Clinical and economic evaluation of the trellis thrombectomy device for arterial occlusions: Preliminary analysis

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Objectives: This preliminary study examined the technical efficacy, safety, and cost of treating arterial occlusions with a single device that combines pharmacologic and mechanical thrombolysis.

Methods: The technical success, bleeding complications, and costs for the first 26 consecutive patients in whom lower extremity ischemia was treated with the Trellis infusion catheter (TIC) were analyzed. Procedure time, thrombolytic infusion time, technical success, bleeding complications (major and intracranial hemorrhage), interventional suite time, and 30-day amputation-free survival were evaluated.

Results: 15 of 26 patients (58%) who received treatment with the TIC had acute arterial occlusions, and 11 of 26 patients (42%) had nonacute arterial occlusions. Nineteen of 26 patients (73.1%) received treatment of an infrainguinal occlusion, and 7 of 26 patients (26.9%) received treatment of a supraininguinal occlusion. Lower extremity native arteries were treated in 18 of 26 patients (69%), and lower extremity bypass grafts in 8 of 26 patients (31%). The technical success rate with TIC treatment was 92%, and the 30-day amputation-free survival rate was 96%. There was no difference in technical success or amputation-free survival rate between acute versus nonacute arterial occlusions, native artery versus bypass grafts, and suprainguinal versus infrainguinal arterial occlusions. Procedure time was 2.1 ± 0.9 hours, and infusion time was 0.3 ± 0.2 hours. There were no bleeding complications; however, 3 of 26 patients (11.5%) required further intervention to treat distal embolization. The overall mean cost for patients with TIC treatment was $3216 ± $1740.

Conclusions: Early results of TIC treatment in patients with arterial occlusions suggest that it is as effective as traditional catheter-directed thrombolysis. Furthermore, there were no bleeding complications, likely the result of TIC requiring shorter procedure and infusion times. (J Vasc Surg 2004;39:556-9.)

Three randomized prospective trials have demonstrated the benefits of catheter-directed thrombolysis (CDT) to treat acute arterial occlusions.1-3 Despite the success of this minimally invasive therapy, CDT does have potential pitfalls, such as risk for intracranial hemorrhage or major bleeding, distal embolization, recurrent thrombosis, prolonged infusion time,4 inferior results in chronically occluded vessels,5 and increased cost.5 In an effort to improve on these deficiencies, several mechanical or rheolytic thrombectomy devices have been developed.

Although a number of mechanical thrombectomy devices can eliminate some of the deleterious effects of CDT, such as bleeding complications and prolonged infusion time, these devices are also plagued by recurrent thrombosis, distal embolization, and high amputation rates.6,7 The Trellis infusion catheter (TIC) was designed to improve on the limitations of both CDT and mechanical thrombectomy devices (Fig 1). The TIC is a hybrid device in that it combines mechanical and pharmacologic thrombolysis by isolating the thrombolytic agent between a proximal and distal occlusion balloon in the thrombosed blood vessel. In theory, this reduces systemic dispersion of the thrombolytic agent, therefore limiting exposure and decreasing bleeding complications by localizing the thrombolytic agent. In addition, aspiration of the lysed clot at completion potentially removes residual active drug. The occluding balloon also has the potential advantage of reducing distal embolization. A battery-powered compliant sinusoidal wire produces oscillations in the catheter, mechanically mixing the clot with the lytic agent, as in a blender. This enhances rapid dissolution of the thrombus by increasing the surface area of clot exposed to the lytic agent. The dissolved clot is then aspirated before balloon deflation.

We examined the technical safety, efficacy, and costs of treating arterial occlusions with the TIC.

METHODS

Between May 2002 and September 2002 data for the first 26 patients in whom the TIC was used to treat arterial occlusions of class IIA or IIB limb ischemia...
were analyzed, and serve as the basis of this report. The TIC is a 510(k) Food and Drug Administration–approved device. All patients gave informed consent for the TIC procedure and data collection. The study was approved by the institutional review board at The Cleveland Clinic Foundation and at Stanford University. Clinical case data from 12 institutions (Appendix, online only) were recorded at the time of the procedure by a manufacturer’s representative, and entered in a manufacturer-sponsored registry. Results are reported in accordance with published guidelines from the Society for Vascular Surgery and the Society for Interventional Radiology. The data collected for analysis included procedure time (time in the interventional suite), infusion time, and 30-day amputation-free survival. Follow-up phone query of each interventionalist was recorded to document 30-day limb salvage and patency data for all patients. In addition, we documented whether the treated vessel had an acute (<14 days) or chronic, nonacute arterial occlusion, whether the vessel treated was a native artery or bypass graft, and whether the treated vessel was suprarenal or infrainguinal. All infrainguinal vessels treated were femoropopliteal bypass grafts constructed with expanded polytetraethyl. Other procedure details recorded included the length of the lesion treated, the specific thrombolytic agent and dosage, and the need for adjunctive interventional or open surgical procedures. Finally, bleeding complications (major and intracranial hemorrhage) were documented. Technical success was determined at the time of the procedure by each interventionalist, who measured and recorded the percentage of thrombus cleared from the treated vessel. Clinical success was determined by 30-day amputation-free survival.

