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A Systematic Review of the Volume–Outcome Relationship for Radical Prostatectomy

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Abstract

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Context—Due to the complexity and challenging nature of radical prostatectomy (RP), it seems reasonable to suppose that both short- and long-term outcomes strongly depend on the cumulative number of cases performed by the surgeon as well as within the hospital.

Objective—To review systematically the association between hospital and surgeon volume and perioperative, oncologic, and functional outcomes after RP.

Evidence acquisition—A systematic review of the literature was performed, searching PubMed, Embase, and Scopus databases for original and review articles between January 1, 1995, and December 31, 2011. Inclusion and exclusion criteria comprised RP, hospital and/or surgeon volume reported as a predictor variable, a measurable end point, and a description of multiple hospitals or surgeons.

Evidence synthesis—Overall 45 publications fulfilled the inclusion criteria, where most data originated from retrospective institutional or population-based cohorts. Studies generally focused on hospital or surgeon volume separately. Although most of these analyses corroborated the impact of increasing volume with better outcomes, some others failed to find any significant effect. Studies also differed with respect to the proposed volume cut-off for improved outcomes, as well as the statistical means of evaluating the volume–outcome relationship. Five studies simultaneously compared hospital and surgeon volume, where results appear to suggest that the importance of either hospital or surgeon volume largely depends on the end point of interest.

Conclusions—Undeniable evidence suggests that increasing volume improves outcomes. Although it would seem reasonable to refer RP patients to high-volume centers, such regionalization may not be entirely practical. As such, the implications of such a shift in practice have yet to be fully determined and warrant further exploration.

Keywords

Prostatic neoplasms; Prostatectomy; Selective referral; Hospital volume; Surgeon volume; Regionalization

1. Introduction

More than 241 000 new cases of prostate cancer were predicted to be diagnosed in 2012, accounting for 29% of all newly diagnosed cancers in men [1]. A significant share of these patients will undergo radical prostatectomy (RP), the most popular definitive treatment for prostate cancer [2]. Contemporary large series have demonstrated that perioperative complication and mortality rates after RP are low but not inconsequential [3–6]. RP remains a challenging urologic procedure because the prostate is in close proximity to the bladder, rectum, and neurovascular supply to the penis. Thus an adequate resection without damaging surrounding tissue presents tradeoffs between cancer control and preservation of functional outcomes such as continence and potency. Since the advent of prostate-specific antigen screening, the incidence of low-risk prostate cancer has risen considerably. As a result, most men will die with prostate cancer, rather than from it. Such a phenomenon has prompted a shift of focus toward quality-of-life outcomes following surgical intervention.

On perioperative complications, a recurring topic is the volume–outcome relationship: in brief, that there is an association between improved surgical outcomes and the yearly caseload of either the operating surgeon or the hospital [7,8]. Given that we are in an age where quality of care after surgery has gained considerable importance in the medical literature, and its measures frequently used to determine the status of the hospital and the experience of the surgeon, the undertaking of an extensive review on the volume–outcome relationship and the possibility of regionalization of care in the context of RP is both timely and necessary. Additionally, the state of RP has evolved toward an increasing utilization of minimally invasive surgeries in recent years, where further insights are needed in the context of such a shift.

We sought to examine the effect of hospital and surgeon volume on perioperative, oncologic, and functional outcomes. The current review attempts (1) to provide an exhaustive list of all relevant studies that examined either surgical or hospital volume, or both, in the context of open and minimally invasive RP; (2) to provide deliberations on the volume–outcome relationship in the context of RP; and (3) to deliver opportune implications on the current practice of urologists, research, and education.

2. Evidence acquisition

2.1. Systematic search strategy

A systematic review was performed on studies that assessed the association between hospital or surgeon volume and outcomes after RP using the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2009 guidelines [9]. Two of the investigators (QDT, MS) performed a systematic search in PubMed, Embase, and Scopus of all studies published from January 1, 1995, to December 31, 2011. An example of a search included the following keywords: “hospital volume” OR “surgeon volume” OR “surgical volume” OR “workload” OR “caseload” OR “procedure volume” OR “procedural volume” *AND* (“surgical complications” OR “postoperative complications”[MeSH]) OR “mortality” OR (“survival rate”[MeSH] OR “survival”[MeSH]) OR “disease-free survival”[MeSH] OR “mortality” [MeSH] OR “neoplasm recurrence” OR “local”[MeSH] OR “recurrence”[MeSH] OR “treatment outcome”[MeSH] OR “treatment outcome”) *AND* “prostatectomy”[MeSH] OR “prostate cancer” OR “prostatectomy” OR “prostatic neoplasms”[MeSH]. We supplemented our searches by asking all other coauthors for details of additional studies.

2.2. Study selection

A stringent selection process of all acquired studies was implemented using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria [10]. The final studies were chosen if they fulfilled all of the following criteria: (1) The subject of the study is RP; (2) hospital and/or surgeon volume is reported as a predictor variable; (3) a measurable end point such as mortality, perioperative complications, or long-term complications is clearly defined; and (4) the study describes multiple hospitals or surgeons. For the purpose of the discussion, systematic reviews and meta-analyses [11–18] were not considered in the remainder of the review.

2.3. Data collection process

The following characteristics were collected from each study: end points, years, design, number of patients, origin of data, case mix factors for which statistical adjustment was made, volume cut-offs, type of statistical analysis, and conclusions. Study measures relied on risk, odds, or hazard ratios. It is notable that an unavoidable risk of bias across studies may have been applicable, given that many reports originated from the use of overlapping population-based cohorts (ie, Nationwide Inpatient Sample [NIS], Surveillance Epidemiology and End Results [SEER]). Consequently, we elected not to perform a meta-analysis and opted for the conventional narrative reviews of the literature [19]. Because patients treated at the same hospital or by the same surgeon may be more likely to experience similar outcomes, if surgical technique or supportive care practices varied among providers and these factors affected outcomes, we also verified whether the analysis accounted for the clustering of outcomes [20].

2.4. Review methods

Inclusion and exclusion of articles were determined by one reviewer (QDT) and confirmed by a second (MS). After a screening of 1854 articles, 45 studies were retained based on the STROBE criteria [10] and with the consensus of all of the authors of this paper.

