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Original Article

Efficacy of uterine artery embolization through a distal radial artery approach for treatment of uterine fibroids

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Abstract: Objectives: Uterine fibroids are common benign tumors of the female reproductive system, primarily affecting women of childbearing age. These tumors worsen patients' quality of life and fertility. Current treatment options for symptomatic uterine fibroids include drug therapy, surgical intervention, and interventional procedures. Among these, uterine artery embolization (UAE) has emerged as an effective interventional treatment. Recently, the transradial approach (TRA) and the distal transradial artery approach (dTRA) have gained attention as alternative access routes for UAE. This study aims to compare the clinical efficacy of TRA and dTRA in UAE for the treatment of uterine fibroids, providing insight to guide clinical decision-making. Methods: A retrospective, multi-center analysis was conducted involving 300 patients with uterine fibroids who underwent UAE between July 2021 and June 2024. Patients were divided into two groups based on the vascular access approach: the control group (n = 144, UAE via TRA) and the experimental group (n = 156, UAE via dTRA). Data on general patient characteristics, ovarian function indicators, perioperative data, postoperative visual analogue scale (VAS) pain scores, and complication rates were collected and analyzed. Multivariate logistic regression was used to identify factors associated with dTRA puncture failure, and a nomogram risk prediction model was constructed. Results: The baseline characteristics of the two groups were comparable, with no significant differences in general information ($P > 0.05$). Also, no significant differences were observed in ovarian function indicators before and after surgery between the two groups ($P > 0.05$). However, the control group exhibited significantly shorter puncture and operation times compared to the experimental group ($P < 0.05$). The number of puncture attempts during the procedure was also lower, and the puncture success rate was higher in the control group ($P < 0.05$). Postoperative pain, as measured by the VAS score, was consistently lower in the experimental group at all time points ($P < 0.05$). The incidence of complications such as hypertonic hematoma of the right hand and forearm, radial artery spasm, and radial artery occlusion was significantly higher in the control group than in the experimental group ($P < 0.05$). Factors influencing dTRA puncture failure included vessel puncture inner diameter, radial artery tortuosity, and previous puncture history ($P < 0.05$), with vessel puncture inner diameter identified as the key determinant. A nomogram predictive model we constructed demonstrated strong reliability and is expected to assist in predicting puncture failure risk in clinical practice ($P < 0.05$). Conclusions: Although the dTRA approach showed a lower puncture success rate compared to TRA, it demonstrated clear advantages in reducing postoperative complications and pain, significantly improving patient compliance. Future efforts should focus on optimizing operative technique to enhance the puncture success rate and expand the clinical use of dTRA, thereby providing more effective treatment options for uterine fibroids.

Keywords: Distal transradial artery access, artery approach, transradial route, uterine artery embolization, uterine fibroids, multicenter retrospective analysis

Introduction

Uterine fibroids are common benign tumors of the female reproductive system, predominantly affecting women of childbearing age. Although their precise pathogenesis remains unclear [1], 25% to 30% of patients with uterine fibroids experience severe clinical symptoms, including

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abnormal menstrual bleeding, anemia, lower abdominal masses, frequent urination, constipation, and even infertility [2]. Currently, treatment options for symptomatic uterine fibroids include drug therapy, surgical intervention, and interventional procedures. However, drug therapy cannot eliminate fibroids and often leads to fibroid recurrence upon discontinuation [3]. Surgical treatment, while effective, is more invasive and may alter the pelvic physiological environment, increasing the risk of uterine rupture during subsequent pregnancies [4].

In 1995, Ravina et al. [5] first reported the successful use of uterine artery embolization (UAE) for treating uterine fibroids. UAE offers advantages such as procedural simplicity, faster postoperative recovery, and fewer complications, making it a favorable treatment option for women of childbearing age with symptomatic fibroids. By convention, UAE is performed through the femoral artery, which offers strong vascular pulsation, a fixed and straight diameter, and a high puncture success rate. However, this approach requires prolonged bed rest postprocedure, elevating the risk of deep vein thrombosis in the lower limbs and bleeding at the puncture site, which adversely affects patient quality of life and compliance with treatment [6].

The transradial approach (TRA) has emerged as an alternative, leveraging the dual blood supply system of the hand formed by the radial and ulnar arteries connected through the palmar arch. This dual circulation reduces the likelihood of compromised hand perfusion in cases of radial or ulnar artery occlusion. Compared to the femoral approach, TRA is associated with fewer puncture site complications, reduced mortality, shorter hospitalization, and improved patient comfort [7]. In a study by Nakhaei et al. [8], the incidence of complications with TRA was reported to be 1.10% lower than that of the transfemoral approach, although radial artery occlusion remains a significant concern [9]. In 2011, Babunashvili et al. [10] described two cases of proximal radial artery occlusion treated through the distal transradial artery approach (dTRA) at the anatomical snuffbox, introducing this approach to the interventional field. The distal puncture site minimizes disruption to the forearm's effective blood supply, significantly reduces the risk of radial artery occlusion, and shortens postoperative compression time.

Currently, dTRA is primarily employed in interventional procedures for cardiovascular diseases. Park et al. [12] demonstrated its technical feasibility and safety in various non-coronary interventional therapies. However, its use in peripheral vascular interventions has been limited due to challenges such as higher puncture difficulty, a steeper learning curve, and extended operation and radiation exposure times [13]. Despite these challenges, dTRA has gained attraction for peripheral interventions due to its advantages, including reduced risk of arteriovenous fistula and nerve injury.

