Cardiovasc Intervent Radiol
https://doi.org/10.1007/s00270-024-03958-9

Ultrasound-guided Transperineal Prostate Thermal Ablation (TPTA) for Benign Prostatic Hyperplasia: Feasibility of an Outpatient Procedure using Radiofrequency Ablation

Thiago Franchi Nunes[1,2,3] · Rafael Dahmer Rocha[4] · Bibiana Ruiz Wehling Ilgenfritz[5] · Flávio Scavone Stefanini[2] · Vinicius Adami Vayego Fornazari[6] · Guilherme Cayres Mariotti[7] · Publio Cesar Cavalcante Viana[8] · Rodrigo Gobbo Garcia[7] · Hugo Alexandre Socrates de Castro[1] · Denis Szejnfeld[1]

Received: 8 October 2024 / Accepted: 20 December 2024

Abstract

Purpose To evaluate the feasibility, safety, and short-term (3-month) results of transperineal prostate thermal ablation (TPTA) as a minimally invasive outpatient treatment for benign prostatic hyperplasia (BPH).

Materials and methods A prospective nonrandomized study of 25 patients with lower urinary tract symptoms secondary to BPH seeking care at 2 interventional radiology centers between March and July 2024. TPTA was performed using a 17G radiofrequency needle with a 10-mm active tip under unconscious sedation combined with bilateral perineal and periprostatic nerve blocks. The primary outcome measure was technical success, defined as successful bilateral ablation of the prostate transition zone. Secondary outcome measures included changes of international prostate symptom score (IPSS), quality of life (QoL), prostate volume, intravesical prostatic protrusion (IPP), prostate-specific antigen (PSA), post-void residual volume (PVR), maximum urinary flow rate (Qmax), and need for BPH medical therapy at 3 months relative to baseline.

Results All procedures were technically successful (100%). The median patient age was 69.4 years (IQR 54–74), and all were discharged within 3 h of the end of the procedure. Sixteen patients (64.0%) were discharged without a urinary catheter, and 6 patients (24.0%) reported mild complications. At 3-month follow-up, there were significant reductions in IPSS (79.1%), QoL score (70.3%), prostate volume (36.9%), IPP (70.8%), PSA (54.7%), and PVR (51.1%), whereas Qmax increased significantly (102.3%). Twenty-four patients (96.0%) reported discontinuation of medical therapy after TPTA.

Conclusion Ultrasound-guided TPTA using radiofrequency ablation is feasible and safe in the outpatient setting, with significant clinical improvements after 3 months of the procedure.

Level of Evidence Level 3 [non-randomized prospective cohort study].

✉ Thiago Franchi Nunes
thiagofranchinunes@gmail.com

1 Department of Radiology, Universidade Federal de São Paulo (UNIFESP), Rua Dr. Ovidio Pires de Campos, 75, Cerqueira César, São Paulo, SP 05403-010, Brazil

2 Interventix, Rua Dr. Antônio Alves Arantes, 398, Chácara Cachoeira, Campo Grande, MS 79040-720, Brazil

3 Present Address: Campo Grande, MS, Brazil

4 Instituto Dahmer Rocha, Rua Orestes Guimarães, 814, América, Joinville, SC 89204-060, Brazil

5 School of Medicine, Universidade de Araraquara (UNIARA), Rua Carlos Gomes, 1338, Centro, Araraquara, SP 14801-340, Brazil

6 Instituto Médico RAINTER, Avenida Ibirapuera, 2907, Conjuntos 901 e 902, Moema, São Paulo, SP 04029-200, Brazil

7 Hospital Israelita Albert Einstein, Avenida Albert Einstein, 627/701, MorumbiSão Paulo, SP 05652-900, Brazil

8 Instituto Do Câncer Do Estado de São Paulo (ICESP), Avenida Dr. Arnaldo, 251, Cerqueira César, São Paulo, SP 01246-000, Brazil

Published online: 09 January 2025

Graphical Abstract

CVIR The official journal of the Cardiovascular and Interventional Radiological Society of Europe
CardioVascular and Interventional Radiology
Springer CIRSE

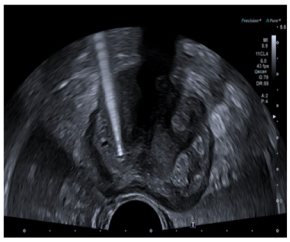
Ultrasound-guided Transperineal Prostate Thermal Ablation (TPTA) for Benign Prostatic Hyperplasia: Feasibility of an Outpatient Procedure using Radiofrequency Ablation

25 patients
treated with TPTA for lower urinary tract symptoms secondary to benign prostatic hyperplasia (BPH)

March to July 2024

Endpoints	
Primary	Technical success, time to discharge, need for a urinary catheter at discharge, and complication rate
Secondary	International prostate symptom score (IPSS), quality of life (QoL), prostate volume, intravesical prostatic protrusion (IPP), prostate-specific antigen (PSA), post-void residual volume (PVR), maximum urinary flow rate (Qmax), and need for BPH medical therapy at 3 months relative to baseline

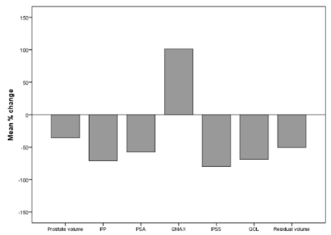
100% technical success



TPTA Procedure

TPTA was performed with the patient under unconscious sedation combined with bilateral perineal and periprostatic nerve blocks. A 17G radiofrequency needle with a 10-mm active tip was positioned in the anterosuperior transition zone of the prostate unilaterally for ablation. After completing the ablation on one side of the prostate transition zone, the procedure was repeated contralaterally.

Mean percentage change in outcomes after 3 months of treatment



3 months

% Reduction		% change (mean ± SD)
IPSS	75.5%	-75.5 ± 14.1
QoL	71.6%	-71.6 ± 10.7
Prostate volume (mL)	36.2%	-36.2 ± 8.0
PVR	44.3%	-44.3 ± 35.4
IPP (mm)	67.7%	-67.7 ± 26.3
PSA	54.8%	-54.8 ± 17.4
% Increase		**% change (mean ± SD)**
Qmax	105.6%	105.6 ± 59.0

Ultrasound-guided TPTA using radiofrequency ablation is feasible and safe in the outpatient setting, with short-term clinical improvements comparable to those of other ablative techniques.

