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OKADA, MASAYOSHI

(Citation)
The Kobe journal of the medical sciences,32(5):151-161

(Issue Date)
1986-10

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/0100488740

Kobe J. Med. Sci. 32, 151/161, October 1986

ALTERNATIVE METHOD OF MYOCARDIAL REVASCULARIZATION BY LASER: EXPERIMENTAL AND CLINICAL STUDY

MASAYOSHI OKADA, HIROSHI IKUTA, KAZUTA SHIMIZU, HIROYUKI HORII, AND KAZUO NAKAMURA

Second Division, Department of Surgery
Kobe University School of Medicine

INDEXING WORDS

high energy CO_2 laser; myocardial revascularization by laser; A-C bypass; cardiac surgery; clinical application of laser

SYNOPSIS

The increased number of patients with coronary artery disease has been obviously recognized and several kinds of operations have been widely performed in Japan.[7] Especially, coronary artery bypass grafting (CABG) for these patients has been a popular surgical intervention.[2] Among these patients there are a few cases for whom CABG could not be carried out, because of diffuse stenoses and small caliber coronary arteries.

The purpose of this study was proposed to an alternative method of myocardial revascularization by high energy CO_2 laser for treatment in these severely ill patients with coronary artery disease. The feasibility of myocardial revascularization from the left ventricular cavity through channels newly created by laser was evaluated in this study.[8] This method was based on the phenomenon that the laser beam could produce fine laser holes and myocardial fibrosis would not occur even over the long term.[4, 5] There are many collateral channels between coronary arteries and

Received for publication : October 11, 1986
Authors' names in Japanese : 岡田昌義、生田 博、清水一太
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veins, or myocardial sinusoids in the myocardium (Fig. 1).[1, 17] Therefore, if laser holes in the myocardium were clearly produced, the ischemic myocardium could be apparently nourished by arterial blood from the left ventricular cavity through newly created channels as well as other collateral channels in the myocardium.

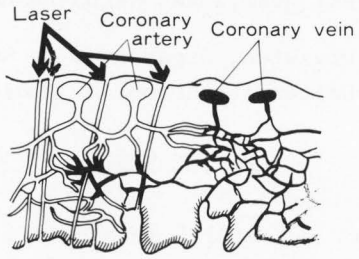


Fig. 1 Microcirculation in the myocardium.

METHOD AND MATERIALS

Thirty-six mongrel dogs weighing 7-15 kg were used in this study. General anesthesia was induced by administering pentobarbital (30 mg/kg) and respiration was maintained by volume controlled respirator. Acute myocardial infarction was produced by multiple ligations of the left coronary artery. On the other hand, laser holes (3-20 holes) were created under beating heart or temporary ventricular fibrillation in the area of the infarcted myocardium (Fig. 2).[9, 10] Laser output was 60-90 W, and irradiation time was

Fig. 2 Newly created laser holes in the ischemic myocardium.

0.12-0.25 sec and the focused beam was carefully utilized in this procedure. Subsequently, transmyocardial laser holes of 0.2 mm in diameter and 10 mm in depth were safely created. Electrocardiographic and hemodynamic changes as well as microscopic findings were evaluated before and after creation of the laser holes in the ischemic myocardium. Left ventriculography was performed and Indian ink was injected in the ventricular cavity to confirm the patency of the created myocardial channels.

RESULTS

Bleeding from the left ventricle occurred immediately after creation of the laser holes. But it stopped after light gauze compression.[11] By post-mortem coronary angiography and staining of nitroblue-tetrazolium after exstirpation of the heart avascular area was recognized in the 30-55% of the free wall in the left ventricle (Fig. 3). Five out of 36 dogs were observed as control group and were only subjected to coronary ligations. Four out of 5 control dogs died of refractory arrhythmias to medication and low cardiac output syndrome within 1 hour after multiple coronary ligations. The remaining 31 dogs were treated as an experimental group. Four out of 18 dogs in the initial group which were followed up in the long-term died 2 of heart failure, 1 of respiratory failure, 1 of bleeding. The other 14 dogs were sacrificed of various time intervals for microscopic examination. Follow-up periods ranged from 3 years to 24 hours after surgery. Arrhythmias and ST elevations on electrocardiogram and worsened hemodynamics following coronary ligations gradually improved after creation of laser holes in the left ventricle (Fig. 4).

