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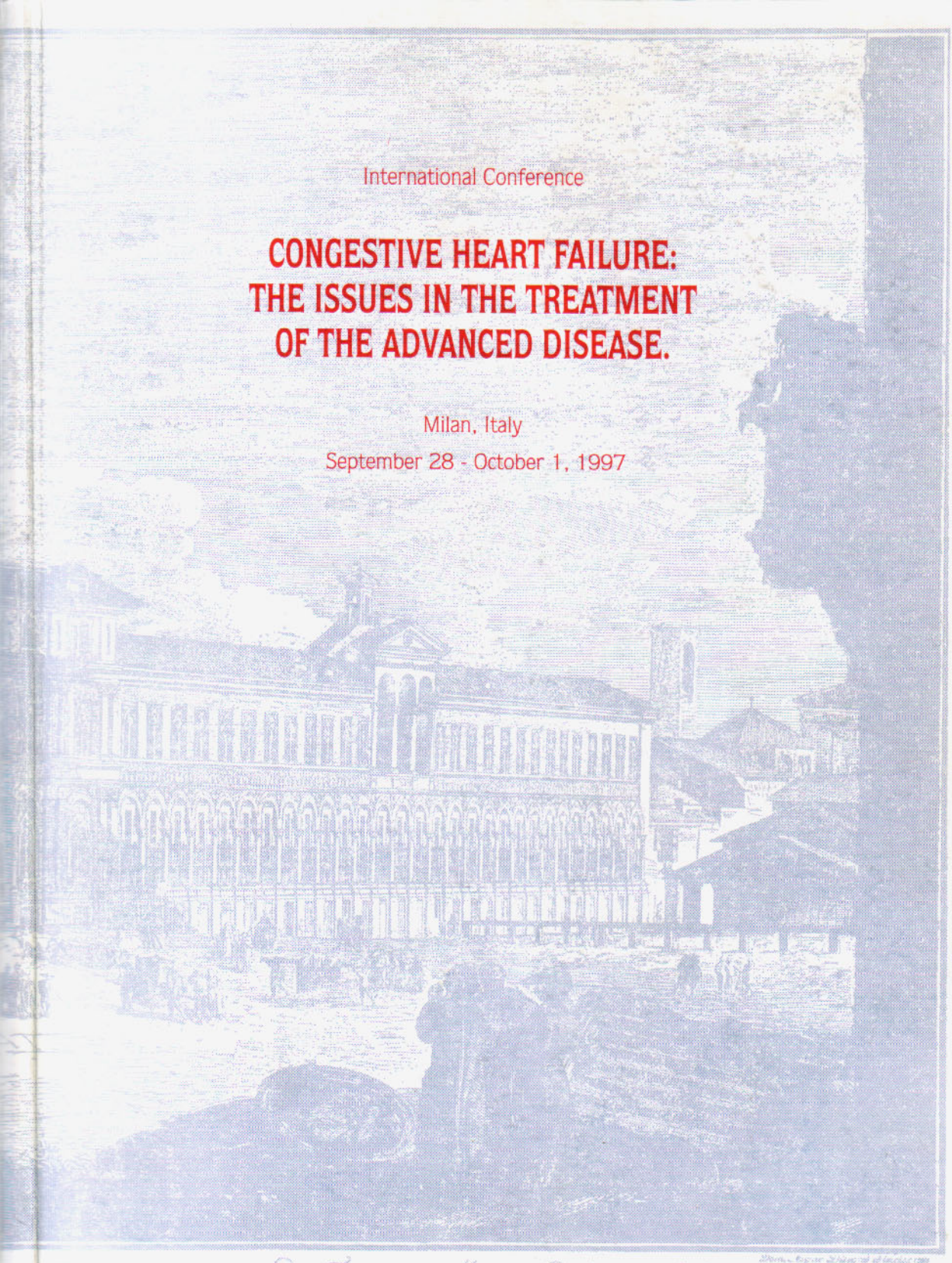