Reports on using dTRA for the treatment of uterine fibroids remain scarce, and there is limited clinical evidence comparing the efficacy of UAE by dTRA versus TRA. This study aims to evaluate and compare the efficacy and safety of UAE performed by these two approaches, identify perioperative complications, and explore risk factors associated with dTRA puncture. The findings aim to provide valuable insight for optimizing treatment strategy for uterine fibroids.

Methods

Patient data

A thorough review of prior studies on dTRA and TRA was conducted to estimate differences in key outcome indicators in the treatment of uterine fibroids via UAE. Based on this review, a medium effect size was anticipated, with the difference between the dTRA and TRA groups in the composite outcome indicators estimated to be approximately 0.5 standard deviations. The sample size estimation formula is shown in (1).

$$n = 2 \times \frac{Z_{1-\alpha/2} + Z_{1-\beta} \times \sigma^2}{\triangle^2} \quad (1)$$

where n represents the required sample size per group. $Z_{1-\alpha/2}$ is the critical value of the standard normal distribution corresponding to the significance level, which is set at 0.05 ($Z_{1-\alpha/2}$ = 1.96). $Z_{1-\beta}$ is the critical value of the standard normal distribution corresponding to the power of the test, which is set at 0.80 ($Z_{1-\beta}$ = 0.84). The variance (σ^2) of the outcome

variable was estimated based on data from previous studies and a pre-test. In the preliminary analysis, the variance of the comprehensive outcome index was estimated to be 1.0. The expected difference (Δ) in the outcome variable between the two groups was assumed to be 0.5 standard deviations. Using these values, the required sample size was calculated as n = 62.72. Therefore, at least 63 patients needed to be included in each group for this study.

In this retrospective analysis, data of patients with uterine fibroids who underwent UAE at Wulin Hospital Affiliated to Jiangsu University and the First People's Hospital of Changzhou from July 2021 to June 2024 were screened by two researchers.

Inclusion criteria: Patients met the diagnostic criteria for uterine fibroids as outlined in [14] and held indications for UAE treatment as specified in [15]; patients had palpable radial and femoral artery pulsations; patients were under 175 cm in height, aged between 20 and 50 years, and were able to communicate normally.

Exclusion criteria: Patients with concurrent pelvic space-occupying lesions or a uterine fibroid diameter exceeding 12 cm; patients with malignant tumors or infectious diseases at other sites; patients with allergies to contrast agents; pregnant or lactating patients.

Patients who met the criteria were divided into two groups based on the puncture approach: the control group (n = 144), which received UAE through TRA, and the experimental group (n = 156), which received UAE through dTRA. The final sample size met the study's expected estimate. This study was approved by the Ethics Committee of Wulin Hospital Affiliated to Jiangsu University.

Treatment methods

Once patients were assessed by the medical team and found to meet the indications for UAE, the applicability of the two puncture approaches, TRA and dTRA, was further explored. Patients were informed about the advantages and potential risks associated with both approaches, and a treatment plan was discussed and agreed upon. It is important to note that patients opting for dTRA must have had a detectable distal radial artery pulse, confirmed through a negative Allen test, and be under 175 cm in height.

In the control group, UAE through TRA was performed. The patients were positioned supine, with the right hand thoroughly disinfected up to the elbow. The arm was instructed to extend and abduct naturally, and the wrist was slightly extended to fully expose the puncture site. The puncture point was selected approximately 2-3 cm from the proximal end of the radial styloid process, which is the strongest point of radial artery pulsation. Local anesthesia (1 mL of 1% lidocaine) was administered at the puncture site. Using the Seldinger technique, a sheath needle was used to puncture the radial artery, and after successful access, a 5F radial artery sheath was placed. To prevent thrombosis and vasospasm, 2000-3000 U of heparin and 0.2 mg of nitroglycerin were injected through the sheath. Subsequently, a vascular sheath and angiography catheter were inserted, and angiography was performed through the abdominal aorta and bilateral uterine arteries. Following angiography, a microcatheter was advanced to the distal end of both uterine arteries, and appropriate-sized embolization microspheres were deployed. Digital subtraction angiography (DSA) was performed post-embolization to confirm successful treatment. Embolization was deemed successful if DSA showed decelerated blood flow in both uterine arteries and the disappearance of abnormal nodular or clumpy staining. After the procedure, the catheter sheath and contrast tubing were removed. Hemostasis was achieved at the radial artery puncture site using an oppressor for 6 hours, with regular decompression every 2 hours. The patient was instructed to remain in a comfortable position, restrict wrist movement for 6 to 8 hours, and avoid weight-bearing on the puncture side. The patient was allowed to get out of bed 1 hour post-surgery. During recovery, the patient was encouraged to eat normally and drink plenty of fluids to aid in the elimination of the contrast agent. Vital signs and puncture site conditions were closely monitored. Additionally, psychological support was provided before, during, and after the interventional procedure. Close observation of the patient's reactions was maintained, and any abnormalities were addressed promptly.

