World Journal of Urology (2018) 36:1117–1126
https://doi.org/10.1007/s00345-018-2229-3

ORIGINAL ARTICLE

Dual-centre randomized-controlled trial comparing transurethral endoscopic enucleation of the prostate using diode laser vs. bipolar plasmakinetic for the treatment of LUTS secondary of benign prostate obstruction: 1-year follow-up results

Zhihui Zou[1,5] · Abai Xu[1] · Shaobo Zheng[1] · Binshen Chen[1] · Yawen Xu[1] · Hulin Li[1] · Chongyang Duan[2,3] · Junhong Zheng[4] · Jiasheng Chen[1] · Chaoming Li[1] · Yiming Wang[1,6] · Yubo Gao[1] · Chaozhao Liang[5] · Chunxiao Liu[1]

Received: 7 December 2017 / Accepted: 7 February 2018 / Published online: 19 February 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract

Purpose Bipolar endoscopic enucleation of the prostate (BEEP) was recommended by the 2016 EAU guidelines as the first choice of surgical treatment in men with a substantially enlarged prostate and moderate-to-severe lower urinary tract symptoms. The main aim of this study was to compare a modified diode laser enucleation of the prostate (DiLEP) to BEEP.

Methods A total of 114 patients with prostate (20–160 mL) were randomized 1:1 into either DiLEP or BEEP in a dual-centre, non-inferiority-design randomized-controlled trial. The primary outcomes included Q_{max} and IPSS at 12 months. Non-inferiority was evaluated by comparing the two-sided 95% CI for the mean differences of Q_{max} and IPSS. Secondary endpoints included other perioperative parameters, postoperative micturition variables, and complication rate.

Results A total of 111 patients (97%) had completed the intent-to-treat analysis, The results showed that DiLEP was comparable to BEEP regarding Q_{max} (28.0 ± 7.0 vs. 28.1 ± 7.2 mL/s) and IPSS (3.0 ± 2.2 vs. 2.9 ± 2.6) at 12 months, the non-inferiority was met for both Q_{max} and IPSS. There were also no significant difference between two groups regarding tissue removal rate (71.8 vs. 73.8%), hemoglobin decrease (0.33 ± 0.66 vs. 0.36 ± 0.75 g/dL), sodium decrease (1.0 ± 2.7 vs. 0.3 ± 2.9 mmol/L), and Clavien III complications (5.3 vs. 1.8%) at 12 months.

Conclusions This DiLEP is an anatomical endoscopic enucleation technique for the treatment of benign prostatic hyperplasia, it is non-inferior to BEEP regarding Q_{max} and IPSS at 12 months postoperatively.

Keywords Benign prostatic hyperplasia · Prostatectomy · Endoscopic enucleation of the prostate · Laser surgery · Diode laser enucleation of the prostate · Randomized-controlled trial

Abbreviations

BPO	Benign prostatic obstruction
BEEP	Bipolar plasmakinetic endoscopic enucleation of the prostate
DiLEP	Diode laser enucleation of the prostate
EEP	Endoscopic enucleation of the prostate
IIEF-5	International index of erectile function
IPSS	International prostate symptom score
LUTS	Lower urinary tract symptoms
OP	Open prostatectomy
PSA	Prostate-specific antigen
PV	Prostate volume
PVR	Postvoid residual
Q_{max}	Maximum urinary flow rate
QoL	Quality of life
RCT	Randomized-controlled trial
SCP	Surgical capsule plane
TURP	Transurethral resection of the prostate

Zhihui Zou and Abai Xu have contributed equally to this manuscript.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00345-018-2229-3) contains supplementary material, which is available to authorized users.

✉ Chunxiao Liu
liuchx888@hotmail.com

Extended author information available on the last page of the article

Introduction

Transurethral resection of the prostate (TURP) is currently the standard surgical treatment for men with prostate (30–80 mL) and moderate-to-severe lower urinary tract symptoms (LUTS) secondary of benign prostatic obstruction (BPO) [1]. However, when evaluating urodynamic parameters, recurrence rate and surgical revision, TURP is evidently inferior to open prostatectomy (OP) [2–4]. In addition, TURP is still associated with significant morbidity, including perioperative bleeding requiring blood transfusion (2%) and TUR syndrome (0.8%) [5]. To address these problems, a variety of endoscopic procedures have been developed. For example, endoscopic enucleation of the prostate (EEP) using bipolar circuitry has been shown to be comparable to OP regarding the efficacy and durability by four randomized-controlled trials (RCTs) and confirmed as an anatomical enucleation technique [6–9]. Furthermore, together with holmium laser enucleation of the prostate, EEP such as bipolar enucleation have demonstrated comparable efficacy but lower morbidity in comparison to OP by two meta-analysis [10, 11], and were recommended by the 2016 EAU guidelines as the first choice of surgical treatment in men with a substantially enlarged prostate and moderate-to-severe LUTS.

Over the recent years, EEP with various other energy sources has been also developed [12], including diode laser enucleation of the prostate (DiLEP), which has been recognized as a safe and effective procedure, and also considered as an anatomical EEP technique [13–15]; However, the relevant RCT remains limited. Therefore, the present aimed to evaluate the overall efficacy and safety of a modified DiLEP and also to compare DiLEP versus BEEP in a dual-center RCT.

Patients and methods

Patients

The study protocol was approved by the Ethics Committee of the two participating hospitals. All subjects signed written informed consent prior to the study. Preoperative assessment included complete medical history, physical examination, prostate volume (PV) by transrectal ultrasound, post-void residual urine (PVR), uroflowmetry, International Prostate Symptom Score (IPSS), quality of life (QoL), International Index of Erectile Function (IIEF-5), prostate-specific antigen (PSA), hemoglobin and electrolytes assay, urine analysis, and urine culture. Consecutive patients (age 50–80) with LUTS due to BPO (prostate size 20–160 mL) were assessed for eligibility. The inclusion criteria were IPSS $\geq$ 12 and the QoL $\geq$ 4, maximum urinary flow rate (Q_{max}) $\leq$ 15 mL/s, and/or The Schafer grade $\geq$ 2, and/or failed medical therapy of BPO, and/or recurrent urinary retention. Exclusion criteria were previous urethral/prostatic surgery, known prostate cancer or urethral strictures, and neurogenic bladder or other neurologic disorder that may affect micturition.

