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Percutaneous Treatment of Left Main Coronary Artery Stenoses

W. Sperker, M. Gyöngyösi, D. Glogar

The poor prognosis of patients with symptomatic left main coronary artery (LM) atherosclerosis treated medically could be improved considerably by coronary artery bypass graft (CABG) surgery. The first percutaneous transluminal interventions of LM stenosis revealed that such procedures were quite difficult to perform and that early mortality was too high to be accepted as a standard treatment. As a consequence, in 1984, the National Heart, Lung, and Blood Institute published a consensus that stenoses of the LM were a contraindication to percutaneous transluminal coronary angioplasty. However, percutaneous interventions on the LM remained in scope, as some patients with high risk for CABG, with contraindications to CABG or with very limited life expectancy still had no other option than a percutaneous intervention of the LM. Furthermore, in the last years, new percutaneous techniques have been developed for interventional cardiology: the use of stents or atherectomy, the use of assist devices like intraaortic balloon pumps or cardio-pulmonary support devices improved the acute and long-term outcome of percutaneous coronary interventions even in patients with high risk or unstable haemodynamic conditions.

On the basis of the haemodynamic situation, the outcomes of percutaneous interventions on protected and unprotected LM stenosis differ considerably: an unprotected LM stenosis paired with ischaemic syndromes always means a highly critical situation that has to be resolved in a very short time. Both protected and unprotected LM stenoses can be the reason for stable and unstable coronary syndromes; however, myocardial ischaemia caused by an unprotected LM stenosis is generally more severe as it more often results in haemodynamic instability requiring emergency bypass surgery, or if an operation is not possible, an emergency percutaneous treatment. The results from percutaneous interventions of protected LM stenoses showed that this kind of treatment is technically easily feasible and associated with a low incidence of short-, mid- and long-term death, myocardial infarction or repeat revascularization (MACE). Elective interventions of unprotected LM stenoses also seem to be safe: short-, mid- and long-term follow-ups demonstrate an acceptably low rate of MACE. Although emergency percutaneous interventions of both protected and unprotected LM disease lead to fairly good acute procedural success rates, a high in-hospital mortality with a further decrease in long-term event-free survival rate, but an acceptable mortality rate can be expected. *J Clin Basic Cardiol 2002; 5: 163–9.*

Key words: angioplasty, stent, left main coronary artery, coronary artery disease

As the oxigenization and nutrition of large parts of the myocardium depend on the left main coronary artery (LM), a significant stenosis of the LM has major impacts on the function of the heart. The prevalences of LM stenosis in patients undergoing coronary angiography range from 2.5 to 10 %; additionally, nearly all patients suffer from a concomitant atherosclerotic disease of other coronary branches [1, 2]. In contrast, an isolated atherosclerotic lesion of the LM is very rare, with reported incidences of 0.15 and 0.07 % (of all angiographed patients), respectively [3–5]. In the Catheterization Laboratories of the University of Vienna Medical Center, Austria, significant stenoses of the LM were diagnosed in 4.7 % of patients undergoing coronary angiography in the time between January 1998 and April 2001.

Exact angiographic detection of LM stenosis sometimes poses problems: Hermiller et al. demonstrated that unrecognised LM disease is widespread and the degree of stenosis often underestimated in patients with normal LM angiograms undergoing interventional procedures [6]. The possible explanations for the limitation of plaque detection by angiography include compensatory vessel enlargement in the face of intracoronary plaque formation, the diffuse distribution of plaque in the vessel as well as technical limitations [7–9]. However, significant true lumen narrowings are rarely overlooked by angiography; in doubtful cases, intravascular ultrasound allows an exact determination of the morphology and degree of LM stenosis.