In the experimental group, UAE was performed through the dTRA. The patients were positioned supine, with the right hand thoroughly disinfected from the elbow to the hand. The right hand was instructed to rest, with slight wrist flexion (10°-15°) and a 10°-30° inclination toward the ulnar side. The metacarpal and interphalangeal joints were relaxed and semibent. If the left hand was punctured, it was disinfected and placed in a resting position in the right groin area. The surgeon stood at the right side of the patient's head for the procedure. The puncture point was selected between the extensor pollicis longus and extensor pollicis brevis tendons (referred to as the "snuffbox area"). Local anesthesia (1 mL of 1% lidocaine) was administered at the puncture site. Using a sheath needle, the radial artery sheath was punctured. After successful puncture, deep anesthesia was administered along the puncture path, with an additional 1 mL of lidocaine injected into the sheath of the 5F radial artery catheter. To prevent thrombosis and vasospasm, 2000-3000 U of heparin and 0.2 mg of nitroglycerin were injected through the sheath.

Data collection

Relevant patient data and indicators were obtained from the hospital's electronic medical records. The general data collected included age, body mass index (BMI), fibroid diameter, fertility history, comorbidities, history of TRA/dTRA puncture, and puncture artery diameter.

Before surgery, all patients underwent color Doppler ultrasound to assess the suitability of the puncture approach (e.g., presence of tortuosity in the radial artery) and to measure the internal diameter of the puncture artery. Patients were positioned supine with their arms naturally extended, and the internal diameters of both the right distal radial artery and the conventional radial artery were measured using color Doppler ultrasound. The internal diameter was defined as the distance from the intima of one vessel to the opposite vessel. The radial artery diameter was measured 2 cm from the center of the right radial head, while the distal radial artery diameter was measured at the level of the hand navicular bone in the "snuffbox" area of the right hand.

Ovarian function indicators were collected before and three months after surgery, including follicle-stimulating hormone (FSH), luteinizing hormone (LH), and estradiol (E2) levels.

Postoperative pain scores were assessed at 1, 12, and 24 hours after surgery using the visual analogue scale (VAS), with scores ranging from 0 to 10, where higher scores indicated more severe pain.

Perioperative indicators were also recorded, including puncture time, intraoperative puncture attempts, total surgical time, radiation dose, and puncture success rate. Puncture time was defined as the time from the start of anesthesia to the successful insertion of the sheath, while total surgical time was measured from the beginning of disinfection to the completion of dressing.

Postoperative complications, including nerve injury, puncture site bleeding, urinary retention, constipation, and others, were recorded in both groups at 7 days post-surgery.

Outcome measures

The primary outcomes include clinical efficacy, puncture success rate, and postoperative complication rate of UAE.

The secondary outcome was to identify the risk factors contributing to dTRA puncture failure, establish a risk prediction model, and perform validation evaluation. This was done to help improve the success rate of clinical dTRA puncture procedures.

The research process is illustrated in **Figure 1**.

Statistical methods

Data analysis was performed using SPSS 27.0 statistical software. Categorical data were expressed as frequencies and percentages, and comparisons between groups were conducted using the chi-square test. Measured-data were tested for normality using the Shapiro-Wilk (S-W) test. Normally distributed data were presented as means ± standard deviations ($\bar{x} \pm s$). Independent t-tests were used for comparisons between groups. For postoperative VAS scores, repeated measures analysis of variance (ANOVA) was performed, with time points (1 h, 12 h, and 24 h after sur-

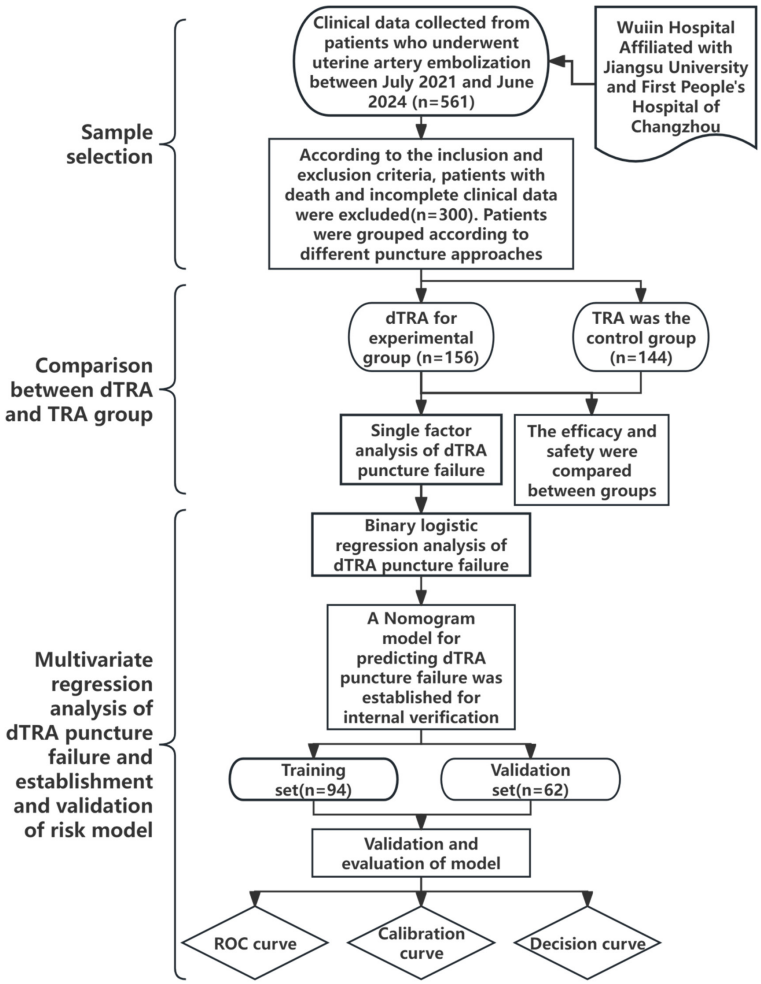

Figure 1. Research flow chart.