Keywords Ultrasound · Guided transperineal · Ablation · Prostate · Radiofrequency · Outpatient · Minimally invasive treatments · Benign prostatic hyperplasia · Lower urinary tract symptoms · Ejaculation sparing · Ultra · Minimally invasive surgical techniques

Introduction

Transurethral resection of the prostate (TURP) and simple prostatectomy (adenoma enucleation) are considered the gold standard surgical interventions for the management of benign prostatic hyperplasia (BPH) [1, 2]. However, both procedures are associated with significant risks, including hematuria, urethral strictures, urinary incontinence, and sexual and ejaculatory dysfunctions, and are contraindicated in patients with a high surgical risk [3–6].

To address these limitations, minimally invasive surgical therapies (MISTs) have been developed, aiming to alleviate lower urinary tract symptoms (LUTS) with fewer complications, reduced rates of sexual and ejaculatory dysfunction, and shorter hospital stay, often allowing for outpatient treatment [7]. Among these, thermo-ablative techniques have emerged as promising approaches for BPH management. These methods rely on the conduction of thermal energy into prostatic tissue to induce coagulative necrosis, resulting in tissue destruction, shrinkage, and subsequent symptomatic relief.

Water vapor thermal therapy (WVTT), a transurethral thermal ablation technique utilizing radiofrequency-generated water vapor, is widely employed for prostates under 80 g. WVTT has demonstrated favorable long-term clinical outcomes [8]. However, the procedure requires multiple transurethral punctures and lacks real-time image guidance, potentially leading to significant periurethral inflammation and necessitating indwelling urinary catheterization for at least 7 days in most patients. Reported adverse events include a high incidence of urinary tract infections (24%), urinary retention (33.8%), and gross hematuria (52%), primarily due to urethral manipulation [9].

Transperineal prostate biopsy is increasingly recognized as the new gold standard for prostate tissue sampling, primarily due to its lower infection rates and reduced reliance on antibiotics [10]. Building on this approach, transperineal-guided thermal ablation has emerged as a technique that offers improved control of ablation zones while minimizing urethral trauma. Early feasibility and safety studies of transperineal laser ablation (TPLA) have shown promising results, suggesting it may be a viable clinical alternative [11–15]. However, the adoption of

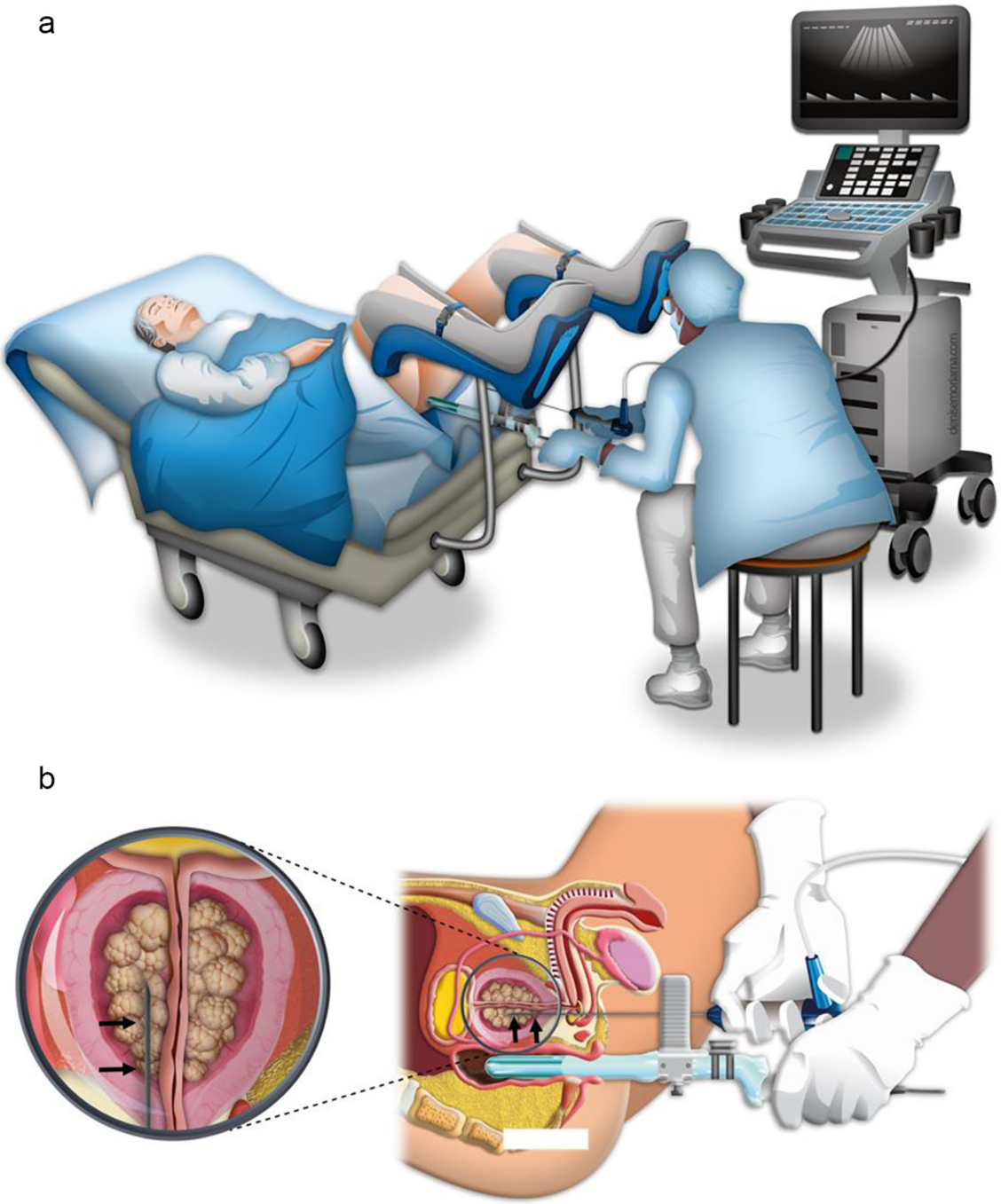


Fig. 1 (**a**) Positioning of the patient and interventional radiologist during the TPTA procedure. (**b**) Positioning of the radiofrequency needle in the transition zone of the prostate (arrows) via transperineal approach, relieving urethral compression

fiber-diode lasers is constrained by their high cost, limited availability, and lack of procedural standardization [16].

The increasing availability of transperineal ultrasound (US) equipment and the established utility of radiofrequency ablation (RFA) in treating benign conditions across multiple organ systems have prompted investigations into its application in BPH [17–21]. The present study aimed to evaluate the feasibility, safety, and short-term (3-month) outcomes of transperineal prostate thermal ablation (TPTA) as minimally invasive outpatient treatment for BPH.

