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Technical and Imaging Outcomes from the UK Registry of Prostate Artery Embolization (UK-ROPE) Study: Focusing on Predictors of Clinical Success

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Abstract

Introduction The UK Registry of Prostate Artery Embolization (UK-ROPE) was a prospective, multicentre study comparing PAE against surgical therapies for symptomatic benign prostatic hyperplasia (BPH). A wealth of data was collected supplementary to the main study outcomes which provide a snapshot of UK PAE practice. We aimed to interpret these data in the hope of providing insight into factors which affect clinical outcome and radiation dose.

Methods 216 patients (mean age 66, mean IPSS 21.3) undergoing PAE at 20 British centres from July 2014 to January 2016 were prospectively followed up to 12 months with retrospective analysis of the data. Technical outcome was evaluated based on procedural and fluoroscopy times, skin dose and dose area product (DAP). Clinical outcome was evaluated through collection of Qmax, IPSS reduction and prostate volume reduction. Multiple analysis of variance (MANOVA) was used to assess the significance of various patients and procedural factors on clinical outcome and patient dose.

Results Significant predictors of technical outcome which affected patient skin dose included severity of CTA-detected atheroma ($p < 0.001$), the practitioner ($p < 0.001$) and use of protective coil embolization ($p = 0.019$). Predictors of clinical outcome included initial prostate size (dichotomized into groups > 80 ml and $= <80$ ml, $d = 1$, $p = 0.0138$), embolic agent (spherical particles < 300 nm performed best, $p = 0.01$) and number of arteries embolized (IPSS reduction of 32.9% in unilateral PAE versus 54.4% for bilateral PAE, $p = 0.026$).

Conclusion We have identified several important factors which are associated with improved clinical outcome and increased patient dose which we hope will facilitate optimal patient selection and encourage improved embolization technique.

Keywords PAE · Prostate · Embolization · Predictor · UK · BPH

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Introduction

An increasing weight of evidence supports prostate artery embolization (PAE) as playing a key role in the management of male lower urinary tract symptoms (LUTS; 1-3). However, several previous meta-analyses evaluating the practice concluded more comparative studies were required

[1–4]. This was also the initial finding of the UK's National Institute of Health and Care Excellence (NICE) who subsequently part-funded a national registry—the UK Registry of Prostate Artery Embolization (UK-ROPE) [5].

UK-ROPE's primary outcomes focused on safety and clinical efficacy of PAE against surgery and have recently been published [6]. As a result of this paper and other recent studies, UK national guidance has been altered; PAE is now considered a standard treatment for benign prostatic hypertrophy (BPH) [7]. Additional to the primary outcomes, a wealth of additional data was collected on patients in the PAE arm of the study which enables a snapshot of PAE practice across the UK. Furthermore, through statistical analysis of these data, we aimed to identify important factors which affect patient outcome as well as patient dose.

Literature on Predictors of Outcome

Several prior studies have successfully identified predictors of successful outcomes following PAE. Many of these factors were identified after the UK-ROPE study protocol was finalized in 2012, and therefore, a considerable number of these data were not collected.

Initial prostate size is a contentious issue in the literature, with several studies both supporting [8–10] and refuting [11–13] its reliability as a predictor of a better clinical outcome. Pre-procedural imaging factors linked to a better outcome include magnetic resonance imaging (MRI) determined Adenomatous dominant BPH [14] and prostate zonal volumetry and ratios [15]. Technical factors have been investigated including the size and type of embolic agent. No difference has been found between spherical and non-spherical agents [16], nor between spherical agents of different size [17]; however, it has been suggested that larger (200 micron) particles achieve a better outcome than smaller (100 microns) particles [18]. Early post-procedural outcomes which can suggest a good clinical outcome at 12 months and later include 24-hour PSA increase [19], 24-hour pain score [10], the presence of MRI infarct pattern [10], [20, 21] and prostate volume reduction [9, 10].

Methodology

The UK-ROPE Study

UK-ROPE was a national observational database of patients treated with PAE or surgical alternatives which collated data from 20 centres. It was organized as a joint venture between the British Society of Interventional Radiology (BSIR) and the British Association of Urological Surgeons (BAUS). The database was collated by the Cardiff-based independent research organization 'Cedar', the involvement of whom was funded by NICE. Procedure costs were covered either through local commissioning streams or through a grant from Cook Medical (Europe), where this was not possible [5]. Overall, 216 patients were recruited to the PAE arm (mean age 66.0 years, mean IPSS 21.3, mean QoL 4.6, mean IIEF 14.4, mean prostate volume 101.2 ml, mean Qmax 8.8 ml/s, mean residual volume 130.0 ml) [6].

Procedural variables that were examined for statistical significance are listed in Tables 1 and 2. Firstly, we asked which independent variables indicated a better clinical outcome for patients. Secondly, we addressed factors that influenced patient dose parameters most significantly.

Inclusion Criteria

Male patients with lower urinary tract symptoms were offered enrolment in the study if they were capable of providing consent (in English) for either PAE, Transurethral resection of the Prostate (TURP), open prostatectomy or holmium laser enucleation of the prostate (HoLEP) at a participating centre [6]. Centres were encouraged only to enrol patients to the PAE arm aged 50–80, with IPSS > 14 or QoL > 3, prostate volume > 40 ml, eGFR > 45 ml min^{-1} m$^{-2,}$ and malignancy excluded if PSA < 4 ng/ml.