3. Evidence synthesis

3.1. Results

3.1.1. Study characteristics—Our search retrieved 45 original articles examining the effect of volume on outcomes after RP. Overall, 12 studies were included with hospital volume as the defined variable (Table 1), 28 studies were included with surgeon volume as the independent factor (Table 2), and 5 studies were included with both hospital and surgeon volume as independent factors (Table 3). A total of 38 studies originated from the United States, 4 originated from the United Kingdom [21–24], and 3 originated from Canada [25–27]. In 26 studies, the results were risk adjusted for age and comorbidities. Twenty-two studies were adjusted for stage and/or grade. Adjustment for clustering was performed in 17 studies. Most of the studies examined hospital and surgeon volume using cut-off points, despite reported disadvantages [28]. These cut-offs were often chosen for presentation purposes, such as the stratification of patients into four equal quartiles. Alternatively, hospital and surgeon volume can be modeled as a continuous variable.

3.1.2. Quality of the studies—Most of these studies were population based (32 of 45), relying predominantly on either SEER-Medicare or the NIS. As such, it is important to understand the unique properties of these two population data sets: The NIS uses hospital-based discharge abstracts and is the sole hospital database in the United States with information on all patients regardless of payer or age, and it is nationally representative of American health care when sampling weights are applied. The NIS provides hospital charges that must be converted using estimated charges-to-cost ratios. Studies of Medicare claims are typically restricted to patients ≥65 yr of age under Medicare coverage but provide longitudinal claims beyond the index admission and actual Medicare reimbursements from hospitals, physicians, and other providers. In that regard, it should be noted that because most studies originated from North America, it remains questionable whether the reported relationship between volume and outcomes is as valid in other parts of the world. Overall, 12 of 45 studies relied on institutional series, where more detailed clinical characteristics and better follow-up information are included compared with observational population-based data. However, it should be cautioned that low-volume institutional series are unlikely to publish their data, and thus the presence of a publication bias is undeniable.

3.2. Radical prostatectomy hospital volume and outcomes

In the context of RP, three US-based studies have shown that increasing hospital volume is inversely associated with the risk of several important end points including mortality [4,5,29]. The RP volume-to-mortality association was also demonstrated in Canadian [26] and UK [21] population-based analyses. In absolute terms, regionalization of RP to high-volume providers in the United States would result in one avoidable event for every 500 RPs performed [29].

With regard to perioperative complications, Yao and Lu-Yao [5], relying on Medicare claims filed between 1991 and 1994, showed that hospital volume was inversely correlated with the risk of serious complications after RP, which was defined based on the consensus of the authors of that report. Specifically, relative to high-volume hospitals, low-volume, medium-low volume, and medium-high volume hospitals had higher relative risks of serious complications by 43%, 25%, and 9%, respectively. Subsequently, Begg et al [3] examined the effect of hospital volume on outcomes of 11 522 men undergoing RP in the SEER-Medicare database. They reported that 27% of patients treated by a high-volume hospital experienced complications versus 32% of those treated by a low-volume provider ($p = 0.03$, adjusted for case mix and clustering). Additionally, four subsequent studies corroborated the fewer perioperative complications and transfusions in higher RP volume hospitals [23,26,30,31].

The effect of increasing hospital volume on length of stay is also well documented [4,5,8,21,22,30,32–34]. In the Yao and Lu-Yao study [5], mean length of stay was about 10% lower comparing the highest with the lowest quartile of hospital volume. Because RP represents a relatively safe procedure, prolonged length of stay is rare. Nonetheless, it contributes significantly to RP costs. In this regard, several investigators sought to assess directly whether hospital charges vary with hospital volume. For example, using hospital volume as a predictor, Ellison et al [7] reported that hospital charges for RP were approximately 15% lower for high- compared with low-volume hospitals.

In other reports, the effect of hospital volume extends beyond the index admission: an inverse association between hospital volume and readmission [5] as well as the need for home health care or transfer to short-term facilities [32], despite adjustment for potential confounders. Lower rates of adverse discharges at high-volume hospitals demonstrate that these institutions are not simply shifting the burden of care from the inpatient to the outpatient setting.

Finally, hospital volume has been shown to affect long-term outcomes such as late urinary complications [3,23], improved recurrence-free survival [35], and the need for salvage therapy, defined as the use of hormone ablative or radiation therapy >6 mo after surgery [7]. With regard to the former, Begg et al [3] showed that late urinary complication rates (bladder neck obstructions, strictures, fistulas) were significantly lower at high-volume hospitals relative to low-volume hospitals ($p < 0.001$, adjusted for case mix and clustering). These findings were corroborated by Judge et al [23], using data from the UK Hospital Episode Statistics. With regard to oncologic outcomes, a study relying on SEER-Medicare data showed that patients treated at lower volume institutions are at increased risk of additional cancer therapy, used here as a proxy for cancer control [7]. However, adjustment for disease characteristics was limited to the limited SEER stratification for grade and stage. Finally, an interesting study by Imperato et al noted that the information contained in pathology reports of RP specimens was of higher quality at high-volume institutions [36].

3.3. Radical prostatectomy surgeon volume and outcomes

If hospital volume influences perioperative outcomes after surgery, then it is all the more likely that the caseload of the individual surgeon will also play a role. Indeed, the surgeon volume–outcome relationship might be particularly pertinent for some end points related to specific surgical maneuvers (eg, positive surgical margin rates or lymph node yield at lymphadenectomy), whereas some end points are more reflective of better organized perioperative hospital care. In this section, we summarize the current findings on this topic.

The relationship between surgeon volume and perioperative adverse events is well established. For example, Hu et al [8] assessed the role of surgical volume on the outcomes of 2292 RPs at 1210 hospitals performed by 1788 surgeons using 1997–1998 Medicare claims. Surgeon volume was classified as high volume (≥40 cases yearly) or low volume (<40 yearly), whereas hospital volume was classified as high volume (≥60 cases yearly) or low volume (<60 yearly). In adjusted analyses, high-volume surgeons had nearly a twofold decrease in overall complications (odds ratio [OR]: 0.53; range: 0.32–0.89) and shorter lengths of stay, relative to low-volume surgeons (4.1 vs 5.2 d; $p = 0.03$). Other studies focusing on length of stay [8,37–41], perioperative complications [3,8,24,41,42], urinary complications [3,24,39,41,42], and transfusions [38,43] corroborated these findings. A 2010 study focusing on minimally invasive RP (laparoscopic or robotic) also found much lower rates of complications in patients treated by high-volume surgeons, with an effect size approaching a 70% relative risk reduction [44].

