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Minimally Invasive Treatment for Benign Prostatic Hyperplasia: Economic Evaluation from a Standardized Hospital Case Costing System

Andrew D. Brown[1] · Steffan F. Stella[2] · Martin E. Simons[1]

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Abstract
Purpose Minimally invasive alternatives to transurethral resection of the prostate (TURP) such as prostate arterial embolization (PAE) and photoselective vaporization of the prostate (PVP) are being explored as adjuncts in the care of patients with benign prostatic hyperplasia. However, there are conflicting reports of the costs of these procedures. The purpose of this study was to compare the direct and indirect hospital costs of TURP, PAE and PVP.
Materials and Methods A chart review was performed in patients who underwent TURP, PVP and PAE from April 2015 to March 2017. All hospital costs were collected in accordance with the Ontario Case Costing Initiative, a standardized medical case costing system. Costs were characterized as direct or indirect and fixed or variable. Probabilistic sensitivity analysis was conducted to study cost uncertainty.
Results During the study period, a total of 209 men underwent TURP, 28 PVP and 21 PAE. Mean age (years) was as follows: TURP 71.43; PVP 73.66; PAE 70.77 ($p = 0.366$). Mean length of stay (days) was as follows: TURP 1.63; PVP 1.55; PAE 1 ($p = 0.076$). Total costs of the PAE group ($3829, SD $1582) were less than both PVP ($5719, SD $1515) and TURP groups ($5034, SD $1997, $p < 0.001$). There was no significant difference in direct costs between the groups. Monte Carlo simulation demonstrated that PAE was the least costly alternative majority of the time.
Conclusions The total hospital costs of PAE at our institution are significantly lower than those of PVP and TURP.

Keywords BPH · Cost · Prostate artery embolization (PAE) · Photoselective vaporization of the prostate (PVP) · TURP

Introduction

Benign prostatic hyperplasia (BPH) is characterized histologically by the nonmalignant proliferation of the epithelial and stromal components of the prostate [1]. These progressive hyperplastic changes are found in over 50% of 60-year-old men and nearly 90% of 85-year-old men [2]. Although benign, this condition can cause significant lower urinary tract symptoms (LUTS). Over 30% of men 65 years of age and older have bothersome urinary symptoms attributed to BPH [3]. The overall BPH cost of care in the USA is estimated to be in between $2.3–4 billion per year [4], and around 20,000 surgical treatments for BPH are performed per year in Canada [5].

Transurethral resection of the prostate (TURP) represents the gold standard in surgical treatment of BPH. However, the surgery is invasive with perioperative and postoperative morbidity seen in up to 20% of cases [6, 7].

✉ Andrew D. Brown
andrew.brown@uhn.ca

[1] Division of Vascular and Interventional Radiology, Department of Medical Imaging, Toronto General Hospital, University Health Network, University of Toronto, 585 University Ave, Toronto, ON M5G 2N2, Canada

[2] Division of Vascular and Interventional Radiology, Department of Radiology, Hamilton Health Sciences, McMaster University Medical Centre, McMaster University, Hamilton, ON, Canada

Up to 10% of patients continue to experience LUTS after TURP with reoperation rates of 1–2% annually [8, 9]. In addition, TURP requires a significant amount of resources in the form of inpatient services, anesthesia and recovery time.

With the risk of postoperative complications, greater emphasis is being placed on the alternatives to traditional TURP. Two such alternatives are photoselective vaporization of the prostate (PVP) and prostate artery embolization (PAE). In PVP, a high-powered potassium titanyl phosphate (KTP) laser light combined with fiber optics vaporizes the overgrown prostate via a transurethral approach. Research suggests that PVP has the potential to provide similar outcomes to TURP [10–12], but at lower cost [13–15]. As an additional benefit, PVP can be performed in an outpatient setting. PAE is an emerging, minimally invasive treatment where embolic material is endovascularly inserted into the branches of the prostatic artery, blocking blood flow to the prostate and causing it to shrink [16]. Recent studies have shown PAE to be comparable to TURP with fewer complications and minimal convalescence [17–20].