Data Collection

Pre-PAE Planning CT Angiogram

Pre-procedural CT Angiogram (CTA) is useful in determining patient anatomy prior for selective arterial embolization (ref Bilhim et al. [23]). The suggested CT protocol for the study was to be performed after administering sublingual Glyceryl Trinitrate (GTN). 120 ml intravenous contrast is injected at 5–6 ml/s (with bolus tracking on the abdominal aorta). The arterial phase is performed at 5 s delay (from L4 to the lesser trochanters). The venous phase is performed at 35 s with identical

Table 1 Frequency of prostatic artery anastomosis

Anastomosis type	Patients (*n*)	Percentage (%)
None	66	27.3
Penile	61	25.2
Rectal	58	24.0
Vesical	50	20.6
Other	7	2.9

Table 2 Summary of ANOVA results for independent variable correlation with skin dose

Parameter	*p* value
CTA atheroma	< 0.001
Radiologist	< 0.001
Use of protective coil embolization	0.019
Type of arterial anastomoses	0.14
Number of arteries embolized	0.91

coverage. Both phases image at least the pelvis. The primary role of CTA was to identify the origin of the prostatic artery and thus facilitate procedural planning. Furthermore, it was used to identify anastomoses with adjacent organs. All anastomoses suggested by CTA were recorded prospectively and compared against findings at procedural angiogram. The specificity and sensitivity were then calculated for CTA detection of anastomoses using digital subtraction angiography (DSA) as the gold standard.

A further role of the CT is to calculate the initial prostate volume. Initial prostate volume was calculated through the formula width × height × depth × 0.52 using multiplanar reformatted windows. Initial prostate volume was then tested for correlation with symptomatic outcome in the multivariate analysis.

Finally, qualitative data with regard to the vasculature were collected and correlated through multivariate analysis against radiation dose parameters. Atheroma of the internal iliac vasculature was graded on a scale of none, mild, moderate and severe based on a subjective assessment of the level of atherosclerosis in the vessels. Tortuosity of the iliac vasculature was graded on a three point scale of mild, moderate, and severe.

Pre-procedural Clinical Assessment

All patients underwent consultation with a Urologist and Interventional Radiologist prior to PAE. Several clinical data points were collected. In terms of symptom questionnaires, international prostate symptom score (IPSS), quality of life (QoL) and international index of erectile function (IIEF) questionnaires were completed by patients. All patients underwent uroflowmetry (collection of post-void residual and maximum flow rate). Prostate-specific antigen (PSA) and estimated glomerular filtration rate were the only essential blood tests prior to the procedure. Checking the coagulation status of the patient was left to the discretion of the performing radiologist.

The Procedure

A variety of technical data relating to the procedure was collected.

The number of prostatic arteries embolized was recorded and correlated with clinical outcomes (If prostatic arteries were identified but not embolized, then the reason for this was recorded). The number of operators in each case was detailed, and each individual operator was assigned an operator number. This was regarded as an independent variable to assess the extent to which the operator influences outcomes.

Embolic agents were grouped into spherical or non-spherical agents, with further subdivision into small, large or mixed agents (if both large and small particles were used in the same case). Spherical small particles were considered those 300 micrometres or less, and large were considered as particles larger than this. Non-spherical small particles were considered as 100 micrometres or less, with large being greater than this size (mixed, if both particle sizes were used). The microcatheter type was recorded and assessed for any difference in symptomatic outcome for patients.

Procedural data were also collected on overall procedural time (minutes), fluoroscopy time (minutes), skin dose (mGy) and dose area product (DAP; μGym^2). These data were used as output variables for a multivariate analysis to assess if certain patient and procedural factors influence procedure time and dose.

Patient Follow-Up

3 Month MRI

Post-PAE MRI was performed to enable assessment of the infarct pattern post-contrast administration and to enable post-PAE volume calculation. Volume was calculated using the volume formula height × width × depth × 0.52 on axial and sagittal T2 sequences. Infarct pattern was determined on axial contrast-enhanced fat-suppressed sequences and classified as confluent (subdivided into symmetrical and asymmetrical), patchy enhancement and full enhancement (no infarct evident).

Questionnaire Follow-up

LUTS severity was assessed using the IPSS questionnaire at 1, 3, 6 and 12 months post-PAE. Erectile function was assessed using the IIEF-5 questionnaire at the same intervals. Percentage reduction in IPSS (normalized values) was calculated and used as an outcome variable in the statistical analysis.

Flow Studies

Uroflowmetry and post-void residual studies were performed at 3 months and 12 months post-PAE. Percentage change in maximum flow rate (Qmax) was used as an outcome variable in the statistical analysis.

Statistical Analysis

Factors Affecting Radiation Dose and Procedural Time

Radiation outcomes (fluoroscopy time, procedural time, skin dose and dose area product) were separately analysed with an analysis of variance (ANOVA), using CTA atheroma, use of protective coil embolization, type of arterial anastomoses, number of arteries embolized and operator as input factors. Mean and marginal means have been reported.

Factors Affecting Clinical Outcome

The main clinical outcome parameters included three variables: IPSS reduction, Qmax improvement and prostatic volume reduction. These variables were normalized to respective baseline values to ascertain significant proportional improvement.

