Usage of excimer laser in coronary and peripheral artery stenosis – analysis of its safety aspect

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▌ Abstract

Introduction. The technology of laser atherectomy has been known for about 20 years. Initial studies were not encouraging due to similar or lower efficacy compared to conventional angioplasty and greater complication rate. The introduction of new, low-profile catheters with high parameters of transmitted energy, a change in the procedure for performing angioplasty and the proper qualification of the lesions resulted in a reduction of adverse effects.
Objective. The aim of the study was to present the current state of knowledge regarding the usage of excimer laser in coronary and peripheral arteries stenosis, its indications and contraindications as well as safety aspect. The article reviews 32 recent publications available on the PubMed and Google Scholar databases.
Abbreviated description of the state of knowledge. The excimer laser emits ultraviolet energy and ablates the tissue in a vessel. The main indications for the use of the laser include: restenosis in the stent, ostial lesions, long, calcified lesions >20 mm and moderately and severely calcified lesions. There are isolated reports describing the use of ELCA in the treatment of acute coronary syndromes. Excimer laser also can be applied in a treatment of stenosis of peripheral arteries.
Conclusion. Excimer laser coronary atherectomy is a safe and feasible technique for the treatment of ISR and is associated with a relatively low recurrent restenosis compared to scoring balloon dilatation alone. It is a very important and safe alternative to classic treatment methods, but further research assessing the usefulness of this procedure is required.

▌ Key words

artherosclerosis, angioplasty, excimer laser, coronary stenosis

INTRODUCTION

Percutaneous coronary angioplasty combined with implantation of an antimitotic drug-eluting stent is currently the main method of treating symptomatic ischemic heart disease. There are some failures that must be taken into account by the operator when performing these procedures. They are the result of anatomical conditions, such as the inability to insert a balloon through a lesion in the coronary vessel – uncrossable lesion or difficulties with the optimal dilatation of the stenosis. These changes prevent adequate predilation and result in insufficient stent expansion to nominal dimensions, which is a very important risk factor for restenosis in the stent and thrombosis.

The use of argon laser angioplasty was first performed in the context of salvaging an ischemic limb in 1983 [1, 2]. Modern xenon laser's technology is based on ultraviolet energy and is capable of disintegrating atheroma without burning or gross fragmentation [3, 4]. The depth of laser penetration is directly related to its wavelength, with the UV laser having less depth of penetration, less heat production and less unwanted tissue damage [4]. With refinements in catheter technology and safe aspects, an innovative xenon–chlorine pulsed laser catheter (ELCA X80) has been used recently for the treatment of

complex coronary lesions, calcified stenosis, chronic total occlusions and non-compliant plaques [4, 5].

Laser coronary angioplasty was developed to modify atherosclerotic plaque and to counteract the limitations of balloon angioplasty – intimal dissection and restenosis [1, 6]. Initially, the successive development of coronary stents, with the simultaneous high costs of laser application, slowed down the development in catheter technology [1]. However, despite the proven effective use of stents in coronary artery disease (CAD), small vessel and ostial lesions make up the common difficulty with patient management [2]. ELCA has been useful in the case of balloon-resistant lesions to simplify stent expansion [2, 7]. Furthermore, other basic indications for the use of an excimer laser including acute coronary syndrome, chronic total occlusion or under-expanded stents, thrombus,and in-stent restenosis highlight the wide range of ELCA use [2, 8, 9].

Use of the ELCA procedure involves a certain risk of complications of which vessel perforation is the worst adverse event; however, it occurs seldom during ELCA [10]. This is why continuous progress in the field of cardiovascular medicine is increasing [1, 11],while taking the safety aspect into account.

The search for clinical trials was based on a detailed protocol developed prior to the commencement of the systematic review paper. It took into account the criteria for including studies in the review, the search strategy, method of selecting articles and the planned methodology for conducting data analysis. The following inclusion criteria

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were used: 1) studies published in English, 2) available as full texts, 3) published in the last 10 years. An analysis of scientific publications available on the PubMed and Google Scholar platforms was carried out using the keywords linked by logical operators: 'excimer laser' and 'angioplasty', as a result of which, after selection by two independent analysts, 32 scientific publications were used. The verification at the level of abstracts and titles was carried out in such a way that all reports considered useful by at least one of the analysts were included in the next stage.