These minimally invasive alternatives to TURP have the potential to reduce costs and resource utilization at the hospital level. The purpose of this study was to analyze the costs of PAE, PVP and TURP in patients with BPH. To our knowledge, there are no published economic evaluations of PAE, PVP and TURP together.

Materials and Methods

The research ethics board (REB) at our institution approved this retrospective chart review study. The study was also compliant with the Health Insurance Portability and Accountability Act (HIPAA).

A chart review was performed in patients who underwent TURP, PVP and PAE from April 2015 to March 2017. The time period was chosen as this represents the beginning of our PAE experience. Canadian Classification International of Health Interventions (CCI) procedure codes were used to identify patients with BPH who underwent TURP and PVP. Patients undergoing PAE were identified from the radiology information system (RIS) using the Montage Search and Analytics platform (Montage Healthcare Solutions, Philadelphia, PA, USA). We excluded patients that received these interventions during an admission for another therapy or illness.

At our institution, TURP and PVP are performed in the operating room with general anesthetic and patients are often discharged on the same day or after a night in hospital. PAE is performed in the angiography suite with conscious sedation, and patients are discharged 2–4 h after the procedure.

Cost data for each procedure and related inpatient hospital care costs were provided by the finance department of our institution—these include costs incurred from the time of admission to subsequent discharge as well as costs related to any re-admissions within 30 days of the procedure. All hospital costs were collected in accordance with the Ontario Case Costing Initiative (OCCI), a standardized medical case costing system for Ontario hospitals [21]. Case costing also known as unit costing, micro-costing, or bottom-up costing is the most specific method of costing, as each case is costed out separately according to resources used and costs of resources in the relevant hospital departments, also referred to as a cost center—the functional units of the hospital. Figure 1 demonstrates a case costing model of hospital service delivery. The model illustrates the inputs used by various hospital departments, to deliver healthcare services to a patient. The costs of these inputs are referred to as direct costs as they are hospital costs related to an individual case and include patient-specific services. These services, such as nursing care, laboratory interventions and imaging exams, are known as intermediate products of their respective departments. The output of the hospital is the collection of services that are patient-specific.

Case costing also allows for the attribution of indirect costs, also known as overhead, of patient care. Indirect costs are hospital costs that cannot be allocated to an individual patient. Relevant overhead costs, such as administrative services, finance and housekeeping, are allocated to hospital departments taking into account the departments utilization of these overhead resources. This study, and the OCCI, includes indirect costs allocated to each patient because this yields the full cost of care and represents a more accurate accounting of hospital costs.

Direct and indirect costs were further characterized as either fixed or variable. Fixed costs are those that remain relatively unchanged regardless of the volume of services or activity. Fixed costs included capital, employee salaries, benefits, building maintenance and utilities. Of note, the case costing approach does not include building depreciation in the calculation of fixed overhead; however, this does not influence the cost difference between interventions. Fixed direct cost for TURP and PVP includes operating room expenses such facilities and utilities. Fixed direct cost for PAE includes operating expenses such as amortization on the imagining equipment and maintenance-related expenses.

Variable costs are those that vary with the volume of services provided. Variable direct costs for TURP include urology consumables, such as the resecting loop, anesthesia supplies and investigations. Variable direct costs for PVP

