Lasers Med Sci (2009) 24:955–960
DOI 10.1007/s10103-009-0650-y

ORIGINAL ARTICLE

Excimer laser debulking for percutaneous coronary intervention in left main coronary artery disease

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Received: 20 January 2009 / Accepted: 29 January 2009 / Published online: 24 February 2009

Abstract Excimer laser has been successfully applied to complex atherosclerotic plaques in acute coronary syndromes; however, its role in debulking in left main coronary artery disease has not been fully explored. Details of a series of 20 patients who underwent excimer laser revascularization of a spectrum of left main coronary artery lesions are presented. Twenty symptomatic patients who received excimer laser debulking were examined for procedural outcome and follow up results. The left main coronary artery was characterized as protected, semi-protected, poorly protected, or unprotected, depending on the presence or absence of patent bypass grafts to the left anterior descending (LAD) and circumflex (CX) arteries. A fully protected left main coronary artery (LMCA) was present in only 20% of the patients. The target lesions included 11(55%) distal LMCA stenoses, six (30%) ostial stenoses, and one (5%) mid-portion lesions. Two (10%) patients had in-stent re-stenosis of the entire length of the LMCA. Small (0.7 mm–1.4 mm) excimer laser catheters were mostly used. A relatively high number of laser energy pulses (1,334±643) were required to achieve adequate debulking. Successful LMCA intervention was performed in 19 (95%) patients, while in-hospital complications occurred in only one (5%) patient. Subacute/late stent thrombosis developed 3 months after the procedure in one patient, and two patients died from non-cardiac causes during follow-up. Lesions in LMCAs can be revascularized in selected patients by laser debulking and adjunct stenting. Inadequate protection by bypass grafts and decreased left ventricular function do not contradict utilization of excimer laser. Small laser catheters and high energy levels are required during laser debulking of stenoses of left main coronary arteries.

Keywords Excimer laser · Acute coronary syndrome · Left main coronary artery disease · Debulking · Thrombus · Plaque · Stent

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Introduction

Atherosclerotic lesions in the left main coronary artery are challenging targets during percutaneous intervention [1–4]. Excimer laser is a technology approved by the Food and Drug Administration (FDA) for treatment of complex atherosclerotic plaques that cause acute or chronic coronary syndromes and peripheral ischemic disease [5]. The application of laser facilitated percutaneous coronary intervention (PCI) in the treatment of left main coronary artery stenosis has not been fully explored. We herein describe the clinical settings, technical aspects and acute results of our early experience with 20 patients who underwent excimer laser coronary angioplasty (ELCA) for the debulking of a spectrum of lesions in the left main coronary artery (LMCA).

Patients and methods

The registry of the cardiac catheterization and interventions laboratories at the McGuire Veterans Affairs Medical Center in Richmond, Virginia, USA, contains data on the application of excimer laser for targeted revascularization of the left main coronary artery in 20 patients with acute coronary syndromes. These interventions were performed from March 2002 to November 2008. We used the Department of Veterans Affairs' computerized patient record system (CPRS) to obtain data pertaining to clinical parameters, the LMCA interventions, and subsequent follow-ups. All patients signed informed consent forms prior to the index intervention. The baseline clinical characteristics of the treated patients are presented in Table 1.

There were 20 patients: one female and 19 male, whose ages ranged from 52–82 years (mean 68.6±8.4 years). Hypertension was present in 17 (85%) patients, 16 (80%) smoked, seven (35%) had diabetes mellitus, and seven (35%) exhibited chronic renal insufficiency. Nineteen (95%) patients presented with unstable angina and one patient (5%) with an acute myocardial infarction (AMI).

The clinical decision to perform PCI of the LMCA was based on symptoms and evidence of ischemia along the anatomic distribution of this vessel and on the suitable morphology of plaques for debulking and stenting, (i.e., angiographic evidence of a more than 70% diameter stenosis of the LMCA with or without accompanying intracoronary thrombus). Patients' preference for percutaneous treatment and contraindications for bypass surgery were taken into account as well. The LMCA was considered to be *protected* if two patent grafts to the left anterior descending (LAD) and circumflex (CX) arteries were present. It was considered to be *unprotected* if the target was either a de novo lesion or if, despite previous bypass surgery, no patent graft to these native vessels was present. A *semi-protected* LMCA was defined when one graft to either the LAD or CX artery was patent. A *Poorly protected* left main coronary artery was characterized by grafts containing severe disease before the anastomosis to a recipient native vessel. Two of the patients with poorly protected left main coronary arteries underwent staged PCI aimed first at revascularization of the stenosed old bypass grafts, with subsequent intervention of the left main coronary artery. Angiographic and procedural data are presented in Table 2. Figures 1, 2, and 3 depict three cases of ELCA in LMCA.