gery) as the within-subject factor. The sphericity assumption was tested using Mauchly's test. If sphericity was violated, degrees of freedom were adjusted using the Greenhouse-Geisser correction. The group factor (dTRA vs. TRA) was included as the between-subjects factor, along with covariates such as age and BMI. Interaction between the time factor and the group factor was explored to assess whether the change in pain scores over time differed between the two groups. The significance of main effects and interaction effects was evaluated using F-tests, with a significance level set at 0.05. Multivariate logistic regression was used to analyze the risk factors associated with dTRA puncture failure. A nomogram predictive model was developed using R4.2.1, with training and validation sets created by Bootstrap sampling (6:4 split). The model's performance was evaluated using the area under the receiver operating characteristic curve (AUC), calibration curve, and decision curve analysis. A *p*-value of < 0.05 was considered significant.

Results

General data comparison

No statistically significant differences were observed in the general data between the two groups (P > 0.05), indicating comparability. The details are presented in **Table 1**.

Comparison of ovarian function indexes

There were no significant differences in ovarian function indexes, including FSH, LH, and E2, between the two groups before and three months after surgery (P > 0.05). See **Figure 2**.

Comparison of perioperative indexes

No significant differences were found in the puncture vessel diameter between the two groups (P > 0.05). However, the puncture time and operation time in the control group were significantly shorter than those of the experimental group (P < 0.05). Additionally, the control group required fewer punctures compared to the experimental group (P < 0.05). The puncture success rate in the control group (94.44%) was significantly higher than that of the experimental group (82.69%) (P < 0.05), as shown in **Table 2**.

Comparison of postoperative pain

The VAS scores in both groups at 12 hours and 24 hours after surgery were significantly lower than those at 1 hour post-operation (P < 0.05). Significant differences in VAS scores between the two groups were observed, with the experimental group showing lower scores at 1 hour, 12 hours, and 24 hours post-surgery

Table 1. Comparison of general data between the two groups [$\bar{x}$±s, n (%)]

Index	Control group (n = 144)	Experimental group (n = 156)	t/χ^2	*P*
Age (years)	33.78±4.68	33.46±4.62	0.740	0.460
BMI (kg/m^2)	21.34±2.13	21.56±2.24	0.519	0.604
Smoking history	4 (2.78)	5 (3.21)	0.047	0.828
Childbearing history	78 (54.17)	84 (53.85)	0.003	0.956
Complication				
Hypertension	46 (31.94)	42 (26.92)	0.911	0.340
Diabetes	16 (11.11)	14 (8.97)	0.380	0.538
Myoma diameter (cm)	7.13±0.70	7.24±0.62	1.524	0.129

Note: BMI: body mass index.

compared to the control group (P < 0.05). The significant main effect of time (F Time = 739.523, P < 0.001) indicated a substantial decrease in pain score over the 24-hour postoperative period, in line with the expected course of pain resolution following surgery. The significant interaction effect (F Interaction = 63.123, P < 0.001) suggested that the dTRA group experienced a different pain score reduction pattern compared to the TRA group, with the dTRA group showing a more rapid decrease in pain score. This have significant clinical implications for improving patient comfort and recovery. Furthermore, the significant inter-group effect (F Inter-group = 379.457, P < 0.001) revealed that the dTRA group consistently had lower pain scores at each time point. This suggests that the dTRA had an advantage in reducing postoperative pain, as shown in **Table 3**.

Comparison of postoperative complications

The incidence of postoperative complications was significantly higher in the control group (54.17%) compared to the experimental group (24.67%) (P < 0.05). Notably, the control group exhibited a significantly higher likelihood of experiencing right hand and forearm tension hematoma, radial artery spasm, and radial artery occlusion than the experimental group (P < 0.05), as shown in **Table 4**.

Univariate and multivariate analysis of dTRA puncture failure

Patients were classified into two groups based on the success or failure of the dTRA puncture: the failure group (n = 27) and the success group (n = 129). Univariate analysis revealed significant differences between the two groups in the internal diameter of the blood vessel, the tortuosity of the radial artery, and a history of dTRA (P < 0.05), as shown in **Table 5**.

A multivariate logistic regression analysis was conducted using the success or failure of dTRA puncture as the dependent variable (failure = 0, success = 1), with the internal diameter of the puncture vessel, radial artery tortuosity, and history of dTRA as independent variables. The results indicated that the diameter of the puncture vessel, the tortuosity of the radial artery, and the history of dTRA were significant risk factors for dTRA puncture failure in patients with uterine fibroids (P < 0.05), as shown in **Table 6**.