The LM has certain anatomic and histologic characteristics which distinguishes it from the distal coronary vessels. In men, the diameter of a normal non-diseased LM is 4.5 ± 0.5 mm and in women is slightly smaller, at 3.9 ± 0.4 mm [10]. The LM originates in the wall of the aorta ascendens; consequently, all diseases of the aorta affect the LM trunk. As the ostium of the LM lies within the aortic wall, the LM trunk lacks adventitia and has a considerable amount of smooth muscle cells and elastic tissue, surrounded by aortic smooth muscle cells. The amount of elastic tissue decreases distally in the coronary tree: thus, the LM trunk has the highest amount of elastic tissue of all the coronary vessels. That is why balloon dilatation of the LM trunk has the possibility of an excellent acute success but the danger of early and late recoil. These anatomic and histologic features of the LM might have contributed to the early discouraging reports on the first percutaneous LM interventions.

Patients who suffer from symptomatic LM atherosclerosis and who receive only medical treatment have a poor prognosis. The one-, two- and three-year survival rates of such patients were 67, 63 and 60 % in the Veterans Administration Cooperative Surgery Study (VACSS); the three-year survival rate reported from the CASS-Study reached 69 % [11]. However, in the ECSS (European Coronary Surgery Study), 82 % of the study population was alive after three years – an explanation for this high survival rate may be the younger age of these patients and the better left ventricular function [12]. Predictors of higher mortality with medical treatment included poor left ventricular function, older age, severity of LM stenosis and left coronary artery dominance. The 4-year survival rate of patients with 3-vessel-disease combined with a LM stenosis treated medically was 60 % in the CASS (Coronary Artery Surgery Study) study [13], while the 15-year survival of patients with medically treated LM stenosis was not more than 27 % [14].

All the studies demonstrated higher survival rates after coronary artery bypass graft operation (CABG) with three-

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year survival of 82 %, 91 % and 91 % in VACSS, ECSS and CASS studies, respectively. In these studies, the surgical mortality ranged from 3.5 % in the CASS and 12 % in the VACSS, including the patients in whom surgery was performed on an emergency basis.

The Problems of Percutaneous Treatment of LM Stenoses

The VACSS study showed undoubtedly that coronary artery bypass graft (CABG) surgery brought big advantages in survival rates over the medical treatment of LM-stenoses [15]. Grüntzig et al. reported about the first percutaneous transluminal interventions (PCI) of LM stenosis, and revealed that such procedures were quite difficult to perform and that early mortality was too high to be accepted as a standard treatment [16]. As a consequence, in 1984 the National Heart, Lung, and Blood Institute published a consensus [17] that stenoses of the left main coronary artery were a contraindication to percutaneous transluminal coronary angioplasty (PTCA).

However, in spite of all these discouraging experiences, percutaneous interventions on the LM remained in scope, as some patients with high risk for CABG (for example patients in a very critical haemodynamic status like acute myocardial infarction or cardiogenic shock), with contraindications to CABG or with very limited life expectancy still had no other option than a percutaneous intervention of the LM. Furthermore, in the last few years, new percutaneous techniques have been developed for interventional cardiology: the use of stents or atherectomy, or the use of assist devices like intraaortic balloon pumps or cardio-pulmonary support devices improved the acute and long-term outcome of percutaneous coronary interventions even in patients at high risk or with unstable haemodynamic conditions.

Consequently, percutaneous interventions of LM stenoses still remained a last therapeutic option for patients with contraindication(s) to CABG or high-risk for CABG. Additionally, besides elective interventions of the protected LM, elective percutaneous coronary angioplasties of unprotected LM stenoses have been attempted in rare cases with good short- and long-term results.

This article briefly overviews the present percutaneous interventional treatment options and their outcome in the case of LM disease.