Table 1 Baseline clinical characteristics (*CAD* coronary artery disease, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *CABG* coronary artery bypass graft, *UA* unstable angina, *NSTEMI* non-ST-elevation myocardial infarction, *STEMI* ST-elevation myocardial infarction)

Patients	Total=20
Age (years)	68.6±8.41
Male gender	19 (95%)
Cardiac risk factors	
Hypertension	17 (85%)
Diabetes mellitus	7 (35%)
Hypercholesterolemia	18 (90%)
History of smoking	16 (80%)
Family history of CAD	12 (60%)
Prior MI	17 (85%)
Prior stroke	2 (10%)
Previous PCI	5 (25%)
Previous CABG	20 (100%)
Clinical presentation	
UA/NSTEMI	19 (95%)
STEMI	1 (5%)
Chronic renal insufficiency	7 (35%)

Procedure

Coronary arteriography and stent implantation were performed in accordance with the current standard techniques. The patients received unfractionated heparin, to achieve an activated clotting time of more than 250 s, or bivalarudin. Glycoprotein 2b/3a inhibitors were administered at the interventionalist's discretion. All patients were given aspirin and were loaded with 300 mg to 600 mg clopidogrel prior to or immediately upon completion of the intervention followed by 75 mg/day for at least 12 months. Serial samples for determination of cardiac biomarkers were collected during the first 24 h after the procedure. A pre-intervention intravascular ultrasound was obtained only in cases where

Table 2 Angiographic and procedural characteristics (*IABP* intra-aortic balloon pump)

Patients	Total=20
Location of lesion	
Ostium	6 (30%)
Mid portion	1 (5%)
Distal	11 (55%)
Entire length (in-stent re-stenosis)	2 (10%)
Left main coronary artery calcium	11 (55%)
Left main coronary artery thrombus	14 (70%)
Left main coronary artery protection level	
Protected	4 (20%)
Semi-protected	12 (60%)
Poorly protected[a]	3 (15%)
Unprotected	1 (5%)
Support of IABP	4 (20%)
Use of glycoprotein 2b/3a inhibitors	6 (30%)

[a] Two of these patients underwent PCI conversion to reach a status of left main coronary artery protection

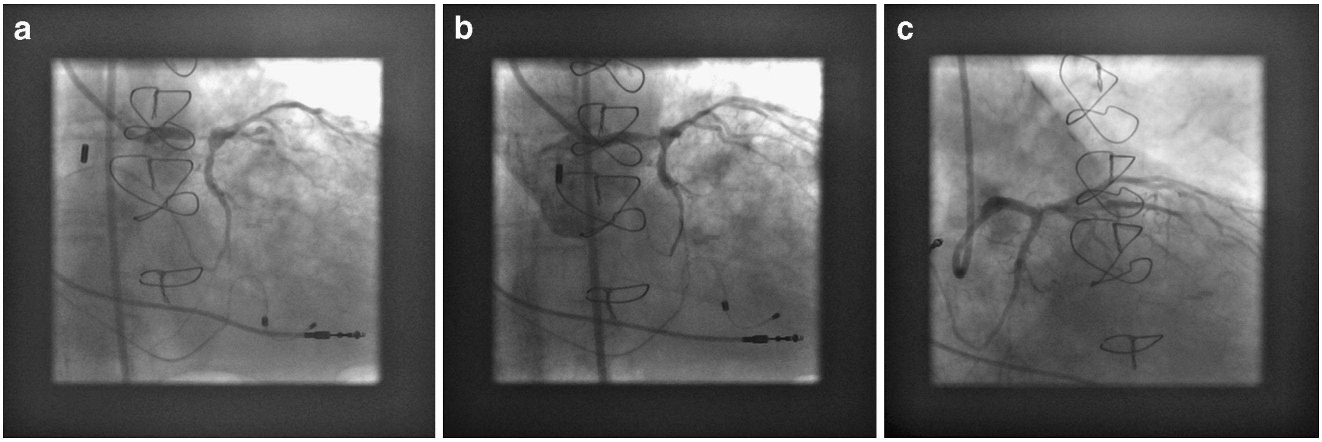

Fig. 1 ELCA in a poorly protected LMCA. First, conversion to protected LMCA status was performed, to enable revascularization of the target lesion in the left main coronary artery. Thus, laser debulking and adjunct stenting of the left internal mammary artery (LIMA) to the LAD artery was initially performed (step 1). The distal right coronary artery (RCA), just beyond the anastomosis of a saphenous vein graft (SVG), containing a critical stenosis with accompanying thrombus, underwent debulking with an X-80, 0.9 mm, excimer laser catheter and stenting with a 2.0/8 mm drug-eluting stent (DES) (step 2). **a** Step 3 of the intervention immediately upon completion of the above-mentioned conversion. Angiography of the left main coronary artery demonstrates critical distal segment stenosis. **b** After debulking with a 1.4 mm concentric optimal spacing (COS) excimer laser catheter. A 'pilot recanalization channel' was created across the target lesion. **c** Final results following adjunct stenting of the LMCA target