Materials and Methods

Patients

This is a prospective nonrandomized study. Approval from Ethics Committee was obtained to conduct the evaluation (CAAE: 74939723.1.0000.5505). Eligible participants were all patients with LUTS secondary to BPH seeking care between March and July 2024 at 2 interventional radiology centers: São Paulo (center A) and Campo Grande (center B). All data were collected prospectively using a secure electronic database accessible only to authorized researchers. This database adhered to strict standards of confidentiality and compliance with local data protection regulations.

Inclusion criteria were age $\geq$ 45 years, moderate-to-severe LUTS due to BPH with an international prostate symptom score (IPSS) $\geq$ 8, prostate volume $\geq$ 30 mL and $\leq$ 200 mL measured by endocavitary US and/or pelvic magnetic resonance imaging (MRI), and dissatisfaction with medical therapy due to lack of clinical efficacy (urinary obstruction symptoms not adequately relieved despite prolonged attempts with medical therapy), intolerance to side effects (such as hypotension or changes in sexual function associated with the use of alpha-blockers or 5-alpha reductase inhibitors), poor adherence to treatment (difficulties in maintaining the long-term therapeutic regimen due to factors such as cost or complexity of the medication schedule), or personal preference (patients seeking minimally invasive alternatives to preserve functions such as antegrade ejaculation).

Exclusion criteria were as follows: (a) patients with clinically suspected prostate cancer or a history of prostate cancer, neurogenic bladder dysfunction, urethral strictures, or bladder stones; (b) severe or unstable clinical conditions, including inadequate cardiac, hepatic, renal, or respiratory function that could increase procedural risk; (c) uncontrolled coagulation disorders, as evidenced by preoperative laboratory tests; (d) active infections that could compromise patient safety during or after the procedure; (e) contraindications determined by the attending physician following a thorough clinical evaluation; and (f) patient refusal to participate in the study or undergo the proposed procedure.

Prior to procedure, all patients provided written informed consent, completed the IPSS and Quality of Life (QoL) questionnaires, were clinically evaluated for comorbidities (hypertension, diabetes, dyslipidemia, smoking, and cardiovascular disease) and use of BPH medication (alpha-blockers, 5-alpha reductase inhibitors, or combination therapy), and underwent laboratory testing (serum prostate-specific antigen [PSA], complete blood count, and coagulation tests), uroflowmetry with analysis of maximum urinary flow rate (Qmax), and imaging (endocavitary US and/or pelvic MRI). Demographic data (age and body mass index [BMI]), perioperative data (American Society of Anesthesiologists [ASA] score and operative time), and postoperative data (time to discharge, time to urinary catheter removal, and presence/severity of complications according to the Clavien-Dindo classification) were also recorded.

Anesthesia Protocol

All procedures were performed under unconscious sedation administered by an anesthesiologist using midazolam, fentanyl, lidocaine, and propofol. Additionally, a local nerve block was applied using 5 mL of 1% lidocaine bilaterally to the perineal nerve, followed by an additional periprostatic block with 5 mL of 1% lidocaine on each side to ensure adequate analgesia during TPTA. This combined approach was designed to maximize patient comfort and procedural safety.

TPTA Treatment Protocol

All TPTA procedures were conducted in a dedicated interventional radiology suite equipped with US and anesthesia support. The environment was designed to ensure sterile conditions and facilitate seamless intraoperative imaging and patient monitoring. The outpatient nature of the procedure was supported by the availability of sedation, real-time imaging, and post-procedure recovery areas within the same facility.

All patients were prescribed and instructed to use the following medications for 7 days, starting 2 days before the procedure: levofloxacin 750 mg once daily; tamsulosin 0.4 mg once daily; and prednisone 20 mg once daily. Dipyrone and/or phenazopyridine were prescribed postoperatively as needed by the patient.

After sedation, the patient was placed in the lithotomy position (Fig. 1A) and his penis was lifted and fixed to the abdomen to fully expose the perineum. The perineal area was sterilized using aseptic technique, fields were placed, and the bladder was catheterized with a 16F 3-way Foley catheter, followed by continuous irrigation with 0.9% saline. Local anesthesia was administered to the perineal region bilaterally (5 mL of 1% lidocaine on each side).

All procedures were performed by 2 interventional radiologists (TFN and DS) with more than 10 years of experience in image-guided techniques, including thermal ablation with radiofrequency for solid organs (liver, kidney, and thyroid) and percutaneous urological procedures, such as prostate biopsies and abscess drainage. This combined expertise in thermal ablation and transperineal

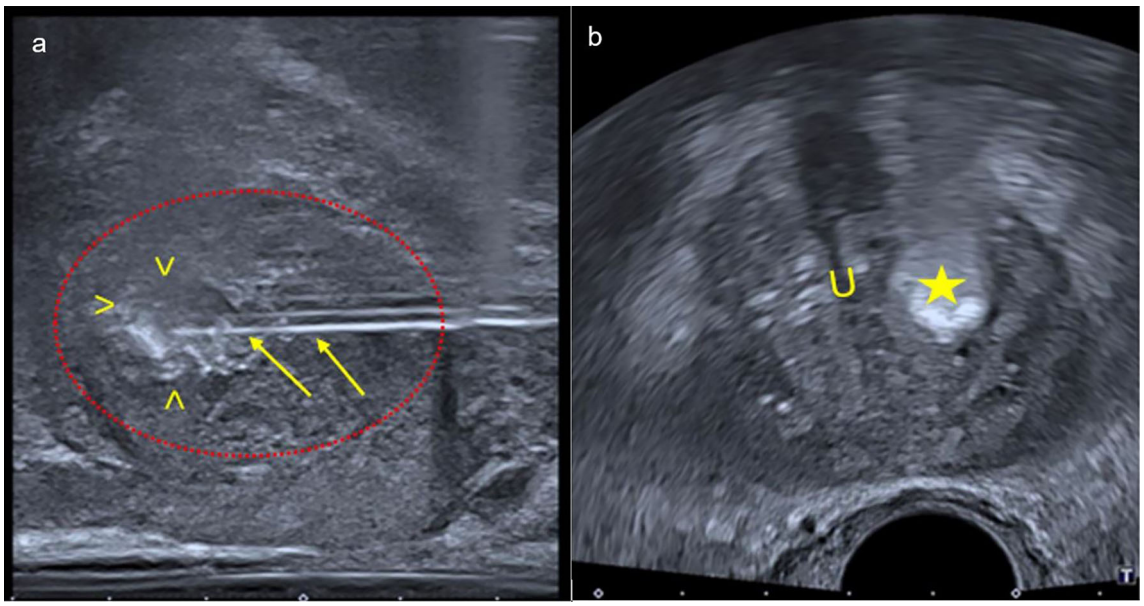


Fig. 2 Ultrasound images during the TPTA procedure. (**a**) Transperineal sagittal view showing the beginning of ablation after positioning the radiofrequency probe (arrows) in the transition zone of the left lobe of the prostate (red dashed circle), with the production of a small amount of tissue vaporization (arrowheads). (**b**) Axial view showing the hyperechogenic ablated area (asterisk), with an adequate safety margin from the urethra (U)

approaches was essential to ensure the safe and precise execution of the technique.