Microscopic findings of newly produced myocardial channels were as follows. Carbonization (100 μ) of the myocardium was found in the first layer and coagulation necrosis (100 μ-200 μ) was observed in the second layer of the created laser channels. Patency of the channels was also seen 2 weeks or 2 months later microscopically (Fig. 5). Two months after laser surgery, the degree of carbonization and coagulation necrosis around the myocardial laser holes had gradully fallen.[3, 12] Fine laser holes in the inside of the left ventricular cavity could be seen 2 months after laser surgery though the area of the punctured myocardium did not indicate a marked fibrotic change (Fig. 6).

Recently, patency of the myocardial laser holes 3 years after surgery could be confirmed microscopically. Endothelial cells and carbon Indian ink particles were found on the surface of the channels[8] (Fig. 7). These findings suggested possible clinical applications due to the feasibility of the long-term patency of the newly created laser channels.

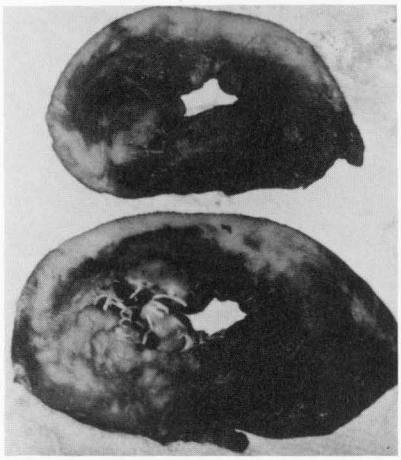


Fig. 3
Infarcted area stained with nitro-blue-tetrazolium ligation and myocardial.

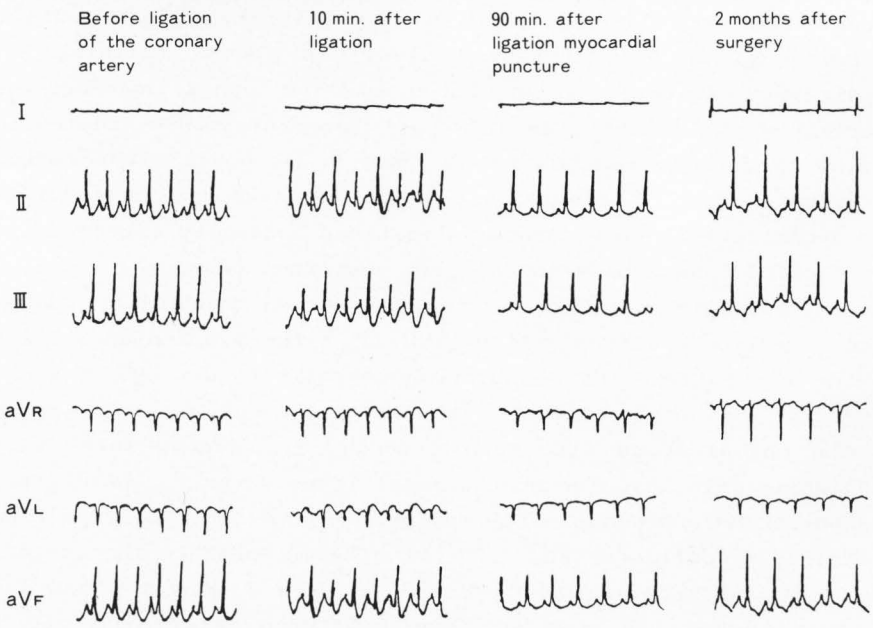
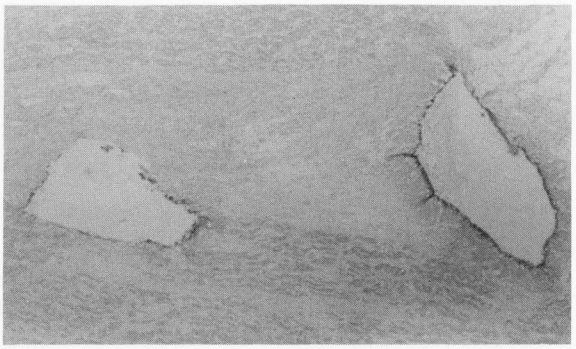
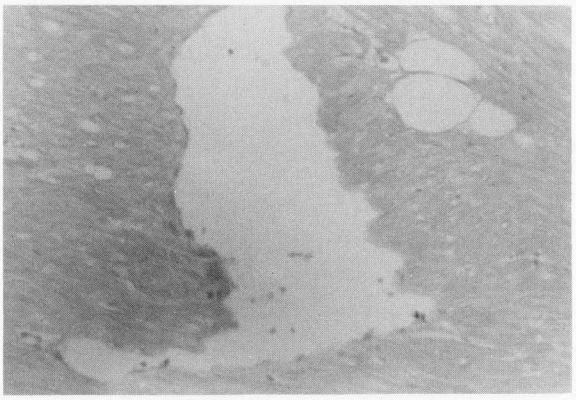


