Italian registry of excimer Laser for percutaneous coronary intervention

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Electromagnetic Radiation Basics

Inside an Atom

1. Electron is pumped to a higher energy level.
2. Pumping level is unstable, so the electron quickly jumps to a slightly lower energy level.
3. Electron relaxes to a lower energy state and releases a photon.
4. Light and an electron in an excited energy level...
5. ...produces two photons of the same wavelength and phase.
6. Amplification
   - Mirror reflects photons.
LASER

Light Amplification by Stimulated Emission of Radiation
Excimer Laser
(Excited Dimer Laser)

Requirements
- Laser Medium
- Excitation
- Optics - High Reflector Mirror (HR)
  - Output Coupler Mirror (OC)
Lasers and the Light Spectrum

Ultraviolet vs. Infrared

Spectrum of Light

- 248 nm KrF laser
- 193 nm KrF laser
- 351 nm XeF laser
- 308 nm XeCl laser
- Excimer (CVX-300)
- Excimer (LASIK)
- Ho:YAG
- CO₂
UV Lasers (10 to 400 nanometer) are unique because they...

- Carry photon energies high enough to break molecular bonds (covalent)
- Avidly absorb in biological tissue
- Have shallow absorption depth, <100 microns
  - Reduces energy required to cut
  - Reduces collateral tissue effects
- Are typically pulsed Lasers
  - Pulse width of 5 to 200ns
  - SPNC’s ~120ns
## Absorption Depth & Mechanism

<table>
<thead>
<tr>
<th>Laser</th>
<th>Wavelength (nm)</th>
<th>Absorption Depth (mm)</th>
<th>Absorption Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>XeCl</td>
<td>308</td>
<td>0.05</td>
<td>Protein - Lipids</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1060</td>
<td>2.0</td>
<td>Protein - Water</td>
</tr>
<tr>
<td>Dye</td>
<td>480</td>
<td>0.5</td>
<td>Protein</td>
</tr>
<tr>
<td>Argon</td>
<td>488</td>
<td>0.5</td>
<td>Protein</td>
</tr>
<tr>
<td>Ho:YAG</td>
<td>2060</td>
<td>0.3</td>
<td>Water</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1320</td>
<td>1.25</td>
<td>Water</td>
</tr>
</tbody>
</table>

### Effect on Biological Tissue

- **CO2**
- **Argon**
- **Ho:YAG**
- **UV Laser**
# Mechanisms of Action

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photochemical</td>
<td>Breaking molecular bonds</td>
</tr>
<tr>
<td></td>
<td>UV light pulse hits tissue for 135 billionths of a second (135ns); the duration of the laser pulse</td>
</tr>
<tr>
<td></td>
<td>50 microns penetration</td>
</tr>
<tr>
<td></td>
<td>Billions of molecular bonds fractured per pulse</td>
</tr>
<tr>
<td></td>
<td>After 135 billionths of a second, laser energy is not emitted</td>
</tr>
<tr>
<td>Photothermal</td>
<td>Producing thermal energy</td>
</tr>
<tr>
<td></td>
<td>Absorption vibrates the molecular bonds of the plaque</td>
</tr>
<tr>
<td></td>
<td>Vibration of bonds heats intracellular water</td>
</tr>
<tr>
<td></td>
<td>Water vaporizes, molecules break apart, therefore rupturing cells</td>
</tr>
<tr>
<td></td>
<td>Expanding vapor bubble forms in 100 millionths of a second (100 μs)</td>
</tr>
<tr>
<td></td>
<td>• 1000 times the duration of the actual laser energy emission</td>
</tr>
<tr>
<td>Photomechanical</td>
<td>Creating kinetic energy</td>
</tr>
<tr>
<td></td>
<td>Expansion and collapse of vapor bubble breaks down tissue</td>
</tr>
<tr>
<td></td>
<td>and clears by-products away from tip</td>
</tr>
<tr>
<td></td>
<td>By-products of ablation are water, gas, and small particles</td>
</tr>
<tr>
<td></td>
<td>Entire process time per pulse is 400 millionths of a second (400 μs)</td>
</tr>
<tr>
<td></td>
<td>• 4000 times the duration of the actual laser energy emission</td>
</tr>
</tbody>
</table>
**AMRO trial:** ELCA Vs.PCI in 308 pts with stable angina and coronary lesions longer than 10 mm: no difference between the two groups in death, myocardial infarction (MI), coronary surgical revascularization, or repeat coronary angioplasty after 6 months following the index procedure. 