The Aplio A ultrasound system (Canon Medical Systems Co. Ltd, Japan) with a high-frequency transperineal probe was used in all procedures. With the patient under sedation, the probe was gently inserted into the anal canal, and the prostate was analyzed in detail regarding its morphology, echogenicity, capsule integrity, prostate volume, and relationship with the bladder wall. After US documentation, the interventional radiologist inserted a 20G × 20 cm needle under transperineal US guidance and performed bilateral perineal nerve block by injecting 5 mL of 1% lidocaine on each side, and an additional 5 mL for periprostatic nerve block.

A 17G RFA needle with a 10-mm active tip (Amica, HS Hospital Service SPA, Italy) was positioned in the anterosuperior transition zone of the prostate unilaterally (Fig. 1B). For safety, ablation was always performed at a distance of at least 8 mm from the urethra and bladder floor to reduce the risk of stenosis, retrograde ejaculation, and cystitis. The RFA probe was powered at 130 W and the needle was slowly pulled caudally. The resulting tissue vaporization permitted real-time observation of the ablated site (Fig. 2A and B). After completing the ablation on one side of the prostate transition zone, the procedure was repeated contralaterally.

Treatment was considered complete when the entire prostate transition zone bilaterally and cranially to the verumontanum appeared hyperechogenic relative to baseline US scan (pre-ablation). After ablation, contrast-enhanced US was performed with left-arm intravenous injection of 2.4 mL of a microbubble contrast agent (SonoVue, Shanghai Bracco Sine Pharmaceutical Corp. Ltd., Shanghai, China), followed by 5 mL of saline, to assess morphological changes, impregnation time, and contrast enhancement intensity and patterns in the prostate (Fig. 3).

After the TPTA procedure, patients were transferred to the post-anesthesia care unit and monitored for at least 1 h. After this period, if the patient was wide awake and the urinary catheter was free of clots, the first attempt to remove the catheter was made. Patients remained in recovery until they were able to void spontaneously without difficulty. In patients with voiding difficulty, pain, or urinary retention, a 16F indwelling urinary catheter was placed again. A new attempt to remove the catheter was scheduled for 24–48 h later or when there was significant urinary extravasation/overflow.

For post-procedure follow-up, patients were contacted daily by telephone and.

complications were recorded according to the Clavien-Dindo classification. Discontinuation of BPH medical therapy was also recorded. After 3 months, patients completed the IPSS and QoL questionnaires again and underwent repeat PSA measurements, uroflowmetry, and prostate US and/or MRI.

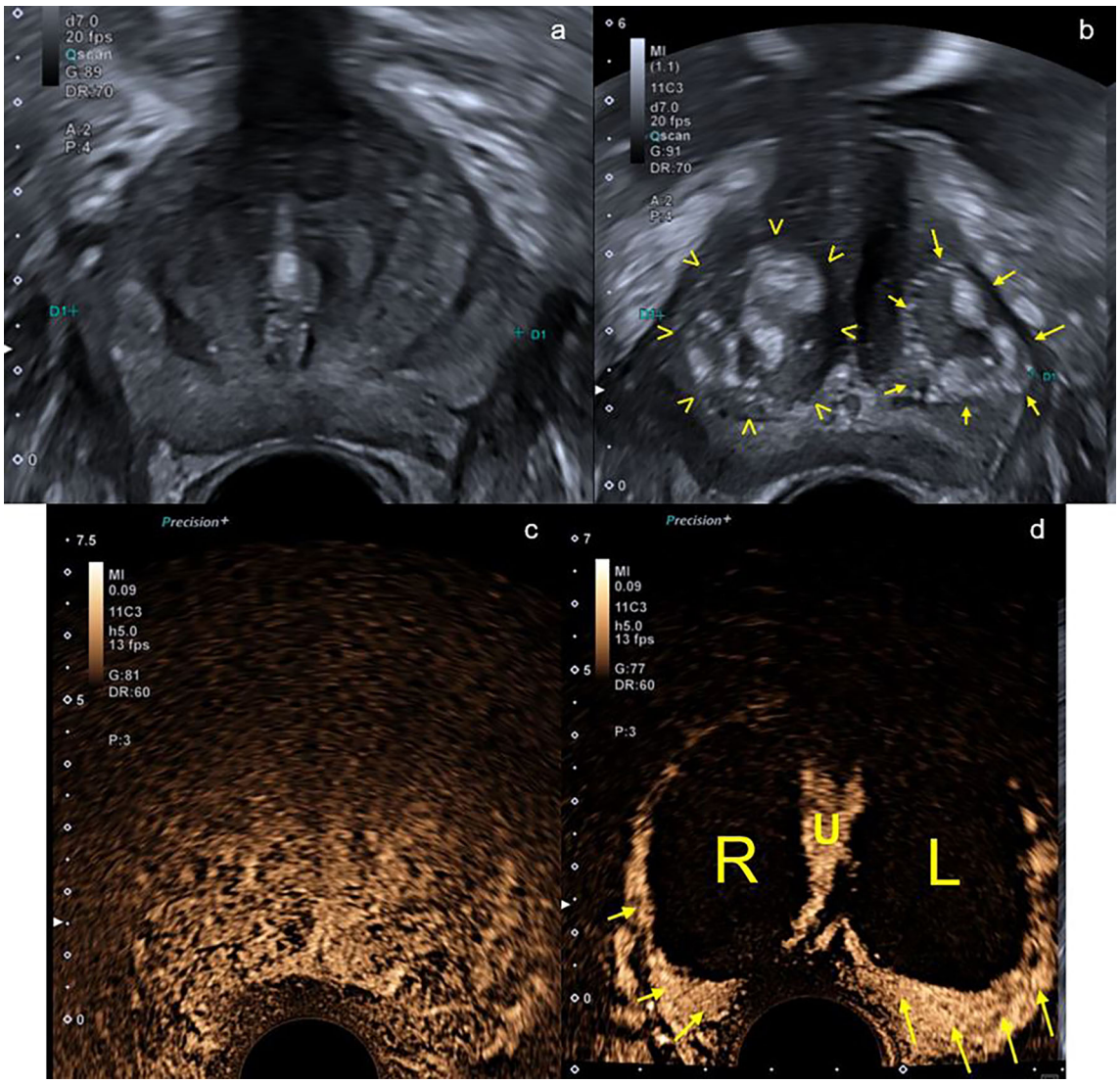


Fig. 3 Ultrasound images of the TPTA procedure. Typical heterogeneous echotexture and echogenicity of the prostate on B-mode image (**a**) and after contrast enhancement (**c**). At the end of the procedure, B-mode image (**b**) showing hyperechogenic changes compromising a substantial part of the right (areas within the arrowheads) and left (area within the arrows) transition zone. These changes are best noticed after administration of the contrast agent (**d**), when an extensive anechoic area is noted in the central zone bilaterally on the right (R) and left (L), characterizing the absence of contrast medium uptake in the ablated sites, with preservation of the peri-urethral region (U) and peripheral zone (arrows)

