Transmyocardial Laser Revascularization

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What is TMR?

- TMR is used to improve blood flow to heart muscle tissue (myocardial tissue).
- This is done using a laser to create small channels in the heart’s muscle to improve blood flow.
- It is used to treat angina, which is chest pain caused by a lack of oxygen to the heart’s muscle tissue.
Angina

- Angina is caused by a lack of oxygen-rich blood in the heart’s muscle, often as a result of plaque.
- This can be corrected with angioplasty but success is not guaranteed.
- TMR is used if Angina persists and cannot be treated with medicine.
Idea Behind TMR

- To use create channels in the heart to stimulate angiogenesis.
- The procedure has been likened to transforming the human heart into one resembling that of a reptile
Procedure

- TMR requires a small opening in the chest to be performed.
- It is often done in conjunction with bypass surgery so no additional opening is required.
- The surgeon uses the laser to create 20 to 40 1mm holes in the wall of the heart.
- Bleeding is reduced by the surgeon’s finger after the holes are created.
- TMR alone takes only 10-15min.
Procedure
Medical Results

- 80-90% of patients who had TMR experienced significant improvements (over 50%) within one year of the operation.
- Many people report immediate relief after the surgery.
- The procedure has been shown to improve quality of life but does not appear to increase life expectancy.
The $\text{CO}_2$ Heart Laser 2

- The $\text{CO}_2$ Heart Laser is a 1000watt laser with a computer synchronized pulse system.
- It was developed by PLC Medical Systems.
- It is specifically designed for TMR.
- Its user interface is a “user-friendly touch screen.”
- It is FDA approved.
CO$_2$ Lasers

- Developed at Bell Labs in the 1960s by Kumar Patel.
- Uses CO$_2$, N$_2$, H$_2$, and sometimes Xe as the active laser medium.
- Output wavelengths range from 9.4 to 10.6 $\mu$m.
- Can output into the GeW range.
CO$_2$ Laser Build

- A tube is filled with the active laser medium.
- The pressure inside the tube is lowered by vacuum pump so current can be run through it at a lower voltage (10’s of kV!)
- Air or water, in high powered lasers, is run over the tube to dissipate heat.
Useful Properties of CO$_2$ Lasers

- They are the highest powered continuous-wave lasers available.
- They have high absorption and low scattering for water.
- This allows the channels to be made with little thermal damage to the nearby tissue.
- Reasonably priced.
Heart Synchronization

- In order to reduce risk of arrhythmia, the laser pulses only when the heart is not moving.
- This occurs when the heart is at its maximum expansion.
- The laser system uses ECG to monitor what the heart is doing.
Electrocardiography

- By using diodes placed on the skin the electrical activities of the heart can be measured.
- The diodes measure the electric potential across the body.
- Using this information one can see the current phase of the heartbeat.
Laser Synchronization

- Using ECG the system makes sure that the laser pulses between R and T waves.
- A rising edge detector senses a predetermined voltage for the ECG to generate a “marker pulse”.
- The marker pulse is synchronized with the trigger pulse and the firing pulse.
Schematic From *Heart-Synchronized Pulsed Laser System* US Patent
Schematic From *Heart-Synchronized Pulsed Laser System*

US Patent
Summary

TMR uses a high-powered CO$_2$ laser to create channels in the wall of the heart.

CO$_2$ lasers work by exciting CO$_2$, N$_2$, and other gases to produce coherent light. The CO$_2$ Heart Laser 2 is a 1000W model.

The Hear Laser 2 uses ECG to synchronize laser pulses.
Sources

- Patent on TMR: http://www.freepatentsonline.com/6053911.html?query=TMR&stemming=on
- American Heart Association: http://www.americanheart.org/presenter.jhtml?identifier=4782
- US patent on *Heart-Synchronized Pulsed Laser System*
- PLC page on the CO\textsubscript{2} Heart Laser 2: http://www.plcmad.com/Products-CO2-Technology.asp
- Wikipedia pages on: CO\textsubscript{2} Lasers, Angina, TMR, and ECG