Input factors included number of operators, number of arteries embolized at procedure, embolic agent, microcatheter used and initial prostate size.

These variables were analysed in a number of ways:

Firstly, the three outcome variables were used to perform a multiple analysis of variance (MANOVA) to identify factors that were associated with a significant difference in combined group means.

Parallel coordinate plots were used to display a breakdown of the multivariate outcomes. Clusters were identified using the MANOVA technique and dendograms plotted for displaying data. In addition, canonical analysis was used to further demonstrate any separation in clustering. Lastly, we performed an ANOVA on the three outcome variables separately to determine any specific relationships with the relevant input factors.

All outliers were removed from the analysis by accepted statistical methods (defined as any element greater than 3 scaled median absolute deviation away from the median). Relationships were deemed significant with p values < 0.05.

MATLAB software was used to carry out statistical and graphical analysis.

Results

From July 2014–January 2016, 216 patients were enrolled to the PAE arm of the study and followed up to 12 months. Normalized and raw data histograms for the three primary outcome variables are shown in Fig. 1.

Pre-PAE CT Angiogram

Data regarding the initial CTA were recorded in 186/216 patients. Anastomoses were suggested by CTA in 89 patients (Table 1). These were confirmed in 81/89 patients. There were 60 patients who were identified to have anastomoses which were not detected on CTA (false negatives). Specificity was therefore 87.1% (95% CI 76.15–94.26%), and sensitivity was 57.5% (95% CI 48.9–65.7%). The most commonly overlooked anastomosis on CTA was penile (38/60, 63.3%).

Factors Affecting Radiation Dose and Procedural Time

The mean fluoroscopy time for patients was 40.6 min. Skin dose was mean 2072.8 mGy, and mean patient dose area product (DAP) was 22,103.2 μGym^2. Mean procedure duration was 145.2 min.

CTA atheroma ($p < 0.001$), protective coil embolization ($p = 0.02$) and radiologist significantly affected skin dose ($p < 0.001$; Table 2). The more severe the atheroma, the higher the skin dose, for example, those patients without atheroma had a mean skin dose of 1614 mGy (marginal mean 3761) versus 7181 mGy (marginal mean 10180) for those with severe atheroma. Where protective coil embolization was used, the skin dose was also higher 2316 mGy (marginal mean 6217) versus 1980 mGy (marginal mean 5455). We found that the type of arterial anastomoses and number of arteries embolized did not significantly affect skin dose.

Statistically significant differences were seen in DAP between different operators ($p < 0.001$). All remaining input factors did not significantly affect the dose.

Fluoroscopy time was significantly affected by the radiologist and the number of arteries embolized, with three arteries having significantly higher dose than two arteries (marginal means, 59.5 vs 49).

Factors Affecting Clinical Outcome

Variables tested in the MANOVA analysis for association with combined clinical outcomes are demonstrated in Table 3.