Risk prediction model of dTRA puncture failure

A nomogram model for predicting the risk of dTRA puncture failure was developed, based on factors identified in the multivariate logistic regression analysis. The model demonstrated reliability, with the internal diameter of the puncture vessel, radial artery tortuosity, and the history of dTRA serving as key predictors for puncture failure (all P < 0.05). Among these factors, the diameter of the puncture vessel was the most influential in predicting failure risk (P < 0.001). According to the model, if a patient does not have radial artery tortuosity, has a history of dTRA, and the internal diameter of the blood vessel is 1.9 mm, the risk score is 152 points, indicating a low risk of dTRA failure (risk of 0.036), as shown in **Figure 3**.

Model calibration and verification

The model's internal validation training set achieved an AUC of 0.892, while the AUC of the validation set was 0.747, demonstrating the model's high predictive performance, as shown in **Figure 4A** and **4B**. To verify the model's accuracy, calibration curves for both the training and validation sets were generated. These curves closely matched the ideal curve after 1000 repeated samplings to correct deviations. The mean and absolute errors for the training set were 0.02 and 0.048, respectively,

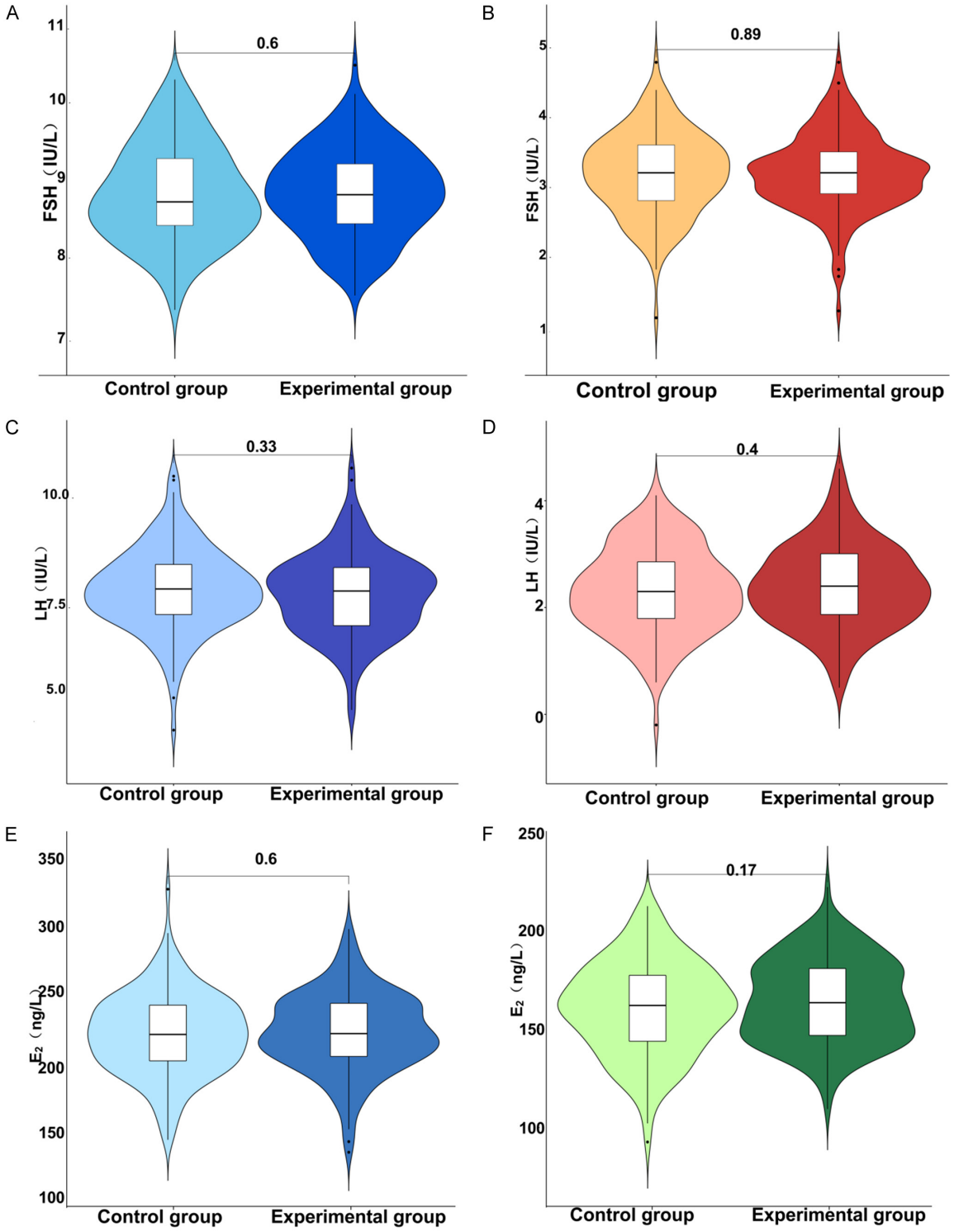

Figure 2. Comparison of ovarian function between patients before surgery and three months after surgery. A: Comparison of FSH levels before surgery between the two groups; B: Comparison of FSH levels three months after surgery between the two groups; C: Comparison of LH levels before surgery between the two groups; D: Comparison of LH levels three months after surgery between the two groups; E: Comparison of E_2 levels before surgery between the two groups; F: Comparison of E_2 levels three months after surgery between the two groups. FSH: Follicle-stimulating hormone; LH: luteinizing hormone; E_2: Estradiol.

