Original Article

The Below-the-Knee Approach to Percutaneous Mechanical Thrombectomy for Lower Extremity Deep Venous Thrombosis: A Retrospective Single-Centre, Single-Arm Study

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Purpose: The objective of this study was to evaluate the safety, efficacy, and feasibility of percutaneous mechanical thrombectomy (PMT) through a below-the-knee (BTK) approach for acute lower extremity deep venous thrombosis (DVT).
Methods: A retrospective review of DVT patients treated with PMT by the BTK approach at our center from April 2022 to August 2023 was performed. Their preoperative demographics, intraoperative data, and postoperative outpatient outcomes were analyzed.
Results: A total of 12 patients (67% men; mean age, 63 years) met the inclusion criteria. The BTK approach was successfully achieved in all patients through the posterior tibial vein (n = 1), anterior tibial vein (n = 2), and peroneal vein (n = 9). PMTs were achieved in 11 (92%) patients. Successful lysis (grade II and grade III lysis) was achieved in all patients with PMT. Four (33%) patients had residual venous occlusion over the popliteal vein. No intraoperative complications or bleeding events occurred in any of the patients.
Conclusion: PMT via BTK puncture seems to be a safe and effective approach for treating lower extremity DVT. It is reserved for highly select patients with a low risk of bleeding and is performed at centers that have experience with this procedure.

Keywords: deep venous thrombosis, percutaneous mechanical thrombectomy, peroneal vein, peripheral intervention, catheter-directed thrombolysis

Introduction

Deep venous thrombosis (DVT) is associated with significant morbidity as a common peripheral vascular disorder. The estimated incidence rate for DVT is approximately 1 in 1000, and it mostly happened in older patients.[1,2] In the acute phase, the most serious complication of DVT is pulmonary embolism (PE). However, patients begin to suffer from postthrombotic syndrome (PTS) after thrombus organization or recanalization due to venous obstruction and valve insufficiency.[3,4]

In the management of DVT, the prevention of PTS is important and could be achieved by restoring venous patency in the acute phase.[5] In the treatment of DVT, catheter-directed thrombolysis (CDT) and percutaneous mechanical thrombectomy (PMT) are methods for restoring luminal patency and venous segment valves.[6] In general, the contralateral femoral vein, jugular vein, and ipsilateral popliteal vein are alternative approaches for CDT and PMT, in which popliteal vein access is most widely used.[3] Unfortunately, the inferior popliteal thrombus cannot be fixed through this access and

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requires knee immobilization during thrombolysis. To solve this shortage, the below-the-knee (BTK) approach has been attempted in the past few years, including small saphenous veins, posterior tibial vein (PTV), anterior tibial vein (ATV), and peroneal vein (PeV).[3,5,7–9] A variety of BTK approaches were used for CDT in early clinical experience and exhibited moderate efficacy and safety. However, there are still some deficiencies, such as the potential risk of hemorrhage and relatively longer treatment time.[10] In contrast, the dosage of thrombolytics was reduced, and the thrombus was resolved more completely in PMT.[6] However, no study has specifically evaluated PMT for the treatment of DVT through BTK access. We believe that the BTK approach to PMT is both safe and effective for the treatment of DVT and hope to verify this finding in this study.

Materials and Methods

This was a retrospective study of DVT patients treated with PMT by the BTK approach at our center from April 2022 to August 2023. The study protocol was approved by the Ethics Committee of the Beijing Friendship Hospital in accordance with the Declaration of Helsinki, and written informed consent was obtained from all study participants. The inclusion criteria were patients with swelling symptoms no longer than 14 days and extensive lower extremity DVT (thrombus involvement from calf vein to popliteal vein and above). This study involved 12 consecutive patients who met the inclusion criteria, and no patients were excluded. Afterward, their medical records were reviewed, and duplex ultrasound or venography was performed to confirm the diagnosis of DVT and identify the occluded venous segments.

Therapeutic method

A dosage of 100 IU/kg body weight of low molecular weight heparin (nadroparin calcium or enoxaparin sodium) was given twice daily to all patients. A retrievable IVC filter (Denali IVC filter; Bard Peripheral Vascular, Tempe, AZ, USA), OptEase (Cordis, Miami Lakes, FL, USA), or Option (Argon Medical, Frisco, TX, USA) was usually implanted through the contralateral femur before PMT.

