Patient outcomes and length of hospital stay after radical prostatectomy for prostate cancer: analysis of Hospital Episodes Statistics for England

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OBJECTIVE

To investigate the morbidity and mortality after radical prostatectomy (RP) in relation to the numbers of RPs carried out at individual hospitals, as recent studies of complex surgery report worse outcomes in low-volume hospitals, and there has been a large increase in RPs for localized prostate cancer.

METHODS

We analysed hospital episode statistics data for all 18 027 RPs in English National Health Service hospitals between 1997 and 2004.

RESULTS

In multivariate analysis, there was a U-shaped association of hospital volume with mortality (*P* for nonlinear trend, 0.004), but this finding was based on only 59 (0.3%) deaths. The mean length of stay was 6 days and decreased by 2.96% (95% confidence interval, CI, 1.98–3.92; $P < 0.001$) per quintile increase in hospital volume. In all, 16.1% of men had 30-day in-hospital complications; 20.3% were readmitted with complications within a year. The odds of 30-day in-hospital wound/bleeding complications decreased by 6% (95% CI 1–11; $P = 0.02$), and miscellaneous medical complications decreased by 10% (0–19; $P = 0.04$) per increase in hospital volume quintile. For re-admissions within a year, the hazard of vascular complications decreased by 15% (6–22; $P = 0.001$), wound/bleeding complications decreased by 8% (2–13; $P = 0.01$) and genitourinary complications decreased by 5% (2–8; $P = 0.002$), per increase in hospital volume quintile.

CONCLUSION

In men undergoing RP the length of hospital stay and rates of some short- and long-term postoperative complications afterward are lower in high-volume hospitals. The magnitudes of these effects on the outcomes studied may be too small and inconsistent to indicate a policy of selective referral to high-volume hospitals. Quality of life and oncological outcomes, however, could not be investigated in this dataset.

KEYWORDS

adverse outcomes, surgical volume, radical prostatectomy, prostate cancer

INTRODUCTION

In Europe and North America prostate cancer is the second commonest cause of male cancer deaths [1], and screening based on PSA testing is driving marked increases in the incidence of early-stage disease [2]. Radical prostatectomy (RP) is an option for treating localized prostate cancer in the UK [3] and USA [4]. About 161 000 RPs were performed in the USA in 2004 [5] and there was a 20-fold increase in RP in England between 1991 and 1999 [3]. Despite the rapid expansion of the use of RP [3], uncertainty remains over its effectiveness in early-stage disease [6–8], with little known about factors influencing common adverse outcomes, such as major postoperative and urinary complications [9–13].

Positive relationships between the number of specific operations undertaken in a hospital and improved outcomes have been reported [14,15]. Hospitals vary markedly in the number of RPs performed [3,9], and studies from the USA suggest inverse relationships of hospital RP volume with length of hospital stay, re-admissions, early complications [9,11,16] and urinary strictures [11,17]. These studies were conducted in the early to mid-1990s and their general applicability to other countries, e.g. the UK, is unknown. As prostate cancer is common, identifying factors related to health delivery and associated with surgical outcome is of considerable clinical and public health importance. We used the Hospital Episode Statistics (HES) database for England [18] to investigate variations in outcomes after RP in relation to hospital volume.

METHODS

The HES database holds information on patients who are admitted to NHS hospitals in England, either as day cases or as ordinary admissions [18]. Each record in the database relates to one 'finished consultant episode', i.e. the period an individual spends under the care of one NHS consultant. Private procedures are mostly excluded from HES as there is no requirement for private hospitals to provide routine data.

Information held in the HES database includes the age and sex of the patient, area of usual residence, reason for admission (diagnosis) to hospital, and procedure undertaken. Data for this analysis were derived from the database extract held at the University of Bristol, which currently contains data for financial years from 1 April 1991 to 31 March 2005.

Anonymised records for men undergoing RP between 1 April 1997 and 31 March 2005 were extracted from the HES database. Episodes involving RP were identified as those with an OPCS4 code of M61 recorded in any of the procedure fields. The main interest was the annual volume of RPs in an NHS hospital trust, derived for each HES financial year. We chose to divide hospital trust volume into quintiles, based on annual volume over the 8-year period (1 April 1997 to 31 March 2005). To account for changes in hospital volume over time, all analyses controlled for HES year of admission. Hospital volume rank tended to track over time (the correlation coefficient for hospitals that existed in both 1997 and 2004 was 0.61).

The degree of comorbidity was classified for each patient by using the Charlson Co-morbidity Index [19], a weighted scale based on a variety of diseases associated with mortality risk. Diagnostic data from across all diagnostic fields were used to create a weighted score and an ordinal variable (0, 'none'; 1, 'mild'; 2, 'moderate'; ≥3, 'severe'). The Index of Multiple Deprivation 2004 (IMD2004) [20] was used as a measure of social deprivation at the small-area level. The index was derived at the ward level of Census Area Statistics and comprises several indicators covering seven domains of deprivation to create a single deprivation score for each ward. Each patient was assigned an IMD2004 score according to their area of residence. For the purposes of analysis, the index was divided into deprivation quintiles. Age (<60, 60–69, ≥70 years) and year of surgery (1997–2000, 2001–2004) were controlled for as potential confounders.