Treatment Strategies for LM Stenoses

Although CABG is still regarded as the optimal choice of treatment for significant LM stenoses, an increasing number of angiographic centers reported an increasing number of percutaneous coronary interventions on LM stenoses. However, in comparison with the surgical approach, the attempts to treat LM stenoses percutaneously remained rare. The investigators of the ULTIMA Registry (Unprotected Left Main Trunk Intervention Multicenter Assessment) reported on 277 LM PTCAs collected from 25 centers during 2 years [18], Laruelle et al. performed 18 LM PTCAs during 3 years [19], Lopez et al. 46 cases within 2 years [20], Karam et al. 39 LM PTCAs during 2.5 years [21], Kornowski et al. 124 LM interventions during 3 years [22], Hoffmann et al. 13 cases during 2 years [23], and most recently, Silvestri et al. performed 140 elective interventions during 5 years [24].

In our center, the Catheterization Laboratory of the University of Vienna Medical Center, 35 LM percutaneous interventions were performed during 2.5 years. During the registration period, 227 patients exhibited significant LM stenoses, 129 of them with an unprotected LM stenosis, while an open bypass artery protected the LM in 98 patients. 105 of the 129 patients with unprotected LM stenoses were bypass operated, 4 of 129 patients with stable angina died waiting for CABG and 20 of 129 patients underwent percutaneous interventions (18 of them emergency percutaneous angioplasty). In 25 of the 98 patients with protected LM stenosis the myocardial ischaemia was related to the LM disease: 5 patients underwent re-CABG, 1 patient received intracoronary thrombolysis, percutaneous transmyocardial laser revascularization was performed in 4 patients and elective PCI was done in 15 patients. In the remaining 73 of the 98 patients with protected LM disease, in whom the non-invasive diagnostic tests proved a myocardial ischaemia not related to LM disease, percutaneous coronary interventions were performed in another stenosed coronary artery or the patients were treated medically. The treatment strategies of LM stenoses of our Cath Lab represent the present status and guidelines for catheter interventions of LM atherosclerotic disease, as only 35 of 227 patients with significant LM stenoses were treated with percutaneous interventions.

From an early stage of the development and evaluation of LM percutaneous interventions two main groups of patients were differentiated regarding their prognostic outlooks: on the one hand patients with a protected LM stenosis in whom a patent bypass graft or natural collaterals protect the left anterior descending, the left circumflex coronary artery or both; on the other hand patients with unprotected LM stenosis.

First, in patients with protected LM stenosis, the myocardial ischaemia and all its symptoms may be related to other stenosed coronary arteries and not to the LM. In contrast, an unprotected LM stenosis paired with ischaemic syndromes always means a highly critical situation that has to be resolved in a very short time. Both protected (with ischaemia related to the LM) and unprotected LM stenoses can be the reason for stable and unstable coronary syndromes; however, myocardial ischaemia caused by an unprotected LM stenosis is generally more severe as it more often results in haemodynamic instability requiring emergency bypass surgery, or if an operation is not possible, emergency percutaneous invasive treatment.

Consequently, big differences between elective and emergency interventions of catheter-based LM interventions exist regarding the acute procedural success, short- and long-term mortality and the occurrence of major adverse cardiac events (MACE: acute myocardial infarction, target lesion revascularization or death). After the first reports on successful LM PCIs, it became obvious that elective procedures on protected and even unprotected LM stenosis can be safe and effective therapeutic choices [19–26]. In contrast, high in-hospital mortality (up to 83 %) with a further decrease in event-free survival during the follow-up have been reported [18, 19, 21, 27–30], with controversial conclusions about the feasibility and safety of catheter-based LM emergency interventions in patients with acute myocardial infarction and cardiogenic shock.