TRANSMYOCARDIAL LASER REVASCULARIZATION

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Abstract

Surgery for coronary artery disease (CAD) is possible in the presence of viable peripheral coronary arteries. When distal coronary branches are involved by atherosclerosis, traditional bypass surgery is not feasible.Transmyocarial laser revascularization (TLMR) is an alternative technique that works through the connections between cardiac chambers and the microvasculature of the myocardium: creation of 1-mm transmural cardiotomies should improve myocardial perfusion. Between February 1996 and March 1997, 13 patients (10 male, 3 female; mean age 67.3 ± 5 years) with CAD (mean number of diseased vessels 2.4), angina (mean CCS class 3.5 ± 0.5), mean ejection fraction 48 ± 14 and viable myocardium, detected by nuclear scans, in segments without graftable coronary arteries, underwent TMLR. Nine patients also underwent coronary bypass (CABG; mean number of bypassed vessels 2.0) on the beating heart without extraxorporeal circulation.

Two patients died (15.4 %). Postoperative inotropic support was used in most cases. At a mean follow-up period of 13.2 months, all remaining patients are alive (5 angina free, 4 in CCS class 1, 2 in CCS class 2).

We believe that TMLR can be considered an effective means to treat angina pectoris refractory to medical therapy in patients with coronary anatomy unsuitable for CABG.Transient myocardial dysfunction occurs in most patients postoperatively; consequently patients should be accurately investigated for preoperative contractile impairment to assess surgical risk.

Introduction

Traditional coronary revascularization (CABG) is feasible in the presence of coronary segments of adequate caliber and run-off, distally to critical stenoses. In the absence of such conditions, transmyocardial laser revascularization (TMLR) has recently been proposed as an alternative procedure. This technique is based on the presence of direct communications (arterio-sinusoidal vessels) between the coronary circulation an the cardiac chambers as demonstrated in antomical studies by Vieussens [1], Lancisi [2] and Wearn [3]. The similarity between the arterio-sinusoidal vascular and capillary walls, and their distribution indicate the possibilty of myocardial perfusion directly from the cardiac chambers [3]. Since 1965 Sen and others proposed the feasibility of myocardial revascularization by creating channels 1 to 2 mm in diameter by means of needles [4-11]. Histologic examination of myocardial tissue subjected to this treatment demonstrated patent channels for periods longer than 8 weeks, with a better tolerance to an ischemic insult caused by surgical ligation of the left anterior descending coronary artery. However, such channels tend to become occluded with time due to fibrin deposits, as shown by Pifarrè [12,13]. In 1981 Mirhoseini was the first to apply laser technology to create such channels for myocardial revascularization.

Patients

Between February 1996 and March 1997, 13 patients with coronary artery disease (CAD) underwent TMLR at our Institution; in 9/13 cases CABG on the beating heart was also performed. All patients had angina CCS class 3 or 4 refractory to maximal medical therapy, two or three-vessel CAD at angiography, and at least one ischemic segment of the left ventricle (anterior, lateral, inferior or posterior) without any graftable coronary branch. Patients' clinical profiles are listed in table 1.

Methods

Preoperatively all patients underwent a Tc99 MIBI rest-stress perfusion scan to identify myocardial ischemic segments perfused by ungraftable coronary arteries. A left anterior thoracotomy was used in patients treated by TMLR alone and a standard median sternotomy was performed when CABG was associated with TMLR. Cardiopulmonary bypass was never used. TMLR was performed after CABG in combined procedures. TMLR was accomplished using a carbon dioxide laser system (The Heart Laser ™, PLC Medical Systems, Inc., Milford, MA, USA). Bleeding from the epicardial entry site of the channels generally ceases spontaneously after a few minutes; only in rare instances is an additional stitch required to acheive hemostasis [15]. The number of holes to be created depends on the extension of the segment to treat by TMLR: each tranmyocardial channel can provide adequate perfuion to approximately 1 cm^2 of myocardial tissue [16]. About 15 to 20 channels are required for revascularization of the territory supplied by the left anterior descending coronary artery, while 8 to 10 suffice for that of the circumflex and 4 to 6 for the posterior descending.
To limit edema caused by the laser beam and its consequences on myocardial contractility, hydrocortisone (12.5 mg/Kg), furosemide (1 mg/Kg) and dopamine are used during the operation; an intraaortic ballon is used when indicated and inotropic support is maintained during the first 24 hours postoperatively; furosemide (50 mg/day) is continued for 15 days.