The patients were placed in the supine position with an occluding cuff above the ankle. The projection angle and the affected limb were adjusted simultaneously to separate the tibia and the fibula maximally. The contrast medium was slowly injected after the tibia, and the fibula was adjusted to separate maximally. A dorsal indwelling needle was used to inject, and then the target vessel showed clearly. The PeV, PTV, and ATV were all considered, and the access sites varied among the patients depending on anatomical factors and displayed venography. The location for puncture was usually in the lower 1/3 of the calf. A 30- to 45-degree angle was held between the microneedle (Cook, Bloomington, IN, USA) and the skin surface; it was also kept perpendicular to the projection table in the meantime. The Seldinger technique was adopted to puncture the target vessel. Under local anesthesia, a 4-F introducer sheath was implanted after the guidewire was advanced to the popliteal vein through the needle. The time from the beginning of the operation to the implantation of the sheath was recorded as the access site establishment time. PMT was performed with a 6-French or 8-French AngioJet thrombectomy catheter (Boston Scientific, Natick, MA, USA). The device was placed into the thrombus along a stiff guidewire. Using the spray function of the AngioJet thrombectomy catheter, the thrombus in the affected vessel, including the popliteal vein, femoral vein, and iliac vein, was pretreated with 250000 IU of urokinase diluted in saline. Power-pulse spray thrombectomy was performed after 20 minutes of dwell time, allowing the initial thrombus to dissolve. The thrombus aspiration time was limited to 240 seconds. After PMT, venoplasty using a 10- to 12-mm balloon catheter (Admiral Xtreme; Invatec, Italy) and 8- to 10-mm balloon catheter (Admiral Xtreme; Invatec, Italy) balloon catheter was performed in the iliac vein and the proximal femoral vein, respectively. After further phlebography, CDT was considered in patients with relatively obvious residual thrombus. During CDT, urokinase was continuously infused into the thrombosed vein using a multi-hole infusion catheter (Multi-Sideport; Cook). A diluted solution of urokinase was infused at approximately 50000 IU/hour. Phlebography was performed by an introducer sheath to determine thrombolysis effects and stop thrombolysis 2 to 3 days after the initial procedure (**Fig. 1**).

Patients received anticoagulant therapy by Xa inhibitors (rivaroxaban and edoxaban) following initial treatment with low molecular weight heparin after discharge, the anticoagulant time and dose were consistent with published guidelines. Patients with Villalta scores >4 were recommended to use compression stockings and less chance of walking.