Study design

This is a dual-centre, open-label, parallel-design non-inferiority RCT (Trial registration: http://www.who.int/ictrp/en/, Identifier: ChiCTR-IPR-15006717). The primary outcomes were Q_{max}, IPSS at 12 months. The secondary outcomes included operation time, tissue removal ratio, morcellation efficiency, total retrieve efficiency, energy delivery, laser fibers and bipolar loops used, decrease in serum hemoglobin and sodium, duration of bladder irrigation, indwelling catheterization, hospital stay, and complication rate. The follow-up was conducted at 1 week, 1, 3, 6, and 12 months postoperatively, and included Q_{max}, IPSS, QoL, PSA, IIEF-5, and adverse events. The PV and PVR were recorded only at 3, 12 months.

The assessment was made by researchers blinded to treatment allocation. AEs related to treatments were recorded according to the modified Clavien classification system [16] and reviewed by an independent clinical events committee consisting of three urologists blinded to treatment. The process of clinical trials and the original results were monitored by a clinical research organization authorized by China Food and Drug Administration.

Sample size, randomization, and statistical analysis

The sample size was estimated using nQuery Advisor 7.0 based on expected no difference in Q_{max} and IPSS between the two arms at 12-month, and non-inferiority limit of − 5 mL/s for Q_{max} and 3 points for IPSS [17]. Estimated standard deviation was 9 mL/s and 5 points for Q_{max} and IPSS, respectively [18–20]. Significant level was 2.5% (one-sided) and power was 80%. The estimation yielded 52 and 45 subjects in each arm based on Q_{max} and IPSS, respectively. Anticipating a drop out of 10%, we planned to enroll 57 subjects in each arm.

The randomization was stratified based on centres. The randomization sequence (1:1 ratio) was developed using the proc plan process of SAS 9.2. Allocation concealment was conducted using sealed opaque envelopes, distributed by the Clinical Research Associate upon the enrollment of each subject.

The analysis was carried out using the SAS statistical package (version 9.2, SAS Institute, Cary, NC, USA).

Normally distributed continuous variables were expressed as mean ± standard deviation, and were compared by *t* tests. Non-normally distributed continuous variables were presented as median and interquartile range, and were analyzed with Mann–Whitney *U* test or Wilcoxon rank-sum test. Categorical variables were expressed as percentages and were compared with the Pearson Chi-square or Fisher's exact test. For Q_{max} and IPSS, the missing data were imputed by last observation carried forward method, and the analyses were conducted following the intention-to-treat principle.

Surgical procedures

All ten surgeons were licensed urologists trained and experienced with DiLEP and BEEP more than 50 cases.

DiLEP

Patients were placed in a lithotomy position under general or spinal anesthesia. A 26F continuous-flow resectoscope equipped with a reusable end-firing 980-nm diode laser fiber was used. Normal saline was used for irrigation. The diode laser (INTERmedic, Spain) was set at 120 W for cutting and 30 W for coagulation. A 26F offset nephroscope, along with a soft-tissue morcellator (HAWK, YSB-III, China), was used.

Step #1: identification of surgical capsule plane (SCP).

Landmarks were identified close to the verumontanum using diode laser, and the urethra mucosa between the median lobe and verumontanum was incised. The beak of resectoscope was used to squeeze the left lobe to the right from the landmark (Fig. 1a), and the SCP of the left lobe would be identified naturally (Fig. 1b). Similarly, the SCP of median and right lobe could be also identified when the beak of resectoscope was squeezed to the right from the SCP of the left lobe (Fig. 1c). Then, the SCP of three lobes were identified around the distal prostatic (Fig. 1d).

Step #2: enucleation of the three lobes.

Starting from the SCP of the median lobe, the beak of resectoscope was used to detach the median lobe retrogradely, and detach the left lobe off pseudocapsule toward bladder neck clockwise from 6 to 12 o'clock (Fig. 1e). The diode laser was used to coagulate all the hemorrhage spots during procedure when need, and to cut off the connection between lobes and bladder neck. Similarly, the right lobe could be also detached off pseudocapsule counter-clockwise. At this time, the whole adenoma would be separated from pseudocapsule, with the urethral mucosa flap connected with distal prostatic apex (Fig. 1f). Cut off the urethral mucosa flap in an inverted resectoscope (Fig. 1f) and push the adenomas into bladder cavity. Then, a smooth prostatic fossa would be discovered, no transition zone tissue residue (Fig. 1g).

Step #3: morcellation of the enucleated adenoma.