We examined three main outcomes: 30-day in-hospital mortality, length of stay, and complications of surgery. Complications were analysed separately as: (i) in-hospital complications within 30 days; and (ii) readmission to hospital for complications within a year of admission. Complications were chosen based on the comprehensive list developed by Alibhai *et al.* [12] for a recent study of short-term complications after RP and converted to the International Center for Disease (ICD)-10 code classification. Data from across all diagnostic fields were used to identify complications, which were grouped into seven mutually exclusive categories: cardiac; respiratory; vascular; wound/bleeding; genitourinary; miscellaneous medical; and miscellaneous surgical. A list of specific complications was also investigated: venous thromboembolism (ICD-10: I82, I26); wound dehiscence (T813); wound infection (T814); and bladder neck stenosis/incision/stricture (Q643, N35, N991, N360, S373). Readmission to hospital for radiotherapy (Z510) was examined as an additional treatment.

RP episodes were excluded if they were coded as being emergency rather than elective admissions (642), female (15), or the consultant speciality was not urology (296). The odds of in-hospital death (for all patients admitted between 1997 and 2004) and complications (patients admitted between 1997 and 2003) within 30 days of the operation were investigated using univariate and multivariate logistic regression. Cox proportional hazards models were fitted to investigate time to re-admission for complications up to a year after the RP for patients admitted between 1997 and 2003. Where there was evidence of no proportionality, separate time-varying hazard ratios were estimated. The mean and median length of stay was calculated for each exposure of interest between 1997 and 2004. Linear regression modelling was used to examine the association between annual hospital trust volume and length of stay in the 2004 financial year. As the distribution of length of stay was skewed, data were log-transformed. A test for trend was done using a Wald test. To test for nonlinear trend we used likelihood ratio tests, comparing a model with 'volume' as a categorical variable to that with volume as a score. Likelihood ratio tests examined interactions between the main exposure (annual hospital trust volume) and age, deprivation, comorbidity and year of admission, on the outcomes studied.

RESULTS

In all, there were 18 027 RPs in English NHS hospitals over the 8-year study period, increasing three-fold from 1135 in 1997 to 3358 in 2004. The percentage of acute NHS hospital trusts performing RP increased from 57.4% in 1997 to 70.1% in 2004. In 1997 the median annual hospital trust volume of RPs was 13 (interquartile range, IQR, 8–20), but in 2004 this had increased to 35 (26–49). Only 9.6% of NHS hospital trusts did ≥50 RPs in 2004 (19.9% did ≥40). The mean annual volume of RPs between 1997 and 2004 per hospital was distributed into the following quintiles: 1–14, 15–22, 23–32, 33–45 and 46–93.

Most patients were aged 60–69 years (55.2%); over the study period, 59 (0.3%) men died in hospital and 2365 (16.1%) had in-hospital complications within 30 days of admission; 2964 (20.3%) were re-admitted to hospital within a year due to one or more of the selected complications (Table 1). Thirty-nine (0.3%) men had radiotherapy within a year of their operation. Table 2 shows that the most common in-hospital complications were for wound/bleeding (6.9%) and genitourinary (6.7%) problems, whilst most re-admissions to hospital within a year were for genitourinary complications (16.4%).

In univariate analysis, hospitals with the lowest volume of RPs had the highest 30-day in-hospital mortality (Table 3). In multivariate models, inverse associations were somewhat attenuated for the two highest volume quintiles, and there was a U-shaped association of hospital volume with mortality, suggesting the possibility of a minimum and maximum threshold for surgery (*P* for nonlinear trend, 0.004). Age and year of admission were the main confounders that attenuated this association. In multivariate models 30-day in-hospital mortality was positively associated with age (*P* for trend 0.003) and mortality was lower in those from the least deprived areas (*P* for trend 0.13). Men with both mild or severe comorbidities had a greater risk of death than men with moderate comorbidities. Mortality was higher in the earlier years 1997–2000 (0.50%), when hospital volumes were much lower, than in 2001–2004 (0.26%), but in multivariate analyses the effect was attenuated, predominantly through adjustment for hospital trust volume and age.

The mean length of stay in hospital for men having RP declined over the study period; in 1997 the median (IQR) stay was 8 (7–11) days, but by 2004 this decreased to 6 (5–8) days. In 2004, the stay was higher in hospitals undertaking the lowest volume of RPs (Table 4), and there was evidence of a linear trend with mean length of stay decreasing by 2.96% (95% CI 1.98–3.92) per increase in hospital volume quintile (*P* for trend <0.001). The length of stay increased with age and with greater deprivation. Unexpectedly, the length of stay was lower in men with moderate and severe than in those with no or mild comorbidities (*P* for trend <0.001).

There was evidence of effect modification between length of stay and deprivation ($P < 0.001$). For people living in the least deprived areas the stay was greater in lower-volume hospital trusts. However, for people living in the most deprived areas, there was no evidence of an association.

In univariate analysis there was an inverse association between hospital volume and in-hospital complications within 30 days, but this association was somewhat attenuated in the multivariate model (Table 5). The odds of in-hospital complications increased with age (*P* for trend <0.001), and in patients admitted between 1997 and 2000, compared to those admitted in more recent years ($P < 0.001$). There was also evidence of effect modification between volume and year of admission on in-hospital complication rates ($P < 0.001$), such that the effect of hospital trusts in the highest-volume quintile was notably greater between 1997 and 2000 than it was between 2001 and 2003. Increasing hospital volume was associated with fewer re-admissions within a year (Table 5), although the relationship was not necessarily linear (*P* for nonlinear trend 0.004). Re-admission rates increased with age and for those living in the most deprived areas.

