

# PAE Articles—Executive Summaries

1. Amouyal, G., Pellerin, O., Del Giudice, C., et al. (2017). Bilateral arterial embolization of the prostate through a single prostatic artery: A case series. *Cardiovasc Intervent Radiol*, May; 40(5):780-787. <https://www.ncbi.nlm.nih.gov/pubmed/27999920>

Peri-prostatic shunts are frequent during prostatic artery embolization (PAE), carrying the risk of limited clinical success because bilateral embolization is sometimes impossible. In these situations, the possibility to reach contralateral prostatic territory from the ipsilateral prostatic artery (PA) and embolize it via peri/intra-prostatic anastomoses could be of interest. This report describes three consecutive patients who underwent successful embolization of both prostatic lobes through catheterization of a PA on only one side. All patients had clinical success after a mean follow-up of 3.3 months.

2. Amouyal, G., Chague, P., Pellerin, O., et al. (2016). Safety and efficacy of occlusion of large extra-prostatic anastomoses during prostatic artery embolization for symptomatic BPH. *Cardiovasc Intervent Radiol*, Sep;39(9):1245-1255. <https://www.ncbi.nlm.nih.gov/pubmed/27412754>

During prostatic artery embolization (PAE), large extra-prostatic shunts carry a high risk of rectal or penile necrosis if embolized. This report compares 11 consecutive patients who underwent protective embolization of large extra-prostatic shunts before PAE to 44 other patients who underwent basic PAE. Clinical success was defined as a decrease of 25% or eight points of International Prostate Symptom Score (IPSS), quality of life (QoL) score < 3 or a one-point decrease, and a maximum urine flow rate (Q<sub>max</sub>) improvement of 25% or 2.5 mL/s. A 100% rate of occlusion of the anastomosis was seen. Bilateral embolization of the prostatic artery was performed in all patients with no additional time of procedure (P = 0.18) but a significant increase of dose area product (P = 0.03). The PERFecTED (Proximal Embolization First, Then Embolize Distal) technique was possible in 64%. With an average follow up of 3.5 months, clinical success was 91% compared to 78% for the entire PAE group. There was no worsening of erectile dysfunction, no rectal or penile necrosis, and no immediate or late clinical complications. Results indicate the protection technique in these high-risk cases is as safe and effective as basic procedures and does not include any additional time of procedure.

3. Amouyal, G., Thiounn, N., Pellerin, O., et al. (2016). Clinical results after prostatic artery embolization using the PERFecTED technique: A single-center study. *Cardiovasc Intervent Radiol*, Mar;39(3):367-375. <https://www.ncbi.nlm.nih.gov/pubmed/26702619>

Prostatic artery embolization (PAE) has been performed for a few years, but at the time of this study there was no report on PAE using the PERFecTED (Proximal Embolization First, Then Embolize Distal) technique outside from the team that initiated this approach. This single-center retrospective open label study reports experience and clinical results using the PERFecTED technique on patients suffering from symptomatic benign prostatic hyperplasia (BPH), who underwent PAE. Thirty-two consecutive patients were treated using the PERFecTED technique and followed up at 3, 6, and 12 months. Results showed a 100% immediate technical success rate with no immediate complications and a 78% clinical success rate after a mean follow-up of 7.7 months. Mean International Prostate Symptom Score (IPSS) decreased from 15.3 to 4.2 (P = .03), mean quality of life (QoL) from 5.4 to 2 (P = .03), mean maximum urine flow rate (Q<sub>max</sub>) increased from 9.2 to 19.2 (P = .25), and mean prostatic volume (PV) decreased from 91 to 62 mL (P = .009). There was no retrograde ejaculation and no major complication. The authors conclude that in some cases the PERFecTED technique is a safe and efficient approach to treat bothersome LUTS related to BPH.

4. Antunes, A. A., Carnevale\*, F. C., da Motta-Leal-Filho, J. M., et al. (2013). Clinical, laboratorial, and urodynamic findings of prostatic artery embolization for the treatment of urinary retention related to benign prostatic hyperplasia. A prospective single-center pilot study. *Cardiovasc Intervent Radiol*, Aug;36(4):978-986. <https://www.ncbi.nlm.nih.gov/pubmed/23580116>

This prospective study describes the clinical, laboratorial, and urodynamic findings of prostatic artery embolization (PAE) in patients with urinary retention due to benign prostatic hyperplasia (BPH). Eleven patients with urinary retention due to BPH underwent physical examination, prostate-specific antigen (PSA) measurement, transrectal ultrasound, and magnetic resonance imaging (MRI). International Prostate Symptom Score (IPSS), quality of life (QoL), and urodynamic testing were used to assess the outcome before and after 1 year. Clinical success was 91% with a mean follow-up of 22.3 months. At the first year follow-up, mean IPSS score was 2.8 points (P = 0.04), mean QoL was 0.4 points (P = 0.001), mean PSA decreased from 10.1 to 4.3 ng/mL (P = 0.003), maximum urine flow rate (Q<sub>max</sub>) improved from 4.2 to 10.8 mL/sec (P = 0.009), and detrusor pressure (P<sub>det</sub>) decreased from 85.7 to 51.5 cm H<sub>2</sub>O (P = 0.007). Before PAE, Bladder Outlet Obstruction Index (BOOI) showed values > 40 in 100% of patients. After PAE, 30% of patients were > 40 (obstructed), 40% were between 20 and 40 (undetermined), and 30% were < 20 (unobstructed). Results indicate clinical and urodynamic parameters improve significantly after PAE in patients with acute urinary retention due to BPH.