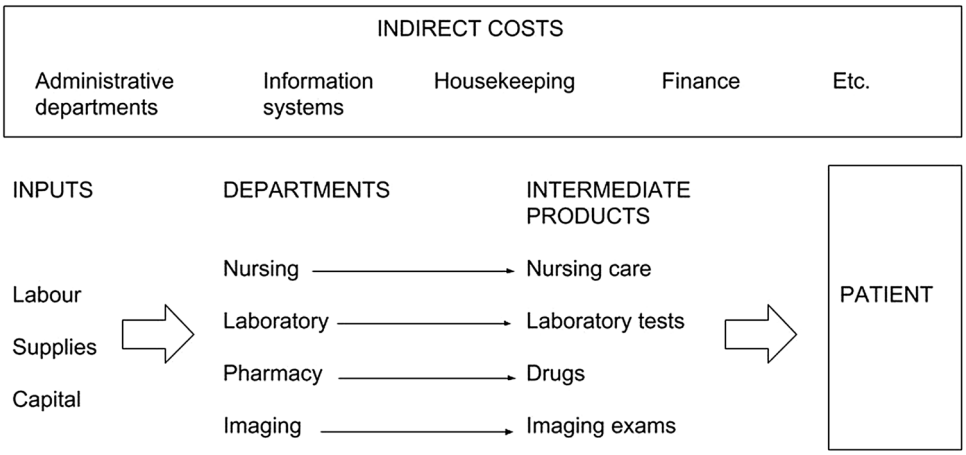

Fig. 1 Model of healthcare service delivery in the hospital setting. Adapted from "Hospital Production Function Model," Ontario Case Costing Guide, Ministry of Health and Long-Term Care

include consumables, such as the PVP laser fibers, anesthesia supplies and laboratory or imaging services. Post-surgical observation for TURP and PVP in the post-anesthesia care unit (PACU) and, if required, the inpatient admission was included as variable direct costs. Variable direct costs for PAE include interventional radiology consumables, such as catheters, wires, and embolic agents, drugs for conscious sedation and any investigations. Post-procedure PAE patients are observed in the medical imaging day unit (MIDU), and nursing costs during this time are based on an hourly salary. This study does not include societal costs such as lost productivity or wages. We excluded physician compensation as this is not borne by the hospital.

Statistical Analysis

Analysis of variance was used to compare the variable, fixed, direct and indirect costs between TURP, PVP and PAE with pairwise comparison performed with the use of Benjamini–Hochberg procedure ($p < 0.05$) [22]. Specifically, we analyzed the cost of pre-admission, OR/Angio suite, anesthesia, PACU/MIDU, inpatient admission and pharmacy. Additionally, the length of stay (LOS) was evaluated for all three groups, and total procedural and post-procedural costs for the course of hospitalization were assessed. The study took place in Canada, and therefore all economic data were obtained in CAD ($). Subsequently, all quotations were converted to US dollars (US$), with US-$1 equivalent to $1.2986, with regard to the annual exchange rate in 2017 [23]. These analyses were performed using *R* statistical software. Probabilistic sensitivity analysis was performed using Monte Carlo simulation with 10,000 random samples. This analysis was performed to account for parameter uncertainty and helps to explore optimal strategy distribution. The model was built using gamma distributions, and the simulation was performed using software TreeAge Pro 2018 (TreeAge Software, Inc., Williamstown, Massachusetts, USA).

Results

Twenty-eight consecutive patients with BPH underwent PAE in our interventional radiology department. A femoral artery approach prostatic arterial embolization was used in 21 patients and a radial approach in 8 patients—one radial puncture was converted to femoral. One patient underwent a repeat PAE for recurrent symptoms 1 year after initial treatment. Two-hundred and nine consecutive patients with BPH underwent TURP, while 29 patients underwent PVP; both procedures were performed in our urology department. One patient in the TURP group was readmitted within 30 days of discharge for complications of the surgery. The cost of this hospitalization was combined with the procedural cost to form a total cost of treatment. There were no re-admissions in the PVP group. The base case analysis showed a cost difference of $934 between PAE and TURP, $528 between TURP and PVP and $1462 between PAE and PVP.

Table 1 demonstrates patient characteristics and cost for all three interventions. There was no significant difference in patient age, LOS or direct costs between the three groups. The indirect costs of PAE where significantly lower than those of PVP and TURP (pairwise p value < 0.001), while the indirect cost of TURP was lower than that of PVP (pairwise p value < 0.001). The total costs of PAE were also found to be significantly lower than the two alternatives (pairwise p value of < 0.001). The difference in total cost between PVP and TURP was not found to be significant (pairwise p value of 0.072).