the operator felt that there was no risk of distal embolization. Procedure-related data are presented in Table 3.

Laser debulking was done to remove obstructive plaque and facilitate stent delivery. The size of the laser catheter was selected in consideration with the degree of target stenosis, i.e., the more severe the stenosis, the smaller the catheter's size. Of the five sizes of excimer laser catheters (Spectranetics, Colorado Springs, CO, USA) that were available (0.7 mm, 0.9 mm, 1.2 mm, 1.7 mm, and 2.0 mm), the 0.9 mm X-80 catheter was most commonly used. The energy parameters were set in accordance with published recommendations for utilization of excimer laser angioplasty [6–8]. Injections of saline solution were incorporated during antegrade and retrograde slow advancement of the laser catheter (0.2–0.5 mm/s) across the target lesion [9]. An intra-aortic balloon pump was used only in selected cases for hemodynamic support.

Endpoints

The primary endpoint for analysis was when there were major adverse cardiovascular events (MACEs), including cardiac death, peri-procedural myocardial infarction (MI),

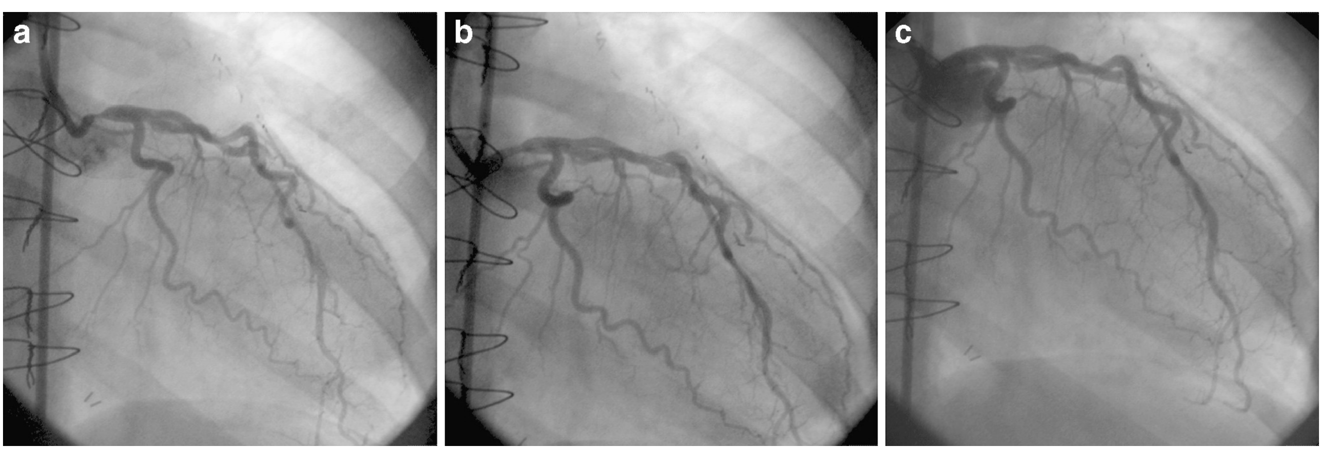

Fig. 2 ELCA in an unprotected LMCA. This patient had undergone coronary artery bypass graft surgery (CABGS) just 8 weeks earlier. He then presented with unstable angina, and both grafts—a LIMA to LAD and a SVG to the CX artery, were totally occluded at their aortic origin. **a** Tight stenosis of ostial LMCA caused marked dampening and ventricularization of the pressure wave form. **b** LMCA lesion appearance after ELCA debulking with X-80 0.9 mm catheter and a 1.7 mm COS catheter. **c** Final angiogram after adjunct stenting with a 4.0/18 mm, bare-metal, stent. 3 years after this intervention; the patient is free of symptoms and there is angiographic confirmation of the LMCA's patency

