Below-knee Bare Nitinol Stent Placement in High-risk Patients with Critical Limb Ischaemia and Unlimited Supragenicular Inflow as Treatment of Choice

K.P. Donas*, A. Schwindt, T. Schönefeld, J. Tessarek, G. Torsello

Department of Vascular Surgery, St. Franziskus Hospital and Center of Vascular and Endovascular Surgery, Münster University Hospital, Hohenzollernring 72, 48145 Münster, Germany

Submitted 14 December 2008; accepted 24 January 2009
Available online 27 March 2009

KEYWORDS
Below-knee stent placement; Xpert stent; Critical limb ischaemia

Abstract
Purpose: To evaluate the effectiveness of nitinol stent placement in long infrapopliteal lesions in patients with critical limb ischaemia.

Materials and methods: Between January 2005 and January 2008, 34 high-risk patients (18 female; mean age: 73.8 ± 6.1 years) with critical limb ischaemia underwent infragenicular stenting. They had serious cardiovascular co-morbidities (>3, such as chronic obstructive pulmonary disease (COPD), congestive heart failure and coronary artery occlusive disease), American Society of Anaesthesiologists score of 3 or more, previous myocardial infarction, coronary stent or bypass. The mean stenosis length was 6.5 ± 0.9 cm (range: 2.2–8 cm), and the mean occlusion length was 7.5 ± 2.9 cm (range: 3–9.6 cm). Primary stent implantation was performed for long stenosis or occlusion based on the TransAtlantic InterSociety Consensus (TASC) C and D classification, secondary stenting for flow-limiting dissections or elastic recoil after balloon dilatation. All patients who returned to the outpatient clinic were assessed for claudication by clinical examination, ankle–brachial index (ABI) measurements, colour flow and duplex Doppler ultrasound (US). Digital subtraction angiography was performed if restenosis or re-occlusion was identified by Doppler US or transcutaneous measurement of partial oxygen pressure (TcpO2) measurements, when appropriate.

Results: The technical success rate was 97.1% (33 of 34 cases). The crude rate of primary patency rate was 91.1% during a follow-up period of 10.4 ± 7.3 months. The mean ankle–brachial index increased significantly following intervention (0.45 ± 0.25–0.92 ± 0.13, p < 0.001). Two patients underwent successful redo angioplasty after tibiopopliteal interventions due to in-stent restenosis (>70%) with relevant limitation of pain-free walking distance. In another patient, bypass surgery to the anterior tibial artery 6 months after primary
Critical limb ischaemia manifests from advanced multi-segmental atherosclerotic disease of the small- and medium-sized vessels of the lower extremity. Surgical bypass has been the first-line treatment of critical limb ischaemia. However, many patients have poor distal target vessels and absence of suitable veins to perform an autologous bypass. In addition, the associated mortality (6%) and morbidity rates (wound infection: 30%, graft infection: 1.5%, myocardial ischaemia: 3% and graft stenosis or occlusion: 15–30%) of the surgical approach for critical limb ischaemia justifies re-evaluation of alternative treatment modalities for this complex vascular problem.¹

During the past decade, new developments in technology and technical skills have led to a continuous improvement in the success rates of percutaneous transluminal angioplasty (PTA) in the treatment of below-knee lesions.²–⁴ The bypass vs. angioplasty in severe ischaemia of the leg (BASIL) trial concluded that in patients with chronic limb ischaemia due to infragenicular occlusive atherosclerosis, lower limb bypass and balloon angioplasty were associated with similar mid-term outcomes concerning amputation-free survival.⁵ On the other hand, endovascular approaches have several limitations.