We examined each group of complications individually (Table 6); in multivariate analyses of 30-day in-hospital complications, the odds (95% CI) of wound/bleeding complications decreased by 6% (1–11; $P = 0.02$), and miscellaneous medical complications decreased by 10% (0–19; $P = 0.04$) per unit increase in hospital-volume quintile. However, the absolute differences were small. The number of complications in the lowest- and highest-volume quintiles, respectively, were: 267 (9.2%)

TABLE 1. Distribution of RPs by age, comorbidity and deprivation indices, and prevalence of adverse outcomes; HES for England, 1997–2004

Characteristic	N (% of total)
Total RPs	18 027 (100.0)
1997–2000	6 207 (34.4)
2001–2004	11 820 (65.6)
Age group, years	
<60	4 636 (25.7)
60–69	9 945 (55.2)
≥70	3 425 (19.0)
Charlson Index	
None	2 455 (13.6)
Mild	249 (1.4)
Moderate	14 110 (78.3)
Severe	1 213 (6.7)
Deprivation (IMD score)	
1 (most deprived)	3 777 (21.0)
2	3 699 (20.5)
3	3 671 (20.4)
4	3 239 (18.0)
5 (least deprived)	3 471 (19.3)
In-hospital deaths within 30 days	
Yes	59 (0.3)
No	17 218 (95.5)
Missing/spell not finished	750 (4.2)
Median (IQR) stay, days (2004)	6 (5–8)
In-hospital complications within 30 days (1997–2003)	
Yes	2 365 (16.1)
No	11 704 (79.8)
Missing/spell not finished	600 (4.1)
Readmission for complications ≤1 year after RP (1997–2003)*	
Yes	2 964 (20.3)
No	9 056 (62.1)
Excluded†	2 570 (17.6)

**79 patients coded as having more than one RP between financial years 1997 and 2003 were excluded. †Complications occurring on the day of the RP were excluded.*

TABLE 2 The number of admissions for complications of RP (1997–2003 combined)

	N (%) complications	
Complications	In-hospital, ≤30 days*	Re-admission at ≤1 year†
Major		
Any	2 365 (16.8)	2 964 (24.7)
Cardiac	435 (3.1)	258 (1.8)
Respiratory	79 (0.6)	229 (1.6)
Vascular	69 (0.5)	302 (2.1)
Wound/bleeding	966 (6.9)	663 (4.9)
Genitourinary	943 (6.7)	2 231 (16.4)
Miscellaneous medical	231 (1.6)	356 (2.5)
Miscellaneous surgical	265 (1.9)	511 (3.6)
Specific		
Venous thromboembolism	36 (0.3)	127 (0.9)
Wound dehiscence	42 (0.3)	87 (0.6)
Wound infection	200 (1.4)	259 (1.8)
Bladder neck stenosis/incision/stricture	46 (0.3)	622 (4.3)
Total	14 069 (100.0)	12 020 (100.0)

**The total number of admissions is lower than in Table 1, as episodes are only included for patients if the spell had ended and the method of discharge is known. †Complications occurring on day of RP were excluded. The total count is lower as 79 patients were coded as having more than one RP between financial years 1997 and 2003.*

TABLE 3 Odds of in-hospital death within 30 days of RP (1997–2004 combined)

Variable	Total RPs*	In-hospital deaths (% of total) at ≤30 days	Odds ratio (95% CI) Crude	Adjusted
Volume of trust†				
Low	3 695	28 (0.76)	1.00	1.00
2	3 503	6 (0.17)	0.22 (0.09, 0.54)	0.29 (0.12, 0.71)
3	3 333	5 (0.15)	0.20 (0.08, 0.51)	0.27 (0.10, 0.72)
4	3 381	10 (0.30)	0.39 (0.19, 0.80)	0.63 (0.28, 1.42)
High	3 365	10 (0.30)	0.39 (0.19, 0.80)	0.77 (0.33, 1.80)
P for trend			0.008	0.39
P for nonlinear trend			0.002	0.004
Age group, years				
<60	4 460	1 (0.02)	0.10 (0.01, 0.75)	0.11 (0.01, 0.83)
60–69	9 527	21 (0.22)	1.00	1.00
≥70	3 272	37 (1.13)	5.18 (3.03, 8.86)	4.02 (2.14, 7.57)
P for trend			<0.001	0.003
P for nonlinear trend			0.002	0.01
Charlson Index				
None	2 386	16 (0.67)	3.65 (1.94, 6.84)	1.12 (0.54, 2.34)
Mild	231	9 (3.90)	21.90 (10.10, 47.45)	7.43 (3.13, 17.68)
Moderate	13 528	25 (0.18)	1.00	1.00
Severe	1 132	9 (0.80)	4.33 (2.02, 9.30)	3.47 (1.54, 7.81)
P for trend			0.002	0.30
P for nonlinear trend			<0.001	<0.001
Deprivation, IMD score				
1 (most deprived)	3 632	22 (0.61)	1.00	1.00
2	3 519	7 (0.20)	0.33 (0.14, 0.77)	0.33 (0.14, 0.77)
3	3 508	10 (0.29)	0.47 (0.22, 0.99)	0.49 (0.23, 1.04)
4	3 102	10 (0.32)	0.53 (0.25, 1.12)	0.58 (0.27, 1.23)
5 (least deprived)	3 352	8 (0.24)	0.39 (0.17, 0.88)	0.49 (0.21, 1.10)
P for trend			0.04	0.13
P for nonlinear trend			0.12	0.10
Year				
1997–2000	5 999	30 (0.50)	1.95 (1.17, 3.25)	1.28 (0.68, 2.40)
2001–2004	11 278	29 (0.26)	1.00	1.00
P			0.01	0.44