Table 2 shows the total cost for each intervention divided by selected hospital cost centers. With regards to PAE, no hospital costs were incurred related to pre-admission,

Table 1 Patient characteristics and overall costs for PAE, PVP and TURP

	PAE	PVP	TURP	*P* value
Age (years)				
Mean (SD)	70.77 (8.72)	73.66 (7.14)	71.43 (8.37)	0.366
Length of stay (days)				
Mean (SD)	1 (0)	1.55 (0.73)	1.63 (1.47)	0.076
Direct costs ($)				
Mean (SD)	3143 (1318)	3573 (966)	3381 (1380)	0.478
IQR	1682	1424	1291	
Minimum–maximum	1252–6315	1942–5327	1147–14,182	
Indirect costs ($)				
Mean (SD)	677 (406)	2146 (563)	1652 (692)	< 0.001
IQR	391	868	785	
Minimum–maximum	381–1399	1211–3227	577–5978	
Total cost ($)				
Mean (SD)	3821 (1582)	2146 (563)	1652 (692)	< 0.001
IQR	1828	2248	1917	
Minimum–maximum	1665–7440	3153–8554	1849–20,160	

IQR interquartile range

Table 2 Hospital cost center for PAE, PVP and TURP

Cost center	PAE		PVP		TURP		*P* value
	Mean	SD	Mean	SD	Mean	SD	
Pre-admission	–	–	$114.54	$27.64	$204.36	$194.26	0.098[b]
OR/Angio suite costs	$3321.87	$1501.88	$2327.41	$641.68	$1636.82	$920.95	< 0.001
Anesthesia	–	–	$203.58	$57.15	$248.32	$143.24	0.099[b]
MIDU/PACU	$520.11	$466.99	$663.18	$136.68	$524.53	$353.19	0.467
Inpatient costs[a]	–	–	$1233.69	$691.18	$1370.15	$1192.72	0.56[b]
Pharmacy	$26.34	$12.37	$79.74	$86.30	$117.27	$188.31	0.056

[a]Inpatient costs include the cost for admission to surgical short stay units (SSU) as well as traditional wards

[b]ANOVA performed using PVP and TURP costs

anesthesia or inpatient admission. A significant difference was found in the procedure-related costs with PAE having higher costs than both PVP and TURP (pairwise *p* value of < 0.001).

Figure 2 demonstrate box-plots comparing general and patient-specific variable direct costs for each intervention. Figure 3 illustrates the variable and fixed indirect costs across all three interventions.

Total costs vary across the three strategies and had more spread variability around the TURP costs (Fig. 4). The probabilistic sensitivity analysis showed PAE was the optimal strategy in 68% of the sampling, while TURP was the optimal strategy in 24% and PVP in 8% (Fig. 5).

Discussion

Prostate artery embolization is a minimally invasive, endovascular treatment for symptomatic benign prostatic hyperplasia. While TURP remains the gold standard treatment for BPH, PAE has a number of advantages such as fewer complications and a shorter length of stay [18, 20]. This suggests PAE may be a less costly alternative to TURP. However, there is also a paradigm shift in urology toward day surgeries and the use of burgeoning minimally invasive interventions such as PVP or Greenlight. PVP has been shown to have comparable patient safety and quality of life outcomes compared to TURP [24, 25]. There is a need for more research comparing costs associated with different treatment pathways for BPH.

This study evaluated the hospital costs associated with three different pathways: PAE, PVP and TURP. The total costs related to PAE were found to be significantly less