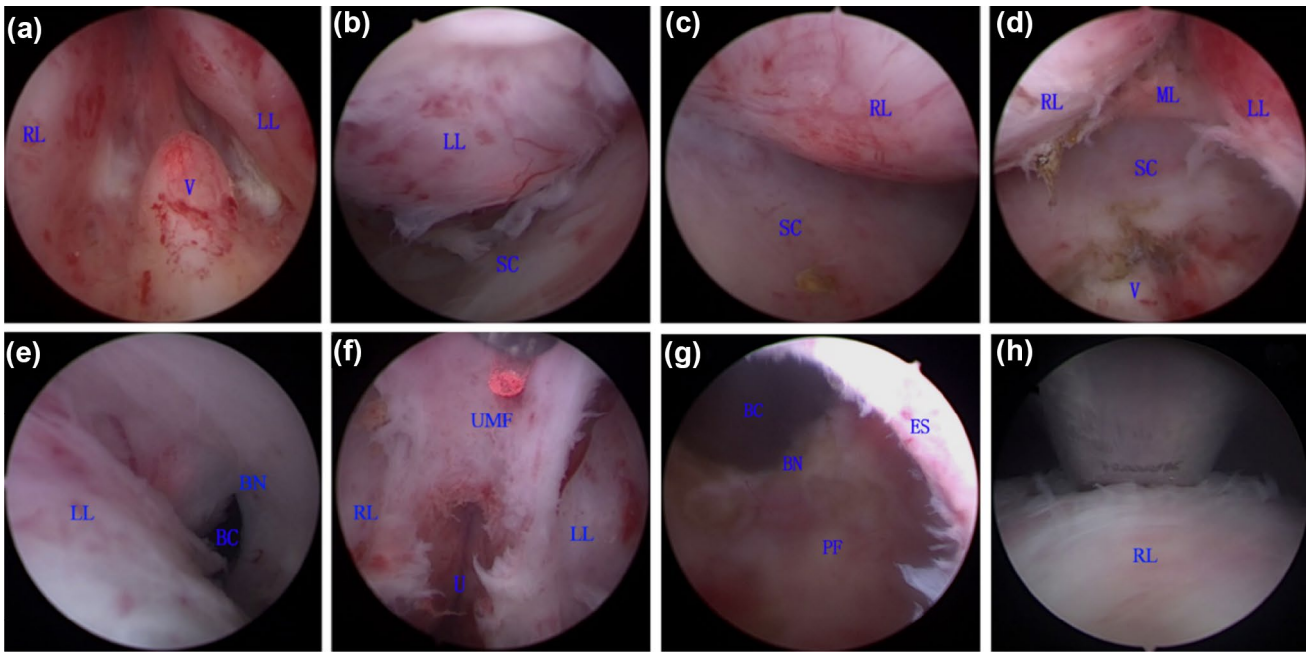

Fig. 1 Modified DiLEP. *V* verumontanum, *LL* left lobe, *RL* right lobe, *ML* median lobe, *SC* surgical capsule, *BC* bladder cavity, *BN* bladder neck, *U* urethra, *UMF* urethral mucosa flap, *PF* prostatic fossa, *ES* external sphincter

A nephroscope was placed to distend the bladder with continuous flushing. A downward technique was used to improve the safety of morcellation (Fig. 1h). Extracted tissue was kept in a container to perform pathological analysis. A standard 22F three-way catheter was inserted for flushing using normal saline.

BEEP

The procedure of BEEP was performed using a previously described technique [18], which is similar to DiLEP exception of the supply vessels and hemorrhage spots were coagulated by the bipolar loop. Identical tissue morcellation technique was carried out in both procedures. The bipolar plasmakinetic system (ScanMed, China) was set at 160 W for cutting and 100 W for coagulation.

Results

Study subjects

From May 2015 to October 2015, 142 patients were screened for eligibility; 28 were deemed ineligible. The remaining 114 subjects were enrolled (57 patients in each arm). Three patients were excluded from analysis (Fig. 2). The baseline characteristics are shown in Table 1.

Perioperative results

All operations were successful. The total retrieval efficiency of DiLEP was inferior to than BEEP (1.1 ± 0.32 vs. 1.3 ± 0.43 g/min, $P = 0.045$), while there were no difference regarding operation time (41.4 ± 18.1 vs. 38.8 ± 16.9 min, $P = 0.430$) including enucleation time and morcellation time. The two arms were also comparable in tissue removal ratio, morcellation efficiency, sodium decrease, hemoglobin