Fig. 4 ECG changes before and after creation by laser holes.



a) Soon after creation (Carbonization and coagulationnecrosis can been seen).



b) 2 months later (Carbonization and necrosis disappeared).

Fig. 5 Microscopic findings soon and 2 months after creation of laser channels.

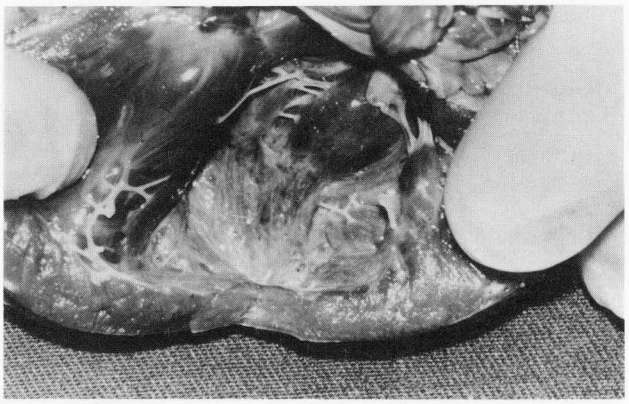


Fig. 6 Macroscopic findings 2 months after surgery.

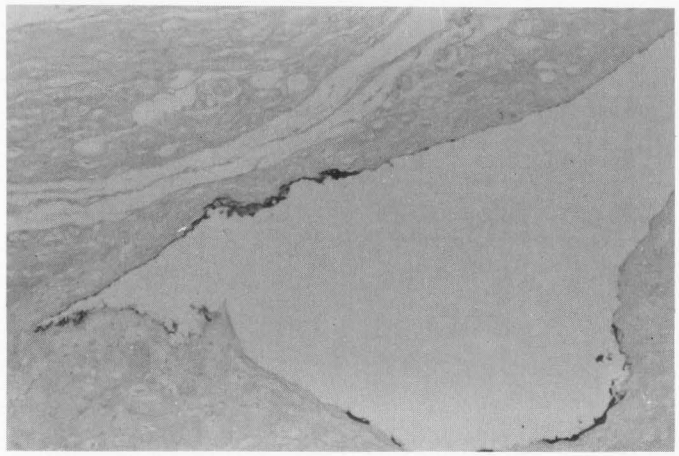
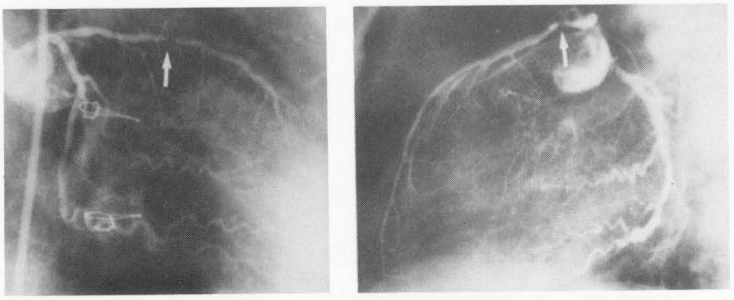


