

Off-Pump Supraarterial Decompression Myotomy for Myocardial Bridging

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ABSTRACT

Background: Myocardial bridging of the left anterior descending (LAD) artery may result in clinical symptoms. Surgery with cardiopulmonary bypass (CPB) is a therapeutic option with considerable risk. We hypothesized that off-pump supraarterial myotomy could be an effective treatment modality.

Methods: Between October 1998 and May 2000, 13 patients were referred for surgery. All were symptomatic despite medical therapy. Anteroseptal ischemia had been proven by thallium scintigraphy in all 13 patients, exercise testing was positive in 11. All patients were operated on with an off-pump approach after median sternotomy.

Results: Mean patient age was 61 ± 8 years (range, 43-71 years). Coronary artery disease mandating additional bypasses was present in 3 patients. The bypasses were done off pump in 2 patients. Conversion to on-pump surgery was necessary in 3 of 13 patients (23%) because of hemodynamic compromise (1 patient), opening of the right ventricle (1 patient), and injury to the LAD (1 patient). Supraarterial myotomy was performed in all patients. One patient who underwent surgery with CPB developed postoperative anteroseptal myocardial infarction. Postoperative exercise testing was performed in all patients and did not reveal any persistent ischemia. Mortality was 0%. All patients were free from symptoms and had not undergone repeat interventions after an average of 51 ± 7 months of follow-up.

Conclusions: Off-pump supraarterial myotomy effectively relieves coronary obstruction but has a certain periprocedural risk as evidenced by 1 myocardial infarction, 1 right ventricular injury, and 1 LAD injury. Long-term freedom from symptoms and from reintervention favor further investigation of this surgical therapy.

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INTRODUCTION

Structural and anatomic abnormalities of the coronary vasculature other than atherosclerosis are infrequent causes of myocardial ischemia. Myocardial bridging has been estimated to occur with a frequency from 0.5% to 33% at coronary angiography [Irvin 1982, Juilliere 1995]. Studies with intravascular ultrasound and Doppler flow wire [Berry 2002] have shown a marked reduction in the luminal area of bridged segments throughout ventricular systole, causing the angiographic "milking effect," which persists into diastole, thereby resulting in reduced coronary flow reserve. Phasic external vessel compression due to myocardial bridging may induce ischemia and anginal symptoms. Myocardial infarction [Berry 2002], atrioventricular block [den Dulk 1983], and sudden death [Cutler 1997] can be associated with myocardial bridges, demonstrating their pathologic potential.

Controversy exists concerning the adequate therapy for patients who remain symptomatic despite optimum medical therapy. Percutaneous transluminal coronary angioplasty (PTCA) [Laifer 1991] and intracoronary stent placement [Klues 1997] have been advocated. However, the majority of patients do not become symptom free by these measures. Therefore, supraarterial debridging myotomy with cardiopulmonary bypass [Iversen 1992] and coronary artery bypass grafting with [Prasad 1995] and without extracorporeal circulation and cardioplegic arrest [Pratt 1999] have been performed, with good results.

This study presents our initial single-center experience with supraarterial decompression myotomy for myocardial bridging without cardiopulmonary bypass.

MATERIALS AND METHODS

Thirteen patients who underwent surgery between October 1998 and May 2000 were included in this study. Mean patient age was 61 ± 8 years (range, 43-71 years). There were 11 men and 2 women. All 13 patients had had angina pectoris preoperatively, which had led to further diagnostic studies.

Conventional coronary angiography prior to surgery demonstrated myocardial bridging of the left anterior descending artery (LAD) in all patients (Figures 1 and 2). The significance of the bridging was evaluated by intracoronary application of acetylcholine. If more severe compression was observed and patients were clinically symptomatic