Table 2. Comparison of perioperative indicators [$\bar{x}$±s, n (%)]

Index	Control group (n = 144)	Experimental group (n = 156)	t/χ^2	*P*
Puncture vessel diameter (mm)	2.01±0.43	2.05±0.40	0.033	0.973
Puncture time (s)	110.78±40.63	145.59±50.31	6.397	< 0.001
Intraoperative puncture times (times)	1.2±0.5	1.6±0.8	5.066	< 0.001
Total operation time (min)	34.64±5.63	43.21±7.12	11.692	< 0.001
Radiation dose (mGy)	864.31±263.13	890.37±290.42	0.529	0.597
Puncture success rate	136 (94.44)	129 (82.69)	10.035	0.002

Table 3. Comparison of postoperative VAS scores ($\bar{x}$±s, points)

Index	VAS				
	1 h after surgery	12 h after surgery	24 h after surgery	$F_{Time}/F_{Interaction}/F_{Inter\text{-}group}$	$P_{Time}/P_{Interaction}/P_{Inter\text{-}group}$
Control group (n = 144)	5.56±1.67	3.77±1.55[a]	1.54±0.67[a,b]	739.523/63.123/379.457	< 0.001/< 0.001/< 0.001
Experimental group (n = 156)	4.03±1.34	1.23±0.62[a]	1.07±0.40[a,b]		
t	8.779	19.017	7.366		
P	< 0.001	< 0.001	< 0.001		

Note: Compared to 1 h after operation, [a]P < 0.05; [b]P was < 0.05 at 12 h after operation. Time: reflect the changes in pain degree over time. Interaction: To observe whether there were differences in the patterns of pain scores over time among different groups of patients. Inter-group: To determine whether there was a significant difference in pain between the two groups. VAS: visual analogue scale.

Table 4. Comparison of postoperative complications in patients [n (%)]

Index	Puncture bleeding	Tension hematoma of right hand and forearm	Urinary retention	Radial spasm	Radial artery occlusion	Radial nerve injury	Total incidence
Control group (n = 144)	8 (5.56)	47 (32.64)	4 (2.78)	12 (8.33)	16 (11.11)	9 (6.25)	78 (54.17)
Experimental group (n = 156)	7 (4.49)	17 (10.90)	6 (3.85)	4 (2.56)	1 (0.64)	3 (1.92)	37 (24.67)
X^2	1.745	60.375	0.265	4.936	15.366	3.651	29.368
P	0.187	< 0.001	0.607	0.026	< 0.001	0.056	< 0.001

Table 5. Univariate analysis of dTRA puncture failure [$\bar{X}$±s, n (%)]

Index	Failed group (n = 27)	Successful group (n = 129)	t/χ^2	*P*
Age (years)	31.85±4.94	33.40±4.57	0.740	0.116
BMI	21.79±1.92	21.45±2.29	0.519	0.480
Blood vessel diameter (mm)	1.82±0.38	2.07±0.39	0.047	0.003
Radial artery is tortuous	15 (55.56)	31 (24.03)	10.671	0.001
dTRA penetration history	19 (70.37)	35 (27.13)	18.443	< 0.001
Combined hypertension	5 (18.52)	37 (28.68)	1.172	0.279
Combined diabetes	3 (11.11)	11 (8.53)	0.182	0.669
Smoking history	3 (11.11)	2 (1.55)	6.578	0.037

Note: dTRA: distal transradial artery approach.

while for the validation set, they were 0.034 and 0.028. These low errors suggest a high accuracy of the model, as shown in **Figure 4C** and **4D**. Furthermore, the threshold probability for the training set ranged from 0 to 0.78, and for the validation set, it ranged from 0.10 to 0.72, indicating that the model yields a high return rate within these thresholds, as shown in **Figure 4E** and **4F**. These results indicate that the nomogram model developed in this study for predicting dTRA puncture failure had significant clinical utility.

Table 6. Logistic regression analysis of puncture failure

Factor	β	*S.E.*	*Wald* χ^2	*P*	*OR (95% CI)*
Blood vessel diameter	2.163	0.744	8.454	0.004	8.700 (2.024-37.394)
Radial artery is tortuous	1.462	0.507	8.335	0.004	4.316 (1.599-11.647)
dTRA penetration history	2.195	0.539	16.612	< 0.001	8.890 (3.125-25.803)

Note: dTRA: distal transradial artery approach.

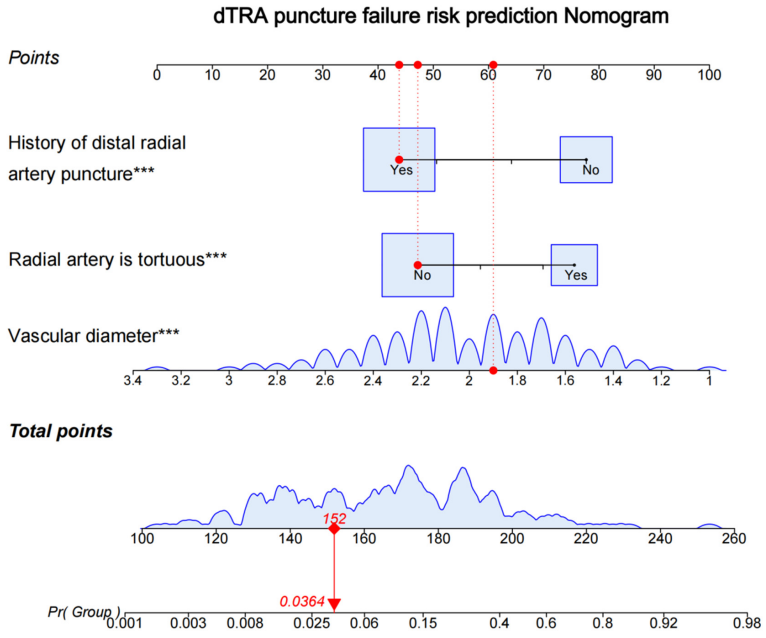

Figure 3. Nomogram model for risk prediction of dTRA puncture failure.