Outcomes

The primary outcome measure of this study was technical success, defined as completion of the planned ablation of the prostate zone, with correct placement of the RFA needle, as determined by real-time visualization of hyperechoic changes during transperineal US and post-procedure confirmation with contrast-enhanced US demonstrating the intended extent of ablation without evidence of significant residual untreated prostate tissue. The target ablation volume was defined as bilateral involvement of the transition zone up to the cranial level of the verumontanum, ensuring a safety margin of at least 8 mm from the urethra and bladder base. Secondary outcome measures included time to discharge, need for a urinary catheter at discharge, complication rate, changes of IPSS, QoL, prostate volume, intravesical prostatic protrusion (IPP), serum PSA, post-void residual volume (PVR), Qmax, and need for BPH medical therapy at 3 months relative to baseline.

Statistical Analysis

Data were analyzed using SPSS, version 20.0. Qualitative variables are expressed as absolute and relative

Table 1 Patient demographics

Characteristic	N = 25
Age (years), mean ± SD	69.4 ± 5.5
BMI (kg/m^2), mean ± SD	27.9 ± 2.9
ASA score ≤ 2, n (%)	14 (56.0)
Comorbidities, n (%)	21 (84.0)
Hypertension	17 (68.0)
Diabetes	9 (36.0)
Dyslipidemia	4 (16.0)
Smoking	3 (12.0)
Cardiovascular disease	1 (4.0)
No comorbidities	4 (16.0)
Preop IUC use, n (%)	2 (8.0)
Preop prostate volume (mL), mean ± SD	92.7 ± 46.4
Preop PSA (ng/dL), median (IQR)	4.6 (1.9–8.4)
Operative time (min), mean ± SD	39.8 ± 13.4
Mild complications, n (%)	6 (24.0)
Hematospermia	3 (12.0)
Painless subcutaneous hematoma	1 (4.0)
Transient hematuria	2 (8.0)

BMI body mass index, *ASA* American Society of Anesthesiologists, *Preop* preoperative, *IUC* indwelling urinary catheter, *PSA* prostate-specific antigen

frequencies. For quantitative variables, the Shapiro–Wilk test was used to assess the normality of data distribution, where normally distributed data are expressed as mean (SD) and non-normally distributed data, as median (IQR). In the baseline vs 3-month comparison, paired Student's t-test was used for normally distributed data and Wilcoxon test for non-normally distributed data. For each patient, the percentage change in the outcomes was calculated as (outcome value at 3 months—pre-procedure value)/pre-procedure value *100, and the results are presented as the mean (SD) of percentage change. The level of significance was set at 5% for all comparisons.

Results

A total of 25 patients underwent TPTA during the study period, 12 in center A and 13 in center B. All procedures were technically successful (100%). The median age was 69.4 years (IQR 54–74), and 14 patients (56.0%) had an ASA score ≤ 2. Hypertension was the most common comorbidity, followed by diabetes. The mean (SD) BMI was 27.9 (2.9) kg/m^2. The mean (SD) prostate volume was 92.7 (46.4) mL, and the median PSA was 4.6 ng/dL (IQR 1.9–8.4). The mean (SD) operative time was 39.8 (13.4) minutes, and all patients were discharged within 3 h of the end of the procedure. Table 1 shows patient demographics.

Mild complications were observed in 6 patients (Clavien-Dindo grade I) postoperatively. One patient developed a painless subcutaneous hematoma in the perineal region and scrotum, 2 had asymptomatic transient hematuria, and 3 reported hematospermia during their first sexual intercourse. All symptoms were self-limiting and did not require any additional care other than guidance and observation. No patient reported anorectal abnormalities (such as perianal pain, fecal incontinence, or procedure-related anorectal lesions), intestinal changes (such as constipation or diarrhea), urinary incontinence, erectile dysfunction, or retrograde ejaculation.

Six patients (24.0%) were discharged with indwelling catheters. The catheter was removed 7 days after the procedure in 1 of these patients, and within 3 days of the procedure in the other 5 patients.

Of 25 patients, 24 (93.7%) were able to discontinue medical therapy after the TPTA procedure.

Short-term Efficacy Analysis

Of 25 patients, 3 were excluded from the short-term efficacy analysis (3-month follow-up): 2 had an indwelling urinary catheter pre-procedure, precluding analysis of IPSS and Qmax; and 1 had previous TURP (6 years prior to the study) and was excluded to minimize potential bias in IPSS, Qmax, and prostate volume calculation. Table 2 shows the main preoperative characteristics of each of the 22 patients included in the efficacy analysis.

At 3-month follow-up, all 22 patients showed significant clinical improvement, with a reduction in IPSS (79.1%) and QoL (70.3%) scores relative to baseline. There were significant reductions in prostate volume (36.9%), PVR (51.1%), IPP (70.8%), and PSA levels (54.7%), whereas Qmax increased significantly (102.3%) (Table 3).

Of 22 patients included in the efficacy analysis, 21 (95.4%) reported discontinuation of medical therapy; only 1 continued to use alpha-blockers.