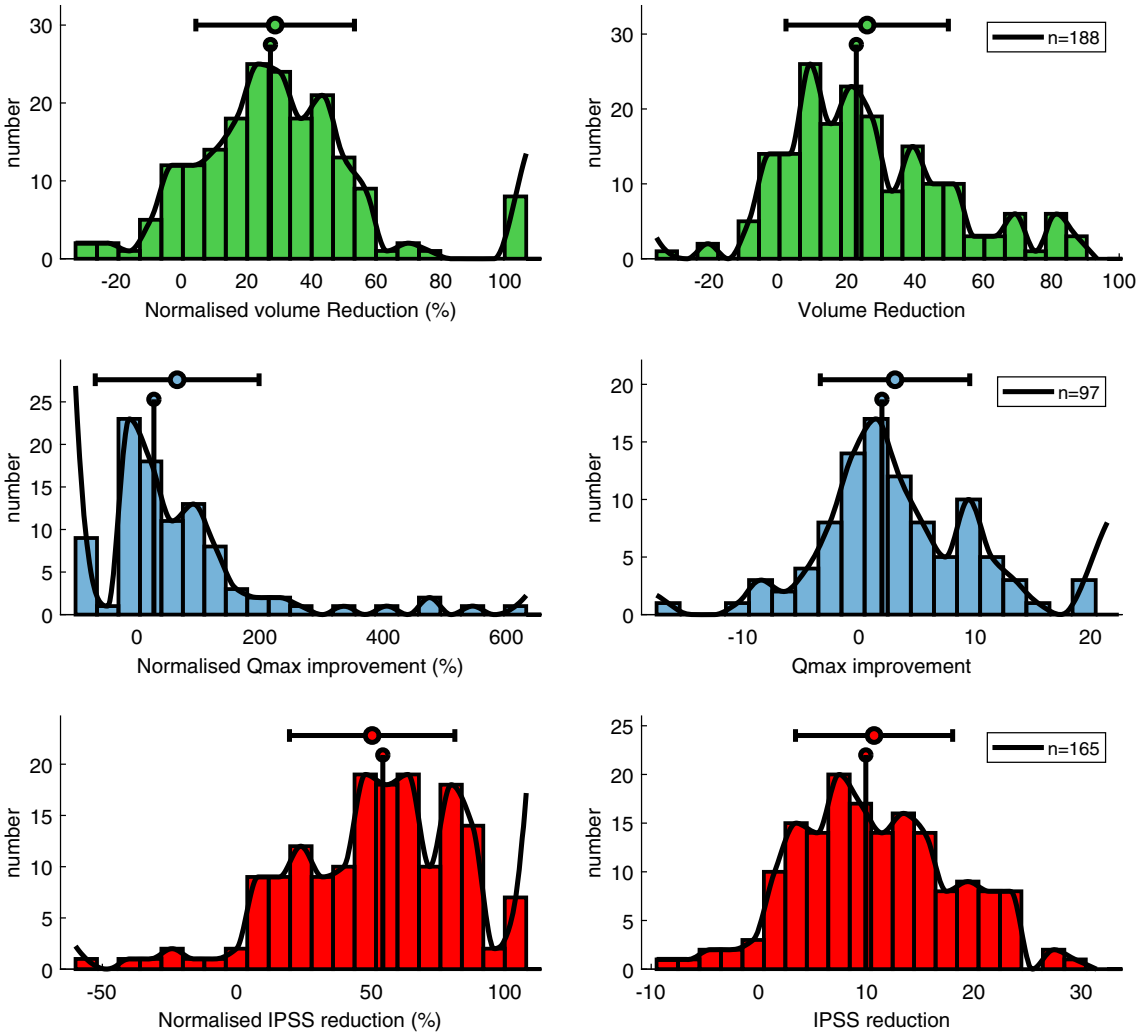

Fig. 1 Normalized (left) and raw (right) data for volume reduction (green), Qmax improvement (blue) and IPSS reduction (red) histograms and smoothed functions for all data. The median (vertical line), mean and standard deviation (horizontal plot) are superimposed. A positive value indicates improvement

Table 3 Summary of MANOVA results for independent variable correlation with clinical outcome (prostate size reduction, IPSS improvement and Qmax increase combined)

Parameter	*p* value
Prostate size	0.01
Embolic agent	0.046
Microcatheter type	0.025
Number of arteries embolized	0.38
Number of operators	0.45

Initial Prostate Size

Initial prostate size was dichotomized into large prostates (> 80 mls, $n = 107$) and small prostates (= <80 mls, $n = 96$), with data being available for 203 patients (Fig. 2). MANOVA analysis demonstrated a significant difference in the group means ($d = 1$, $p = 0.0138$). Parallel coordinate plots (see Fig. 2) show that the differences appeared to mainly arise from differences in IPSS reduction, with larger prostates having a greater IPSS reduction (median = 65%) compared with smaller prostates (median = 46%).

ANOVA and *t* test analysis with each output variable analysed separately (IPSS reduction, Qmax improvement and prostatic volume reduction) confirm a significant difference between the prostate size groups in terms of reduction in IPSS ($p = 0.01$) and not prostatic volume reduction ($p = 0.63$) or Qmax improvement ($p = 0.06$).

Embolic Agent

Embolic agent data were available for 176 patients (Fig. 3). The most commonly used particle size and type was non-

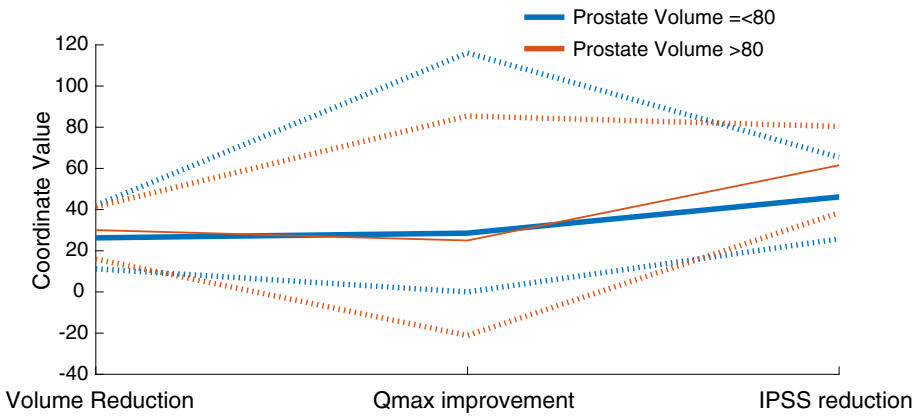

Fig. 2 Parallel coordinate plots. Median values with quartiles plotted for prostatic volumes of less than or equal to 80 (blue) versus those above 80 (red). The median plots demonstrate that larger volume prostates have a higher IPSS reduction compared with smaller volume prostates