**The total number of admissions analysed is lower than in Table 1 and 2, as details of in-hospital deaths were only available for patients if the spell had ended and the method of discharge is known. †The mean annual volume of RPs was distributed into the following quintiles: 1–14, 15–22, 23–32, 33–45, 46–93.*

vs 130 (5.0%) for wound/bleeding, and 67 (2.3%) vs 30 (1.2%) for miscellaneous medical complications. There was no evidence of any associations with cardiac, respiratory, vascular, genitourinary or miscellaneous surgical complications.

In multivariate analyses of re-admission to hospital within a year, the hazard of vascular complications decreased by 15% (6–22; $P = 0.001$), wound/bleeding complications decreased by 8% (2–13; $P = 0.01$) and genitourinary complications decreased by 5% (2–8; $P = 0.002$) per increase in hospital-volume quintile. Numbers of complications in the lowest- and highest- volume quintiles, respectively, were 86 (2.9%) vs 38 (1.4%) for vascular, 142 (5.2%) vs 110 (4.3%) for wound/bleeding, and 449 (16.5%) vs 387 (15.0%) genitourinary. Only 32 (1.1%) men were readmitted for venous thromboembolism in the lowest-volume quintile, vs 19 (0.7%) in the highest (reduction per increase in hospital volume quintile, 11%; −2 to 23; *P* for trend = 0.09).

DISCUSSION

This study is, to our knowledge, the first to investigate variations in the outcomes of RP by hospital volume in England. Its main strength is that the HES database covers all NHS hospitals in England and we were able to examine variations in many RPs. In crude analyses, both 30-day in-hospital mortality (0.76% vs 0.30%) and overall 30-day in-hospital complication rates (21.6% vs 13.4%) were greater in low- than high-volume hospitals. However, multivariate analyses indicated that these associations were explained by case-mix differences. There were lower overall readmission rates in higher-volume hospitals, which were robust to multivariate adjustment, but absolute differences were small (22.5% in the highest-vs 24.3% in the lowest-volume quintiles). Analysing specific in-hospital complications or reasons for readmission, some inverse relationships with hospital volume remained in multivariate models. Whilst these results were 'statistically significant', absolute differences were not large. For example, if all those in the lowest-volume hospitals had been treated in the highest-volume hospitals during the entire study period, there would have been, respectively, 122 and 33 fewer 30-day in-hospital wound/bleeding and miscellaneous medical complications, and 44, 26 and 42 fewer re-admissions within a year for vascular, wound/bleeding and genitourinary complications.

In agreement with others [9,16], after controlling for potential confounding factors, the mean length of stay was lower by about a day in high- (5.65 days) vs low- (6.53 days) volume hospitals. Nevertheless, it remains unclear whether it is the greater surgical and postoperative experience arising from dealing with higher surgical volumes that beneficially influences the length of a patient's stay (e.g. via reductions in morbidity, better pain control), whether high-volume hospitals have more efficient systems in place allowing earlier discharge, or whether lower length of stay drives higher volumes.

TABLE 4 *The length of stay in hospital for RPs (2004)*

	Length of stay, days (95% CI)	
Variable	Crude	Adjusted
Volume of trust*		
Low	6.56 (6.31, 6.82)	6.53 (6.19, 6.89)
2	5.90 (5.67, 6.13)	5.94 (5.63, 6.27)
3	5.74 (5.54, 5.96)	5.83 (5.52, 6.15)
4	6.22 (5.96, 6.49)	6.25 (5.90, 6.62)
High	5.53 (5.32, 5.76)	5.65 (5.35, 5.96)
P for trend	<0.001	<0.001
P for nonlinear trend	<0.001	<0.001
Age group		
<60	5.65 (5.47, 5.84)	6.36 (6.00, 6.75)
60–69	5.85 (5.72, 5.99)	6.53 (6.19, 6.89)
≥70	7.13 (6.81, 7.46)	7.50 (7.00, 8.04)
P for trend	<0.001	0.002
P for nonlinear trend	<0.001	<0.001
Charlson Index		
None	7.80 (7.30, 8.34)	8.00 (7.35, 8.71)
Mild	7.96 (6.53, 9.70)	8.05 (6.55, 9.89)
Moderate	5.82 (5.71, 5.93)	6.53 (6.19, 6.89)
Severe	6.00 (5.64, 6.38)	6.61 (6.12, 7.15)
P for trend	<0.001	<0.001
P for nonlinear trend	<0.001	0.008
Deprivation, IMD score		
1 (most deprived)	6.27 (6.03, 6.52)	6.19 (5.86, 6.54)
2	6.26 (6.02, 6.52)	6.21 (5.87, 6.56)
3	5.96 (5.72, 6.21)	5.92 (5.60, 6.26)
4	5.69 (5.45, 5.94)	5.74 (5.41, 6.09)
5 (least deprived)	5.59 (5.35, 5.83)	5.63 (5.32, 5.96)
P for trend	<0.001	<0.001
P for nonlinear trend	0.63	0.71