History of LM Percutaneous Treatment

After the first discouraging report on percutaneous interventions in unprotected LM stenoses by Grüntzig et al, Stertzer et al. [31] published the 41-month follow-up results of 19 patients who had undergone balloon angioplasty of the LM: the results were relatively favourable with 12 patients [63 %] free from MACE after the 41-month follow-up. In 1989, O´Keefe et al. [32] published a report on 127 patients treated

by balloon angioplasty for LM disease: the best results were achieved in patients with protected LM circulation and the most unfavourable outcomes were observed after emergency interventions. Acute and long-term mortality, however, remained unsatisfactorily high, with 3-year survival rates of 90 % (elective protected), 36 % (elective unprotected) and 30 % (acute). In the early 1990s, limited experiences from a few large referral centres were published. However, systematic data collection in the form of a multicenter registry (ULTIMA registry) was started in January 1994. Summarizing the results of this registry, Ellis et al. [28] concluded that percutaneous revascularization of unprotected LM stenosis should not be considered as an alternative to bypass surgery in most patients. However, in the following years, very promising data from other relatively large series were reported (Tabs. 1 and 2). In the next chapters we give an overview of the results from larger clinical studies on percutaneous treatment of LM stenoses, while the data on smaller patient cohorts are summarized in Tables 1, 2 and 3.

Elective Percutaneous Interventions of Unprotected LM Coronary Artery Stenoses

Balloon angioplasty

Miketic et al. published the results on 252 LM (44 unprotected LM) angioplasties performed between 1992 and 1997 and included in the PTCA Registry of German community hospitals [29]. The overall procedure-related mortality was 9.1 % in unprotected LM PTCAs. The multivariate analysis identified the degree of LM protection (unprotected circulation or protection by natural collaterals or by open bypass grafts), indication for angioplasty (stable/unstable angina pectoris, acute myocardial infarction) and left ventricular ejection fraction as independent predictors for procedure-related death [29]. As balloon angioplasty of the unprotected LM led to an unacceptably high procedure-related mortality, the authors did not recommend interventions on unprotected LMs, not even in emergency situations.

Kosuga et al. [33] reported their results from 107 patients who underwent the procedure under emergency (n = 24) or elective conditions (n = 83). The angiographic success rate was relatively high (96.4 %), and the in-hospital mortality in the elective group low (3.6 %). With limited use of stents (14 % of the cases), the angiographic restenosis rate in the elective group of patients was high (40 %).

Stent implantation

Laruelle et al. [19] published an analysis about 18 patients with unprotected LM-stenosis treated with stents (and additional rotational atherectomy in one patient) in 1998. The 10 elective interventions produced favourable results, with one non-cardiogenic death observed during the 10 month follow-up.

Silvestri et al. [24] reported the acute, short- and long-term results of 140 elective stenting procedures of unprotected LM stenoses (47 patients with high-risk and 93 patients with low-risk for CABG). A procedural success rate of 100 % could be achieved, the one-month mortality was 9 % in high-risk for CABG and 0 % in low-risk for CABG groups. Good follow-up results with 23 % restenosis and 17.4 % target lesion revascularization rates confirmed that a percutaneous intervention on the LM even in patients with high-risk for CABG can be regarded as an acceptable option. The authors concluded that elective stenting of unprotected LM stenosis achieves excellent immediate, medium-term and follow-up results.

Wong et al. [34] summarized their results on 50 elective stenting procedures of unprotected LM stenoses, and reported excellent results with 100 % procedural success, no in-hospital cardiac events and a low (20 %) recurrence of LM stenoses. Like Silvestri et al. [24], the authors concluded that elective stenting may be a safe alternative to CABG in unprotected LM disease [34].

An example of an unprotected LM intervention in a 61 year old male is shown in Figure 1.

Atherectomy

The first multicenter study using balloon dilatation, stents, directional and rotational atherectomy for the treatment of unprotected LM stenoses was the ULTIMA registry, with the first results published by Ellis et al. in 1997 [28]. The authors demonstrated a technical success of 98.9 % in elective cases, and found a significant inverse correlation between long-term cardiac events and left ventricular ejection fraction and presentation with progressive or rest angina. Furthermore, on the basis of their results, the authors recommended the usage of directional atherectomy and stenting as preferred techniques, and a follow-up angiography 6 to 8 weeks after treatment.