The average time in the intensive care unit (ICU) for patients who underwent a single angiography session was 12 ± 6 hours, compared with 24 ± 12 hours for patients who underwent multiple angiography sessions. These numbers were applied to TIC treatment for the cost analysis. All TIC-treated patients had one angiography suite visit.

Therapy specifics were derived from a composition of products and services. Wholesale acquisition cost for thrombolytic therapy was extracted from Price-Chek PT (version 2.16; St Louis, Mo). The cost of the TIC (provided by Bacchus Vascular, Santa Clara, Calif) was $1495, and the cost of bleeding was taken from Kalish et al, who reported the excess hospitalization costs of a bleeding event during systemic thrombolysis for acute myocardial infarction. The cost of angiography suite time and ICU time were based on hospital costs from Creighton University Medical Center adjusted by department-specific and year-specific ratios.

Statistical comparisons were conducted with the χ² test, Fisher exact test, or Mann-Whitney U test, where appropriate. All values represent mean ± SD.

RESULTS

Demographic data for patients treated with the TIC are listed in the Table. Specific thrombolytic agents used with the TIC included Reteplase (7 ± 1.2 units; n = 18; Centocor, Malvern, Pa), Alteplase (5.7 ± 2.6 mg; n = 7; Genentech, South San Francisco, Calif), and Tenecteplase (3 mg; n = 1; Genentech). The average length of occlusions in TIC-treated vessels was 21.5 ± 3.0 cm. The average TIC procedure time was 2.1 ± 0.9 hours, and the average TIC infusion time was 0.3 ± 0.2 hours. Fifty-four percent (14 of 26) of TIC-treated vessels required an adjunctive interventional procedure (angioplasty with or without stenting). Fifteen percent (4 of 26) of patients required an adjunctive open surgical procedure, all of which were done after thrombolysis with the TIC.

Clinical outcomes are shown in Fig 2 (online only). Overall technical success was 92%. There was no difference in technical success for TIC-treated vessels between acute and nonacute arterial occlusion (91.6% ± 1.4% vs 92.2% ±
1.9%; \( P = .92 \). Technical success was greater with native arteries (94.1% \pm 8.9%) than with bypass grafts (86.6% \pm 16.6%), but this did not reach statistical difference (\( P = .15 \)). The technical success rate for suprainguinal and infragenouln occlusions was similar (90.7% \pm 11.7% vs 92.2% \pm 12.4%; \( P = .78 \)). Thirty-day amputation-free survival rate was 96%. For patients with TIC-treated vessels there were no significant differences in 30-day amputation-free survival rates between native arteries and bypass grafts (94.4% vs 100%; \( P = .69 \)), and no differences between acute and nonacute arterial occlusion (93.3% vs 100%; \( P = .45 \)), and no difference between suprainguinal and infragenouln vessel occlusion (100% vs 94.1%; \( P = .33 \)). Finally, there were no episodes of major bleeding complications or intracranial hemorrhage reported with the TIC. Three of 26 patients (11.5%) with TIC-treated vessels had a distal embolic event that required further intervention.

The total cost of the TIC was $3216 \pm $1240. This included use of the ICU, $600; use of the angiography suite, $676 \pm $320; thrombolytic agent infused, $445 \pm $195; TIC, $1495; and bleeding complications, $0. In addition, cost for critical care stay was $600.

**DISCUSSION**

Introduction of new medical devices and technologic advancements mandate continued evaluation of each device for its safety, clinical benefit, and cost-benefit ratio.\(^\text{12}\) This study provides preliminary data in reference to the above for the TIC. We chose a cost-benefit analysis model to evaluate the data, because it enables evaluation of initial data.\(^\text{11}\) Although other models, such as Markov decision analysis, are useful in determining whether one therapy is better than another after longer follow-up, this initial analysis was done to ascertain specifically whether the early efficacy and costs of such a device warrant continued use and investigation from a clinical and economic standpoint.\(^\text{11}\) Future work with larger numbers of patients and possibly randomized trials will enable us to determine whether the long-term results warrant continued use of the TIC and whether it continues to be as effective as CDT and open surgical intervention.