OBJECTIVE

The aim of the study was to present the current state of knowledge regarding the usage of excimer laser in coronary angioplasty and treatment of stent restenosis, as well as its indications, contraindications and safety aspect.

DESCRIPTION OF THE STATE OF KNOWLEDGE

Fundamentals and mechanism of action of the excimer laser. Laser creates a directional beam of high-energy monochromatic light. Excimer laser releases energy in short pulses in the wavelength from 10 to 400 nm (ultraviolet) [1, 4]. In cardiology, the xenon chloride laser is used in which an excited state molecule of XeCl (the excited dimer, from which is formed the name 'excimer') is produced. It releases a photon with a wavelength of 308 nm while becoming a weakly covalent molecule [1, 4, 8]. The photon produces the next two photons of the same wave length after interaction with an excited electron. The whole process takes place in a mixture of a hydrogen chloride solution (0.1%) and the xenon gas where electrical discharge of high-voltage results in the formation of the laser beam [1].

Excimer laser ablates the tissue in arteries with its photochemical (breaking molecular carbon-carbon bonds), photothermal (increasing the temperature of water in cells, inducing cellular rupture, generating a vapour bubble at the catheter ending) and photokinetic/photomechanical properties (clearing byproducts of ablation, like gases, water, and small particles) [1, 4, 8, 12]. The whole process occurs without causing major damages. Released fragments (<10 μm in diameter) are absorbed by the reticuloendothelial system and do not occlude the smallest vessels [4]. Because of its properties, the laser reduces platelet aggregation and protects endothelial cells [2]. The catheter should be advanced slowly through the lesion in the artery (0.5 millimeters/second) to allow adequate absorption of light energy and efficient ablation. Reverse laser treatment can be used after several forward courses for severe atherosclerotic lesions [4]. Excimer laser is now the unique instrument able to vaporize or modify atherosclerotic plaque located underneath a stent or severe calcification [8]. It is especially important to use a saline infusion during the procedure in order to eliminate blood and contrast from the lasing field, and prevent the production of insoluble gas and fast-expanding cavitation bubbles, which can generate intense pressure and result in coronary perforation [1]. 0.9% normal saline infusion is started by the assistant operator who injects a 10 mL bolus just before activation of the laser, and then injects the saline at a rate of 1–3 mL/s until the end of the lasing procedure. Blood and residual contrast is flushed from the entire port system by a 20 mL luer-lock control syringe [1]. Iodinated contrast increases the risk of localised thermal injury because of its effect on the photothermal process. That is why contrast must be removed before laser emission [13]. If saline is not used, the photon laser beam is widely absorbed by contrast or blood, which leads to vapour bubble formation and damage to a blood vessel wall in a mechanism of trauma by intensive pressure wave pulses. When saline is infused into the vessel, the energy of laser radiation is weakened and bubbles are removed, which minimizes the risk of dissection and rupture of the vessel [1].