5. Bhatia\*, S., Harward, S. H., Sinha, V. K., et al. (2017). Prostate artery embolization via transradial or transulnar versus transfemoral arterial access: Technical results. *J Vasc Interv Radiol*, Jun;28(6):898-905. <https://www.ncbi.nlm.nih.gov/pubmed/28396191>

The purpose of this retrospective analysis is to compare safety and feasibility of prostatic artery embolization (PAE) via transradial/transulnar access (TR/UA) and transfemoral access (TFA) among patients with lower urinary tract symptoms (LUTS) or those undergoing preoperative embolization before prostatectomy. Three cohorts were included: the first 32 consecutive PAE procedures performed via TFA (initial TFA), the following 32 procedures performed via TFA (advanced TFA), and the first 32 PAE procedures performed via TR/UA. A technical success rate of 90.6% was seen for initial TFA procedures, 96.9% for advanced TFA procedures, and 93.8% for TR/UA procedures. Mean procedure time was 110.0 minutes in TR/UA group, 155.1 min in initial TFA group, and 131.3 minutes in advanced TFA group (P < .01 and P = .03 relative to TR/UA). Mean fluoroscopy time was 38.8 minutes in TR/UA group, 56.5 minutes in initial TFA group, and 48.0 minutes in advanced TFA group (P < .01 and P = .02 relative to TR/UA). Access site-related and overall adverse events did not vary significantly among study cohorts. These findings suggest TR/UA represents a safe and feasible approach to PAE with a comparable safety profile to TFA.

6. Bhatia\*, S., Sinha, V. K., Bordegaray, M., et al. (2017). Role of coil embolization during prostatic artery embolization: Incidence, indications, and safety profile. *J Vasc Interv Radiol*, May;28(5):656-664. <https://www.ncbi.nlm.nih.gov/pubmed/28284886>

This retrospective analysis aims to determine if prostatic artery embolization with coil embolization (cPAE) is a safe adjunctive measure to prevent non-target embolization in comparison to prostatic artery embolization without coil embolization (nPAE). In 122 patients, 32 underwent cPAE in 39 arteries. Compared with nPAE, cPAE had a nonsignificant increase in dose area product (64,516 μGy·m<sup>2</sup> vs 52,100 μGy·m<sup>2</sup>, P = .053) but significantly longer procedure (160.1 min vs 137.1 min, P = .022) and fluoroscopy (62.9 min vs 46.1 min, P = .023) times. There were no statistically significant differences in major and minor complications between cohorts at 1-month and 3-month follow-up visits. Although cPAE leads to increases in procedure and fluoroscopy times, it is a safe adjunctive technique to occlude communications between the prostatic artery and pelvic vasculature to potentially prevent non-target embolization.

7. Bhatia\*, S., Kava, B., Pereira, K., et al. (2015). Prostate artery embolization for giant prostatic hyperplasia. *J Vasc Interv Radiol*, Oct;26(10):1583-1585. <https://www.ncbi.nlm.nih.gov/pubmed/26408223>

In most cases, benign prostatic hyperplasia (BPH) involves a moderate enlargement of the prostate gland of 25-100 cm<sup>3</sup>. In rare cases, the prostate enlarges massively, weighing more than 500 cm<sup>3</sup>, a condition known as giant prostatic hyperplasia (GPH). In this case report, an 80-year-old man with a decade-long history of lower urinary tract symptoms (LUTS) presented with acute urinary retention and GPH. The patient had been taking tamsulosin for more than a decade and declined open prostatectomy. He was referred to the interventional radiology clinic for prostatic artery embolization (PAE). At the post-PAE 10-day voiding trial, tamsulosin therapy was stopped. Compared to baseline values, the patient's International Prostate Symptom Score (IPSS) improved from 26 (severely symptomatic) to 6 (mildly symptomatic), quality of life (QoL) score improved from 6 (terrible) to 2 (mostly satisfied), and Sexual Health Inventory for Men score improved from 13 (mild to moderate erectile dysfunction) to 17 (mild erectile dysfunction). Magnetic resonance imaging (MRI) performed at 3 months showed the patient's prostate gland to weigh approximately 270 cm<sup>3</sup>. The patient exhibited reduced LUTS. His IPSS and QoL continued to improve and were recorded at 4 and 1, respectively. The authors conclude that PAE could be an ideal first-line treatment for GPH. Currently, there is no consensus on the upper limit of prostate gland weight that can be managed with PAE.

8. Brook, O. R., Faintuch, S., Brook, A., et al. (2013). Embolization therapy for benign prostatic hyperplasia: Influence of embolization particle size on gland perfusion. *J Magn Reson Imaging*, Aug;38(2):380-387. <https://www.ncbi.nlm.nih.gov/pubmed/23239260>

The purpose of this study is to assess the influence of embolic size on the therapy response of prostatic artery embolization (PAE). Twelve beagles underwent PAE, four dogs with each particle size: A: 100-300  $\mu\text{m}$ ; B: 300-500  $\mu\text{m}$ ; and C: 500-700  $\mu\text{m}$ . Prior to and 1 month after the embolization, all dogs underwent prostate dynamic contrast-enhanced (DCE) magnetic resonance imaging (MRI). Time to maximal perfusion intensity for prostate parenchyma increased in B (188 vs. 135 sec,  $P = 0.023$ ) and C (200 vs. 120 sec,  $P = 0.001$ ), whereas it did not change for A (139 vs. 124 sec,  $P = 0.39$ ). The maximal relative intensity increased after embolization in C (3.84 vs. 2.38,  $P < 0.001$ ), while it did not change for A (2.50 vs. 2.44,  $P = 0.36$ ) and B (3.23 vs. 2.9,  $P = 0.21$ ). The extent of visualized intraprostatic urethral wall increased after embolization in B compared with A and C ( $239.5 \pm 138.1\%$  vs.  $56.1 \pm 34.3\%$ ,  $P = 0.04$ ). Enhancement changes correlated with prostate volume changes: prostate volumes in A decreased less as compared with B and C ( $77 \pm 34\%$  vs.  $56 \pm 14\%$ ,  $P = 0.02$ ). Embolization with 300-500 and 500-700  $\mu\text{m}$  particles may provide better results than with 100-300  $\mu\text{m}$  particles in a canine model.