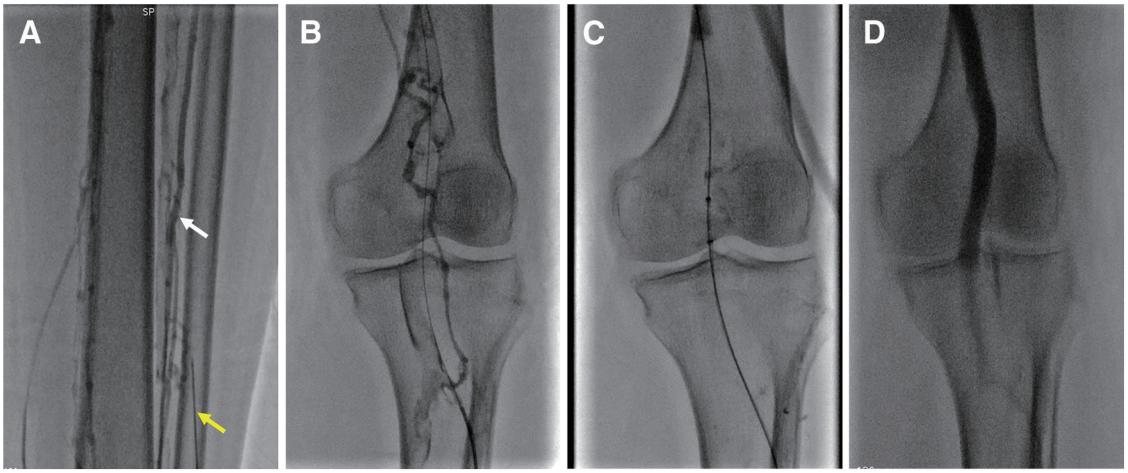

Fig. 1 (**A**) The puncture of the peroneal vein, the white arrow points to the peroneal vein displayed by contrast medium, the yellow arrow points to the puncture needle. (**B**) Contrast outlines thrombus within the popliteal vein. (**C**) PMT was performed with a 6-French AngioJet thrombectomy catheter. (**D**) Venogram after PMT showing patent popliteal veins with a competent valve below a column of contrast. PMT: percutaneous mechanical thrombectomy

Evaluation

The thrombolysis grade was used to assess treatment efficacy at the end of treatment. The phlebography was reviewed carefully and scored and graded according to a modified standard proposed by previous studies.[11] Color duplex sonography and compression ultrasonography were performed 3 months after the surgery and at the end of the follow-up. The definition of venous recanalization is the same as in previous studies.[12] All analyses were performed using SPSS 24.0 software (SPSS Inc., Chicago, IL, USA). Data were expressed as proportions for dichotomous variables and as the mean ± standard deviation or median and interquartile range (IQR) (25th–75th percentiles) for continuous variables.

Results

We identified 12 patients who underwent PMT procedures by the BTK approach with a median follow-up of 7 months (IQR, 5–10 months). The study population, anatomic segments treated, and outcomes are presented in **Table 1**. In **Table 1**, patients are arranged according to the order of treatment. The mean age was 62.7 ± 13.1 years. Most patients were male (67%), and 8 (67%) had unilateral left lower extremity DVT. Three patients were secondary to predisposing factors, including trauma, recent surgery, and complications with cancer. In general, 8 (67%) patients had iliac veins involved and 3 (25%) patients had femoral veins involved, one patient had the popliteal vein involved only.

Nine patients were treated through the peroneal vein; one each underwent PMT via PTV and two via ATV, and the average access site establishment time was 32 ± 16 min. PMT was achieved in 11 (92%) patients. The reason for the failure was that the guide wire failed to pass through the thrombus, probably because the patient had recurrent DVT and had symptoms for 10 days. As a 6F thrombectomy catheter, an AngioJet Solent catheter was used in most patients (81.8%), and only two relatively young patients with extensive thrombi received an AngioJet ZelanteDVT catheter (8F). In the meantime, this patient was the only patient who had concurrent percutaneous transluminal angioplasty (PTA) because the effect of thrombus removal was very satisfactory. Similarly, one patient did not use CDT after PMT because she was over 80 years old. Successful lysis (grade II and grade III lysis) was achieved in all patients who had PMT.

No intraoperative complications occurred in any of the patients, including extravasations, accidental artery injury, accidental nerve injury, and symptomatic PE. Postoperative complications occurred in one patient (8%), and this elderly patient suffered delirium after surgery and resolved with conservative treatment. No bleeding events occurred during thrombolysis.

At the end of the follow-up, eight (67%) patients had residual venous occlusion (RVO). No patients had a recurrence of DVT. Four (33.3%) patients had RVO over the popliteal vein, and they were all treated 10 days after the onset of symptoms.