Kosuga et al. [35] reported on 101 patients who underwent directional atherectomy plus balloon angioplasty, with stents used in only 13 % of the patients for bail-out situations and for a suboptimal atherectomy result. In-hospital MACE was 4.7 % in the elective group (n = 86) and 20 % in the emergency group (n = 15). After 3 years follow-up, 85.8 % of the patients were free from cardiac deaths and 61.7 % free from MACE.

Summarizing the results of the latest larger reported series, elective interventions of unprotected LM stenoses seem to be safe, if stents and in certain cases atherectomy before stent implan-

Table 1. Results of left main coronary artery balloon angioplasty

1st author	Year of publication	No of patients	Protected / unprotected	Device	In-hospital complications	FUP time	FUP events
Stertzer [31]	1985	19	NA	PTCA	1 emergency CABG	41 mo	7 CABG
O´Keefe [32]	1989	117	84 prot 33 unprot 10 acute	PTCA	5 deaths	36 mo	29 deaths
Eldar [42]	1991	8	NA	PTCA	1 death	24 mo	1 death
Rupprecht [36]	1991	14	14 prot	PTCA	1 LM dissection	27 mo	3 restenoses
Crowley [25]	1994	15	12 prot 3 unprot	PTCA 1 DCA	1 AMI	6 mo	4 TLR

acute = acute intervention in emergency situation; AMI = acute myocardial infarction; CABG = coronary artery bypass graft operation; FUP = follow-up; LM = left main coronary artery; mo = months
NA = data not available; no = number; prot = protected LM; PTCA = percutaneous transluminal coronary angioplasty; TLR = target lesion revascularization; unprot = unprotected LM

tation are used. Short-, mid- and long-term follow-up demonstrate an acceptably low rate of death, myocardial infarction and repeat revascularization.

Elective Percutaneous Treatment of Protected Left Main Coronary Artery Stenoses

Balloon angioplasty

Rupprecht et al. [36] published their experience on 14 balloon dilatation procedures of significant protected LM stenoses. Apart from one acute complication, 38 % of the patients had LM restenosis with no further need for revascularization at follow-up.

Stent implantation

Kornowski et al. [22] matched 88 patients with stenting with 36 patients with balloon angioplasty only for their protected LM stenoses. Procedural success was higher in the stent group with a significantly lower number of procedural complications. After 12 month follow-up, however, no clear difference in the event-free survival rates (78 % in the stent group vs 76 % for the balloon-angioplasty group) could be observed.

Lopez et al. [20] observed a significantly larger post-interventional minimal lumen diameter after stent implantation in comparison with non-stent treatment (directional atherectomy or balloon angioplasty) in 42 patients with protected LM stenoses. The authors concluded that the use of stents either alone or after initial atherectomy produces the best immediate angiographic results. Moreover, the benefits of stenting were most pronounced for aorto-ostial lesions, which are generally troubled by elastic recoil. The pretreatment of heavily calcified LM stenoses with rotational atherectomy improved stent deliverability and expansion.

Atherectomy

In 1994 Laster et al. [37] reported on 22 patients with protected LM stenosis: 13 underwent elective atherectomy, while 9 patients received atherectomy after unsuccessful balloon angioplasty. After 24 month follow-up, the survival rate was 100 % with an event-free survival of 89 %.

Yasuda et al. [38] compared the angiographic and clinical outcomes after directional atherectomy (n = 13) with those after conventional balloon angioplasty only (n = 21) in patients with protected LM stenosis. The initial success rate as well as the follow-up results (late lumen loss, restenosis) were significantly better in patients treated with DCA.

The results from percutaneous interventions of protected LM stenoses showed that this kind of treatment is technically easily feasible and is associated with a low incidence of short-, mid- and long-term MACE. Long-term follow-up revealed that the use of balloon angioplasty alone was associated with a higher restenosis rate compared with intracoronary atherectomy or stent implantation.