9. Camara-Lopes, G., Mattedi, R., Antunes, A. A., et al. (2013). The histology of prostate tissue following prostatic artery embolization for the treatment of benign prostatic hyperplasia. *Int Braz J Urol*, Mar-Apr;39(2):222-227. <https://www.ncbi.nlm.nih.gov/pubmed/23683668>

Knowledge of the histological characteristics of prostate tissue following prostatic artery embolization (PAE) is still limited. This study is the first description of prostate histology in benign prostatic hyperplasia (BPH) patients treated by PAE. Two patients underwent transurethral resection of the prostate (TURP) after PAE. The prostate tissues were analyzed histologically. The embolic material within the prostate tissue was easily identified as homogeneous, bright eosin-red spheroids filling the vessel lumens. Ischemic necrosis with chronic inflammatory reactions containing macrophages was seen. Aspects related to the healing process such as fibrotic nodules surrounded by glands with squamous metaplasia of the epithelial lining were observed. In the remaining sections, the classic findings of BPH were still present with the glandular and stromal hyperplasia associated with nonspecific chronic prostatitis. The authors conclude that recognition of the changes caused by PAE has become a very important differential in a chronic granulomatous reaction of the prostate tissue.

10. Carnevale\*, F. C., Moreira, A. M., Harward, S. H., et al. (2017). Recurrence of lower urinary tract symptoms following prostate artery embolization for benign hyperplasia: Single center experience comparing two techniques. *Cardiovasc Intervent Radiol*, Mar;40(3):366-374. <https://www.ncbi.nlm.nih.gov/pubmed/28074310>

This study compares lower urinary tract symptoms (LUTS) recurrence at 12 months following two techniques: original prostate artery embolization (oPAE) and PErFecTED (Proximal Embolization First, Then Embolize Distal) PAE. The study included 105 consecutive patients. Technical success was defined as bilateral embolization and clinical success (non-recurrence) was defined as removal of the Foley catheter in patients with urinary retention, International Prostate Symptom Score (IPSS)  $< 8$  and quality of life (QoL) index  $< 3$  at 12 months of follow-up. Data at 12 months was recorded as follows: oPAE without recurrence ( $n = 46$ ), oPAE with recurrence ( $n = 13$ ), PErFecTED without recurrence ( $n = 36$ ), or PErFecTED with recurrence ( $n = 2$ ). Recurrence was significantly more common in oPAE patients ( $\chi^2$ ,  $P = 0.026$ ). Unilateral embolization was significantly associated with recurrence among patients who underwent oPAE ( $\chi^2$ ,  $P = 0.032$ ). Both techniques are safe and effective methods of treatment of LUTS, but PErFecTED PAE is associated with a significantly lower rate of symptom recurrence.

11. Carnevale\*, F. C., Iscaife, A., Yoshinaga, E. M., et al. (2016). Transurethral resection of the prostate (TURP) versus original and PErFecTED prostate artery embolization (PAE) due to benign prostatic hyperplasia (BPH): Preliminary results of a single center, prospective, urodynamic-controlled analysis. *Cardiovasc Intervent Radiol*, Jan;39(1):44-52. <https://www.ncbi.nlm.nih.gov/pubmed/26506952>

In this study, the clinical and urodynamic results of Transurethral Resection of the Prostate (TURP) are compared to original prostatic artery embolization (oPAE) and PErFecTED (Proximal Embolization First, Then Embolize Distal) PAE methods for benign prostatic hyperplasia (BPH). Thirty patients were randomly assigned to receive TURP or oPAE and were then compared to a cohort of patients treated by PErFecTED PAE. All patients were followed up for a minimum of 1 year. Patients were assessed for urodynamic parameters, prostate volume (PV), International Prostate Symptom Score (IPSS), and quality of life (QoL). Study outcomes showed that all groups experienced significant improvement in IPSS, QoL, PV, and maximum urine flow rate (Q<sub>max</sub>). TURP and PErFecTED PAE yield similar symptom improvement, but TURP is associated with both better urodynamic results and more adverse events. Both TURP and PAE are considered safe and effective treatments.

12. Carnevale\*, F. C., Moreira, A. M., & Antunes, A. A. (2014). The "PErFecTED technique": Proximal embolization first, then embolize distal for benign prostatic hyperplasia. *Cardiovasc Intervent Radiol*, Dec;37(6):1602-1605. <https://www.ncbi.nlm.nih.gov/pubmed/24943914>

The PErFecTED (Proximal Embolization First, Then Embolize Distal) technique has produced greater prostate ischemia and infarction than previously described methods with clinical improvement of lower urinary tract symptoms and lower recurrence rates. This journal article provides an updated guide to performing the PErFecTED technique accompanied by success rates.

**13. Carnevale\*, F. C., da Motta-Leal-Filho, J. M., Antunes, A. A., et al. (2013). Quality of life and clinical symptom improvement support prostatic artery embolization for patients with acute urinary retention caused by benign prostatic hyperplasia. J Vasc Interv Radiol, Apr;24(4):535-542. <https://www.ncbi.nlm.nih.gov/pubmed/23434084>**

The purpose of this single-center prospective study is to show that prostatic artery embolization (PAE) improves quality of life (QoL) and lower urinary tract symptoms (LUTS) in patients with acute urinary retention caused by benign prostatic hyperplasia (BPH). Eleven patients with BPH managed with indwelling urinary catheters underwent PAE. International Prostate Symptom Score (IPSS), ultrasound, magnetic resonance imaging (MRI), QoL, and urodynamic tests were used to assess outcomes. Technical success was 75%, and the rate of clinical success was 91%. No major complications were observed. Follow-up ranged from 19 to 48 months. After 1 year, mean prostate volume (PV) reduction was greater than 30%, symptoms were mild (mean IPSS,  $2.8 \pm 2.1$ ;  $P = .04$ ), no erectile dysfunction was observed, and QoL improved significantly (mean,  $0.4 \pm 0.5$ ;  $P = .001$ ). Given these outcomes, the authors conclude that patients with severe symptoms and acute urinary retention caused by BPH can be treated safely by PAE, which improves clinical symptoms and QoL.

**14. Carnevale\*, F. C. & Antunes, A. A. (2013). Prostatic artery embolization for enlarged prostates due to benign prostatic hyperplasia. How I do it. Cardiovasc Intervent Radiol, Dec;36(6):1452-1463. <https://www.ncbi.nlm.nih.gov/pubmed/23903785>**

Prostatic artery embolization (PAE) has emerged as an alternative to surgical treatments for benign prostatic hyperplasia (BPH). The authors share their approach to PAE including patient selection, techniques, product selection and collaborative approach with urologists to achieve better results.

