)		14 (26.9%)		8 (15.4%)		52	
RP calendar year (number of patients)										
2014	272	25.9	892	24.0	944	24.1	837	23.4	2945	24
2015	445	42.4	1554	41.8	1,678	42.9	1500	41.9	5177	42.2
2016	332	31.6	1270	34.2	1,289	33.0	1245	34.8	4136	33.7
RP modality (number of patients)										
Robotic-assisted laparoscopic	367	35.0	2574	69.3	2,566	65.6	3,400	94.9	8,907	72.7
Laparoscopic	383	36.5	733	19.7	472	12.1	110	3.1	1698	13.9
Open	299	28.5	409	11	873	22.3	72.0	2	1653	13.5
Number of radiotherapy centres	8	72.7	12	63.2	10	71.4	6	75.0	36	69.2
Number of university hospitals	5	45.5	10	52.6	11	78.6	6	75.0	32	61.5

were replaced with 30 sets of plausible values and Rubin's rules [21] were used to obtain estimates and 95% confidence intervals (CI).

All reported p values are two-sided and 0.05 was the significance level. Negative differences represent poorer outcomes compared to the reference group. Data analysis was undertaken using Stata version 15 [22].

RESULTS

Descriptive analysis

The hospital RP volume during the study period varied from 37 to 597 (median of 225.5). About one-fifth of hospitals carried out 60 or fewer procedures annually and one-sixth more than 140 (Table 1). The proportion of men undergoing RARP increased during the study from 54.3% of men diagnosed in 2014 to 71.1% of men diagnosed in 2016. RARP was the surgical modality most frequently performed (72.7% of RPs) in the highest volume group of hospitals (>140 RPs per year) compared with 35.0% of RPs carried out in the lowest volume group (≤60 RPs per year; Table 1). Approximately three-quarters of hospitals in the higher volume groups were university hospitals (78.6% in the 101–140 RPs per year group and 75.0% in the >140 RPs per year group) compared with 45.5% in the lowest volume group (≤60 RPs per year; Table 1).

Of the 10,089 men in the study cohort, 7,702 (76.3%) responded to the questionnaire. All men underwent RP less than 6 months after diagnosis. Overall, 5529 of the men who responded (71.9%) had a RARP. On average, responders were older, more frequently of white ethnicity, had fewer comorbidities and had a more affluent socioeconomic status compared to non-responders (Appendix 2).

There were only small differences in the characteristics of the responders across volume groups (Table 2). Men in the highest volume group tended to be younger, were less often of white ethnicity and more often had locally advanced disease compared with the lowest volume group. We did not find differences between volume groups in the proportion of men who indicated that immediately before the time of diagnosis they had a big problem with their urinary function (6.2%, 6.6%, 7.0%, 6.5% with increasing volume) or their lack of sexual functional (7.8%, 9.5%, 8.7%, 9.3%).

Outcomes

The differences in EPIC-26 urinary continence scores between the four volume groups were small (70.4, 69.5, 71.6, and 72.6 with increasing volume) and none were statistically significant with adjustment for differences in patient-level and hospital-level characteristics ($p = 0.08$; Table 3). When modelling hospital volume as a continuous variable, we found no evidence of a volume-outcome relationship. For each increase in hospital volume of 100 procedures, there was a non-significant increase of 0.70 (95% CI: −0.41 to 1.80; $p = 0.22$) in the urinary continence score. Adding hospital volume as a quadratic term did not improve the fit of the model significantly.

The differences in EPIC-26 sexual function scores between the four volume groups (18.7, 24.2, 24.1 and 26.6 with increasing volume) were slightly bigger than the corresponding differences in urinary continence scores but they did not reach statistical significance with adjustment for differences in patient-level characteristics ($p = 0.20$; Table 3). However, when modelling hospital volume as a continuous variable we found that each increase in hospital volume of 100 procedures was associated with an increase of 1.54 (95% CI: 0.62–2.45; $p = 0.001$) in the sexual function score. We did not find that adding hospital volume as a quadratic term improved model fit significantly.