**ERBAC trial:** 685 pts with complex lesions to excimer laser angioplasty(ELCA), conventional balloon angioplasty(PCI) or rotational atherectomy(RA); procedural success: RA 89%, ELCA 77%, PCI 80% (P=.0019). At 6 months of follow-up, revascularization of the original target lesion was performed more frequently in the rotational atherectomy group (42.4%) and in the excimer laser group (46.0%) than in the angioplasty group (31.9%, P=.013). 

**ELCA registry:** 3000 pts (non randomized) «Excimer laser angioplasty can be safely and effectively applied, even in a variety of complex lesions not well suited for percutaneous transluminal coronary angioplasty”
ELCA procedural success 90%.Complications included in-hospital bypass surgery (3.8%), Q wave myocardial infarction (2.1%) and death (0.5%). Coronary artery perforation occurred in 1.2% of patients (1% of lesions) but significantly decreased to 0.4% in the last 1,000 patients (0.3% of lesions). Angiographic dissection occurred in 13% of lesions, transient occlusion in 3.4% and sustained occlusion in 3.1%.

*Litvack et al , JACC, 1991; 23 (2): 323-9*
Times have changed...

Catheters: 1.4 - 1.7 - 2 mm

Excimer energy:
Wavelength 308 nm,
Pulse length 185 ns
Fluences: 30 to 60 mJ/mm²
Frequency: from 25 to 40 hertz
Lasing cycle: 5-sec on / 10-sec off
IN VITRO
Maximum generated power 1704 mW
Penetration capacity 0.26 mm/sec

Catheters: 0.9 - 1.4 - 1.7 - 2 mm

Excimer energy:
Wavelength 308 nm,
Pulse length 185 ns
Fluences: 30 to 80 mJ/mm²
Frequency: from 25 to 80 hertz
Lasing cycle: 10-sec on / 5-sec off
IN VITRO
Maximum generated power 832 mW
Penetration capacity: 0.59 mm/sec
New Xenon chlorine pulsed laser
Excimer Laser Coronary Angioplasty (ELCA)

Initial experience with a low profile, high energy excimer laser catheter for heavily calcified coronary lesion debulking: parameters and results of first seven human case experiences.

Novel Use of a High-Energy Excimer Laser Catheter for Calcified and Complex Coronary Artery Lesions

93% procedural success rate
86% clinical success rate

DERIST: Registry drug eluting balloon excimer laser coronary artery restenosis in stent treatment

ILARY: Italian registry of excimer laser for percutaneous coronary intervention

ELLEMENT: Excimer Laser LEsion Modification to Expand Non-dilatable sTents

LEONARDO: Prospective trial to examine outcome of high energy laser – facilitated coronary angioplasty on complex calcified and balloon resistant coronary lesions.

ELT-AMI: Excimer Laser vs Thrombus aspiration in Acute Myocardial Infarction
The initial use of old generation lasers in the 1980’s was hampered by the large number of complications (especially coronary dissections and perforations) related to the high quantity of heat delivered to the tissues.

Recently a new generation excimer laser was introduced in interventional practice: it produces laser beams with an ultraviolet wavelength and low release of heat ("cool laser" or cold laser).
Data collected by the Italian Society of Interventional Cardiology on the use of “laser angioplasty” in Italy, starting from the year 2007 show an increasing trend with about 1000 interventions carried out by the end of 2014.

In light of the increased use of the device, and due to its presumed greater safety compared to older generation lasers and its potentially therapeutic effects, this registry was set up to collect safety data, procedural efficiency and impact on outcome of excimer laser assisted PCI.
The ILARY registry aims to recruit all patients who underwent angioplasty with excimer laser (ELCA - Spectranetics) in Italian cath labs from 2007 to 2013 (retrospective period) and from 2014 onwards (prospective period).