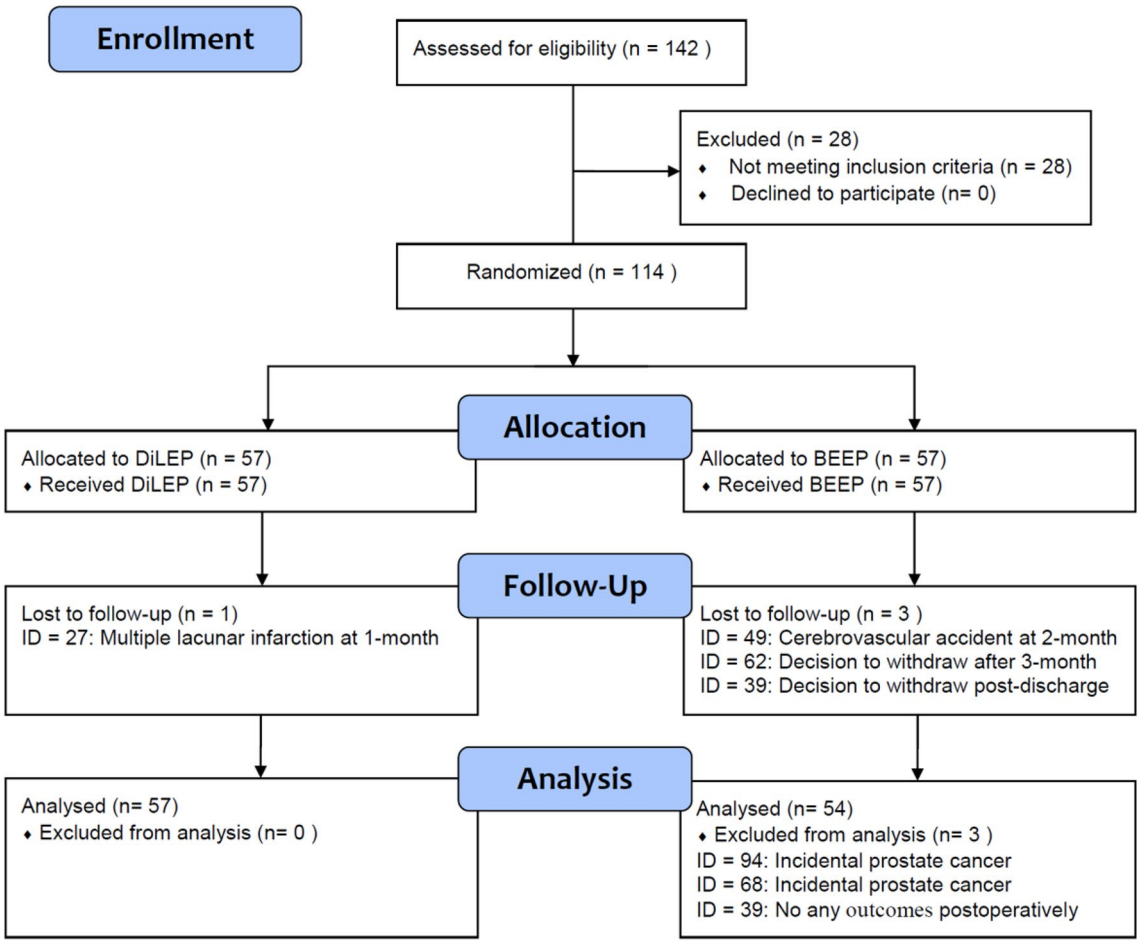

Fig. 2 Flow diagram of the participants through the study

Table 1 Baseline patient characteristics

Characteristic	DiLEP ($n = 57$)	BEEP ($n = 57$)	P value
Age (year)	67.3 ± 7.7	69.4 ± 7.5	0.142*
BMI	22.8 ± 3.3	22.6 ± 3.1	0.752*
Q_{max} (mL/s)	6.9 ± 5.0	5.4 ± 5.1	0.105*
IPSS	23.1 ± 6.1	22.8 ± 7.0	0.897*
QoL	5 (4–6)	5 (5–6)	0.198#
PV (mL)	59.5 ± 28.8	63.4 ± 36.4	0.982*
PSA (ng/mL)	4.4 (2.3–8.2)	5.2 (2.0–11.2)	0.698#
PVR (mL)	9 (0–50.0)	15 (0–77.0)	0.376#
IIEF-5	9 (6–18)	8 (5–19)	0.349#

*Normally distributed variables data analyzed with independent samples t test, and the values shown represent mean ± standard deviation

#Non-normally distributed variables data analyzed with the Mann–Whitney U test and the values shown represent median (interquartile range)

decrease, length of bladder irrigation, catheterization time, and hospital stay (Table 2).

Non-inferiority outcomes

The criterion for non-inferiority was met for both Q_{max} (95% confidence interval of mean difference: − 2.86 to 2.50) and IPSS (95% confidence interval of mean difference: − 0.79 to 1.02) (Table 3). There was a consistent improvement in Q_{max} during the first 6 months after DiLEP and during the first 3 months after BEEP, with sustained increase throughout the 12-month period in both arms (Fig. 3a). There was also a consistent improvement in IPSS during the first 3 months postoperatively, with sustained improvement during the 12-month period in both arms (Fig. 3b). Neither Q_{max} nor IPSS differed between DiLEP and BEEP at any time points.

Table 2 Perioperative data

Characteristic	DiLEP ($n = 57$)	BEEP ($n = 57$)	P value
Operation time (min)	41.4 ± 18.1	38.8 ± 16.9	0.430*
Enucleation time (min)	37.8 ± 16.9	35.1 ± 15.6	0.383#
Morcellation time (min)	3.2 (2.3–4.4)	3.2 (2.4–4.5)	0.770#
Enucleated prostate weight (g)	33.7 (25.7–59.6)	37.2 (23.7–67.2)	0.838*
Tissue removal ratio (%)	71.8 ± 9.3	73.8 ± 9.5	0.269*
Morcellation efficiency (g/min)	12.2 ± 3.2	12.7 ± 4.0	0.520*
Total retrieve efficiency (g/min)	1.1 ± 0.32	1.3 ± 0.43	0.045*
Decrease in hemoglobin (g/dL)	0.33 ± 0.66	0.36 ± 0.75	0.818*
Decrease in sodium (mmol/L)	1.0 ± 2.7	0.3 ± 2.9	0.180*
Postoperative irrigation (h)	21.5 (18.0–26.9)	20.6 (18.1–23.9)	0.244#
Duration of catheterization (h)	44.6 (35.0–53.6)	43.0 (31.7–54.5)	0.767#
Postoperative hospital stay (day)	4 (3–5)	4 (3–4)	0.060#
Energy delivery (kJ)	61.0 (49.5–74.7)	NA	
Energy/mL prostate (kJ/mL)	1.6 ± 0.5	NA	
Fibers/loops used per arm (n)	4	7	

NA not applicable

*Normally distributed variables data analyzed with independent samples t test, and the values shown represent mean ± standard deviation

#Non-normally distributed variables data analyzed with the Mann–Whitney U test and the values shown represent median (interquartile range)

[a]Enucleated prostate weight/preoperative prostate weight)

[b]Enucleated prostate weight/morcellation time)

[c]Enucleated prostate weight/operation time)

[d]Properation minus first postoperative day in serum hemoglobin or sodium

Table 3 Non-inferiority of DiLEP to BEEP

Endpoint	Time point	DiLEP ($n = 57$)	BEEP ($n = 54$)	Difference (95% CI)
Q_{max} (mL/s), mean ± SD	Baseline	6.9 ± 5.0	5.7 ± 5.1	
	12 months	28.0 ± 7.0	28.1 ± 7.2	− 0.19 (− 2.86 to 2.50)
IPSS, mean ± SD	Baseline	23.1 ± 6.1	23.0 ± 6.9	
	12 months	3.0 ± 2.2	2.9 ± 2.6	0.11 (− 0.79 to 1.02)