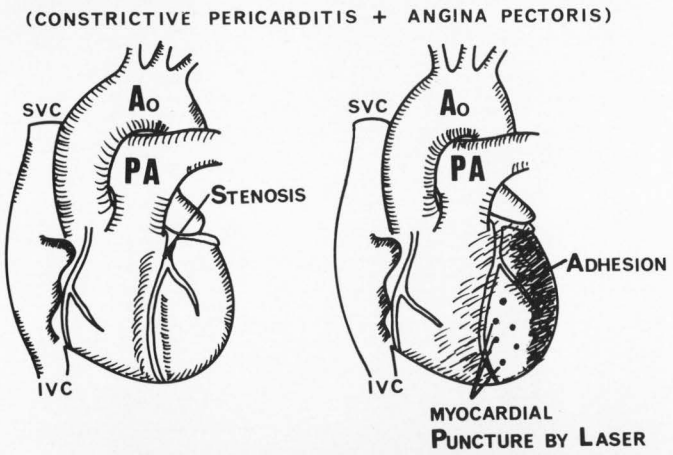
Fig. 7 Microscopic findings 3 years after creation of laser channels.

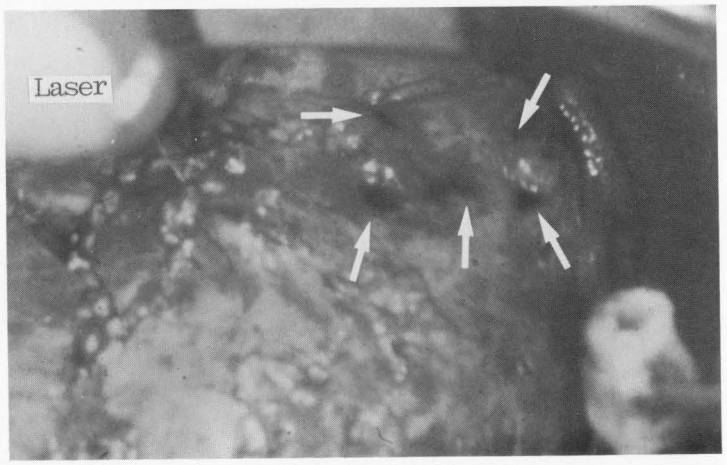
CLINICAL APPLICATION

On the basis of these satisfactory experimental results myocardial revascularization by CO_2 laser was employed for a 55 year-old male patient with constrictive pericarditis and severe anginal attack.[8] Pericardiectomy was done 7 years ago in this patient, because of heart failure due to severe constrictive pericarditis. At this time he was admitted to our clinic, because of severe anterior chest pain. On the coronary angiogram 90% of stenosis at the proximal portion of the left anterior descending artery (LAD) was clearly recognized (Fig. 8a). His operation was on 12th November, 1985. But, the patient did not undergo CABG, because LAD could not be detected due to extensive and strong adhesion of the epicardium. Therefore, a new method of myocardial puncturing by laser (output 85 W, irradiation time 0.2 sec) was utilized and six laser holes were made under fibrillated heart condition in the anterior wall of the left ventricle (Fig. 8b). The postoperative course was uneventful, except for initiation of IABP for a couple of days. Cardiac function had already improved 1 month after surgery (Fig. 9). He is now doing well without any complications 9 months after surgical intervention.



a) Preoperative coronary angiogram.





b) Operative findings.

Fig. 8 Clinical findings of myocardial revascularization by CO_2 laser (55 year-old male).

Cardiac catheterization data		
	Pre op.	Post op.
CI (l/min/m²)	2.74	3.40
LVEDVI (ml/m²)	88	106
LVESVI	18	25
LVEF (%)	80	78