Indications and contraindications for the use of ELCA. There are several indications for the use of excimer laser, from which balloon-uncrossable and balloon-undilatable atherosclerotic lesions in coronary arteries are firstly indicated [1]. When a lesion cannot be crossed with a low-profile device, or when the balloon unsatisfactorily broadens with dilatation, ELCA can be adopted with a high success rate – 96% response in the case of non-calcified lesions. However, the usage of excimer laser in significantly calcified lesions, which are difficult to treat, can be somewhat less efficient – 79% response [4, 5]. In-stent restenosis (ISR), particularly diffuse, is also often described as an important indication for the use of excimer laser [1, 2, 4, 5, 6, 7, 8, 9]. The clinical study of 98 patients with 107 restenotic lesions showed that there was no significance in a trend towards a rarer need for target vessel revascularization at six months in favour of ELCA (21 versus 38% (p=0.083) [4]. However, it was established that lesions treated with ELCA, compared with balloon angioplasty alone, had a greater luminal gain and intravenous ultrasound cross-sectional area, with more intimal hyperplasia ablation [4]. Hirose et al. evaluated the effect of conducting ELCA before scoring balloon treatment for ISR lesions six months after treatment. In the study, recurrent restenosis after PCI in the ELCA group was developed in two lesions (16.7%) and in five lesions (45.5%) in the non-ELCA group [6]. In the ELCA group (12 patients), diameter stenosis increased to 40.3 ± 24.5% at six-month follow-up, and in the non-ELCA group (11 patients) this significantly increased to 60.4 ± 25.2% (p=0.04) [6]. Ishimoto et al., after about 29.8 months of follow-up after treatment of ISR, investigated whether the acute luminal gain in ELCA group (23 patients) was greater than in non-ELCA group (58 patients) in quantitative coronary angiography (1.64 ± 0.48 mm versus 1.26 ± 0.42 mm; p<0.001) [7].

Furthermore, stent under-expansion or under-deployed stent, aorto-ostial lesions, moderately calcified lesions, bifurcation lesions, large thrombus (intracoronary or intragraft, for example treatment of thrombotic saphenous vein graft lesions) are enumerated in the literature [1, 2, 4, 5, 7, 8, 10, 12]. Excimer laser was developed to improve the outcomes of conventional balloon angioplasty and its purpose was primarily restricted to saphenous vein graft, calcified and ostial lesions, total occlusions and lesions more than 20 mm in length, which are a very distinctive, hard to treat subset of lesions [10]. ELCA can be used when balloon inflation alone was insufficient to prepare the affected region, for instance in uncrossable, thrombotic, calcified, or other problematic lesions [2, 4]. In the study, ELCA was used significantly more often in the cases of main branch and ostial lesions, which had commonly weak clinical outcomes (55.6 versus 14.3%; p<0.0005) [2].

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ELCA is known as the only technique able to alter the underlying resistant atheroma by delivering energy to the abluminal stent surface without interrupting the structure of the under-expanded stent [4]. It was noticed in optical coherence tomography (OCT) that during treatment of the restenotic segment, ELCA ablates both the luminal and abluminal atherosclerotic lesions. This means that if the mechanism of vessel obstruction is in part stent under-expansion, the laser increases the probability of achieving greater stent expansion [4]. A reduction in neo-intimal material and the creation of a cleft/dissection plane extending into the media was shown in the OCT after ELCA in a treatment of ISR of the coronary artery. Laser tissue ablation allowed full stent apposition with a drug-coated balloon by disrupting the neo-intima and creating tissue planes [14]. In OCT after ELCA in the treatment of a severe saphenous vein graft lesion, great reduction in the atheroma burden was described. Despite the theoretical micro-particle generation, the laser interaction with tissue resulted in the creation of a fragile intimal surface as a mixture of white thrombus and fibro-atheroma [14]. In resistant and highly calcified lesions, the combined use of laser and rotablation (so-called RASER-PCI) is preferred, as well as using excimer laser in modification of the proximal chronic total coronary occlusion (CTO) cap to ease penetration with a wire during percutaneous coronary intervention [1, 2, 4, 5, 8]. ELCA can be successfully utilized to facilitate subsequent rotational atherectomy (RASER technique) and the application of an adequate stent in extensively calcified lesions. An excimer laser catheter requires a standard 0.014 inches diameter guidewire, and can be used to create a channel through the lesion [13]. This offers the possibility of exchanging guidewires after advancing through the whole lesion, which could not be crossed independently at the beginning of this intervention. Laser debulking is the only safe method to treat thrombus plus the calcified plaque both and cross such a balloon-uncrossable calcified thrombus laden lesion [13].