With regard to mortality, a single UK study, relying on the Hospital Episode Statistics, showed a decreasing rate of surgical deaths with increasing RP volume. In this report, surgeon volume was dichotomized as low (<26 cases per year) versus high volume (≥26 cases per year). In analyses adjusted for age, waiting time, and admission type (emergent vs elective), mortality was statistically significantly lower in high-volume surgeons ($p = 0.009$). Conversely, many studies examining this relationship have not shown a clinical improvement in mortality. Possible explanations include the low rate of events. Alternatively, many investigators suggest that preventing deaths is more a function of hospital resources than surgical skills [45].

The effect of surgeon volume on oncologic outcomes has also been documented, in which increasing surgeon volume is inversely related to the rate of positive surgical margins

[24,46–49], the need for adjuvant therapy [27,41,50,51], and the risk of biochemical recurrence following RP [24,35,52–54]. For example, in the study by Vesey et al [24], relying on data from the British Association of Urological Surgeons complex operations database between 2004 and 2009, the unadjusted rates of positive surgical margins and biochemical recurrence were significantly different above versus below a threshold of 15–20 cases per year. Nonetheless, these findings were not replicated in a population-based assessment examining the same end point [55]. Similarly, lymphadenectomy is important for staging and possibly improving oncologic control, although the latter remains controversial. With regard to RP, previous investigators showed that since the advent of robotic training, variable rates of lymphadenectomy have been observed [56,57]. The rates of lymphadenectomy were lowest if RP was performed via the minimally invasive approach (17% vs 83% for minimally invasive vs open RP; $p < 0.001$). Minimally invasive surgeons are more likely to perform a lymphadenectomy at RP with increasing volume (rates of lymphadenectomy 6%, 9%, and 28% for low-, intermediate-, and high-volume surgeons; $p < 0.001$) [56,58]. There are also data suggesting that once lymphadenectomy is attempted, high-volume surgeons have higher nodal yields. Using a clinical data set, Briganti et al [59] reported a significant association between surgeon volume and node counts, ranging from 15 to 21 from lowest to highest volume. Of particular interest, all surgeons were using the same template for dissection and specimens were examined by the same pathologists, suggesting that nodal yield is influenced by surgical technique.

Empirical evidence supports the volume–outcome relationship with regard to functional outcomes. A study from Memorial Sloan-Kettering Cancer Center reported on functional outcomes at 1 yr for laparoscopic and open surgeons [60]. There was a statistically significant association between surgeon volume and full recovery of urinary and erectile function; for a typical patient, the probability of functional recovery—erectile function defined as an erectile rigidity score of 1 or 2, and urinary function defined as a score of 1—was 21% if treated by a surgeon with an annual volume of 25 versus 47% if the surgeon had an annual volume of 100.

Several investigators have looked at the effect of surgeon volume on hospital costs/charges. In the study by Leibman et al [37], RP performed by a high-volume surgeon (≥12 cases per year) was associated with a $214 average decrease in costs for the year 1996. Ramirez et al [61] examined this relationship in the state of Florida [57]. This study demonstrated that $4 million could be saved if 1000 RPs were redistributed from surgeons with an annual volume of 18 to surgeons with an annual volume of 200. Finally, a study focusing on minimally invasive RP demonstrated significantly higher costs for minimally invasive RP versus open RP for low-volume surgeons ($41 765 vs $35 642) [62]; the opposite trend was recorded in high-volume surgeons ($28 780 vs $32 726), purportedly due to decreased operative time, length of stay, and complications [63]. The additional cost of robotic surgery therefore strongly depends on how frequently the robot is used [64].

Adding to the complexities of the volume–outcome debate in the context of RP is the large-scale diffusion of minimally invasive procedures (ie, laparoscopic, robot assisted) in recent years [65]. Current discussions on minimally invasive RPs predominantly revolve around its comparative effectiveness relative to the open approach, with respect to long-term outcomes.

That said, the question of whether there is an association between volume and outcomes among men who underwent minimally invasive RP is pertinent. Although the current review did not explicitly discriminate between surgical techniques, 11 studies were based on minimally invasive RPs [34,40,41,44,49,50,54,62,63,66,67]. In those analyses, the volume–outcome relationship was equally apparent. It should be presumed that for surgeons or hospitals adopting such novel techniques, the practice-makes-perfect hypothesis might be valid. However, as RP transitions toward an increasing reliance on minimally invasive techniques, it becomes evident that the cumulative experience and learning curve of open surgeons cannot be overlooked for the sake of novelty. In that regard, an important analysis undertaken by Sammon and colleagues [34] conveys an imperative message, where results showed that patients treated at hospitals with a high open RP volume had significantly lower overall postoperative outcomes compared with patients treated at hospitals with a low robotic-assisted RP volume (OR: 0.59; 95% confidence interval [CI], 0.46–0.75), and even comparable rates of blood transfusions (OR: 1.38; 95% CI, 0.93–2.02). Furthermore, previous investigators have raised an important observation, where the rate of lymphadenectomy omission and administration of adjuvant radiotherapy was strongly correlated with surgical technique (open, minimally invasive) [57,59], both of which are strong determinants of oncologic outcomes. As minimally invasive surgeons increase their caseload in upcoming years, the considerations just described will become progressively more essential.

3.4. Relationship between hospital and surgeon volume

If both hospital and surgeon volume have shown to be independently associated with outcome, which has the greater impact? To date, only five reports have assessed the impact of both surgeon and hospital volume within the same cohort of patients. Hu et al [8] reported that surgeon volume was inversely related to complications and length of stay in men undergoing RP; there was no association with hospital volume after adjusting for individual surgical volume. In contrast, Begg et al [3] showed that both surgeon and hospital volumes were independent predictors of postoperative outcomes and late urinary complications. However, only surgeon volume independently predicted the risk of long-term incontinence. Conversely, Alibhai et al [26], relying on Canadian data, showed that only hospital volume was inversely correlated with mortality following RP. It is highly likely that whether surgeon or hospital volume drives the volume–outcome relationship depends on the end point. For example, it is difficult to see how hospital-level processes could affect biochemical recurrence, an end point that seems highly surgeon dependent. However, the risk of mortality is clearly influenced by postoperative care and thus not purely a function of surgeon volume. Further studies are needed to assess the roles of surgical and hospital volume simultaneously on different end points.