Table 1 Study population, anatomic segments treated, and outcomes

Patient number	Sex/age	Affected limbs	Symptom duration (days)	Predisposing factors	Thrombosis involvement	Access site establish time (minutes), mean	Access site	6F/8F device used	Concurrent treatment	Lysis grade	Complications (treatment)	Follow-up (months)	Extent of RVO
(1)	M/43	Left	1	None	PV–FV	70	PTV	6F	PTA + CDT	2	None	19	Calf vein
(2)	F/67	Left	7	Recent trauma	PV–IV	50	ATV	6F	PTA + CDT	3	None	17	Calf vein
(3)	F/62	Left	1	None	PV–IV	35	PeV	6F	PTA + CDT	3	None	13	None
(4)	M/72	Right	4	None	PV–IV	40	PeV	6F	PTA + CDT	2	None	9	None
(5)	F/83	Left	2	None	PV–IVC	20	PeV	6F	PTA	2	Delirium	8	Calf vein
(6)	M/52	Left	7	None	PV	45	PeV	6F	PTA + CDT	2	None	8	None
(7)	M/70	Left	12	Cancer	PV–IV	20	PeV	6F	PTA + CDT	2	None	7	Superficial femoral vein
(8)	M/63	Left	3	None	PV–IV	30	PeV	8F	CDT	3	None	7	Calf vein
(9)	M/61	Left	10	None	PV–IV	25	PeV	–	NA	1	None	5	Common femoral vein
(10)	M/76	Right	14	None	PV–IV	25	PeV	6F	PTA + CDT	2	None	4	Superficial femoral vein
(11)	F/38	Right	10	Recent surgery	PV–IV	15	PeV	8F	PTA + CDT	2	None	3	Superficial femoral vein
(12)	M/66	Right	2	None	PV–FV	15	ATV	6F	PTA + CDT	3	None	3	None

M: male; F: female; IV: iliac vein; FV: femoral vein; PV: popliteal vein; PTV: posterior tibial vein; ATV: anterior tibial vein; PeV: peroneal vein; PTA: percutaneous transluminal angioplasty; CDT: catheter-directed thrombolysis; RVO: residual venous occlusion

Discussion

Although the clinical manifestations of the postthrombotic syndrome can vary substantially between individual patients, it can result in edema, ulceration, and dermatosclerosis as the long-term sequelae of DVT and cause serious health risks with significant loss of function and productivity.[5,13] PTS can result from the lack of recanalization or the destruction of the valves of the affected veins. To reduce the severity and prevalence of PTS, early recanalization procedures were attempted, including CDT and PMT.[14] Previous studies have shown that in DVT patients with popliteal involvement, the postthrombotic popliteal vein reflux is more frequent.[15] However, the thrombus in the popliteal vein cannot be removed directly by popliteal vein access, which is currently the most widely used approach.[3] Since 1997, the BTK approach has been used in DVT treatment for over 20 years.[8] As an antegrade venous approach, the BTK access has the advantages of less valvular damage and sufficient thrombus clearing.[16] The safety of the BTK puncture technique has been demonstrated in previous studies; similarly, the safety of CDT through the BTK approach for acute extensive DVT was also preliminarily confirmed.[3,5,7] In this study, we successfully performed PMT in nine patients using the BTK approach. No intraoperative complications occurred in any patient, and no bleeding events occurred during thrombolysis. Current studies have found that PMT devices such as AngioJet have sufficient safety in the treatment of DVT and can effectively remove thrombosis and reduce the operation time and complications.[6,17] We believe that the main factor affecting the safety of this treatment is the diameter of the target vessel, as the mean diameter of the ATV, PTV, and PeV are all over 3 mm, which meets the illustration for use (IFU) of the AngioJet Solent catheter.[18] The IFU of the AngioJet ZelanteDVT catheter was lower extremity veins over 6 mm in diameter, and we used it in one patient to remove the thrombus from the popliteal vein to the iliac vein, which also met this requirement. Therefore, selecting an appropriate catheter according to the diameter of the target vessel can ensure the safety of PMT treatment through the BTK approach.

PMT is the delivery of a fibrinolytic drug into the thrombus with concomitant thrombus aspiration or maceration.[19] Although PMT can diminish the thrombus burden by means of low-dose fibrinolysis and mechanical therapy, the efficacy of reducing the risk of postthrombotic syndrome while minimizing the risk of bleeding is still controversial. The ATTRACT trial showed that PMT did not reduce PTS as assessed by the Villalta score in 692 DVT patients randomly assigned to receive either anticoagulation alone or anticoagulation plus PMT.[20] In contrast, a meta-analysis of clinical trials showed that PMT results in a low severity of PTS compared to CDT therapy and a shorter duration of treatment.[6] In this retrospective, single-arm study, we evaluated the treatment effect through lysis grade and RVO because of the relatively short follow-up time. The results are consistent with other investigations using CDT therapy CDT through BTK access, and most patients had significant remission of thrombi.[3,5] Apparently, the efficacy depends on the time of onset, and all patients treated 10 days after the onset of symptoms had RVO over the popliteal vein and ultrasound helps to differentiate fresh and soft thrombus by thrombus echogenicity.[21] It seems that PMT through BTK access for acute lower extremity DVT is reserved for highly select patients with a relatively short onset time.