Laser ablation has the possibility to weaken or ablate the underlying restrictive lesion through the implanted stent endovascularly, which enables adequate post-dilation of the stent. Laser catheter can become trapped in stent struts, but in such cases it ablates tissue underneath the stent. A restrictive and superficially stented lesion might be changed significantly beneath the stent and be made potentially adequate for full stent expansion [15]. Although rotational atherectomy can be performed to treat the under-expanded stent, this technique is rarely used in this context [15]. Nevertheless, it has been described as a feasible treatment for stent under-expansion, as in the study by Fernandez et al. More confirmed efficacy of the RASER technique, i.e. the combination of the above-mentioned procedures, is described in the case of CTO with stent fracture and severe calcification, as in the report by Nakabayashi et al. [8].

When equipment is incapable to cross the resistant lesion or proximal cap despite attaining distal wire position in the treatment of CTOs, ELCA might be used. Another benefit is an ablative effect that is transmitted through the lesion structure, potentially weakening bonds between the constituent components of the CTO. The antithrombotic and platelet-suppressive effects of ELCA might decrease the number of thrombotic complications during disobliteration [4]. Excimer laser finds its application in the management of patients with acute myocardial infarction with ST-elevation,

improving myocardial salvage, especially when onset to balloon time (OBT) amounts below six hours and initial thrombolysis in myocardial infarction (TIMI) flow-0/1 [16]. ELCA is also useful in the removal of lead included in cardiac implantable devices, with low complication rates of such an approach simultaneously [17]. In spite of small number of clinical trials supporting the use of ELCA in acute myocardial infarction, excimer laser may be a beneficial device for the promotion of fibrinolysis, thrombus removal, platelet-stunning effects, and concomitant plaque debulking [4, 10]. In a preliminary study from China, the results indicated that ELCA could be safely and effectively used in the interventional therapy of ST- and non-ST-segment elevation acute myocardial infarction, as well as in unstable angina [18].

Excimer laser is considered as a safe and efficient technique. There are no absolute coronary contraindications for usage excimer laser in coronary angioplasty, except for lack of informed patient consent and unprotected left main coronary artery disease, which is actually stated as a relative contraindication [1, 4]. Moreover, acute angulation of more than 45° and coronary dissection are listed as other contraindications. Excimer laser should not be used when lesions in vessels present a diameter smaller than a catheter diameter [1]. ELCA is not indicated when there is a risk of a long length of subintimal guidewire positioning which might exist during hybrid PCI techniques for chronic total occlusions [4].

Laser safety. Usage of excimer laser has been proven in different studies to be a noteworthy and safe method of treatment. ELCA complications do not differ significantly from those encountered during standard percutaneous coronary intervention. In a study conducted by Hirose et al., the success rate of treatment for ISR lesions was 100%, both in the ELCA and non-ELCA group. Severe adverse events, e.g. myocardial infarction, cardiac death, and thrombosis in a stent, did not occur in either group [6]. Ichimoto et al. showed similar results. After comparison of ELCA- and non-ELCA groups, there was no cardiac deaths, no non-cardiac deaths, nor stent thrombosis in either group. Myocardial infarction was observed in one out of 23 patients (4.3%) from ELCA group and in two out of 58 (3.4%) patients from a non-ELCA group (p=0.85). Furthermore, target lesion revascularization was observed in five out of 23 patients (21.7%) from an ELCA group and in 15 out of 58 (25.9%) patients from a non-ELCA group (p=0.70) [7]. There is a risk of coronary artery perforation and bleeding because of contamination with contrast or a break in supplies of the saline flush which can produce excessive heat and increase the risk of vascular rupture [4, 10]. Abrupt vessel closure is also mentioned as a potential adverse event of usage of the laser [1].

In a study by Ocaranza-Sánchez et al. the success rate in the treatment of in-stent restenosis during excimer laser coronary atherectomy (16% of the total application) without further complications was 100% [12]. Despite the fact that the first excimer laser devices did have a significant complication rate (mean coronary perforation rate from 0.5% – 8%, dissection rate 7%), several advancements, for instance the use of small catheters or the use of a flushing technique with normal saline to eliminate any remaining contrast or blood, have resulted in decreasing the rate [1, 10, 18]. In the described study, the overall complication rate was 3.2% due to an isolated case

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of perforation of coronary artery by the guidewire before using the laser.