3.5. Critique of the volume–outcomes literature

It is not universally accepted that the relationship between volume and outcomes is a causal one. The debate essentially rests on two plausible hypotheses: the practice-makes-perfect theory or patient selection [66,68] to and by hospitals and/or physicians that seem to have better outcomes. Whereas the practice-makes-perfect hypothesis assumes a causal relationship between volume and outcome, the selective referral theory posits that apparently superior outcomes for high-volume providers result from case mix. For example, senior clinicians may delegate more junior staff to deal with the difficult cases most likely to have poor outcomes, leading to high-volume providers caring for patients at lower risk and obtaining apparently superior results [69]. There is some evidence in cardiology of a patient selection phenomenon (eg, that patients with a favorable prognosis for survival are selectively referred to high-volume hospitals) [70]. In other instances, it is plausible that high-risk patients may be selectively referred on to high-volume centers. Considering the selective referral and case mix scenarios, there is neither clear evidence confirming such effects nor a clear disconfirmation [71].

Most of the cited studies focus on the effect of structural variables, namely hospital and surgeon volume, on outcomes. The primary advantage of studying structural variables is expediency [72,73]. Relative to direct outcomes assessment, structural variables are easily and inexpensively assessed. Nonetheless, process measures are needed to substantiate the link between volume and outcomes. Whereas there is considerable evidence on the effect of specific processes of medical care on broad perioperative outcomes, such evidence is scant in the context of the technical aspects of RP. Significant data exist to support deep vein thrombosis prophylaxis, perioperative β-blockade, and antibiotic wound prophylaxis [67]. Actual improvements in processes of care specific to RP, however, are more often hypothesized than truly quantified. Uncovering the processes implicated in better care is needed to further understand the relationship between volume and outcomes.

Furthermore, the volume–outcome relationship is not always so clear cut from one study to another, where the absence of a statistically significant effect was at times reported. Such variable results may be related to the end point examined. For example, the association between increasing volume and perioperative mortality was not always observed, probably due to the low event rate, thereby limiting statistical power. Statistical power may also be affected by the categorization scheme used for hospital volume. For example, Hollenbeck et al examined the effect of the highest versus lowest decile of hospital volume and found a significant difference with respect to mortality [29]. Conversely, Trinh et al examined the effect of volume stratified according to tertiles, and they failed to detect any significant difference [74]. It also becomes clear that an additional problem is that currently no commonly accepted cut-off for surgical or hospital volume exists, where invariably better RP outcomes can be expected, nor is the urologic community in agreement on the number of cases that can be reliably described as high volume. The inability to identify this cut-off may be considered an argument against the practice-makes-perfect theory. In any case, it cannot be denied that due to the heterogeneity of the studied populations, as well as of the surgeons and hospitals themselves, it makes it even harder for data reconciliation and interpretation [75].

3.6. Practical implications

3.6.1. Current state of radical prostatectomy care—As demonstrated in the current review, considerable evidence supports the concept that increasing volume improves surgical outcomes. Yet in the context of RP, the distribution of surgeon volume shows that a large number of surgeons perform a small volume of RPs, at least in the United States [76].

Savage and Vickers, relying on the NIS and the Statewide Planning and Research Cooperative System (a database of all discharges in New York State), found that, of urologists performing RP, the most common number performed per year was a single procedure; 80% of surgeons performed ≤10 RPs; only 5% performed ≥50 cases.

As volume and outcomes reporting is incorporated into health care policy, either explicitly or by means of reimbursement changes such as those suggested by the Affordable Care Act, pay-for-performance or pay-for-participation care for complex surgeries such as RP may become further centralized. If a higher surgeon volume is associated with better cancer control and quality of care, then it is evidence based to have a small number of surgeons performing a large number of RPs, instead of many surgeons performing a few cases a year. According to a landmark study by Dudley et al [68], regionalization may significantly reduce adverse outcomes. In this study, the authors estimated that 602 deaths could have been prevented if selective referrals for complex surgeries had been mandated in the state of California for the year 1997. For RP, this would mean that receiving treatment at a high-volume center could thereby minimize duration of in-hospital stay, transfusions, erectile dysfunction, incontinence, and stricture outcomes that will take additional resources (eg, radiology, operating time, medications). In the setting of unsustainable health care costs in the United States, as an example, this action may significantly reduce inefficiency, improve outcomes, and save money [77].

An example of a large-scale initiative for volume-based referrals is the Leapfrog Group for Patient Safety, a coalition of corporations and agencies that buy health benefits on behalf of their enrollees [78]. Based on evidence supporting the volume–outcomes association, the Leapfrog Group initially established minimum hospital volume thresholds for five complex surgeries, and it has recently added two more procedures (aortic valve replacement and bariatric surgery). In the context of urologic oncology, studies have demonstrated that regionalization of care is gradually taking place. Cooperberg et al [79] used data from the NIS to examine temporal trends of hospital volume (1988–2002). The proportion of patients treated at high-volume hospitals increased moderately for bladder and kidney cancer (67–70% and 67–73%, respectively).

Nonetheless, although regionalization of RP may improve outcomes, up to 80% of hospitals would have to stop offering RP. From a realistic policy perspective, there would be a clear disconnect from the conceptual planning and implementation of regionalization; it is not possible to fully redirect hundreds of thousands of men, due to travel distances and expenses and queues, to the 5% of providers with high caseloads. Such provisions would likely widen the gap in quality of care for certain individuals, especially those in rural and/or underserved areas [80]. If regionalization of RP is considered, it would require an established absolute measure of what would be deemed as high volume for hospitals and for surgeons.

Raising the overall quality of care through a collaborative improvement among urologists may be the vanguard of improving outcomes following RP [81]. Such a strategy may be less disruptive and result in a more optimal long-term impact. However, such a collaborative strategy requires providers to perform a minimal threshold of cases that would allow such quality to be measured and improved upon. Nonetheless, in upcoming years, experiments in the delivery of care will probably provide the next major advancement in the field of surgery [82].