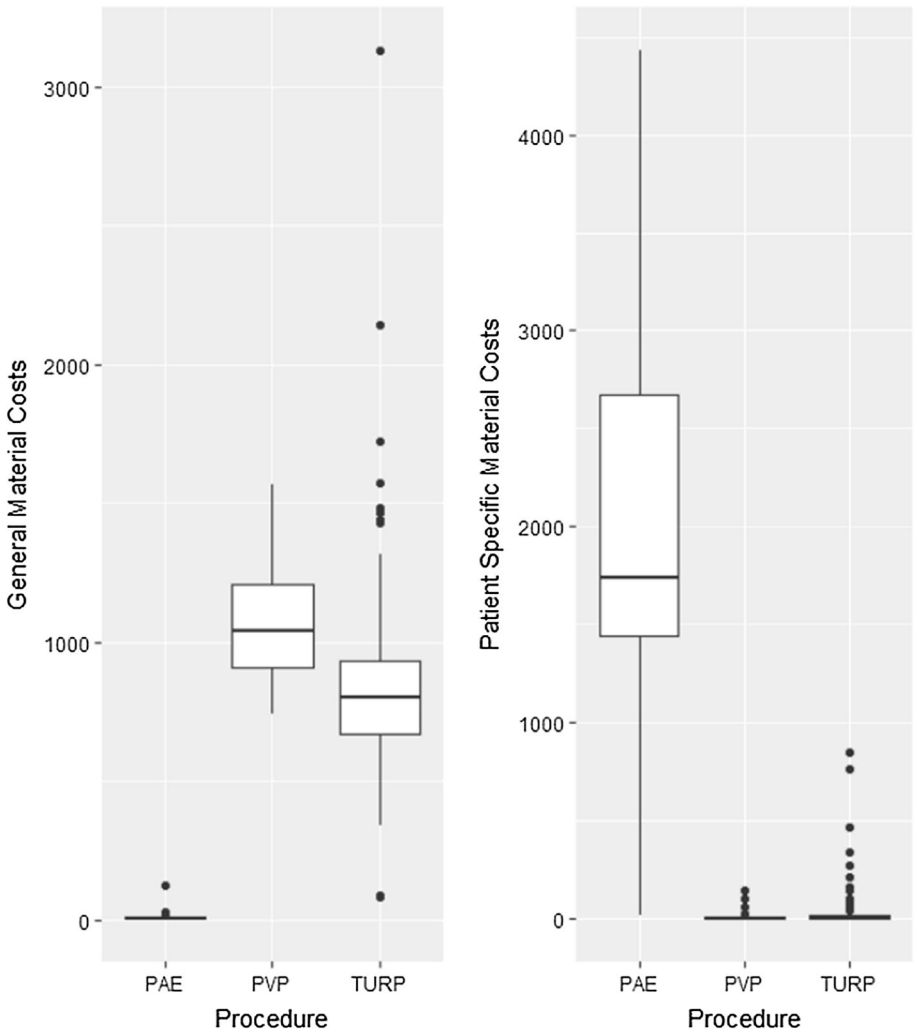

Fig. 2 Box-plot illustrating general and specific variable direct costs across the three interventions

than that of both PVP and TURP despite PAE having significantly higher patient-specific procedure cost. The difference in total cost was driven primarily by the indirect costs of each procedure. Substantial resources and infrastructure are required to prepare a patient for surgery—even in the setting of day surgery. Both PVP and TURP utilize significant perioperative resources such as pre-admission clinics/units, anesthesia, PACU and the surgical short stay units (SSSU) or inpatient ward. Our institution frequently leverages SSSU; while these are less expensive than a traditional ward bed, they still represent a significant expense to the hospital in terms of direct and indirect costs. Except for routine post-procedural monitoring performed in the MIDU, these are costs not associated with PAE. At our institution, post-procedure patients may spend 2–4 h in the MIDU, compared to 1–3 days in the SSSU.

Whitty et. al. [26] compared the costs of TURP and PVP demonstrating similar total costs with lower procedural costs favoring PVP. The authors considered PVP an attractive technology after costs associated with the initial learning curve had stabilized. We also found the total costs of PVP and TURP to be similar.

It has been posited that the direct costs of BPH therapies in the surgical setting, namely anesthesia and ward beds, are the main drivers of cost [27]. However, in this work we demonstrate the importance of also including indirect costs in the analysis. These are costs borne by the hospital, and decision makers require a complete accounting of how various treatment pathways may impact hospital costs. Comprehensive and detailed costs estimates provide for more efficient resource allocation strategies.