**15. Carnevale\*, F. C., da Motta-Leal-Filho, J. M., Antunes, A. A., et al. (2011). Midterm follow-up after prostate embolization in two patients with benign prostatic hyperplasia. Cardiovasc Intervent Radiol, Dec;34(6):1330-1333. <https://www.ncbi.nlm.nih.gov/pubmed/21387120>**

Benign prostatic hyperplasia (BPH) is the most common benign neoplasm in men. This study reports the radiological and clinical midterm follow-up of prostatic artery embolization (PAE) in two patients with acute urinary retention due to BPH—one who underwent bilateral embolization and the other who had a unilateral embolization procedure. Ultrasound and magnetic resonance imaging (MRI) were used for evaluation of effectiveness at 1, 3, 6, and 18 months. International Prostate Symptom Score (IPSS), quality of life (QoL) score, and International Index of Erectile Function (IIEF) score were evaluated until the last 24-month follow-up. By 18 months, the first patient showed a 50% decrease in prostate volume. At 30 months, the patient was voiding normally with an IPSS equal to one and QoL of zero. By 18 months, the second patient showed a reduction in prostate volume of 19.6% and 12.2% by ultrasound and MRI, respectively. At 30 months, the patient was voiding normally, with an IPSS equal to seven and QoL of one.

**16. Carnevale\*, F. C., Antunes, A. A., da Motta-Leal-Filho, J. M., et al. (2010). Prostatic artery embolization as a primary treatment for benign prostatic hyperplasia: Preliminary results in two patients. Cardiovasc Intervent Radiol, Apr;33(2):355-361. <https://www.ncbi.nlm.nih.gov/pubmed/19908092>**

Symptomatic benign prostatic hyperplasia (BPH) typically occurs in the sixth and seventh decades and can be the cause of obstructive urinary symptoms. Preliminary results for two patients treated with prostatic artery embolization (PAE)—one patient underwent bilateral PAE and the other had unilateral PAE—for acute urinary retention due to BPH are reported. The patients were investigated using the International Prostate Symptom Score (IPSS), digital rectal examination, urodynamic testing, prostate biopsy, transrectal ultrasound, and magnetic resonance imaging (MRI). Uroflowmetry and postvoid residual (PVR) urine volume complemented the investigation at 30, 90, and 180 days after PAE. At 6-month follow-up, ultrasound and MRI revealed a prostate reduction of 39.7% and 47.8%, respectively, for the bilateral PAE patient and 25.5% and 27.8%, respectively, for the patient who underwent unilateral PAE. These early results show PAE to be a promising alternative treatment for BPH.

**17. de Assis, A. M., Moreira, A. M., de Paula Rodrigues, V. C., et al. (2015). Pelvic arterial anatomy relevant to prostatic artery embolization and proposal for angiographic classification. Cardiovasc Intervent Radiol, Aug;38(4):855-861. <https://www.ncbi.nlm.nih.gov/pubmed/25962991>**

This study describes and categorizes the angiographic findings regarding prostatic vascularization, proposes an anatomic classification, and discusses its implications for the prostatic artery embolization (PAE) procedure. Angiographic findings from 143 PAE procedures were reviewed retrospectively. Two hundred eighty-six pelvic sides were analyzed. Despite the large number of possible anatomical variations of the male pelvis, four main patterns corresponded to almost 95% of the cases. The authors conclude that evaluation of anatomy in a systemic fashion, following a standard classification, will make PAE faster, safer, and more effective.

**18. de Assis, A. M., Moreira, A. M., de Paula Rodrigues, V. C., et al. (2015). Prostatic artery embolization for treatment of benign prostatic hyperplasia in patients with prostates > 90 g: A prospective single-center study. J Vasc Interv Radiol, Jan;26(1):87-93. <https://www.ncbi.nlm.nih.gov/pubmed/25541446>**

This prospective, single-center, single-arm study investigates the safety and efficacy of prostatic artery embolization (PAE) with spherical microparticles to treat lower urinary tract symptoms (LUTS) associated with benign prostatic hyperplasia (BPH) in 35 patients with prostate volume (PV) > 90 g. Magnetic resonance imaging (MRI), uroflowmetry, and the International Prostate Symptom Score (IPSS) were used to assess clinical and functional outcomes. Mean prostate size decreased significantly from 135.1 g before PAE to 91.9 g at 3 months of follow-up ( $P < .0001$ ). Mean IPSS and quality of life (QoL) index improved from 18.3 to 2.7 and 4.8 to 0.9 ( $P < .0001$  for both), respectively. A significant negative correlation was observed between prostate-specific antigen (PSA) at 24 hours after PAE and IPSS 3 months after PAE ( $P = .0057$ ). PAE is a safe and effective treatment for LUTS secondary to BPH in patients with PV > 90 g.

**19. Feng, S., Tian, Y., Liu, W., et al. (2017). Prostatic arterial embolization treating moderate-to-severe lower urinary tract symptoms related to benign prostatic hyperplasia: A meta-analysis. Cardiovasc Intervent Radiol, Jan;40(1):22-32. <https://www.ncbi.nlm.nih.gov/pubmed/27872988>**

This meta-analysis of 20 eligible studies evaluates the clinical efficiency and safety of prostatic artery embolization (PAE) treating moderate-to-severe lower urinary tract symptoms (LUTS) related to benign prostatic hyperplasia (BPH). Data showed there were statistically significant improvements in International Prostate Symptom Score (IPSS), quality of life (QoL) score, prostate-specific antigen (PSA) level, prostate volume (PV), maximum urine flow rate (Q<sub>max</sub>), and postvoid residual (PVR) without affecting erectile function. Major complications following PAE included pain in the perineum, retropubic area, and/or urethra (9.4%), and hematuria (9.0%). PAE is a very promising alternative treatment for those who do not want or cannot tolerate surgical treatment.