Results

Intraoperative data are summarized in table 2. A mean of 13 channels were performed in each patient. In 3 cases additional stitches on the epicardium were necessary to control bleeding (4-0 polypropylene). A mean of 2.0 coronary vessels were bypassed in patients who underwent associated CABG. The internal thoracic artery was used in 8 patients.

Postoperative results are listed in table 3. Three patients treated by TMLR alone required aortic ballon couterpulsation (in 2 of these, mechanical support was started preoperatively). CK-MB peak levels were 25.7 ± 40.4 U/L. In the immediate postoperative period 5 patinets showed ECG alterations. Mean stay in the intensive care unit was 2.5 days.
Two patients died. A 70-year-old woman with severely depressed ventricular function died of multiorgan failure and in a 75-year-old man death followed pulmonary infection. The postoperative course of all survivors has been free of major complications.
At a follow-up period of 11.5 ± 4.1 no deaths or myocardial infarctions have been recorded. Mean CCS class is 0.5.

Discussion

TMLR is a new technique to acheive revascularization in patients with CAD who are not candidates for ballon angioplasty or CABG. Channels created by the laser beam have inner endothelial surfaces and have been shown to be patent more than 2 years after the procedure [17]. In 1988 Mirhoseini reported the first clinical series (12 patients) treated by TMLR combined with CABG [18-20], showing increased perfusion in areas treated with TMLR, with follow-up ranging from 3 to 32 months. In 1994 Cooley and Frazier proposed TMLR on the beating heart in patients with peripheral CAD, demonstrating for the first time in man the patency of transmyocardial channels in a patient who died 3 months after operation [21]. The same authors showed a significant improvement of anginal symptoms and myocardial perfusion in a series of 21 patients treated with TMLR (preoperative CCS class 3.5 ± 0.5; postoperative CCS class 0.6 ± 0.7; follow-up 4.2 months). In particular, increased perfusion was shown by PET scans, while dobutamine stress echocardiography did not show any amelioration of systolic left ventricular function [15,22].
How laser channels improve myocardial perfusion is still to be cleared. In particular, only indirect evidence of increased transmyocardial blood flow exists, and which phase of the cardiac cycle is involved is not yet known. There seems to be a period of time required for the native myocardial sinusoids to anastomose with the channels created by the laser beam. This fact and myocardial edema caused by laser may partly explain the transient drop in systolic function observed postoperatively. Thus, cardioplegic arrest should probably best be avoided in patients undergoing TMLR. Finally, in experimental studies, high energy CO_2 laser compares favourably to holmium laser in terms of patency rate [23].
About 1000 procedures on cardiopulmonary bypass are performed each year at our Institution, 80% of which are coronary operations. In our experience about 3% of coronary surgical patients cannot be treated by standard CABG because of severe peripheral atherosclerosis. In such patients TMLR (alone or combined with CABG) offers the possibility to acheive complete revascularization.
Operative mortality in our series is comparable to data reported by others [15-24]. This leads to some considerations:
1) the procedure is not without deleterious effects in the postoperative course. One cardiac-related death occurred in a patient with severe left ventricular dysfunction (EF 28%) that postoperatively evolved to low cardiac output syndrome and finally multiorgan failure;
2) patients treated by TMLR are selected among patients with a poor prognosis, related to peripheral and diffuse coronary disease and/or impairment of left ventricular function;
3) aggressive postoperative support is imperative, especially in patients with preoperative left ventricular dysfunction. In fact, TMLR-created channels do not improve myocardial perfusion or contractility immediately after operation.
No death has been recorded in the follow-up period; all patients have shown amelioration of anginal symptoms and reduction of antianginal medications. The main indication for TMLR is thus represented by severe symptoms refractory to maximal medical therapy.
In conclusion, the indications for surgical procedures in end-stage ischemic heart disease have increased during the past ten years, and an increasing number of patients with indication for heart