This study is limited by a relatively small sample of PAE and PVP patients, and this reflects real-world practice and the availability of alternatives for BPH. In this study, we excluded physician compensation as our focus was the cost incurred by the hospital. However, from a societal perspective, the cost of peri-procedural anesthetic care is likely more significant than captured in this study when the compensation of the anesthesiologist and/or the anesthesia assistant is included. Finally, there is little data available on

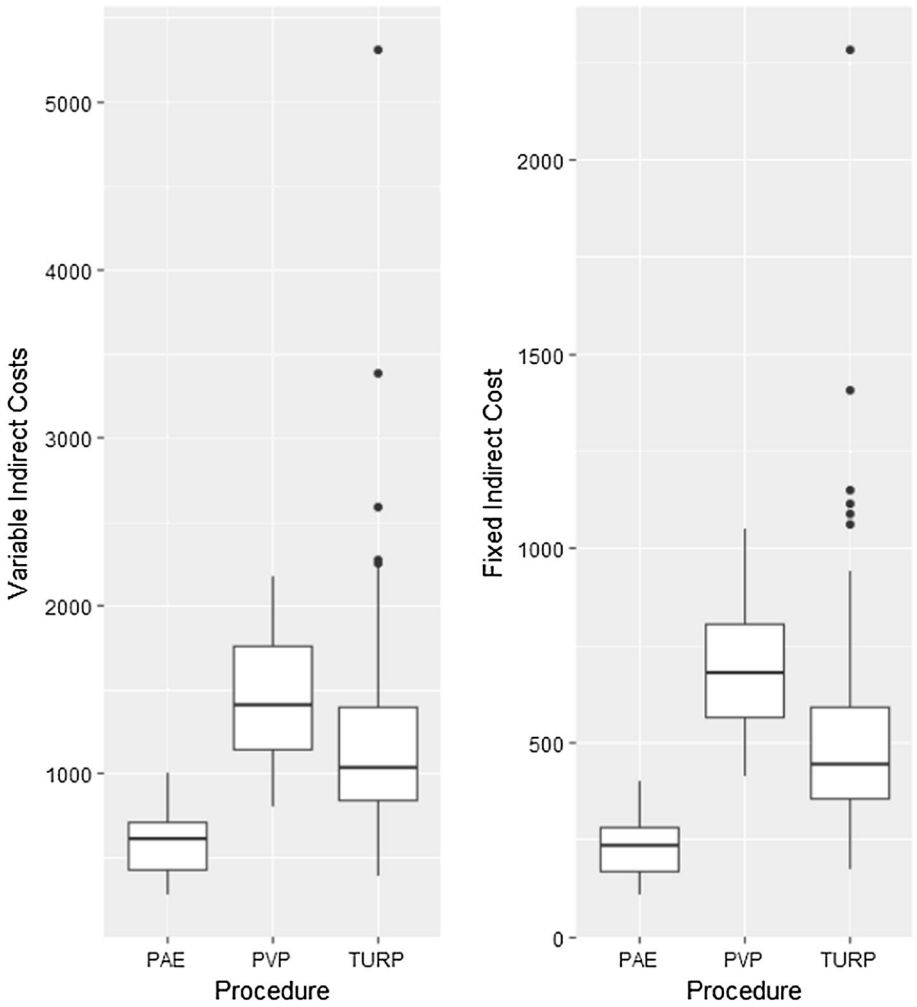

Fig. 3 Box-plot illustrating variable and fixed indirect costs across the three interventions