One goal of this study was to evaluate the safety and technical efficacy of the TIC. The technical success rate (92%) and amputation-free survival rate (97%) indicate that the device was safe and effective for removing thrombus. Fig 2 (online only) is an example of the technical success that can be achieved with the TIC. The mechanical action of the TIC involves an oscillating catheter inside the blood vessel that mixes the lytic agent with the clot. With any intervention involving intraarterial manipulation there is concern about damaging the blood vessel. Although we did not evaluate the effects of the TIC on the intima, there was no reported arterial perforation or dissection secondary to the device. Significant hemorrhagic complications after use of other rheolytic thrombectomy devices have been reported, as high as 14%.\(^\text{13}\) In addition, infusion of a high dose of lytic agent over a short time may cause concern about large systemic dispersion of the drug. Though we did not measure fibrin breakdown products or lytic metabolites, there were no incidents of major or intracranial hemorrhage, attesting to the safety and success of isolating the lytic agent between two occluding balloons and aspirating the contents at completion. Finally, no patients died, and the 30-day amputation-free survival of 97% demonstrates the safety and clinical efficacy of the device. This is significantly better than other reports of other mechanical thrombectomy devices, in which both amputation and mortality rates range between 2% and 18%.\(^\text{6}\)

On the other hand, we did find an 11% incidence of distal embolization. This was higher than expected, and it is possible this resulted from a too short lytic time or inability of the catheter to aspirate large fragments of undissolved thrombus. Since this study was undertaken, the aspiration mechanism of the device has been changed to enable aspiration of larger clots and eliminate the need to advance a sheath over the device. Follow-up of these patients is warranted. Distal embolization is a well-known complication of both CDT and mechanical thrombectomy devices. The true incidence of peripheral embolization after CDT is poorly documented; few studies report the incidence and clinical sequelae. On the other hand, peripheral embolization from mechanical thrombectomy devices has been reported in 2% to 18% of cases.\(^\text{6,14}\) We specifically documented all embolic events, including embolization to small collateral vessels. While only two of five instances of embolization required further intervention, it is possible that the incidence of embolization will decrease with increased familiarity with the device, refinements in technique, and device design improvements.

Previous studies have documented the cost-effectiveness of rheolytic thrombectomy catheters in treatment of acute coronary syndromes,\(^\text{14}\) but none has been reported for the peripheral circulation. The cost analysis from this study demonstrates that the TIC appears to be more cost-effective than traditional CDT (unpublished data). Costs were, on average, $1320 (0.7 times) less with the TIC than with CDT, despite not taking into account overall hospital length of stay, open surgical procedures, adjuvant proce-

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**Demographic data**

<table>
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<th>No. of patients</th>
<th>Age (y)</th>
<th>Gender (%)</th>
<th>Occlusion type (%)</th>
<th>Presentation (%)</th>
<th>Location (%)</th>
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<td>Acute</td>
<td>Suprainguinal</td>
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<td>69</td>
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JOURNAL OF VASCULAR SURGERY  
March 2004  

Sarac et al
dures, cost of additional catheters and devices used (which we could not tabulate in this study), and comparison of the TIC with the least expensive drug. It is possible that the difference in costs may have been significantly greater were these taken into account. Mechanical thrombectomy devices were developed to minimize the risks of open surgical procedures and CDT, inasmuch as mortality from acute limb ischemia remains high.\textsuperscript{18} CDT is less invasive and less physiologically stressful than open surgical revascularization. However, its utility has been questioned because of its high costs.\textsuperscript{5} Similar to CDT, the TIC itself appears expensive, but this report demonstrates that it may save money because of decreased angiography suite time from not having multiple sessions, ICU monitoring postoperatively, quantity of thrombolytic agents needed, and bleeding complications. Clinical and economic comparisons with other rheolytic thrombectomy catheters is warranted.

Despite satisfactory results reported here for both costs and technical efficacy, this study has inherent drawbacks and is not without pitfalls. It is a retrospective evaluation of data and not a randomized trial, only early results are reported, and data from one center were extrapolated for costs. In addition, on average two patients were treated per center, which likely produces a selection biases. However, the procedure times in the angiogram suite derived from Creighton University Medical Center data were close to the angiography suite time and ICU length of stay reported by Korn et al.\textsuperscript{5} Moreover, ICU estimated costs of $1200 per day and general medical ward costs of $600 per day are similar to those reported by Bosch et al.\textsuperscript{16} and the angiography suite costs in our model for CDT are similar to those of other studies reported in the literature.\textsuperscript{17,18}

The Surgery vs Thrombolysis for Ischemic Lower Extremity trial demonstrated that traditional CDT is less effective for chronic lower extremity ischemia. Although the TIC was equally effective for both acute and nonacute lesions, the numbers presented in this report are too small to enable us to draw meaningful conclusions regarding its success in treating chronically occluded blood vessels. Also, it is possible that the nonacute occluded vessels treated with the TIC were subacute (14-30 days) or vessels that may have been easily recanalized without use of the TIC. In addition, there is likely a selection bias in treating nonacute vessels, inasmuch as the lesions treated in this study were those that had a high chance of success with TIC treatment. Furthermore, the size of vessel treated and degree of ischemia in chronically occluded small vessels make comparisons of CDT with the TIC invalid. However, the novel aspects of the TIC that make it attractive for both acute and nonacute lower extremity ischemia in medium to large vessels is that it combines two forms of therapy that aim to lower complication rates such as bleeding and distal embolization. In the former it held true, in that bleeding complications were nil with the TIC, but distal embolization remains a concern.

REFERENCES


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