In an Italian study, excimer laser was successfully applied in 90 out of 96 different complex coronary lesions; procedural success was obtained in 88 lesions, and clinical success in 87 lesions. Perforation, major side-branch occlusion, spasm, no-reflow phenomenon, dissection or acute vessel closure, were not observed. It is worth mentioning that increased laser parameters were used for 49 resistant lesions without any complications [5].

Yoshida et al. analyzed the course of ELCA in 399 patients with 415 lesions in coronary arteries, in 85% related to acute coronary syndrome. Side-effects in the form of artery perforation was identified in eight patients (1.9%) [10]. The angulated bifurcation lesion may be a significant factor to ELCA-induced vessel perforation [10]. Most perforations lead to pseudoaneurysmal changes after PCI in several weeks. This why an early control angiogram ought to be considered [10].

During the procedure, all medical staff and the patient are obliged to wear eye protection to prevent damaging the cornea and the retina by absorption of the radiation from the therapeutic, invisible laser (CVX-300 safety glasses). Moreover, doors should be locked and all windows covered to minimizing the risk of damaging the eyes of bystanders [1, 4].

ELCA in comparison to drug-eluting balloon. Drug-eluting balloons (DEB)/drug-coated balloons (DCB) are angioplasty balloons covered with an anti-restenotic drug (e.g. paclitaxel) and inserted into the narrowed or occluded coronary artery or their branches during PCI, mainly after in-stent restenosis. However, they are not well suited for vessels of small diameter and for ostial lesions, which begin five millimeters from the stem of major coronary arteries [2]. In a study conducted in Japan, patients underwent excimer laser coronary angioplasty when balloon inflation alone was unable to treat problematic lesions, such as thrombotic, calcified or non-crossable ones. All patients had *de novo* artery lesions. While ELCA was remarkably more often used in the cases of ostial lesions and lesions of the circumflex, right coronary, left anterior descending arteries, or high lateral branch, the study showed similar efficacy to standard pre-dilation methods [2]. The study confirmed the safe usage of ELCA prior to paclitaxel drug-eluting balloon angioplasty for treating *de novo* lesions in coronary arteries.

Nakabayashi et al. presented the case of a patient with a second in-stent restenosis of the proximal lesion in the left circumflex coronary artery which occurred 15 years after insertion of a metal stent due to anterior myocardial infarction, and after a year of treatment by drug-coated balloon [8]. Because of a second ISR within a short time, it was decided to use ELCA to eliminate the narrowing. The lesion was dilated by using a scoring balloon with low pressure, which afterwards was filled with the drug-coated balloon. No renewed in-stent restenosis at the lesion was observed in angiography after eight months [8]. ELCA can be an effective complement to drug-eluting balloon therapy in recurrent stenosis.

Miyazaki et al. compared in OCT the results of neointimal modification in patients with in-stent restenosis before DCB treatment with excimer laser coronary atherectomy, plus scoring balloon predilation versus scoring balloon alone [9]. Diffuse restenosis and percent diameter stenosis after PCI

were more frequent in the ELCA group; however, changes in the minimum stent cross-sectional area at follow-up and after PCI showed a significant decrease in this group [9]. The modifications in the neointimal area, late lumen loss and binary restenosis were not significantly different between the ELCA and non-ELCA groups. Comparable rates at one year were shown in target lesion revascularization [9]. It was concluded that ELCA had a probable benefit concerning lesion modification for diffuse restenosis, even though ELCA before drug-coated balloon treatment may partly offset the suppression of neointimal proliferation due to a declined change in the stent and lumen [9].

Another study confirming that excimer laser coronary angioplasty and drug-eluting balloon may be considered as an alternative treatment for ISR was conducted by Ambrosini et al. The multi-centric case-control study compared the angiographic and clinical outcome of percutaneous transluminal coronary angioplasty with excimer laser coronary angioplasty and drug-eluting balloon. The target group consisted of 80 patients with ISR subjected to a nine-month clinical and a coronary angiography follow-up. As a result, a long-term success was achieved in 91% of the patients [19].