20. Frenk, N. E., Baroni, R. H., Carnevale\*, F. C., et al. (2014). MRI findings after prostatic artery embolization for treatment of benign hyperplasia. *AJR Am J Roentgenol*, Oct;203(4):813-821. <https://www.ncbi.nlm.nih.gov/pubmed/25247946>

This retrospective evaluation assesses and describes magnetic resonance imaging (MRI) findings of 17 patients who underwent prostatic artery embolization (PAE) for treatment of benign prostatic hyperplasia (BPH) as part of different prospective studies. Clinical results were evaluated by assessing urinary catheterization and International Prostate Symptom Score (IPSS). Serial MRI examinations were performed, and the prostatic central gland and peripheral zone were evaluated for signal intensity changes and the presence and characteristics of infarcted areas. All patients had clinical success, as defined by the removal of indwelling urinary catheter or decreased IPSS after embolization. Infarcts were seen in 70.6% of the subjects and exclusively in the central gland. Volume reduction of the prostate after embolization was significant (averaging 32.0% after 12-18 months;  $P < 0.001$ ) only in patients with infarcts. The authors conclude that MRI is useful for assessing the development of infarcts and volume reduction in the prostate after embolization. Further studies are needed to correlate these findings to clinical outcome.

21. Gabr, A. H., Gabr, M. F., Elmohamady, B. N., et al. (2016). Prostatic artery embolization: A promising technique in the treatment of high-risk patients with benign prostatic hyperplasia. *Urol Int*, Oct;97(3):320-324. <https://www.ncbi.nlm.nih.gov/pubmed/27322582>

Prostatic artery embolization (PAE) has recently started to be viewed as a promising technology that could be an alternative to different treatment options of benign prostatic hyperplasia (BPH), especially in high-risk patients. This prospective study aims to evaluate the efficacy and safety of PAE in 22 consecutive patients with BPH who were at high risk for surgery and/or anesthesia. All patients enrolled had lower urinary tract symptoms (LUTS) refractory to BPH-related medical therapy or had an indwelling urethral catheter due to refractory urine retention. Before the procedure and then at 1, 3, and 9 months post-intervention, all patients were assessed by detailed medical history, physical examination, serum prostate-specific antigen (PSA) level, uroflowmetry, and abdominal and transrectal ultrasound. The PAE procedure was successful in all patients. Throughout the period of follow-up, there was a significant improvement in LUTS, urinary flow rate, prostate volume (PV), and serum PSA (for all  $P < 0.001$ ). No major complications were reported. These results show that BPH patients with failed medical treatment who are at high risk for surgery and/or anesthesia could be treated safely and effectively with PAE.

22. Golzarian, J., Antunes, A. A., Bilhim, T., et al. (2014). Prostatic artery embolization to treat lower urinary tract symptoms related to benign prostatic hyperplasia and bleeding in patients with prostate cancer: Proceedings from a multidisciplinary research consensus panel. *J Vasc Interv Radiol*, May;25(5):665-674. <https://www.ncbi.nlm.nih.gov/pubmed/24560898>

Benign prostatic hyperplasia (BPH) involves histologic changes associated with unregulated but benign proliferations of glandular and stromal prostate tissue, which can cause physical compression of the urethra and mechanical bladder outlet obstruction (BOO). BOO may produce lower urinary tract symptoms (LUTS)—a cluster of chronic urinary disorders. This report describes the proceedings from a multidisciplinary research consensus panel regarding prostatic artery embolization (PAE) to treat LUTS.

23. Gonçalves, O. M., Carnevale\*, F. C., Moreira, A. M., et al. (2016). Comparative study using 100-300 versus 300-500  $\mu\text{m}$  microspheres for symptomatic patients due to enlarged-BPH prostates. *Cardiovasc Intervent Radiol*, Oct;39(10):1372-1378. <https://www.ncbi.nlm.nih.gov/pubmed/27509889>

This comparative study examines the safety and efficacy outcomes following prostatic artery embolization (PAE) for the treatment of lower urinary tract symptoms (LUTS) due to benign prostatic hyperplasia (BPH) with 100-300  $\mu\text{m}$  versus 300-500  $\mu\text{m}$  tris-acryl gelatin microspheres. Fifteen patients were included in each of the following groups: 100-300  $\mu\text{m}$  (group A) or 300-500  $\mu\text{m}$  (group B) tris-acryl gelatin microspheres. PAE was technically successful in all cases. Patients were followed for a minimum of 12 months. Both groups experienced significant improvement in mean International Prostate Symptom Score (IPSS), quality of life (QoL), prostate volume (PV), serum prostate-specific antigen (PSA), and maximum urine flow rate (Qmax) ( $P < 0.05$  for all). Though both sizes are found to be safe and effective embolic agents for PAE, the greater incidence of adverse events associated with 100-300  $\mu\text{m}$  microspheres suggests that 300-500  $\mu\text{m}$  microspheres may be the more appropriate size for use in PAE.

24. Grosso, M., Balderi, A., Arnò, M., et al. (2015). Prostatic artery embolization in benign prostatic hyperplasia: Preliminary results in 13 patients. *Radiol Med*, Apr;120(4):361-368. <https://www.ncbi.nlm.nih.gov/pubmed/25245496>

This paper reports clinical outcomes after prostatic artery embolization (PAE) in 13 consecutive patients with benign prostatic hyperplasia (BPH) and lower urinary tract symptoms (LUTS). A mean clinical follow-up of 244 days was performed using the International Prostate Symptom Score (IPSS), quality of life (QoL) score, the International Index of Erectile Function (IIEF), blood prostate-specific antigen (PSA) testing and transrectal prostatic ultrasound scan with volume and weight calculation at 3, 6 and 12 months. All patients removed the bladder catheter from 4 days to 4 weeks after PAE. Clinical success was defined when symptoms and QoL improved. PAE was technically successful in 12/13 patients (92%). Patients had a reduction in IPSS (mean, 17.1 points), an increase in IIEF (mean, 2.6 points), an improvement in QoL (mean, 2.6 points) and a volume reduction (mean, 28%) at 12 months. These clinical outcomes are consistent with other literature, demonstrating the feasibility, safety and efficacy of PAE.