transplantation cannot undergo surgery, not only because of the insufficient number of donor organs, but for the high incidence of relative or absolute contraindications, in particular advanced age. When myocardial viability tests are performed (PET scan, dobutamine stress echocardiography), coronary bypass surgery is nowadays feasible with acceptable risk in patients with severe left ventricular dysfunction. Finally, TMLR is a technique that appears to improve the prognosis and quality of life of a subset of patients unsuitable for coronary bypass surgery, whose unfavourable natural history could otherwise be modified only by cardiac transplantation.

Table 1: preoperative patients' status							
Patient	Sex	Age (yrs)	NYHA class	CCS class	Infarcted segments	Coronary disease	LVEF
GI	M	70	2	3	inf - post	3	28
GB	M	70	1	3	inf	3	65
RO	M	71	2	4	inf	3	45
EA	F	64	2	4	ant - lat	2	45
MM	F	64	1	3	ant - lat	2	45
EF	M	74	2	3	ant - lat	3	20
EC	M	62	1	4	-	3	52
RA	M	75	3	3	ant	3	52
AS	F	68	1	3	-	2	69
AP	M	61	1	4	-	2	57
DB	M	65	1	4	ant - lat	3	56
PG	M	70	3	4	post - inf	3	40
AM	M	60	1	4	-	3	60
LVEF = left ventricular ejectoin fraction. ant - post - inf - lat = anterior - posterior - inferior - lateral							

Table 2: intraoperative data			
Patient	CABG	N° of laser-created channels	laser-treated segments
GI	LITA => LAD; SVG => 1Diag	18	inf - post - lat
GB	LITA => LAD; SVG => PD	7	lat
RO	LITA => LAD; SVG => 1Diag; SVG => PD	5	lat
EA	SVG => LAD; SVG => 1Diag	8	lat
MM	LITA => LAD; SVG => 1OM	5	lat
EF	SVG => LAD	6	lat
EC	LITA => LAD; SVG => 2Diag	5	lat
RA	-	54	ant - lat - inf - post
AS	LITA => LAD; SVG => 1Diag	5	lat
AP	SVG => OM; SVG => RM	5	post - lat
DB	-	21	ant - lat
PG	-	11	ant - lat
AM	-	20	inf - post - lat
CABG = coronary artery bypass grafting; LITA = left internal thoracic artery; SVG = saphenous vein graft; LAD = left anterior descending; 1Diag/2Diag = diagonal branches; 1OM = obtuse marginal branches; RM = ramus medianus; PD = posterior descending.			

Table 3: postoperative course						
Patients	ECG alterations in ICU	CK-MB peak (U/L)	IABP	Prolonged inotropic support	Days in ICU	Hospital death
GI	↑ST ant - lat	130	no	yes	3	yes
GB	no	2.3	no	no	1	no
RO	neg T V5,V6	10.3	no	no	4	no
EA	↑ST V2	18.6	no	no	2	no
MM	↑ST diffuse	14.6	no	no	1	no
EF	no	5.4	no	yes	4	no
EC	no	2.5	no	no	1	no
RA	↑ST diffuse	100	yes	yes	7	yes
AS	no	7.6	no	yes	1	no
AP	no	4.3	no	no	1	no
DB	no	12.4	yes*	yes	4	no
PG	no	15.3	no	yes	2	no
AM	no	10.4	yes*	no	1	no
ICU = intensive care unit; IABP = intra-aortic balloon pump; * = IABP started preoperatively						