**The mean annual volume of RPs was distributed into the following quintiles: 1–25, 26–32, 33–41, 42–51, 53–85.*

TABLE 5 *In-hospital complications of RP at ≤30 days, and re-admissions within a year, between 1997 and 2003*

		N complications* or	Odds or hazard ratio (95% CI)	
Variable	Total RPs	re-admissions† (% of total)	Crude	Adjusted
Complications (odds ratios)				
Volume of trust‡				
Low	2 891	624 (21.58)	1.00	
2	2 989	492 (16.46)	0.72 (0.63, 0.82)	0.92 (0.80, 1.06)
3	2 612	433 (16.58)	0.72 (0.63, 0.83)	0.90 (0.78, 1.04)
4	2 983	468 (15.69)	0.68 (0.59, 0.77)	0.98 (0.85, 1.14)
High	2 594	348 (13.42)	0.56 (0.49, 0.65)	0.91 (0.78, 1.07)
P for trend			<0.001	0.48
P for nonlinear trend			0.009	0.44
Age group				
<60	3 552	387 (10.90)	0.74 (0.66, 0.84)	0.80 (0.71, 0.91)
60–69	7 686	1086 (14.13)	1.00	1.00
≥70	2 813	890 (31.64)	2.81 (2.54, 3.12)	1.57 (1.39, 1.78)
P for trend			<0.001	<0.001
P for nonlinear trend			<0.001	<0.001
Charlson Index				
None	2 166	803 (37.07)	4.35 (3.91, 4.83)	3.06 (2.70, 3.47)
Mild	211	102 (48.34)	6.90 (5.24, 9.10)	4.89 (3.66, 6.52)
Moderate	10 807	1290 (11.94)	1.00	1.00
Severe	885	170 (19.21)	1.75 (1.47, 2.09)	1.72 (1.44, 2.05)
P for trend			<0.001	<0.001
P for nonlinear trend			<0.001	<0.001

TABLE 5 Continued

Variable	Total RPs	N complications* or re-admissions† (% of total)	Odds or hazard ratio (95% CI) Crude	Adjusted
Deprivation, IMD score				
1 (most deprived)	2 952	527 (17.85)	1.00	1.00
2	2 835	509 (17.95)	1.01 (0.88, 1.15)	1.04 (0.91, 1.20)
3	2 857	474 (16.59)	0.92 (0.80, 1.05)	0.95 (0.82, 1.10)
4	2 521	406 (16.10)	0.88 (0.77, 1.02)	0.96 (0.83, 1.12)
5 (least deprived)	2 762	435 (15.75)	0.86 (0.75, 0.99)	0.98 (0.85, 1.14)
P for trend			0.007	0.49
P for nonlinear trend			0.86	0.69
Year				
1997–2000	6 011	1219 (20.28)	1.53 (1.40, 1.68)	1.21 (1.09, 1.34)
2001–2003	8 058	1146 (14.22)	1.00	1.00
P			<0.001	<0.001
Re-admissions (hazard ratios)				
Volume of trust				
Low	2 334	566 (24.25)	1.00	1.00
2	2 566	715 (27.86)	1.17 (1.05, 1.31)	1.13 (1.01, 1.26)
3	2 199	578 (26.28)	1.09 (0.97, 1.22)	1.06 (0.94, 1.19)
4	2 587	579 (22.38)	0.91 (0.81, 1.02)	0.89 (0.79, 1.01)
High	2 334	526 (22.54)	0.92 (0.82, 1.04)	0.90 (0.79, 1.02)
P for trend			0.001	0.002
P for nonlinear trend			<0.001	0.004
Age group¶				
<60	3 260	734 (22.52)	0.87 (0.80, 0.95)	0.87 (0.79, 0.94)
60–69	6 802	1733 (25.48)	1.00	1.00
≥70	1 943	491 (25.27)	0.98 (0.88, 1.08)	1.13 (1.01, 1.26)
P for trend			0.018	<0.001
P for nonlinear trend			0.03	0.79
Charlson Index:				
None	1 365	260 (19.05)	0.72 (0.63, 0.82)	0.62 (0.54, 0.72)
Mild	107	24 (22.43)	0.86 (0.58, 1.29)	0.73 (0.48, 1.11)
Moderate	9 798	2482 (25.33)	1.00	1.00
Severe	750	198 (26.40)	1.04 (0.90, 1.20)	1.02 (0.88, 1.18)
P for trend			<0.001	<0.001
P for nonlinear trend			0.32	0.04
Deprivation, IMD score				
1 (most deprived)	2 484	691 (27.82)	1.00	1.00
2	2 394	597 (24.94)	0.88 (0.79, 0.98)	0.88 (0.79, 0.99)
3	2 470	601 (24.33)	0.85 (0.76, 0.95)	0.85 (0.76, 0.95)
4	2 169	503 (23.19)	0.81 (0.72, 0.91)	0.82 (0.73, 0.92)
5 (least deprived)	2 369	541 (22.84)	0.79 (0.71, 0.89)	0.79 (0.71, 0.89)
P for trend			<0.001	<0.001
P for nonlinear trend			0.53	0.59
Year¶				
1997–2000	4 853	1248 (25.72)	1.07 (1.00, 1.16)	1.04 (0.96, 1.13)
2001–2003	7 167	1716 (23.94)	1.00	1.00
P-value			0.05	0.35