Some approaches to improve RP care may be advanced. As already discussed, complete regionalization of RP care remains controversial due to desirability and feasibility. Nonetheless, there is a need for a thorough assessment and measure of procedure-specific processes, with the intent of reaching the level of care with the best outcomes [83]. Indeed, the volume–outcomes literature has demonstrated large differences in outcomes between surgeons; what has not been fully explored is why. For example, there is a 10-fold difference in biochemical recurrence between more and less experienced surgeons [84]. What exactly it is that experienced surgeons are doing differently has not been established. The urologic community should consider empirical research on differences in surgical technique, in an attempt to identify specific aspects of technique that lead to improved outcomes. Centralized outcomes measurement, modeled after the high standards set by bariatric surgeons [85], may be an ideal setting to ensure appropriate control of quality and process compliance [86].

4. Conclusions

Considerable evidence indicates that increasing volume improves surgical outcomes, and the most plausible hypothesis is that the relationship is a causal one. There is also considerable evidence that outcomes vary, even between surgeons with similar volume. It would seem reasonable to refer prostate cancer patients to high-volume centers that monitor outcomes and have implemented quality assurance programs. That being said, given the lack of level 1 evidence on the topic, the overlapping populations from one study to another, as well as the variable end points and methodologies used, the undertaking of a systematic evaluation of the volume–outcome literature in the context of RP remains problematic. Consequently, the implications of a shift in practice have yet to be fully determined.

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Table 1

Studies examining the association between hospital volume and patient outcome after radical prostatectomy*

Study	Design	Data source	Risk adjustment	Hospital volume	End points
Yao and Lu-Yao [5]	Retrospective	SEER Medicare claims (n = 101 604), 1991–1994	Age, race, CCI, surgeon specialty, teaching status	RP volume Categorized in 4 groups: ≤38 (low), 39–74 (medium-low), 75–140 (medium-high), ≥141 (high)	30 d Mortality (RR; 95% CI): low vs high (1.51; 1.25–1.77), medium-low vs high (1.43; 1.17–1.69), medium-high vs high (1.42; 1.16–1.68) Major complications (RR; 95% CI): low vs high (1.43; 1.37–1.48), medium-low vs high (1.25; 1.19–1.31), medium-high vs high (1.09; 1.03–1.15) Prolonged length of stay (mean; 95% CI): low (8.5 d; 8.47–8.56), medium-low (8.2 d; 8.1–8.2), medium-high (7.7 d; 7.7–7.7), high (7.8 d; 7.8–7.9), $p < 0.001$
Ellison et al [4]	Retrospective	NIS (n = 66 693), 1989–1995	Age, CCI	RP volume Categorized in 3 groups: <25/yr (low), 25–54/yr (medium), >54/yr (high)	In-hospital Mortality (OR; 95% CI): low vs high (1.8; 1.2–2.6), medium vs high (1.7; 1.1–2.5) Prolonged length of stay (median): low (5 d), medium (4 d), high (4 d); $p < 0.001$ Total hospital charges (median): low ($15 560), medium ($15 100), high ($13 500); $p < 0.001$
Imperato et al [36]	Cross sectional	SEER Medicare beneficiaries in New York State (n = 583), 1996 only	–	RP volume categorized in 3 groups: [1] 1–4, [2] 5–9, [3] ≥10	RP specimen on operative quality indicators: perineural involvement, vascular involvement, periprostatic fat status, number of nodes submitted, prostate intraepithelial neoplasia (all $p < 0.05$)
Ellison et al [7]	Retrospective	SEER Medicare claims (n = 12 635), 1990–1999	Age, CCI, tumor grade, clinical stage	RP volume categorized in 4 groups: low (1–33), medium (34–61), high (62–108), very high (≥108)	Risk of adjuvant therapy (HR; 95% CI): high vs very high (1.0; 0.9–1.1; $p = 0.6$), medium vs very high (1.1; 1.0–1.2; $p = 0.02$), low vs very high (1.3; 1.1–1.4; $p < 0.001$)
Hollenbeck et al [29]	Retrospective	NIS (n = 141 052), 1993–2003	Age, CCI, race, admission acuity, insurance status	RP volume categorized in 2 groups: low (bottom decile), high (top decile)	In-hospital mortality (OR; 95% CI): low vs high (3.9; 1.8–7.9) Prolonged length of stay (OR; 95% CI): low vs high (4.8; 3.5–6.7)
Judge et al [23]	Retrospective	Hospital Episode Statistics, Department of Health in England (n = 18 027), 1997–2004	Age, CCI, Socioeconomic status, year of surgery	RP volume categorized in 5 groups: low (1–13), 2nd (14–20), 3rd (21–28), 4th (29–41), high (42–93)	Perioperative complications (OR; 95% CI): 2nd vs low (0.9; 0.8–1.1), 3rd vs low (0.9; 0.8–1.0), 4th vs low (1.0; 0.9–1.1), high vs low (0.9; 0.8–1.1) Late urinary complications (OR; 95% CI): 2nd vs low (1.0; 0.9–1.2), 3rd vs low (1.0; 0.9–1.2), 4th vs low (0.8; 0.7–1.0), high vs low (0.8; 0.7–0.9)
Siu et al [33]	Retrospective	NIS (n = 9266), 2003 only	Age, CCI, race, socioeconomic status, admission acuity, hospital structure characteristics	RP volume Categorized in 3 groups: low (≤32), medium (33–82), high (83–383/yr)	Prolonged length of stay (OR; 95% CI): low vs high (3.7; 2.0–6.8; $p < 0.001$)
Mitchell et al [31]	Retrospective	University HealthSystem Consortium Clinical Data Base (n = 48 086), 2003–2007	Hospital size, hospital region, total hospital discharges	RP volume was categorized in 3 groups: low (1–99), medium (100–499),	Prolonged length of stay (mean; p value): low 3.8 d), medium (2.7 d), high (2.1 d); $p < 0.001$ Intensive care unit (%, p value): low (19%), medium (4%), high (1.3%); $p < 0.001$ Postoperative complications (%, p value): low (16%), medium (8.8%), low (5.7%); $p < 0.001$ In-hospital mortality: $p > 0.05$