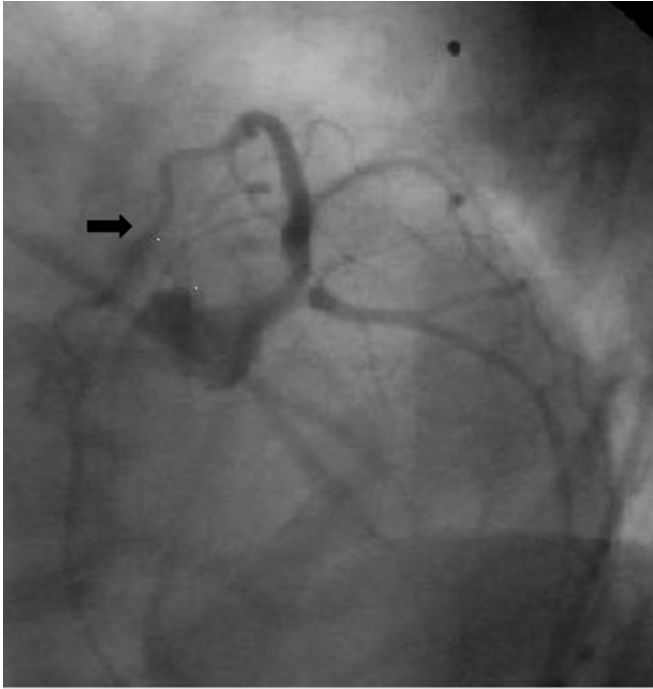


Figure 1. Left anterior oblique projection of mid-left anterior descending artery bridging in diastole (arrow).

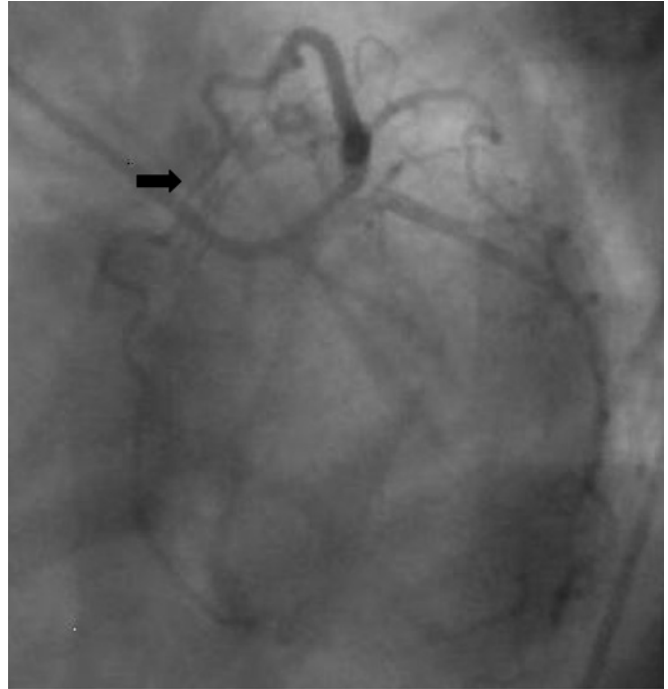


Figure 2. Left anterior oblique projection of mid-left anterior descending artery bridging in systole (arrow).

despite β -blocker therapy, they were scheduled for elective off-pump supraarterial decompression myotomy of the LAD. In case of concomitant coronary artery disease (CAD) affecting other coronary arteries, additional bypasses were to be performed, also off pump.

Anesthesia

Premedication consisted of flunitrazepam 1 mg orally on the evening before and the morning of surgery. The dose of ACE inhibitors, if they were part of the patient's routine medication, was reduced to one half of the normal dose.

Prior to induction of anesthesia, routine hemodynamic monitoring was established, including electrocardiography (ECG) (leads II and V5) and arterial and venous lines. After induction of anesthesia, a 7.5-F pulmonary artery catheter was inserted via the right internal jugular vein. Anesthesia was maintained by intravenous infusions of 3 μ g/kg per hour of sufentanil and intermittent doses of midazolam as clinically deemed necessary. A single-lumen tube was used in all patients. Permanent contractility monitoring by transesophageal echocardiography (TEE) was not employed routinely.

Surgery

All patients underwent median sternotomy and all surgeries were performed by 1 surgeon (M.M.B.). Stabilization was achieved on the beating heart with 2 different commercially available systems (Optiflex; US Surgical, Norwalk, CT, USA and Octopus 1 and 2; Medtronic, Minneapolis, MN, USA). In all patients, the LAD was not snared proximally or distally. Sharp dissection of the overlying myocardial bridge with a beaver blade (R. Beaver, Waltham, MA, USA), using standard coronary artery dissection techniques starting dis-

tally and moving proximally after repositioning the stabilizer, was carried out. Crossing side-branches of the tributary vein were carefully clipped or cauterized. A heart-lung machine and a perfusionist were on stand-by in the operating room. If conversion to extracorporeal circulation became necessary, the patient's heart was cannulated with a venous 2-stage cannula and arrested with 2000 mL of Bretschneider crystalloid cardioplegia given antegradely. Mild systemic hypothermia of 32°C was instituted.

Conversion rate to cardiopulmonary bypass and intra- and postoperative complications were recorded. All patients were examined by exercise testing 4 to 6 weeks postoperatively by the referring cardiologists. The cardiologists continued to follow these patients by regular exercise testing and echocardiography.