CI confidence interval, *SD* standard deviation

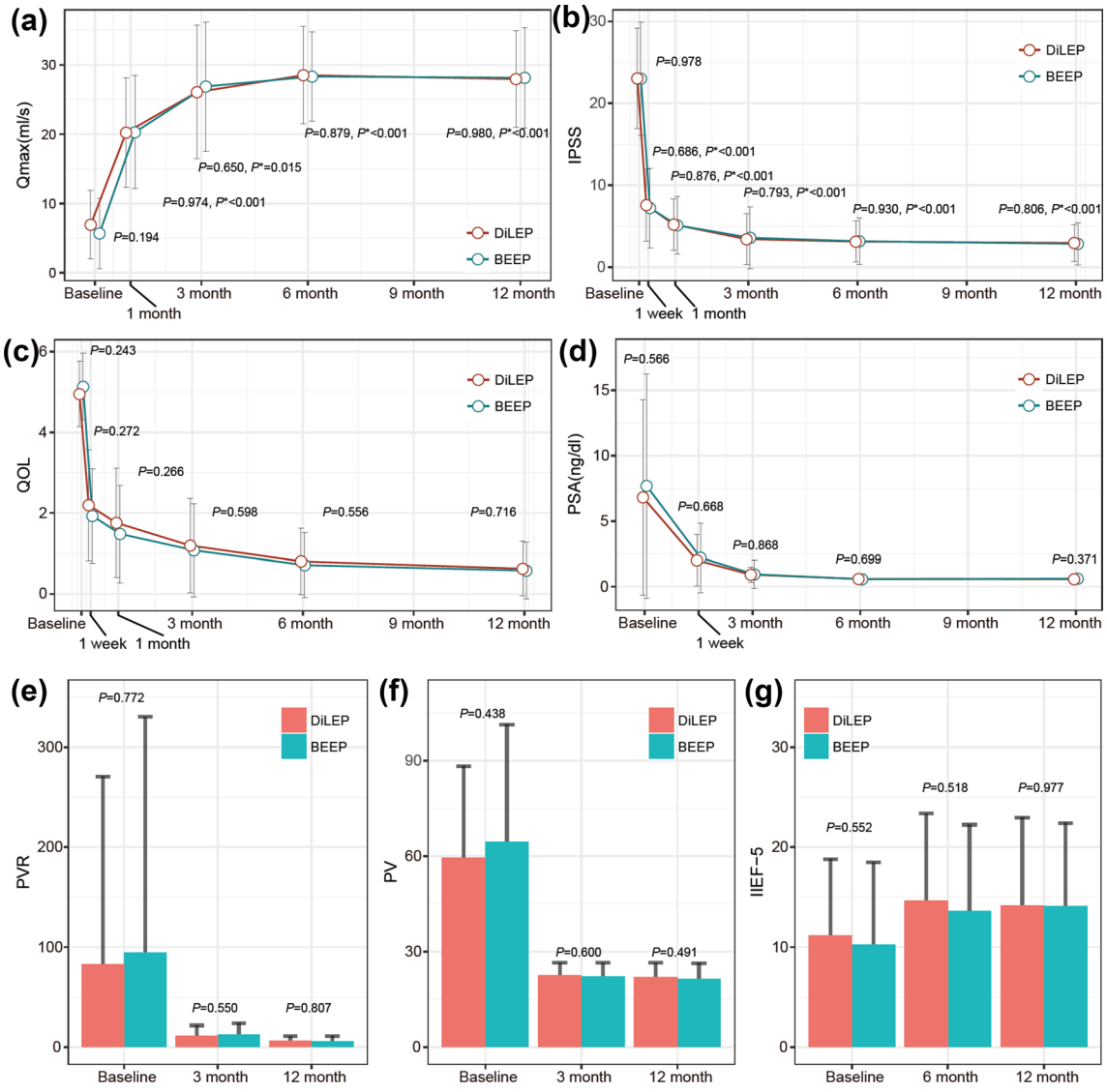

Fig. 3 Outcomes following treatment with the DiLEP or BEEP. **a** Q_{max}, **b** IPSS, **c** QoL, **d** PSA, **e** PVR, **f** PV, **g** IIEF-5

Functional results

QoL, PVR, IIEF-5, PSA, and PV were comparable between the two arms ($P > 0.05$ for all). Both QoL (Fig. 3c) and PVR (Fig. 3e) improved substantially over 12-month in both arms. PSA decreased from 6.8 ± 7.5 to 0.6 ± 0.3 ng/mL (fell by 91.5%) in the DiLEP and from 7.7 ± 8.5 to 0.6 ± 0.2 ng/mL (fell by 92.6%) in the BEEP over the first 6 months, the decreases were sustained until 12 months (Fig. 3d). PV decreased from 59.5 ± 28.8 to 22.6 ± 3.9 mL in DiLEP and from 63.4 ± 36.4 to 22.2 ± 4.3 mL in the BEEP at 3 months (Fig. 3f). IIEF-5 improved from 11.2 ± 7.6 to 14.2 ± 8.8 in DiLEP and from 10.2 ± 8.0 to 14.1 ± 8.3 in BEEP during the first 6 months; effects were sustained throughout the 12-month period (Fig. 3g).

Adverse events

Common AEs in DiLEP and BEEP were discomfort symptoms (19.3 vs. 21.1%) and retrograde ejaculation (45.6 vs. 42.1%). 8.8% patients in each group have been confirmed urinary incontinence and relieved through pelvic floor exercises within 3 months. Three patients in DiLEP (5.3%) vs. one patient (1.8%) in BEEP underwent incision of bladder neck for bladder neck contracture, respectively. There were no capsule perforation, morcellation injuries, TUR syndrome, blood transfusion, and reoperation for residual gland occurred, and no significant difference in AEs between two procedures (Table 4).

Table 4 Adverse events (AEs) assessed by modified Clavien classification

Complications	DiLEP ($n = 57$)		BEEP ($n = 57$)		*P* value
	No. AEs	No. patients (%)	No. AEs	No. patients (%)	
Grade I					
Discomfort symptoms[a]	11	11 (19.3)	12	12 (21.1)	0.815*
Transient incontinence[b]	4	4 (7.0)	3	3 (5.3)	1.000#
Retrograde ejaculation[c]	26	26 (45.6)	19	19 (33.3)	0.180*
Recatheterization	2	2 (3.0)	1	1 (1.8)	1.000#
Overall	43	26 (45.6)	35	24 (42.1)	0.706*
Grade II					
Discomfort symptoms[a]	2	2 (3.5)	2	2 (3.5)	1.000#
Transient incontinence[d]	1	1 (1.8)	2	2 (3.5)	1.000#
Urinary tract infection[e]	3	3 (5.3)	4	5 (8.8)	1.000#
Other	2	2 (3.0)	0	0 (0)	0.496#
Overall	8	6 (14.0)	8	6 (14.0)	1.000*
Grade III					
Bladder neck contracture	3	3 (5.3)	1	1 (1.8)	0.618#
All grades	54	37 (64.9)	45	32 (56.0)	0.338*