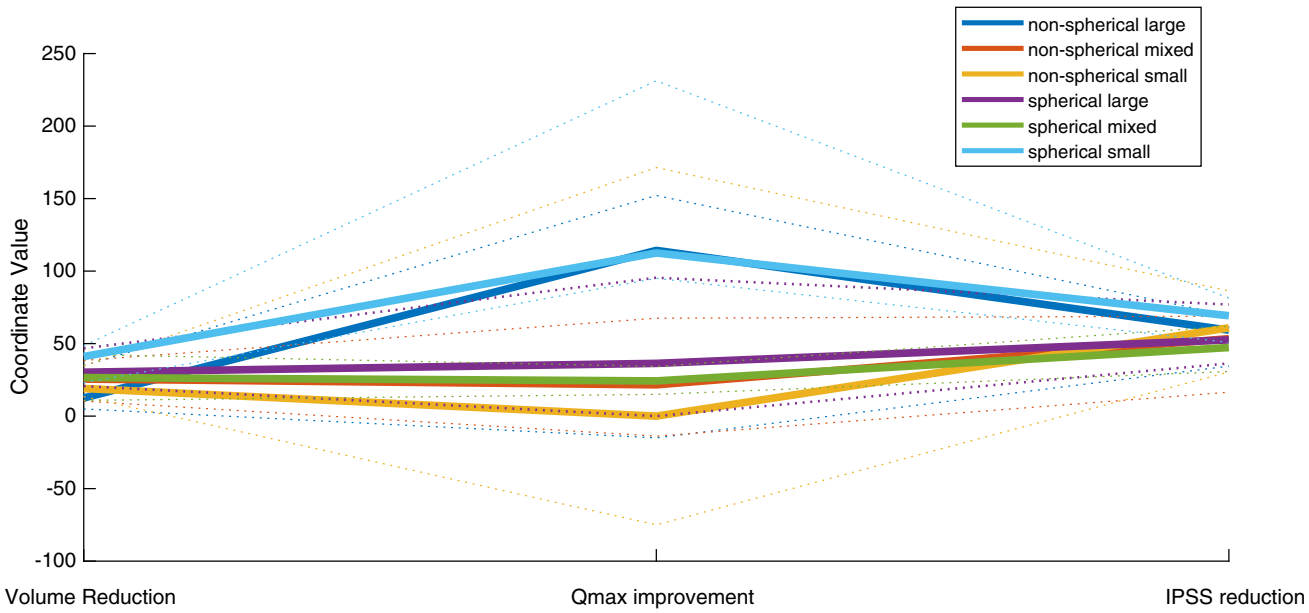

Fig. 3 Parallel coordinate plots. Median values with quartiles plotted for different embolic agents

spherical, mixed size (n = 63), followed by spherical large (> 300 microns, n = 54). The most commonly used brand of embolic agent in our dataset was Cook non-spherical PVA (Cook, Bloomington, IN). Amongst spherical agents, Embozenes (Boston, Marlborough, MA) were most commonly used.

MANOVA analysis identified that the group means (constructed using IPSS reduction, Qmax improvement and prostatic volume reduction) could be separated (d = 1, p = 0.046). Small spherical particles demonstrated optimal outcomes compared with other particle types and size in terms of prostatic volume reduction (median 41.1%), Qmax improvement (median 113%) and IPSS reduction (median 69%; see Fig. 3). Cluster analysis (Fig. 4) showed that embolic agents could be divided into two main groups: small spherical and all other embolic agents.

Furthermore, targeted ANOVA analysis on each outcome measure separately identified that embolic agent could explain the variability in the data for prostatic volume reduction (p = 0.047) and Qmax improvement (p = 0.04) but not IPSS reduction (p = 0.38).

Microcatheter

The three main microcatheters used were Boston Direxion (Boston Scientific, Massachusetts, USA), Cook Cantana (Cook, Indiana, USA) and Terumo Progreat (Tokyo, Japan). Only procedures with a single microcatheter were used in the multivariate analysis for comparison (n = 133). MANOVA analysis demonstrated significant differences in the group means. No catheter performed best in all outcomes. Cook Cantana was significantly different from Boston Direxion and Terumo Progreat (d = 1, p = 0.025, see Fig. 5). Cook Cantana had the greatest median prostatic volume reduction (35.1%) versus Boston (23.8%) and Terumo (22.6%) but only moderate improvement in Qmax