Discussion

In a previous retrospective cohort study by Wang et al. [16], patients with uterine fibroids who underwent UAE through dTRA demonstrated a high puncture success rate, with an average puncture time of 21±8.54 minutes, and no serious complications during a three-day follow-up, highlighting the safety and feasibility of this approach. In our study, we retrospectively compared the clinical outcomes of dTRA and TRA for UAE in the treatment of uterine fibroids. Additionally, we identified factors influencing dTRA puncture failure and developed a risk prediction model for clinical use.

The results of our study indicated no significant differences in ovarian function between the two groups following treatment. Both puncture approaches had a similar effect on uterine blood supply, and dTRA did not cause additional damage to the ovaries. This can be explained by the shared blood supply between the uterus and ovaries, where the ovaries receive a more substantial blood flow from the ovarian artery, in addition to the uterine artery branches [17]. As a result, whether through TRA or dTRA, UAE has minimal direct effect on the ovarian blood supply.

According to a study by Achim et al. [18], the incidence of radial artery occlusion following dTRA was significantly lower compared to TRA, which aligns with the findings of our current study. Compared to TRA, dTRA offers several advantages, including improved patient comfort, reduced postoperative compression, and a decrease in puncture-related complications. In our study, patients who underwent dTRA experienced significantly less pain than those who underwent TRA, and the rates of postoperative complications such as right hand and forearm tension hematoma, radial artery spasm, and radial artery occlusion were lower. Among these, radial artery occlusion, which is a relatively common complication in TRA, is primarily influenced by factors such as patient characteristics, vascular intima injury, the sheath's material and design, puncture technique, and the anticoagulation and hemostasis protocols [19]. Preventive compression of the ulnar artery can help promote preferential blood flow through the radial artery, thus reducing the risk of early radial artery occlusion.

The dTRA puncture point is located on the proximal branch of the superficial palmar arch, at the bony prominence where the first and second metacarpals meet. This location is advantageous as it lacks surrounding nerves, which facilitates accurate puncture point positioning