The same pattern of results was observed when we included only men who underwent RARP (Table 3). There were no significant differences in the volume groups either in urinary continence ($p = 0.12$) or sexual function scores ($p = 0.17$). When modelling hospital volume of RARPs as a continuous variable we did not find evidence of a statistically significant increase of urinary continence scores (0.99 for each 100-procedure increase in hospital volume, 95% CI: −0.18 to 2.17; $p = 0.10$). However, we did find evidence of an increased sexual function score with higher hospital volumes (1.10 for each 100-procedure increase in hospital volume, 95% CI: 0.07–2.12; $p = 0.04$). Again, adding hospital volume as a quadratic term did not lead to significant improvements of fit of the models.

DISCUSSION

Main findings

To our knowledge, this is the first study to explore the relationship between hospital RP volume and patient-reported urinary continence and sexual function at least 12 months after surgery. We did not find significant differences in the EPIC-26 domain scores between the four defined volume groups for these long-term outcomes. However, when hospital volume was modelled as a continuous variable, there was some evidence that the sexual function score increased with higher hospital volumes. The increase in sexual function (a 1.5 increase in sexual function score for a 100-procedure increase in hospital volume) is unlikely to be clinically significant given that the threshold for a MCID is 10–12 points [13].

These results need to be interpreted in the context of the ongoing process of centralisation of RP services, in the English

Table 2. Patient and tumour characteristics by hospital volume of radical prostatectomies per year.

	Hospital volume (%)									
	≤60	**%**	**61–100**	**%**	**101–140**	**%**	**>140**	**%**	**Total**	**%**
Total (patients)	680 (8.6%)		2373 (30.3%)		2473 (31.9%)		2176 (29.2%)		7702	
Total (hospitals)	11 (21.2%)		19 (36.5%)		14 (26.9%)		8 (15.4%)		52	
Age (years)										
<60	157	23.1	598	25.2	601	24.3	604	27.8	1960	25.4
61–70	413	60.7	1452	61.2	1438	58.1	1211	55.7	4514	58.6
>70	110	16.2	323	13.6	434	17.5	361	16.6	1,228	15.9
Ethnicity										
White	637	97.3	2158	96	2237	93.3	1858	92.1	6890	94.2
Mixed	1	0.2	8	0.4	12	0.5	20	1.0	41	0.6
Asian/Asian British	9	1.4	24	1.1	33	1.4	24	1.2	90	1.2
Black/Black British	7	1.1	36	1.6	83	3.5	87	4.3	213	2.9
Other	1	0.2	22	1.0	32	1.3	28	1.4	83	1.1
Miss.	*25*	*3.7*	*125*	*5.3*	*76*	3.1	*159*	7.3	*385*	5
Number of comorbidities (RCS Charlson)										
0	507	74.6	1810	76.3	1883	76.1	1627	74.8	5827	75.7
1	144	21.2	496	20.9	497	20.1	460	21.1	1,597	20.7
≥2	29	4.3	67	2.8	93	3.8	89	4.1	278	3.6
Socioeconomic deprivation status (national quintiles of IMD)										
Least deprived (1)	182	26.8	731	30.8	654	26.4	500	23.0	2,067	26.8
2	151	22.2	588	24.8	605	24.5	561	25.8	1905	24.7
3	147	21.6	499	21.0	492	19.9	507	23.3	1645	21.4
4	122	17.9	322	13.6	379	15.3	371	17.0	1194	15.5
Most deprived (5)	78	11.5	233	9.8	343	13.9	237	10.9	891	11.6
T stage										
1	26	3.8	133	5.6	78	3.2	86	4.0	323	4.2
2	400	58.9	1469	62.0	1534	62.1	1206	55.7	4609	60.0
3	252	37.1	766	32.3	855	34.6	874	40.3	2747	35.7
4	1	0.1	2	0.1	3	0.1	1	0	7	0.1
Miss.	*1*	*0.1*	*3*	*0.1*	*3*	*0.1*	*9*	*0.4*	*16*	*0.2*
N stage										
0	626	98.1	2207	98.3	2278	97.5	2032	97.2	7143	97.7
1	12	1.9	39	1.7	59	2.5	58	2.8	168	2.3
Miss.	*42*	*6.2*	*127*	*5.4*	*136*	*5.5*	*86*	*4*	*391*	5.1
Gleason score										
6-	60	8.8	205	8.7	254	10.3	162	7.5	681	8.9
7-	542	79.8	1848	78.4	1858	75.7	1657	76.4	5905	77.1
8-	77	11.3	303	12.9	343	14.0	350	16.1	1,073	14.0
Miss.	*1*	0.1	*17*	0.7	*18*	0.7	*7*	0.3	*43*	0.6
PSA (ng/ml)										
0-	373	69.7	1421	74.1	1554	69.4	1236	70.2	4,584	71.0
10-	140	26.2	413	21.5	558	24.9	424	24.1	1535	23.8
20-	22	4.1	84	4.4	126	5.6	101	5.7	333	5.2
Miss.	*145*	*21.3*	*455*	*19.2*	*235*	*9.5*	*415*	*19.1*	*1250*	*16.2*
Prostate cancer risk group										
High risk/Locally advanced	297	43.7	964	40.8	1082	43.9	1051	48.5	3394	44.3
Intermediate	376	55.4	1375	58.2	1365	55.4	1103	50.9	4219	55.0
Low risk	6	0.9	22	0.9	15	0.6	14	0.6	57	0.7
Miss.	*1*	*0.1*	*12*	*0.5*	*11*	*0.4*	*8*	*0.4*	*32*	*0.4*