Severe calcification, flow-limiting dissections and elastic recoil are important factors linked to failure and complication rates of infrapopliteal PTA.⁶ Numerous reports⁷–¹² have already attempted to evaluate the role of bare metal, metal-absorbable, carbofilm-coated or drug-eluting stent implantation in distal popliteal and infrapopliteal arteries. However, the present status in the literature provides scant information¹³–¹⁵ about the outcome of self-expanding bare nitinol stents for below-knee lesions. This study aims to assess the feasibility and effectiveness of the self-expanding Xpert stent system (Abbott Vascular, Redwood City, CA, USA) in the treatment of high-risk patients with critical limb ischaemia.

**Patients and Methods**

Between January 2005 and January 2008, 34 high-risk patients (18 female patients; mean age: 73.8 ± 6.3 years) who underwent primary or secondary infragenicular stent placement of below-knee lesions, that is, popliteal (PIII segment) and crural arteries, were retrospectively reviewed. All patients suffered from critical limb ischaemia based on the Rutherford categories. The baseline demographics of the patients are showed in Table 1. Of all the 34 patients, endovascular therapy was performed in 15 stenoses and in 19 occlusions. The mean stenosis length was 6.5 ± 0.9 cm (range: 2.2–8 cm), and the mean occlusion length was 7.5 ± 2.9 cm (range: 3–9.6 cm).

The therapy aimed to improve the run-off and to ensure adequate patency in at least one below-knee vessel to the ankle. The criteria for the stent implantation were long stenosis or occlusion, classified based on the TransAtlantic InterSociety Consensus (TASC) classification C lesions <3–5 cm¹ in three patients (mean length: 4.3 ± 0.6 cm) and TASC D lesions >5 cm¹ in nine patients (mean length: 7.1 ± 1.3 cm) or subsequent after PTA in case of (1) flow-limiting dissections and/or (2) elastic recoil in the others (64.8%).

The inflow of the popliteal artery was unlimited prior to the below-knee intervention. In 25 patients (73.5%), adequate inflow was obtained through PTA or stenting of significant lesions of iliac (n = 3), superficial femoral artery (n = 19) or both (n = 3).

All patients were considered as high-risk patients, defined by serious cardiovascular co-morbidities (>3, such as chronic obstructive pulmonary disease (COPD), congestive heart failure, coronary artery occlusive disease, American Society of Anaesthesiologists score of 3 or more, previous myocardial infarction, coronary stent or bypass). No clopidogrel loading dose was used prior to intervention. The post-interventional anti-platelet treatment included administration of clopidogrel 75 mg daily for 6 weeks and lifelong administration of acetylsalicylic acid 100 mg daily.

Critical limb ischaemia is defined as the presence of rest pain, non-healing ulceration or gangrene and evidence of

**Table 1 Patients’ demographic data**

<table>
<thead>
<tr>
<th>Rutherford category</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15/34 (44.1%)</td>
</tr>
<tr>
<td>5</td>
<td>19/34 (55.9%)</td>
</tr>
<tr>
<td>Age</td>
<td>73.8 ± 6.1</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>16:18</td>
</tr>
<tr>
<td>Factors of high-risk patients</td>
<td></td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>18/34 (52.9%)</td>
</tr>
<tr>
<td>Cardiac insufficiency (NYHA &gt;1)</td>
<td>8/34 (25%)</td>
</tr>
<tr>
<td>Pre-existing renal insufficiency</td>
<td>8/34 (25%)</td>
</tr>
<tr>
<td>Previous myocardial infarction, coronary stent or bypass</td>
<td>6/34 (17.6%)</td>
</tr>
<tr>
<td>ASA = 3 or more</td>
<td>22/34 (64.7%)</td>
</tr>
<tr>
<td>More than three risk factors</td>
<td>31/34 (91.2%)</td>
</tr>
</tbody>
</table>

ASA, American Society of Anaesthesiologists; NYHA, New York Heart Association.
diffuse pedal ischaemia (Fontaine classes III and IV or Rutherford categories 4, 5 or 6; resting arterial pressure (AP) <60 mmHg, ankle or metatarsal pulse volume recording flat or barely pulsatile and toe pressure (TP) <30 mmHg).