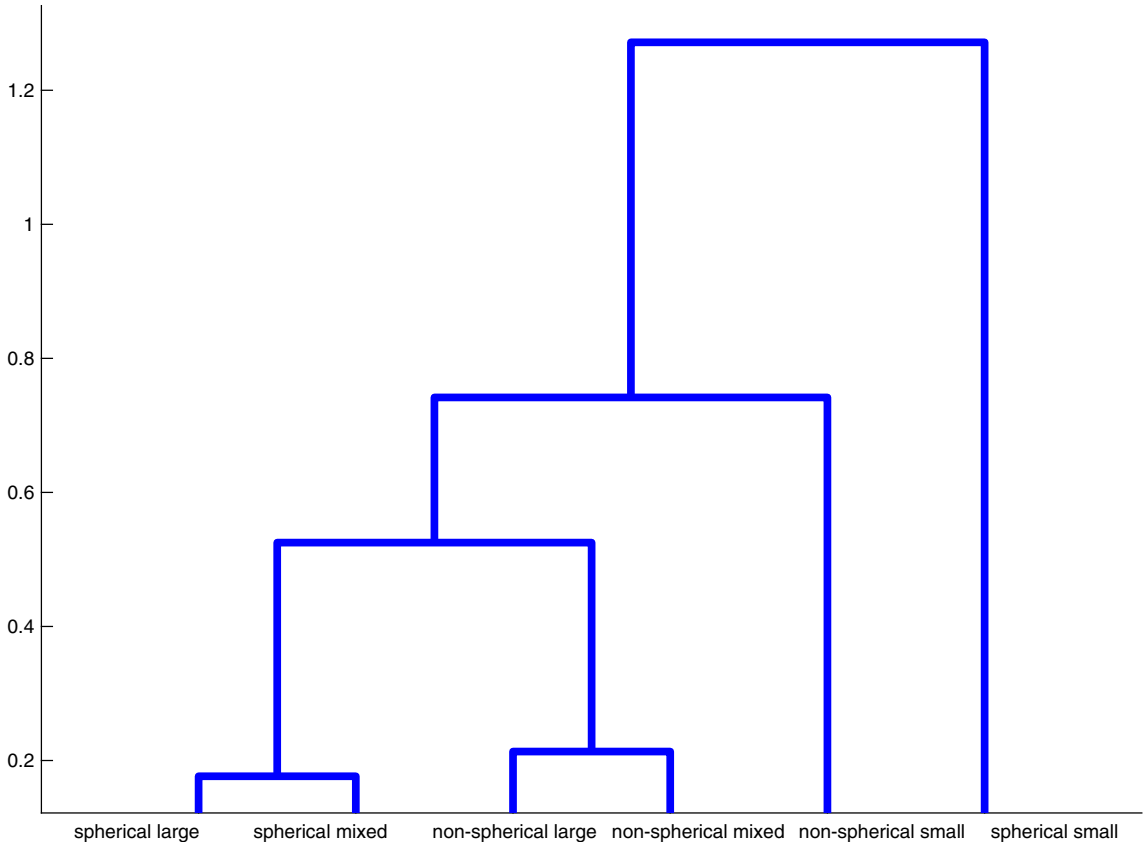

Fig. 4 Dendogram demonstrating clusters identified using MANOVA. Small spherical particles form a separate cluster from the remaining particle types

improvement (18.2%) versus Boston (60%) and Terumo (0%). Cook also had only a moderate IPSS reduction (39.6%) versus Boston (50%) and Terumo (61.9%). Canonical analysis was carried out to identify and display clusters. The first two canonical variables (c1, c2) are plotted on Fig. 6. They show some separation of Cook Cantana (green cluster) from the other two microcatheters.

Microcatheter size was recorded in 125 cases. 2.4 Fr was the most common size (n = 55), followed by 2.5 Fr (n = 31), 2.0 Fr (n = 18), 2.1 Fr (n = 14), 2.7 Fr (n = 4), 2.8 Fr (n = 3).

Each outcome measure was then analysed separately with an ANOVA. No significant difference in Qmax improvement, IPSS reduction or volume reduction was seen with microcatheter type.

Number of Arteries Embolized

Data on the number of arteries embolized were available in 187 patients. In the vast majority of procedures, two arteries were embolized (n = 141), with a maximum of four arteries. MANOVA analysis failed to identify a