Table 2. LM interventions with new devices

1st author	Year of publication	No of patients	Protected / unprotected	Device	In-hospital complications	FUP time	FUP events
Laster [37]	1994	22	22 prot	22 DCA	–	24 mo	20 event-free survivors
Chauhan [30]	1997	28	14 prot 14 unprot 6 em. proc.	11 PTCA 17 stent	5 deaths	16 mo	4 deaths
Ellis [28]	1997	91	91 unprot	51 stent 25 DCA 91 PTCA	11 deaths 4 AMI 1 CABG	12 mo	71 % survival 68 % event-free survival
Lopez [20]	1997	46	43 prot 3 unprot	34 stent 27 R.Ath 2 DCA 3 PTCAs	–	9 mo	6 TLR
Karam [21]	1998	39	39	39 stent	3 deaths	31 mo	6 deaths 1 TLR
Kornowski [22]	1998	124	120 prot 4 unprot	88 stent 36 PTCA	1 death 1 em. CABG 12 AMI	12 mo	3 AMI 21 TLR
Laruelle [19]	1998	10	10 prot	10 stent	1 TLR	10 mo	1 death
Park [26]	1998	42	42 unprot	42 stent	–	6 mo	7 TLR
Yasuda [38]	1998	34	34 prot	13 DCA 21 PTCA	–	NA	DCA: 2 resten. PTCA: 9 resten.
Hofmann [23]	1999	13	13 unprot	12 stent	1 em. CABG	12 mo	2 TLR
Kosuga [33]	1999	107	107 unprot 83 elective	39 PTCA 53 DCA 15 stent	12 deaths 1 AMI 7 TLR	35 mo	1 CABG 30 TLR
Wong [34]	1999	55	55 unprot	55 stent	–	16 mo	9 TLR 1 death
Silvestri [24]	2000	140	140 unprot	140 stent	4 deaths 2 AMI	6 mo	3 deaths 1 AMI 20 TLR
Kosuga [35]	2001	101	101 unprot 86 elective	101 DCA	6 deaths 1 AMI 4 TLR	34 mo	12 deaths

AMI = acute myocardial infarction; CABG = coronary artery bypass graft operation; DCA = directional coronary atherectomy; em. CABG = coronary artery bypass graft operation in emergency situation; FUP = follow-up; NA = data not available; mo = months; No = number; prot = protected LM; PTCA = percutaneous transluminal coronary angioplasty; R.ath = rotational atherectomy; resten. = restenosis of target lesion; TLR = target lesion revascularization; unprot = unprotected LM

Emergency Interventions on LM Stenosis

In the setting of an acute myocardial infarction, cardiogenic shock or in patients with severe unstable angina not treatable