25. Isaacson, A. J., Fischman, A. M., & Burke, C. T. (2016). Technical feasibility of prostatic artery embolization from a transradial approach. *AJR Am J Roentgenol*, Feb;206(2):442-444. <https://www.ncbi.nlm.nih.gov/pubmed/26797376>

This study evaluates the technical feasibility of performing prostatic artery embolization (PAE) with a transradial approach (TRA). Nineteen consecutive PAE patients treated via the transradial artery were reviewed for technical success (bilateral embolization). Technical success was achieved in all 19 procedures indicating PAE performed with a TRA is technically feasible.

26. Isaacson, A. J., Raynor, M. C., Yu, H., et al. (2016). Prostatic artery embolization using Embosphere Microspheres for prostates measuring 80-150 cm<sup>3</sup>: Early results from a US trial. *J Vasc Interv Radiol*, May;27(5):709-714. <https://www.ncbi.nlm.nih.gov/pubmed/27106645>

This single-center US trial evaluates Embosphere® Microspheres for use in prostatic artery embolization (PAE) in 12 patients with prostates measuring 80-150 cm<sup>3</sup> and lower urinary tract symptoms (LUTS). At 3 months, mean improvements in International Prostate Symptom Score (IPSS) and quality of life (QoL) score were 18.3 points and 3.6 points, respectively. No major complications were indicated. Embosphere Microspheres are safe and effective in reducing

LUTS in the early follow-up period after PAE among patients with prostates measuring 80-150 cm<sup>3</sup>.

**27. Kably, I., Pereira, K., Chong, W., et al. (2016). Prostate artery embolization (PAE) in the management of refractory hematuria of prostatic origin secondary to iatrogenic urological trauma: A safe and effective technique. *Urology*, Feb;88:218-221. <https://www.ncbi.nlm.nih.gov/pubmed/26610676>**

Refractory hematuria of prostatic origin (RHPO) is extremely rare, with an iatrogenic etiology even rarer. In this article, three patients presented with RHPO secondary to iatrogenic urologic trauma due to transurethral resection of the prostate (TURP), Foley catheter removal with a suprathreshold international normalized ratio and self-traumatic Foley catheter removal. After management with conservative methods failed to control bleeding, the patients were treated with prostatic artery embolization (PAE). PAE had technical and clinical success without any intra- or periprocedural complications. Hematuria resolved within a period of 24 hours. PAE offers a reasonable option in the treatment of RHPO and may be attempted prior to surgical techniques or sometimes in conjunction.

**28. Kurbatov, D., Russo, G. I., Lepetukhin, A., et al. (2014). Prostatic artery embolization for prostate volume greater than 80 cm<sup>3</sup>: Results from a single-center prospective study. *Urology*, Aug;84(2):400-404. <https://www.ncbi.nlm.nih.gov/pubmed/24929948>**

This study investigates the clinical benefits and safety of prostatic artery embolization (PAE) in 88 patients with prostate volume  $\geq$  80 cm<sup>3</sup>, Charlson comorbidity index (CCI)  $\geq$  2 and affected by benign prostatic obstruction (BPO). Primary end points were the reduction of 7 points of the International Prostate Symptom Score (IPSS) and the increase of maximum urine flow rate (Q<sub>max</sub>). Secondary end points were the reduction of total prostate volume (TPV), postvoid residual (PVR), prostate-specific antigen (PSA), International Index of Erectile Function (IIEF-5) score, and International Prostate Symptom Score-quality of life (IPSS-QoL). Patients were followed up at 3 months, 6 months, and at 1 year. A significant improvement in terms of IPSS (10.40 vs 23.98;  $p < .05$ ) and Q<sub>max</sub> (16.89 vs 7.28;  $P < .05$ ) were seen at 1 year post-PAE in comparison to baseline values. Significant variation was also observed in patients' PVR (18.38 vs 75.25;  $P < .05$ ), TPV (71.20 vs 129.31;  $P < .05$ ), and PSA level (2.12 vs 3.67;  $P < .05$ ). Mean IPSS-QoL significantly changed from baseline to 1 year after PAE (5.10 vs 2.20;  $p < .05$ ). No minor or major complications were reported. Among these patients, this report shows the clinical benefits of PAE for the treatment of lower urinary tract symptoms (LUTS) and/or BPO.

**29. Laborda, A., de Assis, A. M., Ioakeim, I., et al. (2015). Radiodermatitis after prostatic artery embolization: Case report and review of the literature. *Cardiovasc Intervent Radiol*, Jun;38(3):755-759. <https://www.ncbi.nlm.nih.gov/pubmed/25799951>**

Prostate artery embolization (PAE) is a technically demanding new treatment option for benign prostatic hyperplasia (BPH). This case report presents a 63-year-old patient with radiation-induced dermatitis due to high radiation exposure (KAP: 8,023,949 mGy cm<sup>2</sup>) and long fluoroscopy time (72 minutes) after a technically successful PAE. Anatomical and technical aspects are discussed as well as recommendations to decrease radiation exposure in these procedures.

**30. Lin, Y. T., Amouyal, G., Thiounn, N., et al. (2016). Intra-vesical prostatic protrusion (IPP) can be reduced by prostatic artery embolization. *Cardiovasc Intervent Radiol*, May;39(5):690-695. <https://www.ncbi.nlm.nih.gov/pubmed/26542027>**

Prostatic artery embolization (PAE) results in global reduction of prostate volume (PV), but there are no data available on the efficacy of PAE in reducing intra-vesical prostatic protrusion (IPP), an anatomic feature that is clinically related with bladder outlet obstruction (BOO) and lower urinary tract symptoms (LUTS). This prospective study assesses the results of PAE in 18 patients with significant IPP ( $> 5$  mm) due to median lobe hyperplasia and compares the International Prostate Symptom Score (IPSS) decrease and IPP change. IPP on sagittal T2-weighted images before and 3 months after PAE were measured. IPSS and clinical results were also evaluated at 3 months. PAE resulted in significant IPP reduction (1.57 cm  $\pm$  0.55 before PAE and 1.30 cm  $\pm$  0.46 after PAE,  $P = 0.0005$ ) with no complications. IPSS, quality of life (QoL), total prostate-specific antigen (PSA) level, and prostate volume (PV) showed significant reduction after PAE, and maximum urinary flow rate (Q<sub>max</sub>) showed significant increase. No significant change of International Index of Erectile Function (IIEF) was seen. A significant correlation was found between the IPP change and the IPSS change ( $R = 0.636$ ,  $P = 0.0045$ ). Patients can experience significant IPP reduction as well as significant symptomatic improvement after PAE. In this study, these improvements are positively correlated.