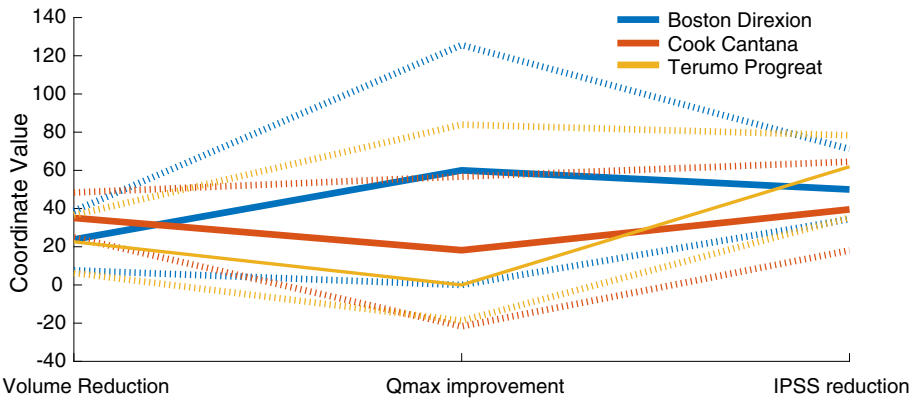

Fig. 5 Median values with quartiles plotted for different microcatheter types

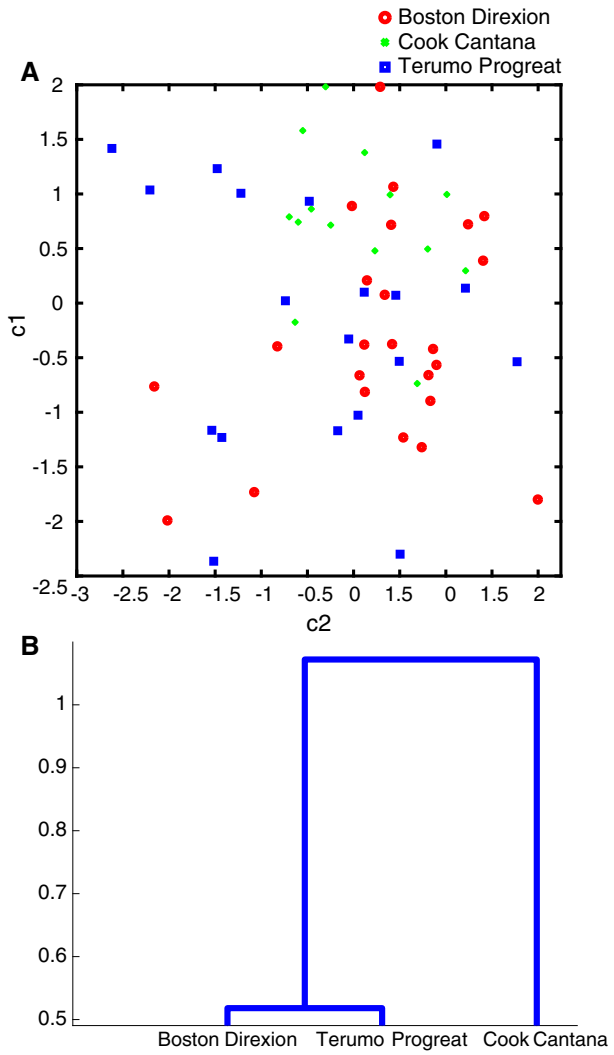

Fig. 6 **A** Grouped scatter plot of the first two canonical variables for different microcatheter types. Cook Cantana appears to be clustered more closely than the other two microcatheter types. **B** Dendogram demonstrating microcatheter clusters identified using MANOVA. Cook Cantana appears to be clustered separately from Boston Direxion and Terumo Progreat

significant difference in the group means ($p = 0.38$; Table 3). In 24 patients, only unilateral embolization was possible.

However, targeted ANOVA analysis with IPSS reduction as the only output factor highlighted that embolizing just one prostatic artery was associated with a significantly smaller IPSS reduction compared with two arteries (32.9 vs. 54.4%, $p = 0.026$). No significant difference was seen between embolization of two prostatic arteries versus three prostatic arteries (54.4 vs. 49.8%). No difference in prostatic volume reduction ($p = 0.86$) or Qmax improvement ($p = 0.42$) was seen between embolization of one, two or three prostatic arteries.

Number of Operators

There was no significant difference between one or two operators for a PAE procedure (MANOVA, $p = 0.45$). With the ANOVA breakdown, there was a significantly greater reduction in volume for two operators vs one operator (31.7 vs. 23.4%, $p = 0.03$), but no difference in Qmax ($p = 0.26$) or IPSS ($p = 0.86$).

Anastomoses and Protective Embolization

Details of intraprocedural anastomoses were recorded in 187 patients. The most frequently occuring anastomosis was penile (25.2%, 61 patients). Protective coil embolization was performed in 25.7% (48/187) patients.

Post-PAE MRI Infarct Pattern

MRI infarct pattern was recorded in 96 patients (Table 4). The most commonly demonstrated infarct patterns were patchy devascularization and asymmetrical confluent (35 procedures each, 36.5%).

Full enhancement (no infarct pattern) was associated with significantly worse outcomes for volume reduction ($p = 0.01$) and Qmax improvement ($p = 0.002$) but not IPSS reduction ($p = 0.75$) compared with the other infarct patterns.

Discussion

It is hoped that a unified analysis on several outcome measures (namely prostatic volume reduction, Qmax improvement and IPSS reduction using multivariate analysis) allows easier interpretation of results given sometimes discrepant trends in different outcomes.

Pre-PAE CT Angiogram

This study supports the finding of previous studies which suggest that CTA is a useful investigation prior to PAE [9, 22–24]. The primary role of CTA is to delineate anatomy and facilitate procedural planning; however, it provides a considerable bonus of being able to detect possible anastomoses. However, as with any diagnostic investigation, the identification of potential anastomotic vessels will vary largely with radiologist experience and radiographic technique.

Furthermore, CTA has the benefit of providing an insight into the degree of atheroma and tortuosity, which was shown to be important factors affecting radiation dose and procedural time.

Table 4 3-month MRI infarct pattern and associated mean 12-month clinical outcome improvement values

MRI infarct pattern	Patients (*n*)	Percentage (%)	Volume reduction (%)	Qmax improvement (%)	IPSS reduction (%)
Confluent—symmetrical	16	16.6	47	35	85
Confluent—asymmetrical	35	36.5	64	33	65
Patchy devascularization	35	36.5	49	28	69
Full enhancement (no infarct)	10	10.4	32	13	8.5

Factors Affecting Radiation Dose and Procedural Time

CTA-detected atheroma severity and vessel tortuosity had a significant association with increased skin dose and therefore are useful in predicting the potential difficulty of a case. Practically speaking, this could facilitate triage of patients in deciding which operator (in terms of experience level) or how many operators should be available for a particular case. The operator was also an important factor deciding skin dose for patients, which is probably multifactoral and reflects experience level and equipment available.

Factors Affecting Clinical Outcome

Initial Prostate Size

Initial prostate size has previously been reported as a rough indicator of clinical success [8, 9]. These results conform with this hypothesis: larger prostates (> 80m) have favourable outcomes compared with smaller prostates. This is particularly the case for IPSS reduction, with a 65% average IPSS improvement compared with 46% for smaller prostates.

Embolic Agent

The choice of embolic agent has previously been investigated by other papers with no overall consensus [17, 25]. The cluster analysis revealed two main separate clusters of embolic agents: small spherical and all other embolic agents. This study demonstrated that small (< 300 microns) spherical embolic agents were marginally favourable compared with other embolic particles. This is potentially due to smaller particles achieving greater penetration to the hypertrophied central gland and therefore better infarction. Alternatively, other confounding factors may explain this difference. Operators with less experience are perhaps more likely to select larger particles to reduce the risk of non-target embolization. Furthermore, larger particles may be used when an optimal catheter position cannot be achieved. These issues may be having a larger bearing on this finding, and it is difficult to draw definite conclusions in a non-randomized study with multiple other factors at play.