ECG changes

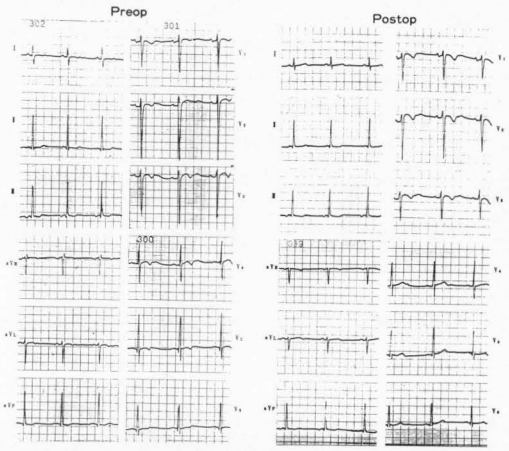


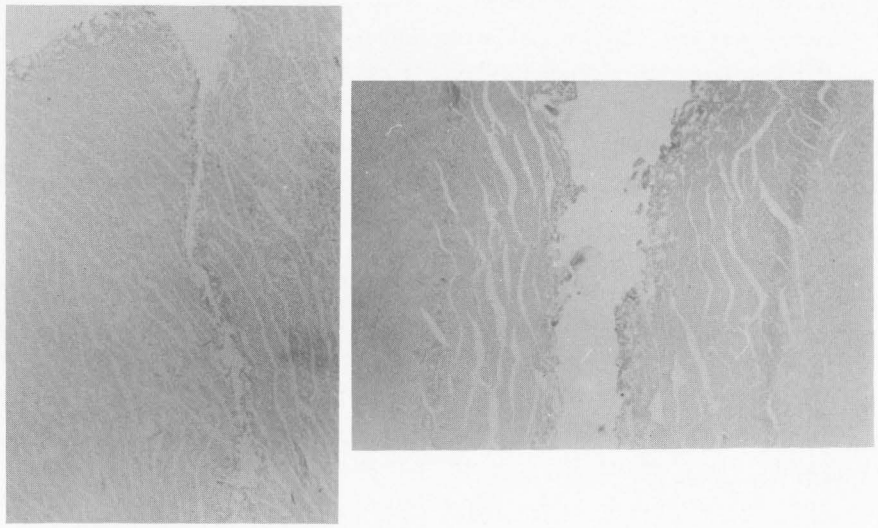
Fig. 9 Pre- and postoperative findings of a clinical case.

DISCUSSION

In the present study a new method of myocardial revascularization by high energy CO_2 laser was performed experimentally and based on its good results a clinical case was successfully experienced. The principle of this method is to supply additional arterial blood from the left ventricular chamber into the ischemic myocardium during the systole. Arterialized blood from the left ventricle was perfused into the ischemic myocardium and connected to the other collateral channels. These phenomena were clearly observed on ventriculogram and microscopic examinations.

Minimal tissue reactions in the laser holes were microscopically confirmed with good collateral channels over the long term.

On the contrary a marked tissue reaction was found by means of electrocoagulation (Fig. 10). Mirhoseini[6, 14] employed this punctured method for 8 patients with severe coronary heart disease. And he showed excellent results with this procedure concerning ventricular function and patent laser holes. The reason why the transventricular laser channels were patent even in the long term was that fine channels were made due to vaporizing the ischemic myocardium by laser. On the basis of these findings this procedure might be recommended in patients with coronary artery disease for whom CABG could not be carried out at all. In the microscopic observations 3 years after laser surgery, patency of the newly created laser holes was clearly recognized by histological examinations. On the basis of these findings, long-term patency of the laser channels could be expected and further clinical application could be considered.[8] An experimental method that supplies arterial blood from the left ventricle into the ischemic area of the myocardium by means of needle puncture has been reported by Sen[16] and other authors since 1965.[15] However, no successful results have been obtained in this field, except for Mirhoseini's report using a laser. Our[13] clinical successful case was the second report following that of Mirhoseini.



a) Laser (Output 80 W). b) Electrocoagulation (Output 80 W).

Fig. 10 Comparisons of microscopic findings by laser and electrocoagulation.

CONCLUSIONS

1. Transventricular puncture could be created by high energy CO_2 laser. A high energy output laser exceeding 80 W was necessary for the thickened myocardium more than 10 mm.
2. Minimal tissue reaction was observed microscopically in the laser holes of the left ventricle.
3. The feasibility of long-term patency of the new channels could be recognized even 3 years after surgery.
4. On the basis of these excellent findings, myocardial puncturing by laser might be clinically recommended in suitable candidates with severe coronary artery disease.

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