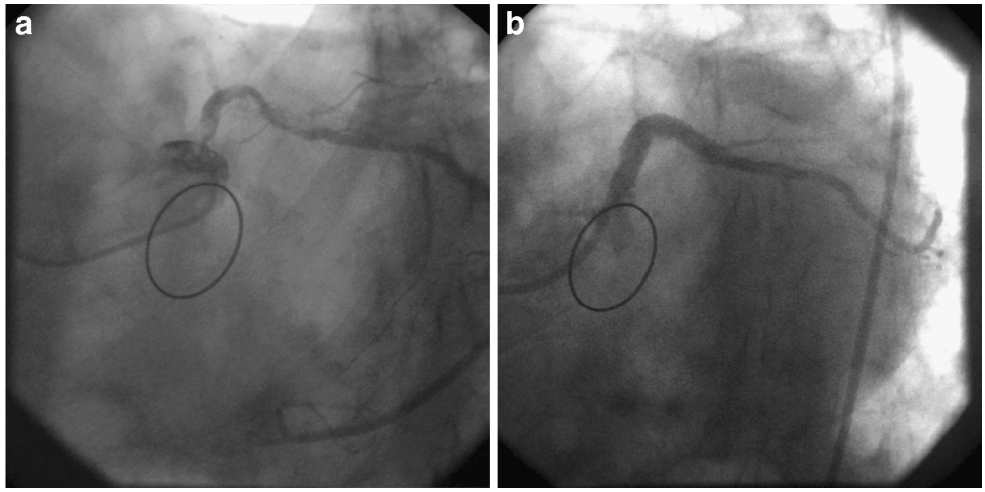

Fig. 3 Protected LMCA treated by ELCA. **a** Before laser treatment: a large thrombus (hazy appearance distal to the tip of the catheter) accompanying a tight stenosis in the ostial-proximal segment as well as the distal segment of the LMCA. A round mitral valve ring is present. **b** After ELCA and adjunct stenting of both segments of the LMCA

stroke, need for emergency bypass surgery or target lesion revascularization by either PCI or surgery. Device success was defined as the ability to cross the entire length of the left main coronary artery stenosis, leading to a reduction in the target lesion's diameter of at least 20% [5]. Technical success was defined as revascularization in the target lesion with less than 30% residual stenosis by visual analysis accompanied by the presence of thrombolysis in myocardial infarction (TIMI) flow grade 3.

Table 3 Intervention data (*DESs* drug-eluting stents, *BMSs* bare-metal stents, *TIMI* thrombolysis in myocardial infarction)

Parameter	
Excimer laser size	
0.7 mm	1
X-80 0.9 mm	13
1.4 mm	7
1.7 mm	2
Number of laser pulses	1,334±643
Laser-induced complications	
Distal embolization	1 (5%)
Perforation	0 (0%)
Pre-laser angiographic stenosis	96.7±2.61
Post-laser angiographic stenosis	62.4±22.4
Final angiographic residual stenosis	11.2±25
Total number of stents	27
Stent length (mm)	14.3±4.07
Stent diameter (mm)	3.08±0.6
DESs	19 (70%)
BMSs	8 (29%)
Bifurcation stents	8 (40%)
Post-procedure TIMI flow	2.94±0.25

Results

The angiographic and procedure related data are presented in Table 2. Eleven (55%) patients had distal LMCA stenoses, six (30%) patients had ostial LMCA stenosis, one (5%) had mid-portion stenosis, and two (10%) patients had in-stent re-stenosis of the entire length of the LMCA. Bifurcation stents were used in eight (40%) patients. Four (20%) patients received prophylactic intra-aortic balloon pump (IABP) support. Six (30%) received treatment with glycoprotein 2b/3a inhibitors. Pre-intervention intravascular ultrasound (IVUS) was performed on five (25%) patients. Post-stenting IVUS was obtained for 15(75%) patients.

The LMCA intervention was successful in 19 (95%) patients. In-hospital complications occurred in one (5%) patient. This patient had procedure-related distal embolization and hemodynamic deterioration necessitating emergency bypass surgery. He further sustained perioperative myocardial infarction and atrial fibrillation but eventually recovered and was discharged. There were no laser catheter-related perforations or dissections. A total of 27 stents was implanted; 19 were drug-eluting stents (DESs) and eight were bare-metal stents (BMSs).

All patients were followed up at the heart clinic (Table 4). The mean duration of follow-up was 26.4 months. One patient developed subacute/late stent thrombosis 3 months after the index procedure. Two patients died during follow-up, from non-cardiac causes.

Discussion

The main findings in this report are: (1) Excimer laser is feasible and safe for the treatment of selected LMCA plaques; (2) small laser catheters and a high quantity of energy pulses are required for efficient debulking.