Miss. missing.

Table 3. Relationship between EPIC-26 domain scores (urinary incontinence and sexual function) and hospital volume of radical prostatectomies per year.

		Urinary incontinence score (MCID = 6–9)		Sexual function score (MCID = 10–12)	
Volume group/ year	**No. of patients (%)**	**Mean score (95% CI)**	**Adjusted[a] difference (95% CI)**	**Mean score (95% CI)**	**Adjusted[a] difference (95% CI)**
Any type of radical prostatectomy ($n = 7702$)					
≤60	680 (8.8%)	70.4 (68.3, 72.5)	1.30 (−3.85, 6.46)	18.7 (17.2, 20.4)	−3.87 (−7.67, −0.07)
61–100	2373 (30.8%)	69.5 (68.4, 70.6)	0	24.2 (23.2, 25.2)	0
101–140	2473 (32.1%)	71.6 (70.5, 72.7)	2.12 (−1.13, 5.38)	24.1 (23.1, 25.1)	0.43 (−3.07, 3.93)
>140	2176 (28.3%)	72.6 (71.5, 73.7)	3.17 (−0.66, 7.00)	26.6 (25.5, 27.7)	2.42 (−0.92, 5.78)
			p value = 0.08		p value = 0.21
Robot-assisted radical prostatectomy only ($n = 5529$)					
≤60	230 (4.2%)	67.5 (63.6, 71.5)	−1.88 (−8.76, 5.00)	19.1 (16.3, 21.9)	−4.51 (−10.75, 1.73)
61–100	1633 (29.5%)	69.5 (68.1, 70.8)	0	25.0 (23.8, 26.2)	0
101–140	1602 (29.0%)	73.1 (71.8, 74.4)	2.36 (−2.19, 6.90)	27.3 (26.0, 28.6)	2.03 (−1.52, 5.58)
>140	2064 (37.3%)	72.7 (71.6, 73.9)	3.05 (−1.36, 7.46)	26.6 (25.4, 27.7)	1.60 (−1.64, 4.83)
			p value = 0.12		p value = 0.17

MCID minimum clinically important difference.
[a]Risk adjustment variables include patient-level characteristics (age, ethnicity, socioeconomic deprivation [Index of multiple deprivation], number of comorbidities [RCS Charlson score; Armitage et al. [8]], disease status) and Hospital level characteristics (University teaching hospital, Radiotherapy centre).