**31. Leite, L. C., de Assis, A. M., Moreira, A. M., et al. (2017). Prostatic tissue elimination after prostatic artery embolization (PAE): A report of three cases. *Cardiovasc Intervent Radiol*, Jun;40(6):937-941. <https://www.ncbi.nlm.nih.gov/pubmed/28175975>**

This study discusses three patients who presented with spontaneous prostatic tissue elimination through the urethra while voiding, following technically successful prostatic artery embolization (PAE) for treatment of benign prostatic hyperplasia (BPH)-related lower urinary tract symptoms (LUTS). All patients were embolized with 100-300  $\mu$ m microspheres alone or in combination with 300-500  $\mu$ m microspheres. Before eliminating the tissue fragments, the three patients all presented during follow-up with intermittent periods of LUTS improvement and aggravation. After expelling the prostatic tissue between 1 and 5 months of follow-up, significant improvements in LUTS and urodynamic parameters were observed in all patients. Urethral obstruction after PAE caused by sloughing prostate tissue is a potential complication and should be considered and managed appropriately in patients with recurrent LUTS after PAE.

**32. McWilliams, J. P., Kuo, M. D., Rose, S. C., et al. (2014). Society of Interventional Radiology position statement: Prostate artery embolization for treatment of benign disease of the prostate. *J Vasc Interv Radiol*, Sep;25(9):1349-1351. <https://www.ncbi.nlm.nih.gov/pubmed/24993818>**

This paper discusses the position of the Society of Interventional Radiology (SIR) with regard to prostatic artery embolization (PAE) as a promising new treatment for lower urinary tract symptoms (LUTS) secondary to benign prostatic hyperplasia (BPH).

**33. Moreira, A. M., Marques, C. F., Antunes, A. A., et al. (2013). Transient ischemic rectitis as a potential complication after prostatic artery embolization: Case report and review of the literature. *Cardiovasc Intervent Radiol*, Dec;36(6):1690-1694. <https://www.ncbi.nlm.nih.gov/pubmed/24091752>**

Complications related to prostatic artery embolization (PAE) are primarily related to non-target embolization. This case report discusses an incidence of ischemic rectitis in a 76-year-old man with significant lower urinary tract symptoms (LUTS) due to benign prostatic hyperplasia (BPH), probably related to non-target embolization. PAE was performed bilaterally. During the first 3 days of follow-up, a small amount of blood mixed in the stool was observed. Colonoscopy identified rectal ulcers at day 4, which had then disappeared without treatment by day 16 post-PAE. PAE is a safe and effective procedure with a low complication rate, but interventionalists should be aware of the risk of rectal non-target embolization.

**34. Rampoldi, A., Barbosa, F., Secco, S., et al. (2017). Prostatic artery embolization as an alternative to indwelling bladder catheterization to manage benign prostatic hyperplasia in poor surgical candidates. *Cardiovasc Intervent Radiol*, Apr;40(4):530-536. <https://www.ncbi.nlm.nih.gov/pubmed/28130568>**

This study evaluates the discontinuation of indwelling bladder catheterization (IBC) and relief of lower urinary tract symptoms (LUTS) due to benign prostatic hyperplasia (BPH) following prostatic artery embolization (PAE) in 43 patients who were poor surgical candidates. PAE technical and clinical success were defined as bilateral prostate embolization and removal of IBC, respectively. Patients were followed up for at least 6 months and evaluated for International Prostate Symptom Score (IPSS), quality of life (QoL), prostate size and uroflowmetric parameters. Bilateral embolization was performed in 33 patients (76.7%), unilateral embolization was performed in eight patients (18.6%), and two patients could not be embolized due to tortuous and atherosclerotic pelvic vasculature (4.7%). Among the patients who were embolized, mean prostate size decreased from  $75.6 \pm 33.2$  to  $63.0 \pm 23.2$  g (signed rank  $P = 0.0001$ , mean reduction of  $19.6 \pm 17.3\%$ ), and IBC removal was achieved in 33 patients (80.5%). Complications were reported in nine patients (21.9%) and included urinary tract infection (three patients, 7.3%) and recurrent acute urinary retention (six patients, 14.6%). Nine patients (22.0%) experienced post-embolization syndrome. These results indicate that PAE is a safe and feasible treatment option for the relief of LUTS and IBC in highly comorbid patients without surgical treatment options.

**35. Russo, G. I., Kurbatov, D., Sansalone, S., et al. (2015). Prostatic arterial embolization vs open prostatectomy: A 1-year matched-pair analysis of functional outcomes and morbidities. *Urology*, Aug;86(2):343-348. <https://www.ncbi.nlm.nih.gov/pubmed/26199151>**

This study evaluates 1-year surgical and functional results and morbidities of prostatic artery embolization (PAE) versus open prostatectomy (OP) in 287 consecutive patients treated for benign prostatic obstruction (BPO), including 80 OP and 80 PAE. A 1:1 matched-pair analysis was conducted. Primary end points of the study were the comparison regarding International Prostate Symptom Score (IPSS), International Index of Erectile Function (IIEF-5), peak flow (PF), postvoid residual (PVR), and International Prostate Symptom Score-quality of life (IPSS-QoL) after 1 year of follow-up. The OP group had lower IPSS ( $4.31$  vs  $10.40$ ;  $P < .05$ ), 1-year PVR ( $6.15$  vs  $18.38$ ;  $P < .05$ ), 1-year PSA ( $1.33$  vs  $2.12$ ;  $P < .05$ ), IPSS-QoL ( $0.73$  vs  $2.78$ ;  $P < .05$ ), IIEF-5 ( $10.88$  vs  $15.13$ ;  $P < .05$ ), and greater PF ( $23.82$  vs  $16.89$ ;  $P < .01$ ). PAE showed higher value of postoperative hemoglobin level (mg/dL) and shorter hospitalization (days) and catheterization (days). Results show PAE can be considered a feasible minimally invasive technique but fails to demonstrate superiority because of the increased risk of persistent symptoms and low PF after 1 year.