Excimer laser also has a vital application in the treatment of coronary in-stent restenosis with peri-stent calcium. In a study by Lee et al., 81 patients with ISR, stent under-expansion and peri-stent calcium >90° were evaluated by comparing lesions treated with or without ELCA. The assessment was possible thanks to OCT imaging performed before and after PCI. As a result, the following significance was obtained in case of excimer laser coronary angioplasty: more calcium fracture (ELCA: 61%, non-ELCA: 12%; p<0.01), larger final minimum lumen area (ELCA: 4.76 mm2 [3.25, 5.57], non-ELCA: 3.46 mm2 [2.80, 4.13]; p<0.01), and a larger previously implanted stent area (ELCA: 6.15 mm2 [4.83, 7.09], non-ELCA: 4.65 mm2 [3.84, 5.40]; p<0.01) [20].

If even after excimer laser application, stent expansion is difficult to achieve, ELCA can be used with simultaneous contrast injection [21, 22]. This approach allows improvement of stent under-expansion in non-compliant calcific lesions. During lasing in combination with contrast medium administration, high-magnitude mechanical stress waves are generated and may influence the vessel wall contributing to dissection or perforation. Alluding to these possible complications, this procedure must be performed within the stent, using only catheters with a diameter of 1mm. Consequently, it enables avoiding macro-bubble formation which is a potential factor increasing the risk of vessel wall trauma, especially by the strong photomechanical effect involving expansion of the mentioned bubbles [21].

Excimer laser in non-dilatable and non-crossable lesions, including CTO. Non-crossable and non-dilatable lesions are of vital concern in percutaneous coronary intervention, often contributing to technical failure, incomplete revascularization and complications. In a study by Fernandez et al., from among 6,882 patients undergoing PCI, 58 experienced balloon failure treated subsequently with ELCA. In this group of patients, 36 cases were due to non-crossable lesions and 22 due to non-dilatable lesions, including 16 cases and two cases of CTO, respectively, in each subgroup. The overall procedural success of ELCA use was achieved in 53 cases (91%), and in 76% of cases ELCA did not require any

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additional atherectomy devices to successfully perform the procedure [23].

A success rate of ECLA in CTO presented by the Rawling et al. amounted to 86–90%. It is underlined that antithrombotic and platelet-suppressive effects of ELCA decrease the risk of thrombotic complications [2]. In the two CTO cases among 22 cases of balloon expansion failure, both were successfully treated with ELCA used alone, while in 16 CTO cases among 36 cases of failure to cross, in 13 cases (81%) excimer laser coronary atherectomy used alone achieved procedural successful outcomes. Minor complications were observed in one case in each group (patients with failure of balloon to cross and failure of balloon expansion in the context of CTO), but not due to use of the laser [23]. Similar data was presented by Mohandes et al. in a study of six patients with chronic total (100%) and functional occlusion, successful dilatation using excimer laser were achieved in five of the six patients (83.3%) [24].

In a study by Fernandez et al., in patients with failure of balloon expansion not related to CTO, no complications associated with the performed procedure were observed. Laser energy was delivered with 9.5±7.8 trains, maximum fluence of 75.0±8.9 mJ/mm2 and frequency of 70.0±17.8 hertz. Nevertheless, in patients with failure of the balloon to cross not related to CTO, a Type III coronary perforation associated with the ELCA catheter was observed in one case. Laser energy was delivered with 15.8±7.3 trains, maximum fluence of 76.8±7.5 mJ/mm2 and frequency of 73.7±15.0 hertz [23].

Laser in angioplasty of peripheral arteries. In-stent restenosis in peripheral arterial disease (PAD) is a significant difficulty in selecting an appropriate treatment procedure. However, achievements in endovascular stent technology have overcome the limitations imposed by conventional percutaneous transluminal balloon angioplasty in patients with PAD [25]. The most important difficulties include elastic recoil, residual stenosis and flow-limiting dissection.