Follow-up

Peri- and post-interventional complications at the puncture site were assessed in the first 24 h. All patients who returned for routine follow-up control in the outpatient clinic were evaluated for claudication by clinical examination, ankle–brachial index (ABI) measurements, colour flow and duplex Doppler ultrasound (US) before hospital discharge at 3, 6 and 12 months later and yearly thereafter. Digital subtraction angiography was performed if restenosis or re-occlusion was identified by duplex Doppler US. The mean follow-up period was 10.4 ± 7.3 months. Our institution does not require ethical approval for reports such as this.

Definitions

Anatomical patency was defined as the absence of recurrent occlusion or stenosis of the treated segment more than 50% in diameter, documented by colour flow and duplex Doppler US or digital subtraction angiography. Technical success was defined as being less than 30% of the final residual stenosis measured at the narrowest point of the treated vascular segment. To document haemodynamic success, resting ABI measurements at baseline, at 12–24 h after endovascular treatment and at most recent follow-up were performed. On a short-term and long-term basis, the ABI-based definition of success was indicated by an increase of at least 0.10 relative to baseline measurement.

The measurement of ABI in the crural arteries in six patients with diabetes mellitus was not reliable due to medial sclerosis of the Mönckeberg type. They had an ABI index >1.5 of the lower limbs. To noninvasively assess the influence of stent placement in the peripheral circulation of these patients, we used transcutaneous measurement of partial oxygen pressure (TcpO2) at the dorsal site of the foot. The TcpO2 electrodes (the Clark-type oxygen-sensing electrodes) were attached to the skin, and the heating element of the electrode was warmed to 45 °C. One electrode was attached to the dorsum of the foot and the other to the chest. The TcpO2 measurements were performed, with the patient resting in the supine position, using the Hellige O2 monitor.

Clinical success was defined by sustained clinical improvement, as categorised by Rutherford guidelines, and included haemodynamic and clinical measures.

Complications of treatment were classified on the basis of outcome according to the reporting standards of the Society of Interventional Radiology. An ethical approval for the present retrospective study was not necessary at our institution.

Intervention

The contralateral common femoral approach with the use of 5F sheath and 0.035 Terumo guidewire was preferably used. The indications for ipsilateral puncture of the common femoral artery were previous vascular reconstruction by synthetic patch or bypass and morphology of the iliac artery unsuitable for cross-over manoeuvre, that is, steep aortic bifurcation, tortuous or calcified iliac arteries, or failure to cross the lesions from the contralateral side due to poor pushability. An angiography of the infrarenal abdominal aorta, iliac and peripheral segments was performed as well. In order to catheterise the contralateral ilio-femoral segment with ipsilateral crural lesions using the cross-over technique, the 5F sheath was changed to 6F long sheaths (90 cm). Intra-operative administration of 5000 IU heparin was routinely made.

For PTA, low-profile balloon catheters (Submarine and Amphirion; Invatec, Roncadelle, Italy) with diameters ranging from 2 to 4 mm and lengths ranging from 20 to 80 mm were used based on the size of the relevant artery. The balloon pressure ranged from 6 to 16 atm, and balloon inflation was performed routinely at the stented lesion. The criteria for the stent implantation after PTA were (1) TASC C lesions <3–5 cm and TASC D lesions >5 cm, (2) flow-limiting dissections and/or (3) elastic recoil.

The Xpert stent system (Abbott Vascular, Redwood City, CA, USA) is a self-expanding nitinol stent, specifically designed for infragenual lesions of small vessels. The device is compatible with a 4F sheath and has a diameter of 3–8 mm and a length of 20–60 mm. Recently, the stent is also available in a length of 120 mm. Fig. 1a–c show intra-operative angiography of the right infrapopliteal arteries after the successful Xpert stent system implantation in popliteal segment (III) and fibular artery.