NHS since 2002, that has gained further impetus since the introduction of RARP [4, 5]. Four in five English NHS hospitals carried out more than 60 RPs per year during the study period and these hospitals carried out more than 90% of all RPs.

Relationship to previous research

A systematic review of the volume-outcome relationship for RP, mainly including studies carried out in the United States, concluded that there is consistent evidence of an association between hospital volume and short-term outcomes (surgical complications, blood loss and length of stay) [6]. An assessment of in-hospital outcomes after all RPs performed in Germany between 2006 and 2013 (221,331 procedures) reported that hospital volume is the most important factor for improved in-hospital outcomes (mortality, blood transfusion and length of stay) [23]. A recent, large database study of over 100,000 patients also reported a volume-outcome relationship between hospital RARP volume and short-term outcomes (perioperative complications and oncological outcomes) [7]. However, the evidence on associations with longer-term functional outcomes is less clear. Our results address this important evidence gap with respect to long-term urinary continence and sexual function.

Some studies carried out in high-volume centres reported better PROs after RP than population-based studies [24, 25]. However, our results do not support the explanation that the superior functional outcomes seen in these high-volume centres can be explained merely by the fact that they have a higher than average volume of procedures. Other quality-related factors, for example specific quality assurance programmes or differences in patient selection or referral are more likely to be evident in expert centres, which may explain the differences in functional outcomes [26].

We found similar results when analysing the volume-outcome relationship in all men and in men who had RARP. This is in line with the emerging evidence that RARP is likely to have better short-term outcomes but similar long-term outcomes compared to other RP modalities [2, 27, 28].

Strengths and limitations

A key strength of our study is that we report outcomes for a recent cohort of patients from all English hospitals that provide RP. Men were identified on the basis of routine cancer registry data including every man diagnosed with PCa in the English NHS. As such, it presents a highly representative population. Given that less than 5% of healthcare expenditure in England covers procedures outside the NHS provided by the private sector, our study cohort also represents a near-complete cross-section of the population of men with PCa undergoing surgical treatment [29].

Patient selection and survey administration were independent of surgeons and other healthcare professionals, eliminating the possibility of selection and reporting bias. Furthermore, we had a robust sample size (7700 men) and a high response rate to the survey (73.4%). We observed some differences between responders and non-responders, but it is unlikely that these have affected the volume-outcome relationship that we report, as the response rate did not vary according to volume group, with only small differences in the men's characteristics between the volume groups. Neither did we find differences in baseline function based on patients indicating whether their urinary incontinence or lack of sexual function was a big problem immediately before the time of diagnosis. The comparisons of the functional outcomes were adjusted for a range of patient characteristics, which further reduces the possible effect of confounding. Finally, the study benefitted from the use of a validated instrument that is widely used to determine sexual and urinary function after PCa treatment (EPIC-26).

Our results provide a snapshot of the functional outcomes collected at least 18 months after diagnosis. This implies that we were not able to explore whether hospital volume had an impact on the speed of functional recovery after surgery or whether there is a trade-off between functional outcome and cancer cure. Data on nerve-sparing technique were unavailable in this study.

A recent systematic review reported that increasing surgeon experience (>50 RPs/year) is associated with better urinary incontinence recovery rates, although the authors highlight key methodological limitations of this research with respect to variability in the definition of both surgeon experience and urinary incontinence, with inconsistent use of validated measures [30]. We did not investigate a potential relationship between surgeon volume and PROs for a number of reasons. First, the administrative information available identifies the experienced urologist who is 'responsible' for the care episode but not the

'operating' surgeon. In hospitals with a team-based approach and those with a relatively large number of trainee surgeons, the responsible urologist and the operating surgeon are not necessarily the same. Thus, observed volume for an individual surgeon may not be truly accurate. Second, there is evidence that short-term outcomes are more affected by the overall surgical management, including the surgeon's experience and skill, whereas longer-term outcomes may be more affected by the support provided by the wider multidisciplinary team, including the provision of support services. These factors support consideration of hospital rather than individual surgeon volume [6].