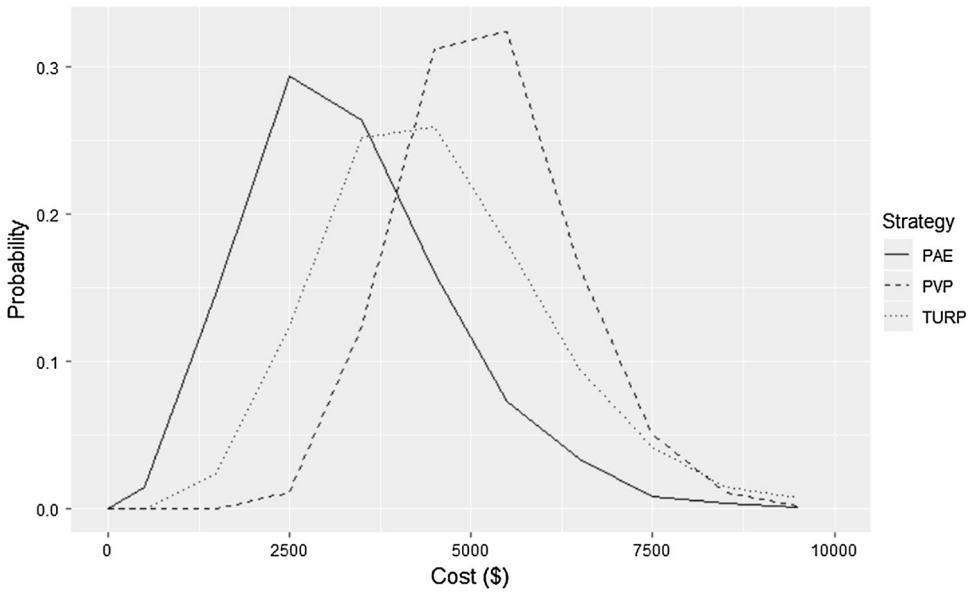

Fig. 4 Probabilistic sensitivity analysis of the three strategies across simulation sampling

the durability of PAE. While only one patient in our cohort was retreated, the exact re-treatment rate is unknown and may have implications for downstream costs. Future studies of PAE should be designed to include economic

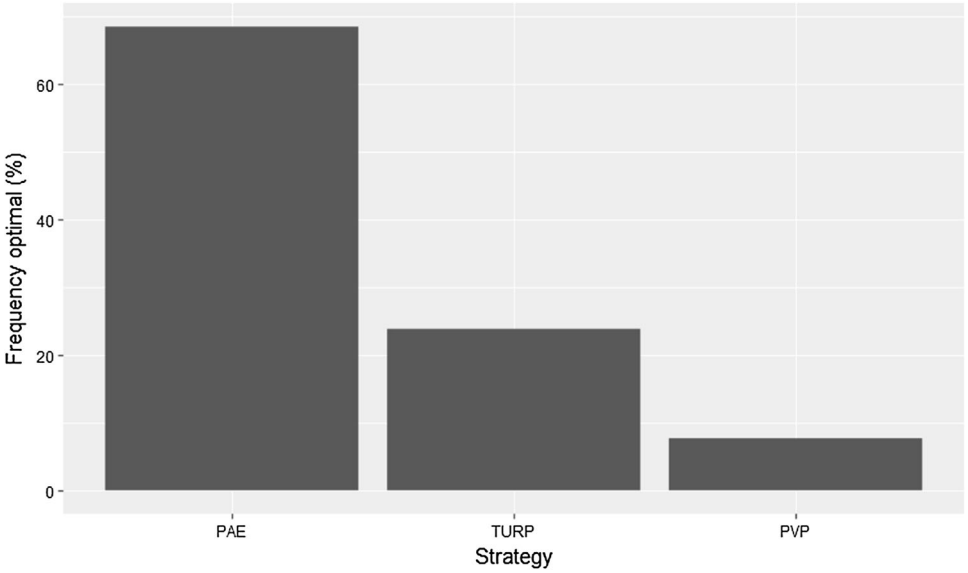

Fig. 5 Optimal strategy frequency related to cost savings

analysis alongside clinical trials to evaluate the effectiveness of PAE for men with lower urinary tract symptoms secondary to BPH.

Conclusions

Our study results demonstrate that PAE is significantly less expensive than both PVP and TURP in terms of total costs. These costs differences are driven by the indirect costs of surgery and should be considered by hospital decision makers when comparing the cost of these alternative treatments for BPH.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval For this type of study, formal consent is not required.

Informed Consent This study has obtained IRB approval from research ethics board (University Health Network), and the need for informed consent was waived.

Consent for Publication For this type of study, consent for publication is not required.

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