In a study by Hajibandeh et al., assessing the outcome of particular treatment strategies in PAD, four randomized controlled trials were analyzed. Two targets were set as outcome measures: recurrent ISR and freedom from target lesion revascularization. In the case of excimer laser atherectomy plus standard balloon angioplasty compared to standard balloon angioplasty, after six months, a higher freedom from target lesion revascularization was observed [25].

Lui et al. evaluated the clinical data of 17 patients with chronic obstructive femoropopliteal arterial disease. The aim of the study was to evaluate the safety and feasibility aspect of excimer laser atherectomy (ELA) in combination with drug-coated balloon angioplasty in the group of patients. The following information was taken into account: 12-month primary patency rate, technical success rate, procedural success rate, bailout stenting rate, target lesion revascularization and major adverse events. The occlusion length was 23.3±8.9 cm; technical success rate – 100%, procedural success rate – 88.2%. Bailout stenting was used in five of the 17 patients (29.4%) and the 12-month primary patency rate amounts to 82.4%. In two patients, adverse effects were reported – distal embolization (1 case) and flow-limiting dissection (one case) [26]. Overall, ELA combined with DCBA (DCB angioplasty) was recognized as a safe and feasible first-line endovascular procedure in patients with chronic femoropopliteal arterial disease [26, 27, 28].

Similar conclusions to Lui et al. were drawn by Geach [28] who compared freedom from target lesion revascularization at six months follow-up, procedural success, target lesion revascularization at 12 months follow-up, and lesion patency in two groups of patients: those undergoing ELA with percutaneous transluminal angioplasty (PTA) (117 patients) and undergoing only PTA (56 patients). The safety end-point related to major adverse effects over 30-day follow-up was also taken into account. ELA with PTA proved to be superior to PTA alone, both for the efficacy as well as safety outcomes [28].

Robotically performed excimer laser coronary atherectomy. In two cases presented by increasing [11]. This method found application in complex high-risk interventions, left main interventions, and peripheral interventions [29, 30, 31]. It is worth mentioning that the first use of ELCA during robotic PCI with a second generation CorPath GRX robotic system was described in this study. Such a new approach enabled guided catheter manipulation and facilitated the insertion of stents through more tortuous lesions [32]. However, further research assessing the safety and effectiveness aspects of the combined robotic and laser atherectomy is required [11]. Other studies have also analyze the safety and efficacy of the second generation CorPath GRX robotic system; however, the role of the excimer laser was not taken into account [29, 30].

Mahmud et al. claim that among 315 patients with complex coronary disease who underwent 334 PCI procedures, technical success with R-PCI (robotic-assisted-PCI) was 91.7%, while the rate of major adverse cardiovascular events amounted to 0.93% [29]. Furthermore, the pioneer report by Mahamaid et al. [30] confirmed the feasibility of robotic PCI for unprotected left main stenosis. In a group of six subjects with unprotected left main stenosis, only two underwent PCI with Impella percutaneous left ventricular assist device. In each case, residual stenosis in angiography amounted to 0%

CONCLUSIONS

ELCA is a feasible tool in catheterization simplifying the management of patients with uncrossable or undilatable lesions. Furthermore, it adds to the useful armamentarium in interventional cardiology as stents remain under-expanded after inserting.

Excimer laser coronary angioplasty and the drug-eluting balloon are deemed as alternative treatment for in-stent restenosis. DCB alone treatment was inferior to ELCA in combination with DCB treatment. Pre-treatment using ELCA may influence the pressure of the scoring balloon – in many cases decreasing it significantly.

ELCA is reported to be a safe and useful technique for the treatment of ISR associated with a relatively low recurrence of restenosis.

Perforations / dissections are the main side-effects of excimer laser use, mainly due to angulated bifurcation lesions. However, some improvements including flushing technique with normal saline and the use of smaller diameter catheter has reduced the complication rate.

Further research is required to assess the usefulness of this procedure, involving larger populations and longer longitudinal follow-up periods.

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