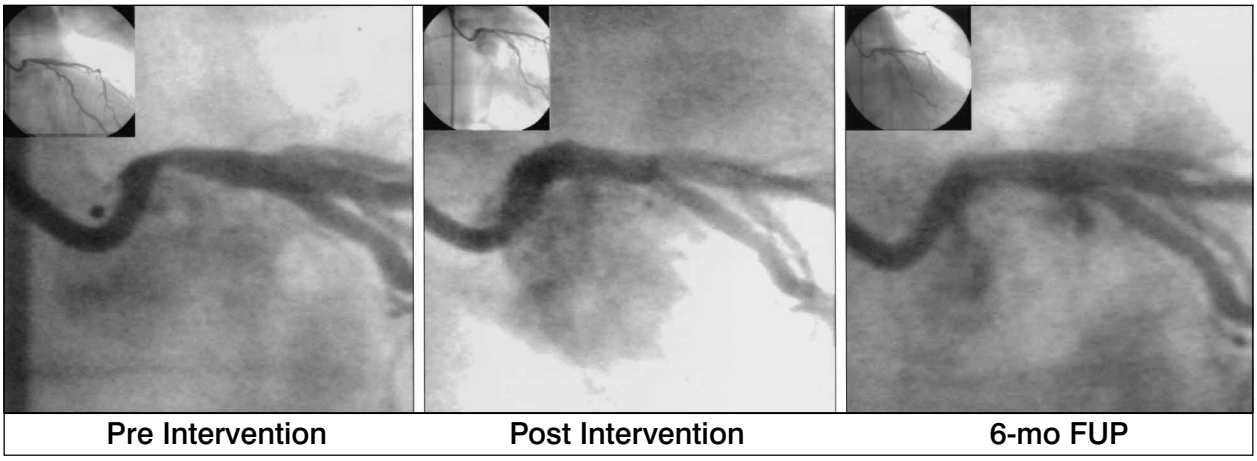

Figure 1. Angiograms of an unprotected left main coronary artery intervention and of the 6-month follow-up (6-mo FUP) result

by medication alone, the prognosis of a percutaneous intervention in the LM is not as favourable as in elective interventions and lower survival rates have to be expected. Ellis et al. [28] published a high procedure-related complication rate [25 %] and in-hospital mortality [69 %] of patients with acute myocardial infarction due to unprotected LM stenosis. Marso et al. [18] published a subanalysis of the ULTIMA registry on 40 patients with acute myocardial infarction (37 of them in cardiogenic shock) who underwent emergency percutaneous treatment of unprotected LM stenoses. The in-hospital death rate was 55 % for the entire group (70 % for the PTCA group and 35 % for the stent group). The 12 month survival rate was 35 % and 53 % for the PTCA and stent groups.

Using stents, balloon angioplasty and directional atherectomy for the emergency treatment of 24 patients with unprotected LM stenosis, Kosuga et al. [33] achieved an in-hospital survival rate of 62.5 % and a 5-year survival rate of approximately 50 %. In a second study using primarily directional atherectomy and stents for bail-out situations or suboptimal atherectomy results only, in-hospital survival was 86.7 %.

Although emergency percutaneous LM interventions lead to fairly good acute procedural success rates, this treatment option remains highly questionable, due to the high in-hospital mortality. Even though the survival rates after LM percutaneous interventions in emergency situations may seem extremely low, the bad results are similar to the results achieved in patients with cardiogenic shock for any cause. Interestingly, even if the patient's haemodynamic condition can be stabilized, a high incidence of restenosis and low event-free survival rate with an acceptable long-term mortality has to be expected.

Table 3. Acute interventions in high-risk patients

1st author	Year of publication	No of patients	Protected / unprotected	Device	In-hospital complic.	FUP time	Long-term results
O´Keefe [27]	1989	10	NA	PTCA	5 deaths	36 mo	3 alive 0 event-free
Crowley [25]	1994	15	NA	PTCA 1 DCA	1	12 mo	4 TLR
Chauhan [30]	1997	6	NA	PTCA stent	5 deaths	16 mo	1 event-free
Laruelle [19]	1998	8	NA	8 stent	2 deaths 1 AMI 1 em. CABG	7 mo	1 death
Karam [21]	1998	39*	39 unprot	39 stent	3 deaths	23 mo	6 deaths 2 TLR
Kornowski [22]	1998	124	120 prot 4 unprot	88 stent 36 PTCA	1 death 1 em. CABG 12 AMI	12 mo	3 AMI 21 TLR
Kosuga [33]	1999	24	24 unprot	10 PTCA 6 DCA 8 stent	9 deaths 5 re-PCI	35 mo	3 deaths
Marso [18]	1999	40	40 unprot	23 PTCA 17 stent	8 CABG 22 deaths	12 mo	8 CABG 1 death
Kosuga [35]	2001	15	15 unprot	15 DCA	2 deaths 3 re-PCI	34 mo	NA

* 6 patients with stable angina, 26 patients with unstable angina, 4 with recent AMI, 3 with AMI and total occlusion of the LM