Discussion

BPH is a major global health concern that imposes substantial economic burdens on healthcare systems worldwide [22]. Although TURP and surgical prostatectomy are considered the gold standard treatments, they are associated with notable drawbacks. In younger and healthier patients, these interventions often lead to ejaculatory and sexual dysfunction, while in older individuals with higher comorbidity burdens, the requirement for general

Table 2 Description of each patient included in the efficacy analysis (n = 22)

Case	Age (years)	Comorbidities	Medications	Prostate volume (mL)	PSA (ng/dL)	IPP (mm)	IPSS	Qmax	Operative time (min)	Postop IUC duration (days)	Early complications
1	70	–	–	78	1.63	0	12	8.50	50	1	Hematospermia
2	68	SAH, CVD	Combination therapy	128	5.50	25	18	8.00	44	2	–
3	70	–	Alpha–blockers	152	6.87	0	31	8.00	55	0	–
4	74	SAH	Combination therapy	170	9.43	24	14	9.70	62	0	Painless subcutaneous hematoma
5	68	SAH, dyslipidemia	5–alpha reductase inhibitors	198	9.19	14	14	7.60	52	0	–
6	54	Dyslipidemia	5–alpha reductase inhibitors	58	4.60	25	27	5.00	23	0	Transient hematuria
7	65	SAH	5–alpha reductase inhibitors	140	7.50	17	17	10.40	52	0	–
8	65	SAH	Alpha–blockers	176	7.32	0	14	8.50	49	0	Hematospermia
9	68	SAH, DM	Combination therapy	85	7.68	14	14	11.50	43	7	Hematospermia
10	73	SAH, smoking	Combination therapy	119	15.00	11	14	5.60	41	0	–
11	68	–	Alpha–blockers	64	2.50	2	16	5.80	30	0	–
12	71	DM	Alpha–blockers	100	11.19	5	30	5.00	37	0	–
13	72	DM	Alpha–blockers	42	1.28	1	22	9.80	27	0	–
14	72	DM	Alpha–blockers	48	1.14	2	31	7.70	24	1	–
15	76	SAH	Combination therapy	74	3.70	5	29	10.10	41	1	–
16	74	SAH	Combination therapy	126	9.20	31	31	10.00	49	3	–
17	73	SAH	Alpha–blockers	87	1.12	5	19	9.50	23	0	–
18	77	SAH	5–alpha reductase inhibitors	54	6.55	9	15	11.0	28	0	–
19	67	SAH, DM	Alpha–blockers	86	3.80	4	14	10.30	19	0	–
20	63	SAH, DM, obesity	Alpha–blockers	54	2.26	5	31	9.00	31	0	–
21	72	SAH, DM	Alpha–blockers	30	0.90	3	33	6.10	29	0	–
22	67	–	Alpha–blockers	45	0.67	0	23	10.00	20	0	–

PSA prostate-specific antigen, *IPP* intravesical prostatic protrusion, *IPSS* international prostate symptom score, *Qmax* maximum urinary flow rate, *Postop* postoperative, *IUC* indwelling urinary catheter, *SAH* systemic arterial hypertension, *CVD* cardiovascular disease, *DM* diabetes mellitus

Table 3 Outcomes after 3 months of treatment

Outcome	Baseline n = 22	3 months n = 22	% change (mean ± SD)	*p*
Prostate volume (mL), mean ± SD	96.1 ± 48.4	60.7 ± 30.3	-36.9 ± 9.9	< 0.001*
PVR, median (IQR)	33.5 (24.0–54.3)	13.5 (10.0–21.3)	-51.1 ± 31.9	< 0.001**
IPP (mm), median (IQR)	5.0 (1.8–14.8)	0.5 (0–7.3)	-70.8 ± 26.8	< 0.001**
PSA (ng/dL), median (IQR)	5.05 (1.54–8.06)	2.05 (0.90–4.20)	-54.7 ± 15.3	< 0.001**
IPSS, median (IQR)	18.5 (14.0–30.3)	4.0 (2.0–5.0)	-79.1 ± 13.7	< 0.001**
QoL, mean ± SD	4.1 ± 1.1	1.1 ± 0.5	-70.3 ± 11.5	< 0.001*
Qmax, mean ± SD	8.5 ± 2.0	16.3 ± 2.0	102.3 ± 55.5	< 0.001*

PVR post-void residual volume, *IPP* intravesical prostatic protrusion, *PSA* prostate-specific antigen, *IPSS* international prostate symptom score, *QoL* quality of life, *Qmax* maximum urinary flow rate

*Paired Student's t-test

**Wilcoxon test

anesthesia, prolonged hospitalization, and potential postoperative complications pose additional challenges.

The ideal minimally invasive treatment for BPH should be widely accessible, cost-effective, and associated with minimal complications. Furthermore, it should exert minimal disruption to patients' daily routines and possess a short learning curve to facilitate widespread adoption by healthcare providers.

Strategies aimed at reducing prostate parenchymal volume without necessitating tissue removal are primarily achieved through embolization or thermal ablation techniques. Prostatic artery embolization (PAE) is a relatively recent addition to the American Urological Association (AUA) guidelines [23] and offers several advantages, including its feasibility as an outpatient procedure and the ability to be performed under local anesthesia. However, PAE presents certain limitations, such as high costs, radiation exposure, requirement for advanced angiographic equipment with computed tomography capabilities, which are not universally accessible, and a steep learning curve for interventional radiologists [24–27].

WVTT, such as the Rezum® system, has demonstrated excellent long-term outcomes, with reintervention rates reported to be below 5% at 5 years of follow-up. However, the procedure involves urethral manipulation, which necessitates the use of an indwelling urinary catheter for a minimum of 7 days postoperatively. Additionally, patients often experience moderate-to-severe dysuria during the first 30 days following the procedure [8, 28].

Percutaneous ablation of the prostate via the transperineal approach has the potential to combine the favorable outcomes observed with the Rezum® system while eliminating urethral manipulation, thereby offering a more comfortable postoperative recovery for patients. This approach was first described by Patelli in 2017 with laser (TPLA), and its safety and efficacy were further evaluated in several studies [14, 16, 29–31]. Recently, Patelli published long-term efficacy results of 40 patients undergoing TPLA, reporting only 2 mild complications and sustainable clinical improvement [32]. The transperineal approach is safe, with lower infection rates than in endorectal prostate biopsies, being recommended as the method of choice in some guidelines [10]. Another potential advantage of the transperineal approach is its applicability in patients with urethral abnormalities, penile prostheses, or a history of pelvic irradiation. Additionally, it minimizes the risk of perioperative urethral injury, further enhancing its clinical utility.

Our study yielded comparable findings, with only mild complications (Grade I) observed, none of which caused significant patient discomfort or necessitated additional medical intervention. Notably, no cases of sexual dysfunction or retrograde ejaculation were reported by the participants.

Although this study does not specifically address cost analysis, numerous investigations have highlighted the significant economic benefits of ablation procedures compared to surgical resections, particularly in the management of both benign and malignant diseases [33–36]. Globally, healthcare costs exhibit substantial heterogeneity and are influenced by multifactorial dynamics. For example, Pacella et al. [37] estimated the cost of a single laser fiber for transperineal prostate treatment at approximately €800, with 3–4 fibers typically required per procedure, amounting to a total cost of €2,400–€3,200 per patient. Conversely, Ayoub et al. [34] reported the average cost of a single RFA probe to be approximately $1,249. The cost of RFA probes used in thyroid procedures is comparable to that of probes used in prostate ablation, with only one

probe required per patient, making it a cost-effective alternative in specific clinical scenarios.