**The total number of admissions analysed is lower than in previous Tables, as episodes are only included for patients if the spell has ended and the method of discharge is known. †Complications occurring on day of RP excluded; the total count is lower as 79 patients were coded as having more than one radical prostatectomy operation between 1997 and 2003. ‡The mean annual volume of RPs was distributed into the following quintiles: 1–13, 14–20, 21–28, 29–41, 42–93. ¶Proportional hazards assumption was not satisfied for either age group or year of admission. There was evidence of an increased hazard of readmission for those aged ≥70 years at 6–12 months after RP. For those admitted between 1997 and 2000, the hazard was increased from 3–12 months after RP.*

TABLE 6 Multivariate models examining in-hospital complications within 30 days of RP, between financial years 1997 and 2003

	Odds ratio (95% CI)*						
Variable	Cardiac	Respiratory	Vascular	Wound/Bleeding	Genitourinary	Miscellaneous medical	Miscellaneous surgical
Volume of trust							
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.86 (0.64, 1.16)	0.98 (0.48, 2.00)	0.71 (0.36, 1.42)	0.90 (0.74, 1.09)	0.98 (0.80, 1.21)	0.76 (0.52, 1.11)	1.16 (0.80, 1.69)
3	0.84 (0.62, 1.15)	1.39 (0.71, 2.74)	0.74 (0.37, 1.50)	0.88 (0.72, 1.08)	0.91 (0.73, 1.13)	0.69 (0.47, 1.04)	1.15 (0.78, 1.69)
4	0.97 (0.71, 1.31)	1.45 (0.72, 2.92)	0.59 (0.27, 1.32)	0.84 (0.68, 1.04)	1.12 (0.90, 1.40)	0.74 (0.49, 1.12)	1.00 (0.66, 1.51)
High	0.96 (0.69, 1.34)	0.71 (0.29, 1.76)	0.78 (0.34, 1.78)	0.76 (0.60, 0.96)	1.11 (0.87, 1.44)	0.61 (0.38, 0.98)	1.19 (0.78, 1.84)
P for trend	0.979	0.894	0.371	0.022	0.347	0.043	0.669
P for nonlinear trend	0.586	0.222	0.765	0.934	0.427	0.719	0.729
Age group, years							
<60	0.55 (0.41, 0.75)	1.37 (0.77, 2.43)	0.85 (0.44, 1.66)	0.80 (0.66, 0.97)	0.78 (0.62, 0.98)	0.83 (0.59, 1.17)	0.98 (0.71, 1.35)
60–69	1.00	1.00	1.00	1.00	1.00	1.00	1.00
≥70	1.90 (1.49, 2.43)	2.63 (1.48, 4.69)	1.75 (0.94, 3.26)	1.68 (1.41, 2.00)	1.46 (1.22, 1.74)	1.16 (0.81, 1.67)	1.44 (1.04, 2.01)
P for trend	<0.001	0.784	0.255	<0.001	<0.001	0.173	0.330
P for nonlinear trend	<0.001	0.001	0.12	<0.001	<0.001	0.53	0.04
Charlson Index							
None	1.28 (0.97, 1.69)	0.86 (0.43, 1.69)	0.71 (0.32, 1.58)	2.02 (1.68, 2.42)	8.32 (6.94, 9.96)	1.05 (0.70, 1.57)	1.48 (1.03, 2.12)
Mild	3.94 (2.53, 6.14)	0.59 (0.08, 4.44)	6.54 (2.75, 15.57)	2.86 (1.97, 4.15)	8.22 (5.78, 11.69)	2.44 (1.18, 5.02)	4.03 (2.25, 7.23)
Moderate	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Severe	2.16 (1.57, 2.98)	3.05 (1.64, 5.66)	3.07 (1.52, 6.18)	1.13 (0.84, 1.51)	1.46 (1.03, 2.06)	2.00 (1.30, 3.08)	1.56 (0.98, 2.47)
P for trend	0.789	0.033	0.046	<0.001	<0.001	0.260	0.184
P for nonlinear trend	<0.001	0.04	<0.001	<0.001	<0.001	0.003	<0.001
Deprivation, IMD score							
1 (most deprived)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.07 (0.80, 1.43)	1.05 (0.55, 2.03)	2.10 (0.97, 4.54)	0.98 (0.80, 1.19)	1.08 (0.88, 1.33)	1.02 (0.69, 1.51)	1.01 (0.68, 1.51)
3	0.94 (0.70, 1.27)	0.70 (0.33, 1.45)	1.65 (0.74, 3.70)	0.96 (0.79, 1.17)	0.89 (0.72, 1.11)	1.00 (0.68, 1.48)	1.01 (0.68, 1.50)
4	0.89 (0.65, 1.21)	0.95 (0.47, 1.93)	1.50 (0.65, 3.50)	0.98 (0.80, 1.21)	0.95 (0.76, 1.20)	0.87 (0.57, 1.33)	1.07 (0.71, 1.61)
5 (least deprived)	0.97 (0.72, 1.32)	0.98 (0.50, 1.93)	1.43 (0.62, 3.34)	0.78 (0.63, 0.97)	1.07 (0.86, 1.34)	0.83 (0.55, 1.27)	1.62 (1.12, 2.34)
P for trend	0.491	0.832	0.762	0.056	0.998	0.289	0.011
P for nonlinear trend	0.78	0.69	0.28	0.44	0.27	0.95	0.31
Year							
1997–2000	0.92 (0.74, 1.14)	1.42 (0.87, 2.33)	1.73 (1.00, 2.98)	1.12 (0.96, 1.30)	1.25 (1.06, 1.46)	1.35 (1.01, 1.81)	1.26 (0.96, 1.66)
2001–2003	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P	0.445	0.162	0.051	0.141	0.008	0.041	0.102