No significant difference was seen between small and large non-spherical agents. Other studies have reached conflicting conclusions on this issue. Bilhim et al. demonstrated improved volume reduction and Qmax improvement with small non-spherical particles, but larger particles improved IPSS to a greater extent [25]. Furthermore, a smaller study of smaller (100–300 micron) versus larger (300–500 micron) spherical agents previously found no difference in outcomes [8, 9, 17].

Microcatheters

Evidence for an optimal microcatheter is inconclusive, and clinical outcomes are a poor reflection of a catheter performance. It should be mentioned that microcatheter diameter varied between centres. A better assessment would be through depth of catheterization, presence of spasm or dissection Although our multivariate analysis revealed two main clusters: Cook Cantana forming its own cluster and the remaining two (Boston and Terumo), this did not translate into favourable scenarios in all outcome measures. Cook Cantana saw the most prostatic volume reduction (35%), but Boston Direxion and Terumo Progreat performed favourably in IPSS reduction and Qmax improvement. Furthermore, targeted ANOVA on all three outcome measures separately did not reveal any significant difference between microcatheters.

Number of Vessels Embolized

In the vast majority of procedures, two arteries were embolized at procedure. Predictably, there was a significant difference in IPSS reduction when two arteries were embolized (54.4%) compared with 1 (32.9%). However, no such benefit was seen comparing two arteries embolized with more than two arteries embolized. In many cases, these additional vessels are likely to be supplying the peripheral zone/posterior gland and thus provide inconsequential gland infarct.

Operator

Perhaps predictably, the operator was found to be an independent variable that significantly influenced both dose and clinical outcomes to a large degree. No assumptions can be reliably made as to what this variability is due to, but it is likely to reflect a combination of experience level, technique and fluoroscopy equipment.

Post-PAE MRI

Patients with no discernible MRI infarct pattern post-PAE (full gland enhancement) unsurprisingly had worse outcomes for volume reduction and Qmax improvement. However, no statistical difference was demonstrated between patchy and confluent infarct patterns, which suggest practitioners who achieve patchy infarct after PAE should not be disheartened; the patient is still likely to have a successful clinical outcome.

Study Weaknesses

Although significant efforts were made to unify clinical practice and procedural technique for the registry, a variation in practice is inevitable in such a large multicentre study. Particularly qualitative data points, such as CTA determined tortuosity, will be subject to more significant inter-observer variability than controlled trials and admittedly weakens the strength of conclusions drawn. Furthermore, data entry errors are likely to have skewed data, which is likely to have influenced particularly the skin dose entries. On balance, this is the nature of a registry study design which has the benefit of enabling a more real-world assessment of PAE.

Furthermore, many centres in this study had performed few PAE procedures prior to commencement of the registry. Clinical outcomes may therefore not reflect the true potential of PAE. Also, this factor may confound and weaken many of the associations identified.

An additional weakness is the differential modality for volume collection (CT pre-PAE and MRI post-PAE). This will lead to a potential error in the volume reduction figure which features in the multivariate analysis.

A multitude of factors were collected during the study, several of which were found to influence dose. Despite this, the following variables were not collected as part of the registry: patient body mass index (BMI), fluoroscopic equipment and number of cone beam CTs performed. These variables are likely to have a significant impact on dose outcomes, and our findings are therefore weakened by the omission of these variables. Several other variables known to predict a good outcome after PAE were not collected as part of the study protocol, including pre-PAE MRI features [14, 21] and 24-hour PSA increase [19], which would have been useful to corroborate with recent papers suggesting the importance of these findings.

Conclusion

The main aim of this paper was to release the additional data collected in the PAE arm of the UK-ROPE study to provide a snapshot of PAE technique in the UK.

In terms of correlation with good clinical outcome, the only major patient factor which indicates a good outcome was initial prostate size. The main procedural factor found to correlate with a better clinical outcome was embolic agent (spherical agents < 300 microns).

In terms of radiation, procedural factors which were found to significantly affect skin dose for the patient were the operator performing the procedure, if coil embolization of anastomosis was performed due to anastomoses, and the degree of atheroma (CTA determined).

Funding The UK-ROPE study was funded through multiple streams. The involvement of an independent academic evaluation centre 'Cedar' was funded through the National Institute for Health and Care Excellence (NICE). Procedure costs were covered either through local commissioning streams or through a grant from Cook Medical (Europe), where this was not possible.

Compliance with Ethical Standards

Conflict of interest Nigel Hacking was in receipt of a research grant to run the UK-ROPE study from Cook Medical, has received honoraria from Boston Scientific and Celonova as a speaker and has been on Advisory boards for BTG. Tim Bryant has proctored for Boston Scientific and Terumo and has received speaker honorariums from Boston Scientific. Sachin Modi has received a speaker honorarium from Boston Scientific. The other authors declare no conflict of interest.

Ethical Approval All procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Patient Consent Informed consent was obtained from all individual participants included in the study. Consent for publication was obtained for every individual person's data included in the study.

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