However, laser ablation has certain limitations, including the lack of standardized fiber designs and inadequate control of heat dispersion [11], which restrict its widespread use, particularly in low- and middle-income countries. Furthermore, comparative studies evaluating laser ablation and RFA in patients with thyroid nodules have demonstrated the superiority of RFA in achieving greater reductions in thyroid nodule volume [38].

Our technique has been shown to be safe when performed in an outpatient setting, aligning with the well-documented observation that outpatient procedures are generally more cost-effective than inpatient care. This cost efficiency is primarily attributed to reduced facility and staffing requirements inherent in outpatient care.

Our 3-month assessment of secondary outcome measures showed meaningful clinical improvement, with significant reductions in IPSS (79.1%), QoL score (70.3%), prostate volume (36.9%), IPP (70.8%), PSA (54.7%), and PVR (51.1%), as well as a significant increase in Qmax (102.3%). We also highlight that 24 patients (96.0%) were able to discontinue medical therapy after the TPTA procedure. These values are comparable to those reported in the first TPLA study and superior to the short-term results after PAE, where prostate volume reduction and clinical improvement usually occur later [11, 39].

This study has several limitations, including the lack of a control group, which limits direct comparisons with other techniques or treatments, and a small cohort size with limited follow-up. As an initial study, our objective was to assess feasibility, safety, and short-term clinical efficacy, which justifies the smaller sample size. While no formal power calculation was performed, we believe that the sample size was appropriate to identify preliminary trends in efficacy and safety, as well as to provide essential data to guide future studies with larger sample sizes and more robust designs, including randomized trials, to confirm and expand our findings. Regarding the follow-up period, the primary focus was to explore immediate and short-term outcomes (3 months), providing a solid foundation for subsequent investigations. Long-term studies are planned to evaluate the durability of clinical effects and outcomes over extended periods. Furthermore, certain procedural aspects require further investigation, such as determining the optimal power settings, evaluating the feasibility of performing the procedure without urinary catheterization, and validating the long-term clinical benefits. Additionally, appropriate patient selection criteria need to be established to optimize outcomes and ensure the procedure's efficacy and safety.

Conclusion

US-guided TPTA using RFA has been demonstrated to be a feasible and safe procedure in an outpatient setting. It provides short-term clinical improvements comparable to those of other ablative techniques, such as TPLA and Rezum.

Acknowledgements We thank Mr. Claudio Amabile, PhD, H.S. Hospital Service Spa, Rome, Italy, for the scientific support.

Author's Contribution Conceptualization: TFN, RDR, BRWI, HASdC, DS; Data Curation: TFN, RDR, HASdC, DS; Formal Analysis: TFN, RDR, HASdC, DS; Funding Acquisition: Not applicable; Investigation: TFN, RDR, BRWI, GCM, DS; Methodology: TFN, RDR, FSS, GCM, HASdC, DS; Project Administration: TFN, RDR, FSS, DS; Resources: TFN, RDR, FSS, DS; Software: TFN, RDR, DS; Supervision: TFN, RDR, PCCV, RGG, HASdC, DS; Validation: TFN, RDR, PCCV, RGG, DS; Visualization: TFN, RDR, HASdC, DS; Writing—Original Draft Preparation: TFN, RDR, VAVF, DS; Writing—Review & Editing: TFN, RDR, VAVF, PCCV, DS.

Funding This study was not supported by any funding. The authors have no relevant financial or non-financial interests to disclose.

Data Availability All relevant data are within the paper.

Declarations

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

Consent for Publication Consent for publication was obtained for every individual person's data included in the study.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

IRB Approval This report was approved by the Research Ethics Committee of Universidade Federal de São Paulo, Brazil (protocol number: CAAE 74939723.1.0000.5505).

References

1. Lerner LB, McVary KT, Barry MJ, et al. Management of lower urinary tract symptoms attributed to benign prostatic hyperplasia: AUA GUIDELINE PART II-surgical evaluation and treatment. J Urol. 2021;206:818–26.
2. Oelke M, Bachmann A, Descazeaud A, et al. EAU guidelines on the treatment and follow-up of non-neurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol. 2013;64:118–40.
3. Gratzke C, Schlenker B, Seitz M, et al. Complications and early postoperative outcome after open prostatectomy in patients with