**36. Sun, F., Crisóstomo, V., Báez-Díaz, C., et al. (2016). Prostatic artery embolization (PAE) for symptomatic benign prostatic hyperplasia (BPH): Part 2, insights into the technical rationale. *Cardiovasc Intervent Radiol*, Feb;39(2):161-169. <https://www.ncbi.nlm.nih.gov/pubmed/26563245>**

Rationale of prostatic artery embolization (PAE) in the treatment of benign prostatic hyperplasia (BPH) is conventionally believed to include two parts: shrinkage of the enlarged prostate gland as a result of PAE-induced ischemic infarction and potential effects to relax the increased prostatic smooth muscle tone by reducing the number and density of  $\alpha 1$ -adrenergic receptors in the prostate stroma. This review describes new insights into the likely mechanisms behind PAE, such as ischemia-induced apoptosis, apoptosis enhanced by blockage of androgens circulation to the embolized prostate, secondary denervation following PAE, and potential effect of the nitric oxide pathway immediately after embolization. Studies on therapeutic mechanisms in PAE may shed light on potentially new treatment strategies and development of novel techniques.

**37. Sun, F., Crisóstomo, V., Báez-Díaz, C., et al. (2016). Prostatic artery embolization (PAE) for symptomatic benign prostatic hyperplasia (BPH): Part 1, pathological background and clinical implications. *Cardiovasc Intervent Radiol*, Jan;39(1):1-7. <https://www.ncbi.nlm.nih.gov/pubmed/26581418>**

Pathological features of benign prostatic hyperplasia (BPH) dictate various responses to prostatic artery embolization (PAE). Awareness of the pathological background of BPH is essential for interventional radiologists to improve clinical outcomes and develop new treatment strategies in clinical practice of PAE.

**38. Sun, F., Sánchez, F. M., Crisóstomo, V., et al. (2011). Transarterial prostatic embolization: Initial experience in a canine model. *AJR Am J Roentgenol*, Aug;197(2):495-501. <https://www.ncbi.nlm.nih.gov/pubmed/21785100>**

The objective of this study is to prospectively evaluate pathologic responses to transarterial prostatic embolization and its technical safety in a canine model. Ten adult male beagle dogs were surgically castrated and given hormonal therapy for 4 months to induce prostatic hyperplasia. The dogs were randomly assigned to a transarterial prostatic embolization group ( $n = 7$ ) or a control group ( $n = 3$ ). All dogs were sacrificed for pathologic study. Transrectal ultrasound and magnetic resonance imaging (MRI) were performed to evaluate pathologic responses. Four dogs had significant shrinkage of the prostate, and the other three had an increase in prostate size. Imaging examinations and necropsy revealed a huge cavity occupying almost the entire prostate in the three dogs with increased prostate size. No complications associated with transarterial prostatic embolization were encountered. The results suggest that transarterial prostatic embolization is a safe procedure that has potential clinical applications in the care of patients with benign prostatic hyperplasia (BPH).

**39. Teoh, J. Y., Chiu, P. K., Yee, C. H., et al. (2017). Prostatic artery embolization in treating benign prostatic hyperplasia: A systematic review. *Int Urol Nephrol*, Feb;49(2):197-203. <https://www.ncbi.nlm.nih.gov/pubmed/27896579>**

This systematic review of the current evidence on prostatic artery embolization (PAE) in treating men with benign prostatic hyperplasia (BPH) includes a total of five records: two randomized controlled trials and three non-randomized cohort studies. Transurethral resection of the prostate (TURP) resulted in better International Prostate Symptom Score (IPSS) than PAE. Open prostatectomy had better IPSS, quality of life (QoL) score, maximum urinary flow rate (Qmax) and postvoid residual (PVR) but worse International Index of Erectile Function (IIEF) score than PAE at 1 year. Unilateral PAE had a higher rate of poor clinical outcome than bilateral PAE, but the difference became statistically insignificant after adjusting for age; IPSS, QoL score, Qmax, PVR, IIEF score, prostate volume (PV) and prostate-specific antigen (PSA) level did not differ between the two groups. PAE with  $100 \mu\text{m}$  polyvinyl alcohol (PVA) particles resulted in greater reduction in PSA level, but worse IIEF score than PAE with  $200 \mu\text{m}$  PVA particles; IPSS, QoL score, Qmax, PVR, PV and poor clinical outcome did not differ between the two groups. Evidence on different aspects of PAE is limited. Further studies are warranted to investigate the role of PAE as compared to

other forms of medical and surgical treatment.

**40. Uflacker, A., Haskal, Z. J., Bilhim, T., et al. (2016). Meta-analysis of prostatic artery embolization for benign prostatic hyperplasia. J Vasc Interv Radiol, Nov;27(11):1686-1697. <https://www.ncbi.nlm.nih.gov/pubmed/27742235>**

This meta-analysis of available data on prostatic artery embolization (PAE) includes six articles published between November 2009 and December 2015. At 12 months post-PAE, prostate volume (PV) decreased by 31.31 cm<sup>3</sup> (P < .001), prostate-specific antigen (PSA) levels remained unchanged (P = .248), postvoid residual (PVR) decreased by 85.54 mL (P < .001), maximum urinary flow rate (Q<sub>max</sub>) increased by 5.39 mL/s (P < .001), International Prostate Symptom Score (IPSS) improved by 20.39 points (P < .001), quality of life (QoL) score improved by -2.49 points (P < .001), and International Index of Erectile Function (IIEF) score was unchanged (P = 1.0). The most common complications were rectalgia/dysuria (n = 60; 9.0%) and acute urinary retention (n = 52; 7.8%). Overall, PAE improves Q<sub>max</sub>, PVR, IPSS, and QoL endpoints at 12 months, with a low incidence of serious adverse events (0.3%). Although minor adverse events may be common (32.93%), no adverse effect on erectile function in this study was seen.

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