In one patient, the implantation of the Xpert stent system was not possible due to friction caused by extensive atherosclerosis of the anterior tibial artery, and, therefore, the Chromis Deep stent (Invatec, Roncadelle, Italy) was used. The Chromis Deep stent is cobalt–chromium balloon-expandable stent with a closed cell design.

Statistical analysis

Descriptive data are presented as mean ± standard deviation (SD) and range, if appropriate; nominal data are given as counts and percentages; continuous quantitative data were compared with the non-parametric, two-sample, Wilcoxon signed-rank test. Statistical significance was set at a p-value of less than 0.05. The primary patency rate was calculated by crude rates.

Results

The technical success rate was 97.1% (33 of 34 cases). In one patient, the implantation of the Xpert stent system was not possible due to friction caused by extensive atherosclerosis of the tibial artery, and, therefore, the Chromis Deep stent was successfully implanted.

Contralateral access was performed in 26 cases (76.4%). An ipsilateral access was preferred in eight patients. Four patients had had a previous vascular reconstruction of the contralateral side by synthetic patch, two patients had unsuitable morphology of the iliac bifurcation and the other two had failed endovascular re-canalisation of the lesions
from the contralateral common femoral artery. The total number of applied stents was 38 (mean: 1.1 ± 0.3 per patient; range: 1–2 per patient): 29 stents were deployed in the crural axis and nine stents in the distal popliteal artery. In 32 out of 34 patients (94.1%), a single stent was implanted. In two patients (5.9%), a stent-overlapping was necessary due to extensive flow-limiting dissection.

No early (<30-day) morbidity and mortality was noted, and the primary cumulative patency was 100%. The primary cumulative patency rate at 10.4 ± 7.3 months was 93.75%. Two patients underwent successful redo angioplasty due to in-stent restenosis (>70%) in the tibioperoneal trunk and due to relevant limitation of pain-free walking distance at 6 and 8 months after the primary procedure. No evidence of stent fracture was noted in these cases. One patient presented with rest pain with angiographic evidence of inadequate inflow to the occluded segment and, therefore was treated by extra-anatomic bypass to the anterior tibial artery.

The 6-month amputation-free interval for the patients who suffered from critical limb ischaemia was 100%, with a 100% limb-salvage rate. All patients showed improvement of their symptoms, that is, healing of the ulceration for the patients with trophic lesions. The ABI index increased at 12–24 h significantly (pre-intervention: 0.45 ± 0.25; post-intervention: 0.92 ± 0.13, p < 0.001). A sustained improvement of the ABI index has been shown at 6 months post-interventionally (0.77 ± 0.23, p < 0.001). The six patients with diabetes mellitus and not reliable ABI measurements showed an increase in baseline TcPO2 values of the limb with the leading symptom from 9.3 ± 3.3 to 23.3 ± 2.3 mmHg (p > 0.5).

The overall complication rate was 5.8% (2 of 34). Two patients suffered from false aneurysms at the puncture site in the groin after antegrade access and use of 6F sheath. A surgical evacuation of the haematoma and revision of the common femoral access was necessary. No patient died due to procedure-related cause during either the procedure or the follow-up period. Moreover, no evidence of cardio-respiratory complication, such as myocardial infarction or decompensate respiratory insufficiency or impairment of the renal function, was noted in our patient group. Table 2 summarises the results of our study.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Overview of the results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with critical limb ischaemia who underwent below-knee bare-stent placement</td>
<td>34</td>
</tr>
<tr>
<td><strong>Primary patency</strong></td>
<td>93.75%</td>
</tr>
<tr>
<td><strong>Re-interventions</strong></td>
<td></td>
</tr>
<tr>
<td>Balloon angioplasty</td>
<td>2/34 (5.8%)</td>
</tr>
<tr>
<td>Bypass surgery</td>
<td>1/34 (2.9%)</td>
</tr>
<tr>
<td>Major adverse event</td>
<td>0/34 (0%)</td>
</tr>
<tr>
<td><strong>Access-site complications</strong></td>
<td>2/34 (5.8%)</td>
</tr>
<tr>
<td>Bypass surgery: extra-anatomic tibial anterior bypass (Stockmann bypass); Major adverse events including deaths and major amputations; Access-site complications: haematoma/bleeding with surgical repair.</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Patients with critical limb ischaemia normally present with long diffuse segments of stenotic and/or occlusive disease, in densely calcified vessels, with compromised in-flow and poor run-off. Moreover, these patients are typically elderly with severe co-morbidities, making the surgical bypass prohibitive in these cases. Therefore, successful re-vascularisation of these complex lesions remains challenging and increases the interest in further development of endovascular strategies in this clinical entity.