AEs adverse events

*Data analyzed with the Pearson Chi-square

#Data analyzed with the Fisher's exact test

[a]Discomfort symptoms include irritation, pain and intermittent gross hematuria

[b]Evaluated by 1-h urine pad test at 1 month

[c]Retrograde ejaculation was calculated using the number of all subjects as denominator, it was 74.3% in DiLEP and 61.3% in BEEP when calculated using the number of subjects able to engage in intercourse as denominator

[d]Three patients were administrated solifenacin tablets for overactive bladder

[e]Urinary tract infection was defined as: irritative symptoms with fever or urine test ≥ WBC 3 + and positive urine culture

Discussion

Bipolar-plasmakinetic transurethral enucleation and resection of the prostate (TUERP/PKEP) was designed and has been routinely performed in clinical practice at our department since January 2001 [21]. In TUERP, the adenoma was completely dissected along the SCP in a similar way as a surgeon's index finger does during OP, which is comparable to HoLEP, and also considered as anatomical enucleation technique [18]. Moreover, in HoLEP, the adenoma was enucleated by the blasting expansion power due to the pulsed nature of holmium laser during HoLEP, and the tissue was retrieved using morcellator, whereas, in TUERP, the adenoma was enucleated by applying the blunt power using the beak of resectoscope and resected with a bipolar loop. Recently, this enucleation technique had been improved and applied into DiLEP. Notably, our preliminary experiences demonstrated that DiLEP associated with better hemostatic properties than HoLEP when the diode laser was used in a non-connected manner. Consequently, this dual-centre randomized-controlled non-inferiority trial was undertaken to compare DiLEP with BEEP for the first time.

Currently, various EEP procedures have been developed and introduced [22]; However, there was an obvious discrepancy between these objectively parameters in those mentioned literatures, including the mean Q_{max} change (varied from 8.3 to 23.9 mL/s), and mean PSA reduction (67–93%). These discrepancies might be attributed to the different EEP techniques employed, which could be divided into three categories based on retrieved tissue: (1) similar enucleation (the adenoma was partly removed close to SCP), (2) partial enucleation (a part of the adenoma was dissected along SCP), and (3) anatomical enucleation (the entire adenoma dissected along SCP).

DiLEP should be considered as an anatomical EEP. The SCP identification is the crucial step for DiLEP. In the previous studies, SCP was identified by making an incision to the verumontanum-proximal urethral mucous [18] or from an incision of bladder neck [23]. In the present study, the SCP was simply identified with the 'blunt squeezing technique' by squeezing the right or left lobe approximate to verumontanum using the beak of the resectoscope. According to our experiences, this "blunt squeezing technique" is a simple and rapid method for the identification of SCP, which also

ensures the anatomical enucleation of the adenoma at the apex, and avoids the sharp cutting injury or thermal damage to the sphincter caused by energy sources. In addition, the entire adenoma was dissected along the SCP during procedures; some intractable adenomas during OP could also be removed by diode laser under endoscopic vision. Thus, hypothetically DiLEP may be considered superior to OP regarding urodynamic parameters and reoperation rates. This is confirmed by the fact that the change in the mean Q_{max}, 21.0 mL/s in DiLEP was not significantly different to the change in OP (11.0–21.4 mL/s) [6–9]. The mean tissue retrieval rate was 71.8%, and the percentage reduction in PSA was up to 91.5% in DiLEP, which appeared to higher than PSA reduction (78.6–90.1%) for OP [7, 8]. Furthermore, no reoperation was required due to residual adenoma at 12-month follow-up. Taken together, these findings suggested that the adenoma was removed entirely, leading to significantly improved functional outcomes, including IPSS, QoL, PVR, and IIEF.

Bleeding and TUR syndrome remain major challenges for TURP, particularly in patients with larger prostates, due to a continuous bleeding and water absorption during TURP. However, the blood vessels of adenoma were blocked immediately and usually only once at SCP during EEP, which minimized the bleeding and water absorption compared to TURP. This was reflected by the minimal estimated blood loss and water absorption, in the current study and available literature [24]. Furthermore, diode laser has been associated with excellent hemostatic properties [25], It has also been demonstrated that DiLEP (1380 nm) was also associated with less blood loss compared to TURP in an RCT [15] and as compared to laparoscopic adenomectomy in control study [26], the hemoglobin decrease of DiLEP (0.24–0.71 g/dL) in the two studies was consistent with this trial (0.356 g/dL). Furthermore, the two RCTs also showed that DiLEP was superior to BEEP regarding hemoglobin decrease [14, 27]. However, the current dual-centre RCT demonstrated that there was no significant difference in terms of blood loss and water absorption, which may be attributed to the constant intravenous fluid management in all patients or the tissue morcellator was used in the both groups, while these biases were not controlled in the previous trials.

The previous studies have showed longer operate time with EEP compared to TURP [28]. Nevertheless, tissue morcellation significantly promoted the development of EEP. The efficiency of 12.5 g/min of tissue morcellation in the present study was responsible for a higher retrieval efficiency (1.12 g/min) and a shorter operation time (40 min) than TURP (0.8 g/min and 55.3 min, respectively) [19]. Moreover, we also believed that bleeding and water absorption could be further reduced with the advances in the equipment and technique concerning morcellation. Taken together, these findings suggested that with tissue morcellator, DiLEP could significantly eliminate the TUR syndrome and blood transfusion. For these reasons, men with the mild-to-medium prostate (20–80 mL) and substantially enlarged prostate (80–160 mL) were included in this RCT. Indeed, in our department, men with prostate volume over 280 mL were successfully treated with DiLEP and BEEP.

Of note, both the groups had 8.8% transient incontinence postoperatively which were insignificant as compared to that of TURP (0–5%) [5]; However, when the men with a prostate size of ≤ 80 mL were only considered, the transient incontinence decreased to 2%. We speculated that urinary incontinence was possibly correlated with larger prostate volume which was consistent with previously reported [29].