Study	Design	Data source	Risk adjustment	Hospital volume	End points
Hanchanale et al [22]	Retrospective	Hospital Episode Statistics, Department of Health in England (*n* = 14 300), 1998–2005	Age, waiting time	RP volume categorized in 4 groups: very low (≤16), low (16–25), medium (25–37), high (≥38/yr)	Perioperative mortality (%): very low (0.4%), low (0.3%), medium (0.1%), high (0.2%); $p = 0.08$ Prolonged length of stay (% above 75th percentile): very low (36%), low (25%), medium (16%), high (23%); $p < 0.001$
Trinh et al [30]	Retrospective	NIS (*n* = 89 965), 2001–2007	Age, CCI, race, surgical approach, hospital region, teaching status, insurance status, year of surgery	RP volume categorized in 3 groups: low (≤34), intermediate (35–90), high (≥91/yr)	Homologous blood transfusion (OR; *p* value): high vs low (0.35, $p < 0.001$) Prolonged length of stay (OR; *p* value): high vs low (0.19; $p < 0.001$) Intraoperative complications (OR; *p* value): high vs low (0.80; $p = 0.01$) Postoperative complications (OR; *p* value): high vs low: 0.63; $p < 0.001$
Trinh et al [32]	Retrospective	NIS (*n* = 89 965), 2001–2007	Age, CCI, race, surgical approach, hospital region, hospital location, teaching status, insurance status, morbidity status, year of surgery	RP volume categorized in 3 groups: low (≤34), intermediate (35–90), high (≥91/yr)	Prolonged length of stay (OR; *p* value): high vs low (0.2; $p < 0.001$), intermediate vs low (0.5; $p < 0.001$) Adverse discharge disposition (OR; *p* value): high vs low (0.6; $p < 0.001$), intermediate vs low (0.5; $p < 0.001$)
Sammon et al [34]	Retrospective	NIS (*n* = 77 616), 2009 only	Age, CCI, race, insurance status, teaching status, hospital location, hospital region, surgical approach, year of surgery	RP volume categorized in 4 groups: low (≤14), intermediate (15–32), high (33–78), very high (≥79/yr)	Available in original publication

CCI = Charlson Comorbidity Index; CI = confidence interval; NIS = Nationwide Inpatient Sample; OR = odds ratio; RP = radical prostatectomy; RR = relative risk; SEER = Surveillance Epidemiology and End Results.

*Displayed in chronological order.

Table 2

Characteristics of studies examining the association between surgeon volume and patient outcome after radical prostatectomy*

Study	Design	Data source	Risk adjustment	Surgical volume	End points
Litwiller et al [38]	Retrospective	Hospital records (n = 428), 1984–1994	Age, CCI, tumor stage	Continuously coded	Estimated blood loss: $p > 0.05$ Blood transfusion: $p > 0.05$ Prolonged length of stay: r^2: 0.23; $p < 0.05$
Karakiewicz et al [25]	Retrospective	Quebec Health Plan Claims Data (n = 4997), 1988–1996	Age, physician age, hospital type, year of surgery	Continuously coded	30-d mortality: $p > 0.05$
Leibman et al [37]	Planned Clinical Pathway Implementation Baseline Analysis	Hospital records, before and after pathway implementation (n = 856), 1994–1997	–	RP volume categorized in 2 groups: low (<12), high (≥12)	Prolonged length of stay: low (5.8 d), high (5.3 d); $p < 0.001$ Hospital charges: low ($11 798), high ($11 113); $p < 0.001$
Eastham et al [47]	Retrospective	Hospital records (n = 4269), 1983–2002	PSA, clinical stage, tumor grade, surgery data, surgeon	Continuously coded	Positive surgical margins: coefficient: −0.0007; $p = 0.01$
Dash et al [43]	Prospective	Consecutive prospectively enrolled patients	Age, race, Administration of hormonal therapy, clinical stage, tumor grade, prostate volume anesthesia type	RP volume categorized in 2 groups: low (≤15), high (>15/yr)	Blood transfusion (OR; 95% CI): low vs high (8.6; 3.95–18.86)
Bianco et al [42]	Retrospective	SEER Medicare claims (n = 5238), 1992–1996	Age, CCI, stage, hospital volume	RP volume categorized in 2 groups: low (<20), high (≥20/yr)	Perioperative Complications $p < 0.001$ Late urinary Complications $p < 0.001$ Long-term incontinence: $p < 0.001$
Chun et al [46]	Retrospective	Hospital records (n = 2402), 1996–2004	PSA, clinical stage, tumor grade	Continuously coded	Positive surgical margins (OR; p value): 1.01; $p < 0.001$
Ramirez et al [61]	Retrospective	Florida Inpatient Data	Age, CCI, race	Continuous	Total hospital charges (coefficient, p value): −25.0, $p < 0.001$)
Vickers et al [71]	Retrospective	Multi-institutional series (n = 7765), 1987–2003	PSA, clinical stage, tumor grade	RP volume categorized in 5 groups: 1st (<50), 2nd (50–99), 3rd (100–249), 4th (250–999), 5th (>999)	Biochemical recurrence (%; 95% CI): ≤10 cases (18%; 12–26%) >250 cases (11%; 7–16%); $p < 0.001$
Briganti et al [59]	Retrospective	Institutional series (n = 120), 2002–2007	PSA, clinical stage, tumor grade	RP volume categorized in 2 groups: low (≤144 extended PLND), high (>144 extended PLND) and Continuously coded	Lymph node invasion (OR; p value): continuously coded (1.001; $p = 0.04$), high vs low (1.8; $p = 0.009$)
Hu et al [41]	Retrospective	SEER Medicare claims (n = 2702), 2003–2005	Age, CCI, race, hospital region	Continuously coded	Perioperative complications (OR; 95% CI): 0.98; 0.95–1.02); $p = 0.05$ Prolonged length of stay (coefficient; 95% CI): 0.006 (−0.03; 0.04) Risk of salvage therapy (OR; 95% CI): 0.92; 0.88–0.98; $p < 0.05$) Anastomotic strictures (OR; 95% CI): 0.93; 0.87–0.99; $p < 0.05$