Table 4 Early and late clinical events (*TLR* target lesion revascularization)

MACE	Number
In-hospital	1 (5 %)
Follow-up	
Non-cardiac death	2 (10 %)[a]
Subacute/late stent thrombosis	1 (5 %) - after 3 months
TLR	1 (5 %)

[a] One patient died after 3 weeks, and the other died after 2 years and 2 months

The traditional treatment of choice for significant atherosclerotic disease of the LMCA is bypass surgery. However, the availability of stents has rendered various left main coronary artery lesions amenable to percutaneous intervention [2, 10–12]. The advent of coronary stents dramatically lowered the incidence of abrupt vessel closure, and the application of DESs decreased the risk of unprotected LMCA in-stent re-stenosis. Additionally, patients with unprotected LMCA disease treated with PCI had favorable early outcomes in comparison with those with coronary artery bypass grafts (CABGs).

Excimer laser is an FDA-approved percutaneous technology for the treatment of complex atherosclerotic plaques in the settings of acute and chronic coronary ischemic syndromes and ischemic peripheral disease [13, 14]. This laser has been shown also to be safe and effective for patients with depressed left ventricular function [15]. The generator of the excimer laser produces electromagnetic energy in the ultraviolet wavelength (308 nm). The emission is transmitted via flexible catheters to the target lesion, resulting in bioabsorption and debulking of irradiated plaques and thrombi [16]. In the pre-stent era, laser had been sporadically used for LMCA intervention [5, 17, 18].

The presence of two patent grafts in the left coronary artery circulation offers improved protection and reduced risk during PCI for left main coronary artery disease. However, when graft protection is not available, as seen with totally occluded grafts or in de novo left main coronary artery lesions, the risk of LMCA intervention is considered to be higher. Nevertheless, in this series, the laser appeared to modify such risk and provided adequate debulking, regardless of the pre-intervention degree of graft protection.

Laser success in our series of patients was gained, despite the common presence of angiographic findings of thrombi (70% of lesions), an established predictor of PCI complications [19]. This relates to the unique interaction of laser light with a thrombus. During laser activation, acoustic shock waves propagate onto the thrombus, causing physical impact on the fibrin mesh with resultant effective fibrinolysis [20]. Furthermore, the excimer laser creates a special stabilization effect on the platelets within the thrombus, a process termed 'the stunned platelets phenomenon' [21]. The suppression of activated platelets then leads to improved thrombus control during percutaneous intervention. Calcified lesions in this series required greater laser fluence than did non-calcified stenoses (22). High fluence laser energy may be successfully used in moderately to heavily calcified lesions, as observed by other investigators [22, 23].

Selection of the size of the laser catheter for debulking the left main coronary artery takes into consideration the morphology of the target stenosis. We recommend the usage of small catheters for tight occlusions. In our series this preference was manifested by frequent utilization of the small 0.9 mm catheter. Proper lasing technique entails slow advancement during antegrade and retrograde activation across the lesion. This is required to ensure maximal absorption and debulking and to avoid adverse effects of the laser catheter on the surrounding wall [24]. Injections of saline solution were used to remove contrast medium ahead of the laser catheter tip in order to control the high synergistic effect of dye on laser-generated acoustic shock waves [9].

Although useful as a debulking technique, excimer laser is not a panacea for LMCA treatment. In addition to the failure of the laser in one of our patients, a case of severe thrombotic LMCA stenosis was described by Nurkalem and associates, which was completely resistant to the effect of 1.7 mm concentric and 2.0 mm eccentric excimer laser catheters [25]. Other successful modalities for debulking in LMCA disease include rotablator [11, 26], directional atherectomy [11, 27], and cutting balloon [28]. There are no studies comparing these devices in this scenario; consequently, their utilization remains at the discretion of the interventionalist. In summary, we propose that selected patients with LMCA disease can be treated effectively with laser debulking and adjunct stenting. Corroboration of this experience is required prior to its gaining wider acceptance as a treatment modality for PCI in LMCA disease.

Study limitations

This retrospective report represents experience in a selected, relatively small, group of patients. While demonstrating acceptable safety, acute gain and follow-up results, this experience was limited and cannot serve either as a recommendation or a confirmation of an exclusive role for excimer laser in the treatment of LMCA disease. Potentially, a different approach incorporating other interventional modalities could have provided similar or superior results.

Conclusions

This report demonstrates that excimer laser angioplasty was feasible and safe in the treatment of selected cases of LMCA disease. Proper lasing technique and the selection of small laser catheters are required. The ability of the laser to debulk and facilitate stenting enables revascularization to be performed, even when there is compromised graft protection.

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