A variety of venous access approaches have been described for CDT or PMT in the management of lower extremity DVT. Retrograde venous approaches, such as the contralateral femoral vein, have disadvantages of valvular injury due to the access direction being against the direction of blood flow and insufficient removal of the thrombus.[5]

Antegrade venous approaches are generally used and can reduce resistance due to valves and reduce the risk of mechanical damage to valve leaflets.[22] A previous study compared approaches from the small saphenous vein, great saphenous vein, and ipsilateral popliteal vein. Although the safety and effectiveness of these approaches have been preliminarily demonstrated, they were not conducive to lysis of the inferior popliteal vein and calf vein thrombosis.[23] However, the BTK approaches of PTV, ATV and PeV provide a more distal point to the thrombus of the target vein in patients with more distal infrapopliteal disease. Another advantage of these accesses was that the patient was placed in the supine position during introducer sheath implantation, so they do not need to change position after the procedure. Since there is no convincing clinical trial study, it is still controversial which access has the most advantage at present. Bendix et al.[5] and Liu et al.[7] studied different approaches to CDT for DVT. They compared PTV, popliteal vein, and femoral vein. Their studies both showed that the PTV approach is safe and sensible for the treatment of lower extremity DVT. Wang et al.[3]

studied 125 DVT patients who were treated with CDT through an ATV approach with an incidence of bleeding of approximately 10%, which showed that it is an alternative to the traditional approach. However, relatively few studies have applied PeV access, and Teng et al.[9] performed central venous catheter thrombolysis through PeV in 23 patients with a low rate of complications. However, a previous anatomical study suggested that the PeV was not recommended as a BTK access since it was relatively small in all deep calf veins.[18] In this study, the PeV approach was commonly applied to most of the patients for several reasons. First, the PeVs were not involved in thrombus burden in most patients, a prerequisite for successful puncture. Second, the puncture of the PeV under angiography or ultrasound guidance is relatively simple as it ascends close to the peroneal artery, which is the most commonly used retrograde approach for infrainguinal arterial chronic total occlusions in our center.[24] Third, the PeV approach had less requirement for the patient's position compared with the ATV or PTV approach, as they require a small amount of internal rotation and external rotation, respectively. We believe that all of these BTK approaches are feasible and need to be selected according to the clinician's experience and thrombus involvement. There are some disadvantages too. First, BTK approaches may lead to longer procedural time due to small diameters and variations; second, the risk of artery or nerve injury should be considered as well. It has a steep initial learning curve and can be time-consuming in several cases, mainly due to difficulties in percutaneous puncture of distal veins, even under ultrasound or fluoroscopic guidance. In this study, the access site establishment time is gradually shortened with the accumulation of experience; the combination of venography and ultrasound may be helpful.

Limitations

There are several notable limitations. First, this study is inherently subject to selection bias, and a relatively small number of patients were enrolled at a single institution. Second, although all patients received clinical follow-up, the duration of follow-up varied widely, and the lack of long-term follow-up also limited the potential identification of patients who developed venous incompetency, PTS, and recurrence. However, this study was designed to evaluate the safety of the BTK approach for DVT treatment by PMT, not necessarily to prevent future long-term events.

Conclusion

PMT via BTK puncture is a feasible and safe procedure and may be used as an alternative approach in the treatment of lower extremity DVT. It is reserved for highly select patients with a low risk of bleeding and is performed at centers that have experience with this procedure.

Declarations

Ethical approval

The studies involving human participants were reviewed and approved by the Institutional Ethical Review Board of Beijing Friendship Hospital. The patients/participants provided their written informed consent to participate in this study.

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Availability of data and materials

The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

Authors' contributions

WL was involved in protocol/project development, data collection and management, data analysis, and manuscript writing. LJ and HF were involved in project development and data analysis. XC was involved in manuscript review and editing. ZZ was involved in project development, manuscript review, and editing. All authors have read and approved the manuscript.

Disclosure statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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