AMI = acute myocardial infarction; complic. = complications; DCA = directional coronary atherectomy; em. CABG = emergency CABG; FUP = follow-up; mo = months; NA = data not available; prot = protected LM; No = number; PTCA = percutaneous transluminal coronary angioplasty; TLR = target lesion revascularization; unprot = unprotected LM

Catheter Complications Related to Left Main Disease

During diagnostic angiographic procedures or percutaneous coronary angioplasty of the other coronary arteries, the overall risk for a complication related to the LM is low;

however, if such complications occur they tend to be life-threatening and contribute to a large part of the total catheter-related mortality [38]. Consequently, patients who do develop complications during percutaneous coronary angiography or angioplasty should undergo emergency coronary bypass grafting.

The LM specific complications during LM interventions involve acute LM occlusion resulting in acute myocardial infarction, acute cardiac failure and cardiogenic shock; consequently, such complications require emergency bypass operations.

Predictors of Prognosis After Angioplasty of the LM

Several factors influence the outcome of percutaneous interventions of LM stenoses: degree of LM protection (unprotected circulation or protection by natural collaterals or by open bypass grafts), left ventricular function and the clinical symptoms before the intervention (stable or unstable angina, acute myocardial infarction) are significant predictors for procedure-related death [29]. Similarly, Ellis et al. [28] found the event-free survival rate to be significantly influenced by the presence of unstable angina, low left ventricular ejection fraction, and a non-use of directional coronary atherectomy as a percutaneous treatment modality for LM stenosis. Kornowski et al. [22] did not show a statistically significant improvement of late results after stent implantation; however, unstable angina, a lower postinterventional minimal lumen diameter (MLD) and the presence of diabetes mellitus significantly worsened the prognosis. Karam et al. [21] compared the 7 patients who suffered cardiac death with the 30 survivors and found a tendency to higher age and a higher proportion of women in the non-surviving group, besides the already mentioned predictive factors, e.g. 3-vessel disease, impaired left ventricular function, small postinterventional minimal lumen diameter and unstable angina pectoris.

Recommendations for Percutaneous Treatment of LM Stenoses

On the basis of the summarized knowledge of the large clinical studies on LM percutaneous treatment, the evolution of angioplasty devices and the current AHA guidelines [40, 41], percutaneous coronary angioplasty of protected LM stenosis can be a safe and effective treatment, while in the case of the unprotected LM stenosis, CABG should be preferred.

If a) CABG is refused by the patient, the physician or the surgeon, or CABG is contraindicated for any reason or impractical due to severe co-morbidity; or b) a rescue procedure on the unprotected LM stenosis needs to be done (critical haemodynamic condition due to ongoing myocardial ischaemia, cardiogenic shock with no time to wait for emergency bypass surgery), the following steps are recommended:

1. Second check of the indications for and contraindications to CABG;
2. Stabilization of the patient's condition (infusions, catecholamines, etc.);
3. Ensured surgical stand-by;
4. Use of an intraaortic balloon pump, cardiopulmonary support devices and other assist devices;
5. Use of stents or directional atherectomy followed by stent implantation;
6. Early control angiography (4–6 weeks after the procedure);
7. Elective CABG if there is no contraindication to bypass operation.

Conclusions

Since the first percutaneous transluminal angioplasties of LM stenoses were performed, techniques and success rates of the percutaneous interventions have improved. Best results can be achieved in patients with protected LM stenosis undergoing elective percutaneous interventions: the high acute procedural success pairs with low acute, subacute and follow-up cardiac event rates. Elective interventions of unprotected LM stenosis can also be safe with low intervention complication rates; however, the percutaneous treatment must be performed more cautiously, with the use of cardiopulmonary assist devices and surgical stand-by. Patients in critical haemodynamic status due to acute closure of LM have a low chance to survive, and besides a high acute procedural success rate, high in-hospital mortality has to be expected. In these patients, after haemodynamic stabilization and successful percutaneous LM angioplasty, an elective CABG should be performed during the early follow-up period.

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