Implications

Our study demonstrates that it is unlikely that a "volume-based policy" will lead to further improvements of functional outcomes after RP in the English NHS, where most hospitals providing PCa surgery already carry out at least 60 procedures per year. Volume-based policies are commonly implemented either by decreasing the number of low-volume providers by setting a minimum threshold or by increasing the number of high-volume providers through centralisation of care. Our findings demonstrate that it can be assumed that hospitals performing more than 60 RPs per year produce acceptable urinary continence and sexual function and further centralisation is unlikely to lead to additional improvements of clinical significance but it may have a negative impact on access, especially for patients from disadvantaged groups [31]. It is also important to note that the volume-outcome relationship may vary according to the complexity of the surgical procedure that is studied [31].

Volume-based policies follow the idea that "practice makes perfect" [31]. However, a recent study suggested that selective referral or patient choice may have had an impact on the current configuration of the English NHS hospitals that provide PCa surgery [32]. Hospitals adopting robotic surgery early and employing experienced urologists with a strong media reputation were particularly attractive to patients given that the volumes of RPs increased in such centres [33, 34]. These findings re-emphasise the need to be cautious about inferring causation when interpreting the relationship between hospital volume of RPs and outcomes.

CONCLUSIONS

The results from this study have important implications for PCa services in many countries. We conclude that it is unlikely that there will be clinically significant improvements in urinary continence and sexual function with further centralisation of RP services beyond the level observed in the English NHS, where four in five hospitals providing PCa surgery undertake at least 60 procedures per year.

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ACKNOWLEDGEMENTS

We thank all men who returned the survey questionnaires and Quality Health (www.quality-health.co.uk) for administering the survey. We thank NHS staff for their support in collecting the clinical data. The cancer registry data used for this study are based on information collected and quality assured by Public Health England's National Cancer Registration and Analysis Service (www.ncras.nhs.uk), part of Public Health England. Hospital Episode Statistics data were made available by NHS Digital (www.digital.nhs.uk). JN had full access to all the data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis. Data are not available to other researchers as it uses existing national datasets.

AUTHOR CONTRIBUTIONS

Conceived and/or designed the work that led to the submission, acquired data, and/or played an important role in interpreting the results: JN, MM, TEC, MGP, AS, AA, HP, JvM, NWC and PC. Drafted or revised the manuscript: JN, MM, TEC, MGP, AS, AA, HP, JvM, NWC and PC. Approved the final version: JN, MM, TEC, MGP, AS, AA, HP, JvM, NWC and PC. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: JN, MM, TEC, MGP, AS, AA, HP, JvM, NWC and PC. JN had full access to the data in the study and final responsibility for the decision to submit for publication.

COMPETING INTERESTS

JN, MM, TEC, MGP, AS, AA, HP, JvM, NWC and PC are members of the Project Team of the National Prostate Cancer Audit (www.npca.org.uk) which is commissioned by the Healthcare Quality Improvement Partnership (www.hqip.org.uk) as part of the National Clinical Audit and Patient Outcomes Programme, and funded by NHS England and the Welsh Government. Neither HQIP nor NHS England or the Welsh Government had any involvement in the study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. The researchers had full independence from the Healthcare Quality Improvement Partnership. JvM reports a contract with the Healthcare Quality Improvement Partnership for the provision of the National Prostate Cancer Audit (www.npca.org.uk) funded by the Healthcare Quality Improvement Partnership (www.hqip.org.uk). HP was supported by the University College London Hospitals/University College London Comprehensive Biomedical Research Centre. MGP was partly supported by the NHS National Institute for Health Research through an Academic Clinical Fellowship (ACF-2014-20-002). The views expressed in this article are those of the authors and not necessarily those of the NHS or the Department of Health and Social Care. NWC has attended and received honoraria for advisory boards, travel expenses to medical meetings, and served as a consultant for AstraZeneca, Astellas, Bayer, Janssen, Sanofi Aventis, Takeda, Ipsen and Ferring.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41391-021-00443-z.

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