RESULTS

A total of 13 patients underwent intended off-pump division of myocardial bridging after remaining symptomatic with β -blocker therapy. All patients were in Canadian Cardiovascular Society (CCS) class III. Three patients (23%) had a history of myocardial infarction. Ejection fraction was 59% \pm 9% (range, 40%-69%) as determined by angiography. In all patients the additive and the logistic EuroSCOREs were calculated preoperatively. The additive EuroSCORE was 4.7 \pm 2.3 (range, 2-9), and the logistic EuroSCORE, indicating the patient's mortality risk, was 4.3 \pm 3.5 (range, 1.51-13.33). Three patients suffered from peripheral vascular disease, and 1 patient had chronic obstructive lung disease necessitating bronchodilator therapy. Nine of 13 patients were hypertensive and on regular antihypertensive medication; 3 were diabetics, with insulin therapy being necessary in 1 patient only.

Table 1. Perioperative Data of Patients with Myocardial Bridging (N = 13)

Division without extracorporeal circulation	10 (77%)
Conversion to extracorporeal circulation	3 (23%)
Reasons for conversion	1 Hemodynamic compromise 1 Injury to right ventricle 1 Injury to the left anterior descending artery
Patients with additional bypass grafts	4 (25%) 3 with 1 graft 1 with 2 grafts
Maximum creatin kinase	188 ± 151 U/L (50-477 U/L)
Postoperative blood loss (first 24 h)	963 ± 158 mL
Patients requiring transfusions	4 (30%)
Incidence of low output	2 (15%)
Intensive care unit stay	1 d (n = 12) 2 d (n = 1)
Perioperative myocardial infarction	1 (anteroseptal myocardial infarction)
Mortality	0

Preoperative resting ECGs and echocardiographic studies were performed on all patients with negative results except in 1 patient with a positive resting ECG. Exercise testing results were positive in 11 of 13 patients. Thallium scintigraphy demonstrated anteroseptal myocardial ischemia in all 13 patients. Prior to referral for surgical therapy, 3 patients underwent additional intravascular ultrasound studies to examine the potential for stent implantation. Interestingly, none of these patients had plaque formation proximal to the bridge. One patient had previously undergone PTCA and consecutive stent implantation of the LAD. No isolated PTCA had been attempted in our study group.

On coronary angiography a “milking effect” was seen in all patients. Three patients had significant additional CAD, affecting the right coronary artery in 2 patients and the circumflex plus the right coronary artery in 1 patient.

Demographic and perioperative data are provided in Table 1. In all patients myocardial bridging could be divided completely. We attempted to determine the length of the myocardial bridging in the last 8 patients. Average length was 4.3 ± 1.2 cm. In 9 patients the bridge was located over the mid-LAD, in the other 4 over the proximal LAD.

Conversion to cardiopulmonary bypass became necessary in 3 patients. The reasons were hemodynamic compromise in 1 patient with bridging of the proximal LAD and injury in 2 patients, to the right ventricle in 1 patient and to the LAD in 1 patient, with bridging of the middle LAD. The latter received a saphenous vein graft to the LAD. The patient with hemodynamic compromise had double-vessel disease of the right and circumflex arteries. After initially successful beating-heart supraarterial myotomy of the LAD and bypass grafting of the right coronary artery the patient became compromised

during exposure of the circumflex artery and the surgical procedure had to be converted to cardiopulmonary bypass.

The bridging was divided completely in all patients. None of them showed palpable plaque formation proximal to the bridge.

All patients with concomitant coronary artery disease received additional saphenous vein grafts. In the 2 remaining cases the right coronary artery was grafted on the beating heart.

The immediate postoperative course was uneventful in all patients. Twelve patients spent 1 day in the intensive care unit, 1 patient required 2 days of intensive care unit therapy. The patients were discharged to the referring cardiologist after 9 ± 2 days (range, 8-16 days). The patient who was hospitalized for 16 days suffered from serous drainage from her sternotomy incision and was managed conservatively. One patient suffered a perioperative apical myocardial infarction on postoperative day 5. Of note, 4 patients developed intermittent atrial fibrillation. In all 4 of these patients preoperative β -blocker therapy was resumed.

All patients were tested by Holter ECG prior to being discharged home. This study was performed 22 ± 3 days postoperatively (range, 21-31 days) and was negative in all 13 patients. Additional thallium scintigraphy was performed in 4 patients only. Routine follow-up of these patients by Holter ECG and echocardiography was entirely normal in 12 patients. No readmissions for any cardiac event or any reinterventions have been recorded so far. Length of follow-up was 1560 ± 211 days (range, 1102-1870 days). All patients have remained in CCS class 0 or I postoperatively.