Being an all-comers registry it has no specific exclusion criteria.
INDICATIONS
(challenging lesions: tough or containing thrombus)

- Chronic Total Occlusions (CTO)
- By-pass graft occlusion/degeneration
- Calcified and fibro-calcified lesions
- Balloon failure
- Stent dilatation failure
- In-stent Restenosis
- Ostial lesions and small vessel lesions
- Long lesions and lesions in tortuous vessels
- Bifurcational lesions
- AMI
The primary end-points of the study are to evaluate:

- **Procedural success**
- **Incidence of in-hospital complications**

**Procedural success** will be defined as the final reduction of lumen diameter stenosis <50% with TIMI 3 flow and no major in-hospital complications.

**In-hospital complications include** death, emergency CABG, development of new Q-waves caused by myocardial infarction, target vessel revascularization, dissection and perforation.

**Perforation** is defined as the spilling and persistence of contrast medium outside the vessel with or without associated clinical complications.

**Dissection** is considered a complication if it is associated with clinical consequences (death, myocardial infarction, troponin elevation or the need for emergency CABG).
ILARY Registry
ITALIAN CENTERS
well balanced geographic distribution

Genoa
Milan
Turin
Brescia
Udine
Venice
Ferrara
Ancona
Avellino
Potenza
Catanzaro
Catania
Siracusa
Florence
Turin
Genoa
Rome
Latina
Naples
Palermo
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650 patients treated with ELCA
650 pts

ELCA Indications include:

- AMI: 37.7%
- IN-STENT RESTENOSIS: 11.5%
- CALCIFIED LESIONS, CTO: 15.8%
- UNDER-EXPANDED STENT: 7.4%
- BY-PASS GRAFT: 8.2%
- BALLOON FAILURE: 19.4%
650 pts
Treated Coronary Arteries

- Left Main Coronary Artery - LMC
- Left anterior descending Artery - LAD
- Right Coronary Artery - RCA
- Circumflex Artery - LCx

17.60% 3.40% 43% 36%
650 pts
Laser Catheter Size
(small size 80%)
650 pts
Laser Energy
(low-medium level 60%)

- Low: 45%
- Medium: 25%
- Medium/High: 15%
- High: 15%

Legend:
- 45/25
- 60/40
- 80/60
- 80/80
Results

- PROCEDURAL SUCCESS: 97.7%
- Perforation: 0.15% (1 pt)
- Dissection: 3.53% (23 pts)
- Urgent CABG: 0.30% (2 pts)
- Death: 0.15% (1 pt)

650 pts
17 patients

- 6 Undilatable fibrocalcified long lesions
- 4 Ostial calcified lesions
- 3 ISR
- 4 Under-expanded stents

Failure:
none

Complications:
1 long dissection of LAD coronary artery requiring multiple stent implantation and IABP assistance
1 acute thrombosis due to heparin resistance
Clinical Case

- B.S. male, 81 y

- In December 2012, SCA NSTEMI -> complex coronary multivessel disease -> triple CABG: LIMA to LAD, one graft to the postero-lateral branch and one graft to the intermediate artery

- In February 2014, unstable angina -> Cath Lab
Coronary angiography

Right coronary: thin, diffuse atherosclerosis

LIMA to LAD open
Saphenous veins closed
Coronary angiography

Calcific and tubular critical stenosis (90%) on ostium Cx, slow flow

Calcific and tubular critical stenosis (90%) on ostium intermediate
Laser assisted angioplasty

SPECTRANETICS ELCA 0.9-mm excimer laser catheter.

Lesion on Cx crossed with the laser
80 mJ/mm²/80 Hertz

Lesion on intermediate crossed with the laser
60 mJ/mm²/40 Hertz
Laser assisted angioplasty

After debulking

Kissing stents
Laser assisted angioplasty

Final result
What we learned from this Registry:

- The laser is effective in almost all complex coronary lesions
- It can be used in all branches including the left main coronary artery
- The most commonly used laser catheter is the 0.9 mm one
- It is essential to vary the amount of energy according to the type of lesion to be treated
- The risk of vessel perforation is very low (0.15%)
This Registry suggests that **laser coronary angioplasty is a simple, safe and effective technique for the management of complex coronary lesions.**

Furthermore, **higher laser energy** levels delivered by this catheter **improve the device performance without increasing complications.**

**The most commonly used laser is the 0.9 mm catheter** regardless of the caliber of the vessel; it allows to **easily cross any lesion and to obtain enough debulking to successfully perform PCI.**