benign prostatic enlargement: results of a prospective multicenter study. J Urol. 2007;177:1419–22.
4. Reich O, Gratzke C, Bachmann A, et al. Morbidity, mortality and early outcome of transurethral resection of the prostate: a prospective multicenter evaluation of 10,654 patients. J Urol. 2008;180:246–9.
5. Ahyai SA, Gilling P, Kaplan SA, et al. Meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic enlargement. Eur Urol. 2010;58:384–97.
6. Rassweiler J, Teber D, Kuntz R, Hofmann R. Complications of transurethral resection of the prostate (TURP)–incidence, management, and prevention. Eur Urol. 2006;50:969–79.
7. Christidis D, McGrath S, Perera M, Manning T, Bolton D, Lawrentschuk N. Minimally invasive surgical therapies for benign prostatic hypertrophy: the rise in minimally invasive surgical therapies. Prostate Int. 2017;5:41–6.
8. McVary KT, Gittelman MC, Goldberg KA, et al. Final 5-year outcomes of the multicenter randomized sham-controlled trial of a water vapor thermal therapy for treatment of moderate to severe lower urinary tract symptoms secondary to benign prostatic hyperplasia. J Urol. 2021;206:715–24.
9. Babar M, Loloi J, Tang K, Syed U, Ciatto M. Emerging outcomes of water vapor thermal therapy (Rezum) in a broad range of patients with lower urinary tract symptoms secondary to benign prostatic hyperplasia: a systematic review. Low Urin Tract Sympt. 2022;14:140–54.
10. Kaplan-Marans E, Zhang TR, Hu JC. Differing recommendations on prostate biopsy approach to minimize infections: an examination of the European association of urology and American urological association guidelines. Eur Urol. 2023;84:445–6.
11. Patelli G, Ranieri A, Paganelli A, Mauri G, Pacella CM. Transperineal laser ablation for percutaneous treatment of benign prostatic hyperplasia: a feasibility study. Cardiovasc Intervent Radiol. 2017;40:1440–6.
12. Rosati D, Lombardo R, De Nunzio C, Leonardo C, Tubaro A. Transperineal interstitial laser ablation of the prostate, a novel option for minimally invasive treatment of benign prostatic obstruction. Eur Urol. 2021;80:673–4.
13. Frego N, Saita A, Casale P, et al. Feasibility, safety, and efficacy of ultrasound-guided transperineal laser ablation for the treatment of benign prostatic hyperplasia: a single institutional experience. World J Urol. 2021;39:3867–73.
14. Cai HJ, Fang JH, Kong FL, et al. Ultrasound-guided transperineal laser ablation for percutaneous treatment of benign prostatic hyperplasia: a new minimally invasive interventional therapy. Acta Radiol. 2022;63:553–8.
15. van Kollenburg RAA, van Riel LAMJG, Bloemen PR, et al. Transperineal laser ablation treatment for lower urinary tract symptoms due to benign prostatic obstruction: Protocol for a prospective in vivo pilot study. JMIR Res Protoc. 2020;9:e15687.
16. Chughtai B, Rojanasarot S, Neeser K, Gultyaev D, Amorosi SL, Shore ND. Cost-effectiveness and budget impact of emerging minimally invasive surgical treatments for benign prostatic hyperplasia. J Health Econ Outcomes Res. 2021;8:42–50.
17. Napoli A, Alfieri G, Andrani F, Scipione R, Manganaro L, Pecorini F, Catalano C. Uterine myomas: focused ultrasound surgery. Semin Ultrasound CT MR. 2021;42:25–36.
18. Nunes TF, Szejnfeld D, Xavier AC, et al. Percutaneous ablation of functioning adrenal adenoma: a report on 11 cases and a review of the literature. Abdom Imaging. 2013;38:1130–5.
19. Szejnfeld D, Nunes TF, Giordano EE, et al. Radiofrequency ablation of functioning adrenal adenomas: preliminary clinical and laboratory findings. J Vasc Interv Radiol. 2015;26:1459–64.
20. Santos GPL, Kulcsar MAV, Capelli FA, et al. Brazilian consensus on the application of thermal ablation for treatment of thyroid nodules: a task force statement by the Brazilian Society of Interventional Radiology and Endovascular Surgery (SOBRICE), Brazilian Society of Head and Neck Surgery (SBCCP), and Brazilian Society of Endocrinology and Metabolism (SBEM). Arch Endocrinol Metab. 2024;68: e230263.
21. Sinclair CF, Baek JH, Hands KE, et al. General principles for the safe performance, training, and adoption of ablation techniques for benign thyroid nodules: an American thyroid association statement. Thyroid. 2023;33:1150–70.
22. Ye Z, Wang J, Xiao Y, Luo J, Xu L, Chen Z. Global burden of benign prostatic hyperplasia in males aged 60–90 years from 1990 to 2019: results from the global burden of disease study 2019. BMC Urol. 2024;24:193.
23. Sandhu JS, Bixler BR, Dahm P, et al. Management of lower urinary tract symptoms attributed to Benign Prostatic Hyperplasia (BPH): AUA Guideline Amendment 2023. J Urol. 2024;211:11–9.
24. Bilhim T. Long-term PAE results: what do we know. Semin Intervent Radiol. 2022;39:577–80.
25. Bilhim T, Costa NV, Torres D, Pinheiro LC, Spaepen E. Long-term outcome of prostatic artery embolization for patients with benign prostatic hyperplasia: single-centre retrospective study in 1072 patients over a 10-year period. Cardiovasc Intervent Radiol. 2022;45:1324–36.
26. Carnevale FC, de Assis AM, Moreira AM. Prostatic artery embolization: equipment, procedure steps, and overcoming technical challenges. Tech Vasc Interv Radiol. 2020;23: 100691.
27. Ayyagari R, Rahman SZ, Grizzard K, et al. Multicenter quantification of radiation exposure and associated risks for prostatic artery embolization in 1476 patients. Radiology. 2024;310: e231877.
28. Bilhim T, Betschart P, Lyatoshinsky P, Müllhaupt G, Abt D. Minimally invasive therapies for benign prostatic obstruction: a review of currently available techniques including prostatic artery embolization, water vapor thermal therapy, prostatic urethral lift, temporary implantable nitinol device and aquablation. Cardiovasc Intervent Radiol. 2022;45:415–24.
29. Türk Y, Devecioğlu İ, Çilesiz NC, Nuhoğlu B. Transperineal microwave thermoablation for benign prostatic hyperplasia-related lower urinary tract symptoms in an elderly patient. Diagn Interv Radiol. 2024. https://doi.org/10.4274/dir.2024.232639.
30. Bertolo R, Iacovelli V, Cipriani C, et al. Ejaculatory function following transperineal laser ablation vs TURP for benign prostatic obstruction: a randomized trial. BJU Int. 2023;132:100–8.
31. Lo Re M, Polverino P, Rivetti A, et al. Transperineal laser ablation (TPLA) of the prostate for benign prostatic obstruction: the first 100 patients cohort of a prospective, single-center study. World J Urol. 2024;42:402.
32. Patelli G, Altieri VM, Ierardi AM, et al. Transperineal laser ablation of the prostate for symptomatic benign prostatic hyperplasia: long-term follow-up in 40 patients. J Vasc Interv Radiol. 2024;35:1187–93.
33. Schalch MS, Costa ACN, de Souza RP, Guerra FLB, Guerreiro R, De Cicco R. Radiofrequency ablation of thyroid nodules: prospective cost-effectiveness analysis in comparison to conventional thyroidectomy. Arch Endocrinol Metab. 2021;65:752–7.
34. Ayoub NF, Balakrishnan K, Orloff LA, Noel JE. Time-driven activity-based cost comparison of thyroid lobectomy and radiofrequency ablation. Otolaryngol Head Neck Surg. 2023;169:830–6.
35. Cronan J, Horný M, Duszak R Jr, et al. Invasive procedural treatments for symptomatic uterine fibroids: a cost analysis. J Am Coll Radiol. 2020;17:1237–44.
36. Papi G, Novizio R, Brunetti M, Mauri G. Impact of the introduction of minimally invasive treatments of the thyroid (MITT)

for benign thyroid nodules in an Italian hospital: a cost-minimization analysis. Endocrine. 2023;82:126–33.
37. Pacella CM, Patelli G, Iapicca G, et al. Transperineal laser ablation for percutaneous treatment of benign prostatic hyperplasia: a feasibility study. Results at 6 and 12 months from a retrospective multi-centric study. Prostate Cancer Prostatic Dis. 2020;23:356–63.
38. Cesareo R, Egiddi S, Naciu AM, et al. Efficacy of radiofrequency and laser thermal ablation in solving thyroid nodule-related symptoms and cosmetic concerns. A systematic review and meta-analysis. Rev Endocr Metab Disord. 2022;23:1051–61.
39. Abt D, Müllhaupt G, Hechelhammer L, et al. Prostatic artery embolisation versus transurethral resection of the prostate for benign prostatic hyperplasia: 2-yr outcomes of a randomised, open-label, single-centre trial. Eur Urol. 2021;80:34–42.