TABLE 6 Continued

Variable	Odds ratio (95% CI)*						
	Cardiac	Respiratory	Vascular	Wound/Bleeding	Genitourinary	Miscellaneous medical	Miscellaneous surgical
Readmission within a year							
Volume of trust							
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.59 (1.09, 2.32)	1.16 (0.78, 1.74)	1.01 (0.74, 1.38)	1.10 (0.87, 1.38)	1.03 (0.91, 1.17)	1.17 (0.85, 1.61)	1.17 (0.90, 1.53)
3	1.23 (0.82, 1.86)	1.04 (0.68, 1.60)	0.71 (0.50, 1.02)	0.91 (0.71, 1.17)	1.01 (0.88, 1.15)	1.19 (0.86, 1.65)	0.97 (0.72, 1.29)
4	1.23 (0.80, 1.89)	0.91 (0.58, 1.43)	0.58 (0.39, 0.85)	0.82 (0.64, 1.06)	0.85 (0.74, 0.98)	0.88 (0.61, 1.25)	0.97 (0.72, 1.29)
High	1.46 (0.93, 2.29)	1.07 (0.68, 1.69)	0.61 (0.41, 0.93)	0.78 (0.60, 1.02)	0.84 (0.73, 0.98)	0.76 (0.51, 1.11)	0.89 (0.66, 1.22)
P for trend	0.364	0.837	0.001	0.010	0.002	0.078	0.212
P for nonlinear trend	0.123	0.716	0.459	0.504	0.218	0.150	0.470
Age group, years							
<60	0.59 (0.40, 0.88)	0.99 (0.70, 1.40)	0.77 (0.56, 1.04)	1.01 (0.84, 1.21)	0.89 (0.80, 0.98)	0.88 (0.67, 1.16)	0.69 (0.55, 0.87)
60–69	1.00	1.00	1.00	1.00	1.00	1.00	1.00
≥70	2.04 (1.49, 2.79)	1.77 (1.24, 2.52)	1.36 (0.99, 1.86)	1.21 (0.97, 1.51)	1.00 (0.88, 1.13)	1.57 (1.18, 2.09)	0.82 (0.62, 1.07)
P for trend	<0.001	0.011	0.004	0.238	0.044	0.002	0.093
P for nonlinear trend	0.50	0.05	0.87	0.23	0.18	0.15	0.003
Charlson Index							
None	1.58 (1.11, 2.24)	1.04 (0.69, 1.55)	0.71 (0.49, 1.03)	0.81 (0.62, 1.05)	0.49 (0.41, 0.59)	0.93 (0.67, 1.30)	0.80 (0.59, 1.09)
Mild	3.11 (1.67, 5.79)	1.63 (0.74, 3.58)	0.99 (0.43, 2.28)	1.52 (0.88, 2.63)	0.61 (0.38, 0.96)	1.25 (0.60, 2.58)	0.27 (0.07, 1.10)
Moderate	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Severe	2.34 (1.56, 3.52)	0.96 (0.54, 1.69)	0.98 (0.60, 1.58)	1.16 (0.86, 1.55)	1.10 (0.94, 1.28)	1.23 (0.82, 1.84)	0.88 (0.61, 1.27)
P for trend	0.462	0.793	0.093	0.069	<0.001	0.420	0.269
P for nonlinear trend	<0.001	0.53	0.71	0.20	0.01	0.62	0.06
Deprivation, IMD score							
1 (most deprived)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.95 (0.67, 1.35)	0.75 (0.51, 1.10)	0.85 (0.61, 1.19)	0.94 (0.74, 1.18)	0.89 (0.78, 1.01)	0.77 (0.56, 1.06)	0.96 (0.74, 1.25)
3	0.73 (0.50, 1.07)	0.63 (0.42, 0.94)	0.80 (0.57, 1.13)	0.90 (0.71, 1.14)	0.89 (0.79, 1.01)	0.69 (0.50, 0.97)	0.91 (0.69, 1.18)
4	0.71 (0.48, 1.06)	0.73 (0.49, 1.09)	0.88 (0.62, 1.25)	0.91 (0.72, 1.17)	0.83 (0.72, 0.95)	0.88 (0.64, 1.22)	0.85 (0.64, 1.13)
5 (least deprived)	0.67 (0.45, 0.99)	0.54 (0.35, 0.83)	0.64 (0.44, 0.93)	0.95 (0.75, 1.20)	0.85 (0.75, 0.97)	0.93 (0.68, 1.28)	0.86 (0.65, 1.13)
P for trend	0.013	0.006	0.042	0.609	0.009	0.877	0.187
P for nonlinear trend	0.89	0.55	0.61	0.89	0.47	0.11	0.99
Year:							
1997–2000	1.10 (0.83, 1.46)	0.90 (0.67, 1.21)	1.35 (1.04, 1.74)	0.90 (0.76, 1.07)	1.03 (0.94, 1.13)	0.93 (0.74, 1.18)	0.93 (0.76, 1.13)
2001–2003	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P	0.515	0.493	0.022	0.253	0.504	0.566	0.461

Notes as in Table 5.