Besides, three patients (5.3%) in DiLEP and one patient (1.8%) in BEEP have been confirmed as bladder neck contracture at 12-month postoperatively; However, the difference between the two groups was not statistically significant. Furthermore, the higher complication rate of the Clavien III complications in DiLEP should not be ignored due to a low sample seize of the study and lower statistical power to detect their difference, this may be considered the limitation of this study. Other limitations are the shorter follow-up period and the unevaluated learning curve. Further defined and large RCTs comparing DiLEP with TURP or HoLEP are needed.

Conclusion

The modified DiLEP was comparable with BEEP in terms of safety and efficacy at 12-month postoperatively. Both are size-independent procedure providing complete removal of the transition zone, satisfied micturition improvement, and low morbidity for men with moderate-to-severe LUTS/BPO. However, our experiences need to be confirmed and the long-term follow-up is needed.

Acknowledgements We would like to thank all the patients and surgeons, attending colleagues, study nurses in this study, thanks to the Clinical Research Associate and independent clinical events committee member of this trial.

Author contributions CL: project development, data management and analysis, and manuscript editing. ZZ: project development, data analysis, manuscript writing, medical illustration design, and video edit. AX: manuscript editing and data analysis. CD: data analysis. CL and JC: data collection. CL, JZ, YX, JC, HL, YW, YG, and CL provide technical or intellectual support.

Funding Funded by Guangzhou Science Technology Key Program (201504301009390).

Compliance with ethical standards

Conflict of interest The authors have nothing to disclose.

Informed consent Written informed consent was obtained from all subjects.

Ethical approval Ethical approval has been taken from Institutional Ethical Committee.

References

1. Gratzke C, Bachmann A, Descazeaud A, Drake MJ, Madersbacher S, Mamoulakis C, Oelke M, Tikkinen KA, Gravas S (2015) 2015 EAU guidelines on the assessment of non-neurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol 67(6):1099–1109. https://doi.org/10.1016/j.eururo.2014.12.038
2. Roos NPWJ, Malenka DJ, Fisher ES, McPherson K, Andersen TF, Cohen MM, Ramsey E (1989) Mortality and reoperation after open and transurethral resection of the prostate. N Engl J Med 320(17):1120–1124. https://doi.org/10.1056/NEJM198904273201705
3. Madersbacher S, Lackner J, Brössner C, Röhlich M, Stancik I, Willinger M, Schatzl G (2005) Reoperation, myocardial infarction and mortality after transurethral and open prostatectomy: a nationwide, long-term analysis of 23,123 cases. Eur Urol 47(4):499–504. https://doi.org/10.1016/j.eururo.2004.12.010
4. Simforoosh NAH, Kashi AH, Zare S, Tabibi A, Danesh A, Basiri A, Ziaee SA (2010) Open prostatectomy versus transurethral resection of the prostate, where are we standing in the new era? A randomized controlled trial. Urol J 7(4):262–269
5. Ahyai SA, Gilling P, Kaplan SA, Kuntz RM, Madersbacher S, Montorsi F, Speakman MJ, Stief CG (2010) Meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic enlargement. Eur Urol 58(3):384–397. https://doi.org/10.1016/j.eururo.2010.06.005
6. Rao JM, Yang JR, Ren YX, He J, Ding P, Yang JH (2013) Plasmakinetic enucleation of the prostate versus transvesical open prostatectomy for benign prostatic hyperplasia > 80 mL: 12-month follow-up results of a randomized clinical trial. Urology 82(1):176–181. https://doi.org/10.1016/j.urology.2013.02.032
7. Ou R, Deng X, Yang W, Wei X, Chen H, Xie K (2013) Transurethral enucleation and resection of the prostate vs transvesical prostatectomy for prostate volumes > 80 mL: a prospective randomized study. BJU Int 112(2):239–245. https://doi.org/10.1111/bju.12181
8. Geavlete B, Stanescu F, Iacoboaie C, Geavlete P (2013) Bipolar plasma enucleation of the prostate vs open prostatectomy in large benign prostatic hyperplasia cases—a medium term, prospective, randomized comparison. BJU Int 111(5):793–803. https://doi.org/10.1111/j.1464-410X.2012.11730.x
9. Chen S, Zhu L, Cai J, Zheng Z, Ge R, Wu M, Deng Z, Zhou H, Yang S, Wu W, Liao L, Tan J (2014) Plasmakinetic enucleation of the prostate compared with open prostatectomy for prostates larger than 100 grams: a randomized noninferiority controlled trial with long-term results at 6 years. Eur Urol 66(2):284–291. https://doi.org/10.1016/j.eururo.2014.01.010
10. Li M, Qiu J, Hou Q, Wang D, Huang W, Hu C, Li K, Gao X (2015) Endoscopic enucleation versus open prostatectomy for treating large benign prostatic hyperplasia: a meta-analysis of randomized controlled trials. PLoS One 10(3):e0121265. https://doi.org/10.1371/journal.pone.0121265
11. Lin Y, Wu X, Xu A, Ren R, Zhou X, Wen Y, Zou Y, Gong M, Liu C, Su Z, Herrmann TR (2016) Transurethral enucleation of the prostate versus transvesical open prostatectomy for large benign prostatic hyperplasia: a systematic review and meta-analysis of randomized controlled trials. World J Urol 34(9):1207–1219. https://doi.org/10.1007/s00345-015-1735-9
12. Herrmann TRW (2016) Enucleation is enucleation is enucleation is enucleation. World J Urol 19(1):19–22
13. Buisan O, Saladie JM, Ruiz JM, Bernal S, Bayona S, Ibarz L (2011) Diode laser enucleation of the prostate (Dilep): technique and initial results. Actas Urológicas Españolas (English Edition) 35(1):37–41. https://doi.org/10.1016/s2173-5786(11)70010-5
14. Xu A, Zou Y, Li B, Liu C, Zheng S, Li H, Xu Y, Chen B, Xu K, Shen H (2013) A randomized trial comparing diode laser enucleation of the prostate with plasmakinetic enucleation and resection of the prostate for the treatment of benign prostatic hyperplasia. J Endourol/Endourol Soc 27(10):1254–1260. https://doi.org/10.1089/end.2013.0107
15. Lusuardi L, Myatt A, Sieberer M, Jeschke S, Zimmermann R, Janetschek G (2011) Safety and efficacy of eraser laser enucleation of the prostate: preliminary report. J Urol 186(5):1967–1971. https://doi.org/10.1016/j.juro.2011.07.026
16. Mamoulakis C, Efthimiou I, Kazoulis S, Christoulakis I, Sofras F (2011) The modified Clavien classification system: a standardized platform for reporting complications in transurethral resection of the prostate. World J Urol 29(2):205–210. https://doi.org/10.1007/s00345-010-0566-y
17. Bachmann A, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, Grimm MO, Benejam J, Stolzenburg JU, Riddick A, Pahernik S, Roelink H, Ameye F, Saussine C, Bruyere F, Loidl W, Larner T, Gogoi NK, Hindley R, Muschter R, Thorpe A, Shrotri N, Graham S, Hamann M, Miller K, Schostak M, Capitan C, Knispel H, Thomas JA (2014) 180-W XPS GreenLight laser vaporisation versus transurethral resection of the prostate for the treatment of benign prostatic obstruction: 6-month safety and efficacy results of a European Multicentre Randomised Trial–the GOLIATH study. Eur Urol 65(5):931–942. https://doi.org/10.1016/j.eururo.2013.10.040
18. Liu C, Zheng S, Li H, Xu K (2010) Transurethral enucleation and resection of prostate in patients with benign prostatic hyperplasia by plasma kinetics. J Urol 184(6):2440–2445. https://doi.org/10.1016/j.juro.2010.08.037
19. Zhao Z, Zeng G, Zhong W, Mai Z, Zeng S, Tao X (2010) A prospective, randomised trial comparing plasmakinetic enucleation to standard transurethral resection of the prostate for symptomatic benign prostatic hyperplasia: 3-year follow-up results. Eur Urol 58(5):752–758. https://doi.org/10.1016/j.eururo.2010.08.026
20. Yang SS, Hsieh CH, Chiang IN, Lin CD, Chang SJ (2013) Prostate volume did not affect voiding function improvements in diode laser enucleation of the prostate. J Urol 189(3):993–998. https://doi.org/10.1016/j.juro.2012.08.256
21. Shaobo Zheng CL, Yawen Xu et al (2005) Intraluminal nucleation in transurethral vaporization and electro-resection of the prostate. Chin J Urol 26(8):558–561
22. Herrmann TR (2016) Long-term outcome after endoscopic enucleation of the prostate: from monopolar enucleation to HoLEP and from HoLEP to EEP. Der Urologe Ausg A 55(11):1446–1454. https://doi.org/10.1007/s00120-016-0245-8
23. Gilling PJ (1998) Holmium:YAG laser enucleation of the prostate combined with mechanical morcellation preliminary results. Eur Urol 33(1):69–72
24. Lusuardi L, Mitterberger M, Hruby S, Kunit T, Kloss B, Engelhardt PF, Sieberer M, Janetschek G (2015) Update on the use of diode laser in the management of benign prostate obstruction in 2014. World J Urol 33(4):555–562. https://doi.org/10.1007/s00345-014-1327-0
25. Herrmann TR, Liatsikos EN, Nagele U, Traxer O, Merseburger AS, Eau Guidelines Panel on Lasers T (2012) EAU guidelines