To our knowledge, the present study reports one of the largest series of stent implantation in the crural arteries in patients with critical limb ischaemia. In comparison with the report of Bern,\(^1\) we found a high technical success rate (97.1%) and a limb-salvage rate of 100%.

Only two (5.8%) of our patients required a stent overlap, due to unavailability of stents of 80 mm or 120 mm length at that time. Generally, stent-overlapping minimises the vessel lumen and increases flow disturbances with consecutive neo-intimal hyperplasia, which is linked to restenosis or re-occlusion. Moreover, according to Duda et al.,\(^15\) the above-mentioned phenomenon may be an underlying mechanism for the occurrence of stent fractures.

The positive impact of nitinol stents in femoro-popliteal arteries, in terms of significantly improving of patency rates, compared with stainless steel stents or balloon angioplasty with optional stenting has already been described.\(^12,13,16\) At the moment, the literature provides scant information about the feasibility and effectiveness of bare nitinol stent placement in below-the-knee lesions. Kickuth et al.\(^14\) performed a 4F-sheath-compatible, self-expanding nitinol stent-supported angioplasty by the Xpert system in distal popliteal and crural arteries and found a marked clinical improvement of 80%. The trial showed an excellent pushability and trackability of the stent, which is specifically designed for small vessels with a low strut profile.

The flexibility of the device is beneficial, especially for the infragenicular lesions of the third popliteal segment and proximal part of the crural arteries. This technical point contributes to optimising the vessel lumen and minimising the flow disturbances, even in tortuous anatomy. The length of the device up to 120 mm allows the treatment of long lesions, which are very common in the crural arteries.

Limitations of the Xpert stent system are the poor visibility, especially in cases of severe calcification of the vessel lumen. Therefore, in one case with focal tortuous calcification and high friction in the middle segment of the tibial artery, we used a balloon-expandable stent. Moreover, below-knee stent placement is only possible in cases of unlimited supragenicular inflow. This condition is rarely present due to the multi-segmental nature of the disease and requires simultaneous treatment of the more proximal lesions which can often be hazardous, especially in case of TASC D lesions.

Siablis et al.\(^17\) compared sirolimus-eluting stents to bare-metal stents in infrapopliteal lesions in the critical limb ischaemia population. The outcomes of this non-randomised prospective study showed a significant improvement of 6-month patency rate (92% vs. 68%, \(p = 0.002\)) for the patients group treated by sirolimus-eluting stent in short lesions using 20-mm stents. On the other hand, majority of the infrapopliteal lesions are long and, therefore, any attempt to draw conclusion about superiority of one type of the stents is questionable.

Limitation of the present study is the fact that it is retrospective, non-randomised data analysis, with a small number of patients without a control group. Although this series reflects feasibility, any comparison with crural PTA or bypass seems premature at the present moment. However, in case of high-risk patients with critical peripheral arterial disease and unlimited supragenicular inflow, below-knee stent-supported angioplasty should be considered as a bailout procedure of first choice.

Conflict of Interest/Funding

None.

References

14. Kickuth R, Hak Keo H, Triller J, Ludwig K, Do DD. Initial clinical experience with the 4-F self-expanding Xpert stent system for