Study	Design	Data source	Risk adjustment	Surgical volume	End points
Jeldres et al [27]	Retrospective	Quebec Health Plan Claims Data (*n* = 7937), 1989–2000	Age, CCI	Cubic spline	Risk of secondary therapy: biphasic relationship: $p = 0.02$ (up to 24 RPs performed)
Klein et al [53]	Retrospective	Multi-institutional series (*n* = 7683), 1987–2003	Clinical stage	RP volume categorized in 5 groups: 1st (≤49), 2nd (50–99), 3rd (100–249), 4th (250–999), 5th (≥1000) and 2 groups: low (≤10), high (≥250)	Biochemical recurrence: Low risk (absolute difference between high and low, 95% CI): 2.5%, 1.7–4.0%; $p < 0.001$ Intermediate risk (absolute difference between high and low, 95% CI): 1.9%, 1.5–2.6%; $p < 0.001$ High risk (absolute difference between high and low, 95% CI): 1.3%, 1.0–1.6%; $p = 0.02$
Prasad et al [56]	Retrospective	Medicare claims (*n* = 2072), 2003–2005	Age, CCI, race, hospital region, surgical approach	Continuously coded	Rate of PLND (OR; 95% CI): 1.14; 1.10–1.19; $p = 0.05$
Kattan et al [52]	Retrospective	Multi-institutional series (*n* = 7724), 1987–2003	PSA, clinical stage, tumor grade	Continuously coded	Biochemical recurrence Preoperative risk: (concordance index): 0.767 with surgeon volume vs 0.764 without surgeon volume ($p = 0.1$) Postoperative risk: (concordance index): 0.812 with surgeon volume vs 0.811 without surgeon volume ($p = 0.1$)
Vickers et al [54]	Retrospective	Multi-institutional series (*n* = 4702), 1998–2007	PSA, clinical stage, tumor grade	RP volume categorized in four groups: 1st (<50), 2nd (50–99), 3rd (100–249), 4th (≥250)	Biochemical recurrence (absolute risk difference, 95% CI): ≤10 vs ≥750 cases (8%, 4–12%; $p = 0.005$)
Choi et al [50]	Retrospective	SEER Medicare claims (*n* = 8831), 2003–2007	Age, CCI, race, marital status, education, income, population density, clinical stage, tumor grade	RP volume categorized in 3 groups, according to surgical technique: *MIRP* low (≤17), medium (18–52), high (53–424) *ORP* low (≤11), medium (12–25), high (24–94)	Risk of adjuvant therapy MIRP low (7%), medium (4.7%), high (4.5%); $p = 0.02$ ORP low (7%), medium (6.8%), high (5.7%); $p = 0.04$ Prolonged length of stay MIRP low (2.3%), medium (1.9%), high (1.8%); $p = 0.02$ ORP low (3.6%), medium (3.3%), high (2.8%); $p < 0.001$ Blood transfusion MIRP low (23%), medium (21%), high (16%); $p = 0.01$ ORP low (3.3%), medium (2.0%), high (1.6%); $p = 0.3$ Postoperative complications MIRP low (22%), medium (21%), high (22%); $p = 0.9$ *ORP* low (26%), medium (21%), high (16%); $p = 0.01$ Stricture *MIRP* low (6.4%), medium (4.6%), high (5.4%); $p = 0.5$ ORP low (16%), medium (16%), high (9.7%); $p < 0.001$ Secondary therapy MIRP low (7.2%), medium (4.6%), high (4.8%); $p = 0.01$ *ORP* low (7.0%), medium (7.0%), high (5.8%); $p = 0.1$
Lowrance et al [39]	Retrospective	SEER Medicare claims (*n* = 5923)	Age, CCI, race, location, marital status, income, PSA, clinical stage, pathologic	Continuously coded	Prolonged length of stay ($p < 0.001$) Medical or surgical complications ($p = 0.3$) Urinary Complications ($p < 0.05$)

Study	Design	Data source	Risk adjustment	Surgical volume	End points
			stage, number of lymph nodes examined, lymph node involvement, Gleason score, year of diagnosis stage, number of lymph nodes examined, lymph node involvement, Gleason score, year of diagnosis stage, number of lymph nodes examined, lymph node involvement, Gleason score, year of diagnosis stage, number of lymph nodes examined, lymph node involvement, Gleason score, year of diagnosis		
Vickers et al [60]	Retrospective	Single institutional series (n = 1910), 1999–2007	Age, CCI, PSA, clinical stage, tumor grade, year of surgery	Continuously coded	1-yr erectile and urinary function Probability of recovery: ≤25/yr (21%), ≥100/yr (47%); p = 0.005
Vickers et al [48]	Retrospective	Multi-institutional series (n = 7765), 1987–2003	PSA, clinical stage, tumor grade, year of surgery	RP volume categorized in 5 groups: 1st (<50), 2nd (50–99), 3rd (100–249), 4th (250–999), 5th (≥1000)	Positive surgical margins (relative risk difference, 95% CI): ≤10 vs ≥250/yr (1.59, 1.43–1.76); p = 0.02
Secin et al [49]	Retrospective	Multi-institutional series (n = 8544), 1998–2007	PSA, clinical stage	RP volume categorized in 4 groups: 1st (<50), 2nd (50–99), 3rd (100–249), 4th (250–1100)	Positive surgical margins (relative risk difference, 95% CI): ≤10 vs ≥ 250/yr (4.8; 1.5–8.5); p = 0.007
Budäus et al [40]	Retrospective	Florida Hospital Inpatient Datafile (n = 2439), 2002–2008	Age, CCI, race, year of surgery, hospital volume	RP volume categorized in 3 groups: low (≤15), intermediate (16–63), high (64–171)	Prolonged length of stay (OR, 95% CI): intermediate vs low (0.36; 0.27–0.50; p < 0.001), high vs low (0.29; 0.22–0.38; p < 0.001)
Budäus et al [63]	Retrospective	Florida Hospital Inpatient Datafile (n = 2666), 2002–2008	Age, CCI, race, year of surgery	RP volume categorized in 3 groups: low (≤15), intermediate (16–63), high (64–171)	Total hospital charges (OR; 95% CI): intermediate vs low (0.41; 0.33–0.51; p < 0.001), high vs low (0.10; 0.06–0.10, p < 0.001)
Budäus et al [44]	Retrospective	Florida Hospital Inpatient Datafile (n = 2666), 2002–2008	Age, CCI, race, year of surgery	RP volume categorized in 3 groups: low (≤16), intermediate (17–76), high (77–500/yr)	Complications (OR; 95% CI): intermediate vs low (0.45; 0.33–0.63; p < 0.001), high vs low (0.28; 0.19–0.41; p < 0.001) Transfusions (OR; 95% CI): intermediate vs low (0.26; 0.13–0.61; p < 0.001), high vs low (0.15; 0.10–0.39; p < 0.001)
Hu et al [58]	Retrospective	SEER Medicare claims (n = 5448), 2004–2006	Age, CCI, race, risk groups, hospital region surgical approach	Continuously coded	Rate of PLND (OR; 95% CI): 1.008 (1.004–1.011); p < 0.001
Vesey et al [24]	Retrospective	BAUS Section of Oncology Complex Operations Database	Age, CCI, PSA, clinical stage, tumor grade	Continuously coded	Intraoperative complications Postoperative complications Positive surgical margins p < 0.01 Biochemical recurrence OR: 0.98; p < 0.05
Williams et al [51]	Retrospective	SEER Medicare claims (n = 42 47)	Age, CCI, race, PSA, clinical stage, tumor grade, surgical approach, hospital region, year of surgery	RP volume categorized in 4 groups: *ORP* low (≤7), intermediate (8–15), high (16–29), very high (≥30) MIRP low (≤14), intermediate (15–36), high (37–89), very high (≥90)	Positive surgical margins; p > 0.05
Williams et al (2011)	Retrospective	SEER Medicare claims (n = 4247)	Age, CCI, race, marital status, education, income, region, population density, clinical stage, tumor grade,	RP volume categorized in 4 groups: *ORP* low (≤7), intermediate (8–15), high (16–29), very high (≥30) MIRP low (≤14),	Risk of adjuvant cancer therapy (HR; 95% CI): very high vs low (0.60; 0.46–0.78, p < 0.001). All other volume categories were p > 0.05