DISCUSSION

Myocardial bridges have frequently been found in autopsy studies (up to 78% of cases) [Ferreira 1991], even though symptomatic patients are scarce. Muscle bridges are more common in men and tend to affect patients after their fourth decade of life [Angelini 1983]. Mostly, the LAD is affected, although 2 reports of right coronary artery involvement exist [Woldow 1994, Vongpatanasin 1997].

Serious sequelae such as myocardial infarction [Berry 2002], atrioventricular block [den Dulk 1983], left heart failure [Roul 1999], and sudden death [Cutler 1997] can be associated with myocardial bridges. Thrombus formation [Ramos 1993, Agirbasli 1997], vasospasm [Ciampricotti 1988], endothelial dysfunction [Kuhn 1991], and impaired coronary flow reserve [Ge 1994, Klues 1997] have been proposed as underlying mechanisms. The severity of symptoms has been linked to the localization of the bridge and the presence of left ventricular hypertrophy or an increased intraventricular pressure [Ferreira 1991, Iversen 1992]. The various proposed mechanisms form the basis for management with calcium channel antagonists for the relief of vasospasm and β -blockers to lower heart rate and to decrease myocardial contractility. Nitrates may worsen ischemia by accentuating the luminal narrowing at the bridging site in the systolic phase [Noble 1976].

Two distinct types of myocardial bridging have to be differentiated. Most are superficial bridges that cross the underlying LAD transversely toward the apex of the heart and are unlikely to limit coronary blood flow. In other cases a muscle bundle can be observed that arises from the right ventricular

Table 2. Results of Surgical Interventions for Myocardial Bridging*

Reference	N	Surgical Intervention	Result
[Hill 1981]	1	Decompression myotomy on CPB with cardioplegic arrest	Asymptomatic
[Hillman 1999]	1	Decompression myotomy on CPB with cardioplegic arrest	Asymptomatic 12 mo postoperatively
[Iversen 1992]	9	Decompression myotomy on CPB with cardioplegic arrest	Asymptomatic but length of follow-up unknown
[Prasad 1995]	1	Decompression myotomy and LITA-LAD bypass on CPB (fibrillating heart)	Asymptomatic 6 mo postoperatively
[Pratt 1999]	2	Off pump LITA-LAD grafting without myotomy	Asymptomatic 4 and 16 mo postoperatively
[Roul 1999]	1	Decompression myotomy on CPB with cardioplegic arrest	Asymptomatic 13 mo postoperatively

*CPB indicates cardiopulmonary bypass; LITA, left internal thoracic artery; LAD, left anterior descending artery.

apical trabeculae and surrounds the LAD before termination in the interventricular septum [Ferreira 1991]. This particular muscle fiber arrangement could explain systolic twisting and compression of the artery, creating the angiographic milking effect. This milking effect has been associated with symptomatic myocardial ischemia when more than 75% luminal narrowing is seen during systole [Stables 1995].

Impaired coronary flow reserve is due to persistent vessel diameter reduction within diastole after phasic systolic compression. Schwartz and coworkers [1997] used intracoronary Doppler and quantitative angiography to demonstrate delayed diameter gain during early diastole and persistent middiastolic diameter reduction of >30%. The incomplete relaxation during diastole results in reduced coronary flow during early and middiastole and lowers the ischemic threshold [Hill 1981, Klues 1997].

Controversy exists regarding proper management of symptomatic patients. PTCA and intracoronary stent placement have been advocated [Stables 1995, Klues 1997]. A major argument is the possibility to avoid or delay surgery in patients with single-vessel disease confined to the compressed LAD. Concerns also exist regarding formation of scar tissue after surgery and recurrent external compression. Long-term data are lacking on whether stents are able to maintain geometry and resist compressive forces and on the rate of in-stent restenosis when stents are deployed for myocardial bridging.

Surgery has been the most frequently used treatment modality in symptomatic myocardial bridging (Table 2). Bypass surgery, alone or combined with supraarterial myotomy, and supraarterial myotomy alone have been employed. Iversen et al [1992] reported excellent functional results and a low operative risk with supraarterial myotomy using cardioplegic arrest and cardiopulmonary bypass. Pratt and coworkers [1999] used a beating-heart approach to treat 2 patients. Both patients received arterial grafts, 1 through a submammary incision and 1 after median sternotomy. No supraarterial myotomy was attempted.