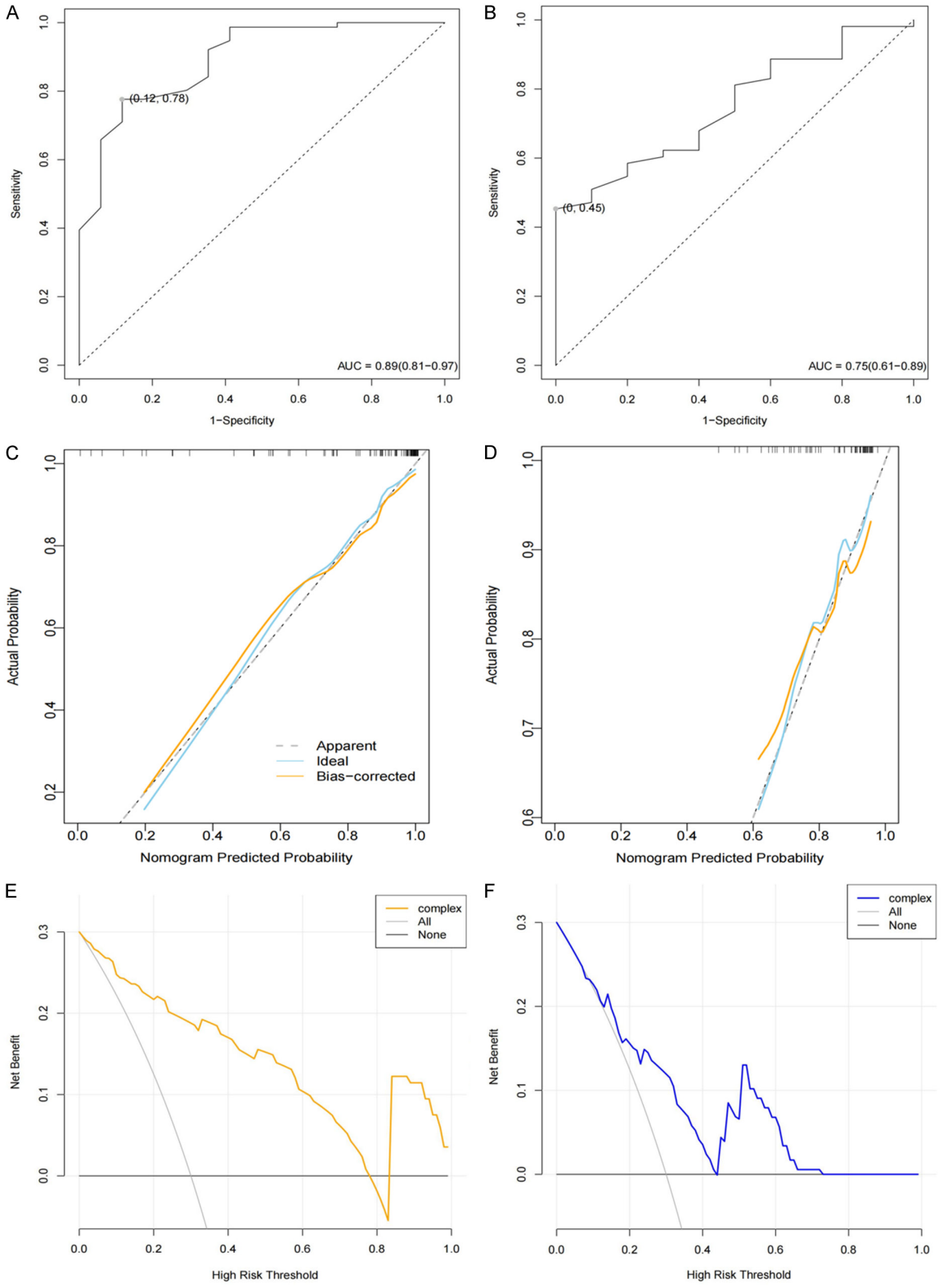

Figure 4. Evaluation and verification of the model. A: ROC curve of the training set; B: ROC curve of the verification set; C: Calibration curve of the training set; D: Calibration curve of the verification set; E: Decision curve of the training set; F: Decision curve of the verification set.

and effective hemostasis. Additionally, the presence of both the superficial and deep palmar arches, formed by the radial and ulnar arteries, helps maintain forward blood flow in the radial artery during compression hemostasis or occlusion, thereby further reducing the risk of radial artery occlusion [20].

In this study, the puncture and operation times for TRA were significantly shorter, and the number of punctures required was lower compared to dTRA. This is primarily due to the smaller inner diameter of the distal radial artery, its more curved anatomical structure, and the fixed, easily accessible nature of the TRA puncture site. The TRA site is also characterized by stronger and more prominent pulsations, which makes it easier to identify and puncture [21]. As a result, dTRA is technically more challenging, but its procedure can still be performed with a certain predictable time duration.

The logistic regression analysis in this study identified severe arterial dilation and a small puncture vessel diameter as significant factors contributing to dTRA puncture failure. Previous studies [22, 23] have indicated that for patients with tortuous blood vessels in the forearm and upper arm, a guide wire can be used to straighten the posteriorly tortuous vessels. However, the situation with the upper limb arteries differs from the subclavian artery, which has relatively less surrounding tissue and no muscle tissue fixation. Even if a guide wire is bent, it can be difficult to straighten, complicating the procedure and leading to a higher risk of puncture failure. Furthermore, standard puncture kits are typically equipped with a straight and relatively thick guide wire, which has limited ability to navigate through tortuous radial arteries. Excessive force during manipulation can easily result in radial artery perforation or dissection, often forcing the surgeon to abandon the dTRA approach [24, 25].

Additionally, our study found that a previous history of dTRA puncture was an important factor influencing puncture failure. This is likely due to tissue adhesion at the puncture site following a prior procedure. During the healing process, scar tissue forms, which lacks the elasticity and flexibility of normal tissue. As a result, the surrounding anatomic structures become distorted, making it difficult for the puncture needle to follow the normal anatomical path. This significantly increases the difficulty of the procedure and raises the risk of puncture failure [26].

Based on these findings, we propose several countermeasures to mitigate the risk of dTRA puncture failure. In clinical practice, for patients undergoing dTRA puncture, particularly those with tortuous vessels in the forearm or upper arm or suspected subclavian artery tortuosity, a more detailed angiographic evaluation should be performed before surgery. Special attention should be given to the shape, curvature, and direction of the subclavian artery in addition to conventional upper extremity angiography. Furthermore, a thorough inquiry into the patient's prior puncture history and any complications related to previous punctures should be made before proceeding with the procedure.

This study has several limitations. While dTRA offers many advantages in terms of safety and patient comfort, there is currently a lack of peripheral interventional equipment tailored for this approach. For instance, most catheters are either too short, have a rigid tip material, or feature a small angle, resulting in poor vessel wall adherence or difficulty in reaching the distal end of the vessel. This contributes to a relatively higher failure rate of puncture. Additionally, the radial artery's slender structure limits the ability to use catheter sheaths larger than 7Fr, and anatomic variations are more frequent than with the femoral artery. Furthermore, this study did not explore the long-term effects of dTRA and TRA treatment, such as effects on fertility, recurrence of fibroids, or changes in quality of life. Further research is needed to investigate these factors.

Conclusion

This study used a retrospective dual-center analysis to compare the clinical outcomes of dTRA and TRA for UAE in the treatment of uterine fibroids. The results highlight that while dTRA provides significant advantages in reducing postoperative complications and pain, it is associated with a lower puncture success rate, particularly in patients with arterial tortuosity and a previous history of puncture. Moving forward, optimizing procedural techniques, selecting appropriate puncture tools, and

enhancing preoperative evaluations and postoperative care are essential steps to improve the puncture success rate and increase the clinical value of dTRA. These measures will contribute to better treatment options for patients with uterine fibroids.

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Disclosure of conflict of interest

None.

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