Study	Design	Data source	Risk adjustment	Surgical volume	End points
			PSA, risk groups, year of surgery PSA, risk groups, year of surgery	intermediate (15–36), high (37–89), very high (≥90)	

CCI = Charlson Comorbidity Index; CI = confidence interval; MIRP = minimally invasive radical prostatectomy; NIS = Nationwide Inpatient Sample; OR = odds ratio; ORP = open radical prostatectomy; PLND = pelvic lymph node dissection; PSA = prostate-specific antigen; RP = radical prostatectomy; SEER = Surveillance Epidemiology and End Results.

*Displayed in chronological order.

Table 3

Characteristics of studies examining the association between surgeon/hospital volume and patient outcome after radical prostatectomy*

Study	Design	Data source	Risk adjustment	Hospital volume	Surgical volume	Statistically Significant end points
Begg et al [3]	Retrospective	SEER Medicare claims (*n* = 11 522), 1992–1996	Age, CCI, race, clinical stage	RP volume Categorized in 4 groups: low (≤33), medium (34–61), high (62–107), very high (≥114)	RP volume Categorized in 4 groups: low (≤10), medium (11–19), high (20–32), very high (≥33)	Perioperative complications (%) Hospital volume low (32%), medium (31%), high (30%), very high (27%); $p = 0.03$ Surgical volume low (32%), medium (31%), high (30%), very high (26%); $p = 0.001$ Late urinary Complications (%) Hospital volume low (28%), medium (29%), high (23%), very high (20%); $p < 0.001$ Surgical volume low (28%), medium (26%), high (27%), very high (20%); $p < 0.001$ Long-term Incontinence (%) Surgical volume low (20%), medium (20%), high (19%), very high (16%); $p = 0.04$
Hu et al [8]	Retrospective	SEER Medicare claims (*n* = 2292). 1997–1998	Age, CCI, race, hospital type, hospital region, year of surgery	RP volume Categorized in 2 groups: low (<40), high (≥60/yr)	RP volume Categorized in 2 groups: low (<40), high (≥40/yr)	Anastomotic stricture (%) Hospital volume low (27%), high (20%); $p = 0.01$ Surgical volume low (22%), high (12%); $p = 0.01$ Perioperative complications Hospital volume low (22%), high (17%); $p = 0.05$ Prolonged length of stay (mean) Hospital volume low (5.2 d), high (4.4 d); $p = 0.01$ Surgical volume low (5.2 d), high (4.1 d); $p = 0.01$
Gooden et al [35]	Retrospective	SEER Medicare claims (*n* = 8349), 1991–2002	Age, CCI, race, clinical stage, tumor grade	RP Categorized in 3 groups: low (≤63), medium (64–116), high (≥138)	RP categorized in 3 groups: low (≤9), medium (10–19), high (20–77)	Recurrence-free survival time: hospital volume low vs high: 25th percentile, 45 mo, 95% CI, 42.0–50.0 vs 64 mo, 95% CI, 57.0–70.0 Surgical volume low vs high: 25th percentile, 60 mo, 95% CI, 54.0–68.0 vs 73 mo, 95% CI, 66.0–81.0
Hanchanale et al [21]	Retrospective	Hospital Episode Statistics, Department of Health in England	Age, admission acuity, waiting time	RP categorized in 2 groups: low (<26), high (≥26/yr)	RP categorized in 2 groups: low (<16), high (≥16/yr)	Perioperative mortality (OR; 95% CI) Hospital volume high vs low (0.4; 0.17–0.90; $p = 0.028$) Surgical volume high vs low (0.32; 0.13–0.75); $p = 0.009$
Alibhai et al [26]	Retrospective	Canadian Institute for Health Information (*n* = 25 404), 1990–2001	Age, CCI, year of surgery	Continuously coded	Continuously coded	In-hospital mortality (OR; 95% CI): Hospital volume (0.82; 0.69–0.99; $p = 0.037$) Complications (OR; 95% CI): Hospital volume (0.89; 0.87–0.91; $p < 0.001$ Surgical volume (0.84; 0.82–0.87; $p < 0.001$)

CCI = Charlson Comorbidity Index; CI = confidence interval; MIRP = minimally invasive radical prostatectomy; NIS = Nationwide Inpatient Sample; OR = odds ratio; ORP = open radical prostatectomy; PLND = pelvic lymph node dissection; PSA = prostate-specific antigen; RP = radical prostatectomy; SEER = Surveillance Epidemiology and End Results.

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