Prasad et al [1995] have advocated suture fixation of the edges of the divided bridge on adjacent tissue to retract them from the LAD. Whether this strategy will prevent scar tissue formation is unknown. The reported follow-up of their patient is 6 months. We performed such suture fixation in 1 patient only. Because no patient has become symptomatic again we believe that it is possible to avoid such fixation sutures.

In our series, the operation could be completed as planned, ie, without cardiopulmonary bypass and cardioplegic arrest, in 10 of 13 patients (77%). The left internal mammary artery

was not used. It could have been used in our patient with injury to the LAD, but we decided to harvest a segment of the greater saphenous vein during emergency cannulation.

Our average follow-up of 1560 ± 211 days without repeat referral indicates that supraarterial myotomy on the beating heart may be an alternative to stent placement and to other more invasive surgical procedures. Hillman et al [Hillman 1999] reported a 10-year-old boy with decompression myotomy on cardiopulmonary bypass who has remained symptom free at 1 year, supporting the concept that supraarterial decompression myotomy is sufficient surgical therapy.

Certain limitations apply to this study. First, follow-up by means of thallium scintigraphy and coronary angiography in all patients would be highly desirable. Only a minority of patients gave consent for another scintigraphy postoperatively. Second, longer follow-up is necessary to determine if scar formation will eventually occur. Ideally, 2 randomized studies should compare drug-eluting stents and beating-heart supraarterial myotomy to evaluate the long-term benefit of both therapies and of on- versus off-pump surgery, with a specific focus on complications. Because of the scarcity of such patients referred for surgery, it is unlikely that these studies can ever be conducted.

Our observed conversion rate of 23% is likely to be reduced with growing experience in off-pump cardiac surgery among surgeons and anesthesiologists. Meanwhile, permanent TEE has established its relevance for online monitoring of cardiac performance and rapid intervention to maintain hemodynamic stability.

In the light of the available literature data, this series of off-pump supraarterial decompression myotomies for myocardial bridging is the largest performed. The initial experience with beating-heart supraarterial decompression myotomy for myocardial bridging is favorable. Although this approach to complete relief for the patient is feasible, the surgical risks of the procedure, namely injury to the right ventricle and the LAD, are considerable. Follow-up in this study group has been favorable so far, with normal Holter ECGs, no recurrence of angina pectoris, and no further interventions.

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REVIEW AND COMMENTARY

1. Editorial Board Member IE521 writes:

The paper is interesting because it reports on a new approach to divisions of myocardial bridges. Despite the fact that the authors need to be congratulated on attempting a difficult operation off pump, it remains debatable whether the off-pump approach really offers advantages. The patient population is relatively young, and the LAD bridge was a single problem in the majority of patients. A relatively short pump run and a short cross-clamp time could have been expected. Two major complications in this series (right ventricular perforation, injury to the LAD requiring a bypass graft) demonstrate that the technique presented is very difficult and probably lacks adequate overview on the LAD region.

Maybe the statement that the problems encountered will vanish with experience is therefore too optimistic. Remember that a few years ago an intramyocardial course of a coronary artery was regarded as a contraindication for off-pump coronary surgery and is still regarded as difficult by the majority of surgeons. Accidental opening of the right ventricle, however, also occurred in the series, which is described in the report by Iverson et al [1992].

The suggestion to prospectively randomize patients to off-pump surgery and drug-eluting stent placement is interesting, but I would rather suggest comparison of off- and on-pump surgery and look for differences in complications, which are considerable in the current series. In addition, because of lack of adequate patient numbers, comparative studies will probably never be conducted.

It can be debated that in cases of conversion, selective cannulation of both venae cavae would be the better approach because entrance into the right ventricle may require complex right ventricular repair.

Authors' Response by Dr. Mersa Baryalei:

In response to Editorial Board Member IE 521, our statement that the problems encountered will vanish with experience has been changed. His/her proposal for a study comparing off- and on-pump surgery has been added, including the expected limitations for conducting such a study.

2. Editorial Board Member KT512 writes:

First, I congratulate the authors on their paper.

a) What do the authors think about the indication of PTCA of the patient with negative results of exercise testing?

b) Did the authors perform the suture fixation of the edges of the divided bridge on adjacent tissue to retract from the LAD?

Authors' Response by Dr. Mersa Baryalei

In response to Editorial Board Member KT512, we believe that there is no indication for PTCA in patients with negative results for exercise testing. In addition, we discussed this issue with our cardiologists, Prof. Erbel and coworkers, who have considerable experience with PTCA and stenting

of myocardial bridges, and they also see no indication for PTCA, because the long-term results are not satisfying.

Regarding suture fixation of the edges of the divided bridge, we have added additional information. We have not performed this procedure routinely, but only in the first patient.