Our data indicate, despite the limited evidence of its effectiveness [3,5,8] and the many men being operated on in both the USA and England, that RP cannot be considered a trivial procedure. In the UK, the National Institute for Clinical Excellence recommends that hospital Trusts undertaking radical surgery for prostate and bladder cancer perform at least 50 such operations each year [21]. However, <10% of Trusts did ≥50 RPs in 2004/5, and only 19.9% did ≥40 (allowing for the fact that on average each Trust undertaking radical urological surgery performs around 10 radical cystectomies per year [22]).

The present study has several limitations. First, the choice of what outcomes to analyse depended on the information contained in the HES database. We would have preferred to have captured data on all deaths within 30 days, but were limited to in-hospital deaths. In a relatively low-risk procedure such as RP, the quality of life amongst men after surgery is an essential consideration, predominantly in terms of subsequent erectile dysfunction and urinary incontinence, but we were unable to measure this. Second, adjustment for case-mix cannot be easily addressed within HES. We controlled for comorbidity (Charlson Co-morbidity Index), age and deprivation, all of which had univariate associations with in-hospital mortality, length of hospital stay, re-admissions and complications. However, residual confounding is a possible explanation for the variations observed, given the complex issues surrounding patient selection [15,23]. Third, we could not investigate the possibility of reverse causality, e.g. that hospitals achieving better outcomes receive more referrals and hence accrue larger volumes [15]. Finally, we could not examine the relative and/or synergistic effects of hospitals vs individual surgeon volume. Others have suggested that surgeon volume accounts for a large proportion of the apparent effect of hospital volume, regardless of the surgical volume of the hospital in which they practice [24]. Furthermore, surgeons undertaking a higher volume of operations may have better oncological operative outcomes in terms of negative margin rates and subsequently improved recurrence free survival. No attempt was made in the present study to analyse data according to individual surgeons, in part because such coding might not reflect who actually did the surgery (trainee or consultant), even though the individual carrying out the operation might be important to outcomes.

Several studies have shown that for complex, high-risk surgical oncology procedures (e.g. pancreatectomy, esophagectomy and liver resection [25]), hospitals performing more surgery have better outcomes, with absolute mortality differences between high- and low-volume hospitals of >10% [15]. Studies focusing on prostate cancer have shown smaller, less consistent absolute effects of hospital volume on mortality after RP (0.1–0.2% mortality differences in favour of higher-volume hospitals [15]). In the present study, although 30-day in-hospital mortality was greater in high- (0.76%) than low- (0.30%) volume hospitals, the attenuated effects in the fully adjusted model suggest that the association is at least partly explained by confounding, and very few deaths would therefore be saved by selective referral to high-volume hospitals for RP.

In line with the present study, others have shown small absolute differences between high- and low-volume hospitals in postoperative morbidity (27% vs 33%) [11]; urinary complications (20% vs 28% [11]); rates of readmission in 30 days (4.1% vs 5.0% [9]); any complications (26.3% vs 31.3% [9]); and length of stay (7.81 vs 8.51 days in one study [9], 6.1 vs 7.3 days in another [16]). In line with Lu-Yao *et al.* [13] and Alibhai *et al.* [12], we found that greater age was strongly associated with increased mortality, length of hospital stay, short-term complications and re-admissions. These age associations were not explained by comorbidity or deprivation, suggesting that for clinicians making recommendations about RP, age considerations are as important as the presence of comorbidity. There was evidence that greater deprivation was positively associated with death after RP, length of hospital stay and 1-year readmission rates in multivariate models. There was no evidence that this association was driven by differences in age or comorbidity, or selective referral of more deprived men to low-volume hospitals, as was shown in a previous USA study of complex surgery [26]. It will be important for future research to understand the mechanisms driving these socio-economic inequalities in RP outcome, so that the policy implications can be realized.

In conclusion, our national data suggest that in English hospitals the volume of RP is associated with the length of a man's hospital stay and the rates of some short- and long-term complications after RP. However, the magnitudes of these effects in population terms are small or largely explained by differences in case mix. A policy of selective referral to high-volume hospitals for some complex surgical procedures has been advocated [27], based for example on links between higher hospital volume and lower operative mortality for pancreatectomy, esophagectomy and liver resection [25]. Based on the outcomes studied, our data do not support calls for selective referral to high-volume hospitals for RP in the UK. Further research should investigate quality of life and oncological outcomes in relation to hospital RP volume.

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CONTRIBUTORS

R.M. and S.E. had the original idea for the study. A.J. undertook all the statistical analyses. All authors contributed to the interpretation and writing of the paper. R.M. is the guarantor.

CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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Abbreviations: **RP**, radical prostatectomy; **HES**, Hospital Episodes Statistics; **IQR**, interquartile range; **IMD**, Index of Multiple Deprivation; **ICD**, International Center for Disease.