on laser technologies. Eur Urol 61(4):783–795. https://doi.org/10.1016/j.eururo.2012.01.010
26. Lusuardi L, Hruby S, Janetschek G, Mitterberger M, Sieberer M, Colleselli D, Kunit T, Hitzl W, Kloss B (2015) Laparoscopic adenomectomy versus eraser laser enucleation of the prostate. World J Urol 33(5):691–696. https://doi.org/10.1007/s00345-014-1476-1
27. Wu G, Hong Z, Li C, Bian C, Huang S, Wu D (2016) A comparative study of diode laser and plasmakinetic in transurethral enucleation of the prostate for treating large volume benign prostatic hyperplasia: a randomized clinical trial with 12-month follow-up. Lasers Med Sci 31(4):599–604. https://doi.org/10.1007/s10103-016-1883-1
28. Fayad AS, Elsheikh MG, Zakaria T, Elfottoh HA, Alsergany R, Elshenoufy A, Elghamarawy H (2015) Holmium laser enucleation of the prostate versus bipolar resection of the prostate: a prospective randomized study. "Pros and Cons". Urology 86(5):1037–1041. https://doi.org/10.1016/j.urology.2015.08.004
29. Elmansy HM, Kotb A, Elhilali MM (2011) Is there a way to predict stress urinary incontinence after holmium laser enucleation of the prostate? J Urol 186(5):1977–1981. https://doi.org/10.1016/j.juro.2011.06.063

Affiliations

Zhihui Zou[1,5] · Abai Xu[1] · Shaobo Zheng[1] · Binshen Chen[1] · Yawen Xu[1] · Hulin Li[1] · Chongyang Duan[2,3] · Junhong Zheng[4] · Jiasheng Chen[1] · Chaoming Li[1] · Yiming Wang[1,6] · Yubo Gao[1] · Chaozhao Liang[5] · Chunxiao Liu[1]

1 Department of Urology, Zhujiang Hospital of Southern Medical University, 253 Middle Gongye Avenue Road, Guangzhou 510280, Guangdong, China

2 Department of Biostatistics, School of Public Health, Southern Medical University, Guangzhou, Guangdong, China

3 State Key Laboratory of Organ Failure Research, National Clinical Research Centre for Kidney Disease, Guangzhou, Guangdong, China

4 Department of Urology, The Second Affiliate Hospital of Shantou University Medical College, Shantou, Guangdong, China

5 Department of Urology, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China

6 Department of Urology, Ludwig-Maximilians University, Munich, Germany