Left Main Coronary Artery Disease: Is CABG Still the Gold Standard?

Martin K. C. Ng,*† MBBS, PhD, Alan C. Yeung, MD*

*Division of Cardiovascular Medicine, Stanford University Medical Center, Stanford, CA;
†Department of Cardiology, Royal Prince Alfred Hospital, Sydney, Australia

Severe stenosis of the left main coronary artery (LMCA) is a coronary artery-disease manifestation of critical prognostic importance. As a consequence of the survival advantage conferred by coronary artery bypass grafting (CABG) over medical therapy, lesions in the LMCA have been considered a standard indication for CABG for nearly 3 decades. Initial attempts to treat LMCA disease percutaneously by balloon angioplasty resulted in poor clinical outcomes, leading many to regard significant LMCA disease as a contraindication for percutaneous coronary intervention (PCI). However, the development and refinement of coronary stenting over the last 15 years, followed by the recent introduction of drug-eluting stents, has fueled renewed interest in percutaneous treatment of LMCA disease. Outcomes of recent studies using sirolimus- and/or paclitaxel-eluting stents for treatment of LMCA disease have yielded rates of in-hospital and 1-year mortality that compare favorably with those of surgery. This article will review the natural history of LMCA disease, the outcomes of CABG for LMCA disease, and the history and recent developments regarding PCI for LMCA disease.

[Rev Cardiovasc Med. *2005;6(4):187-193*]

Key words: Coronary artery disease • Left main • Stenting

Ever since the first clinical report of left main coronary artery (LMCA) disease by James Herrick in 1912,[1] many studies have shown that significant stenosis of the LMCA is the most prognostically significant manifestation of coronary disease.[2,3] Clinical outcomes in medically treated patients with LMCA disease are generally poor, with a 3-year mortality rate of around 50%. As a consequence of the survival advantage conferred by coronary artery bypass grafting (CABG) over medical therapy,[4] lesions in the LMCA have been

considered a standard indication for CABG for nearly 3 decades. Initial attempts to treat LMCA disease percutaneously, by balloon angioplasty, resulted in poor clinical outcomes, leading many to regard significant LMCA disease as a contraindication for percutaneous coronary intervention (PCI). However, the development and refinement of coronary stenting over the last 15 years, followed by the recent introduction of drug-eluting stents (DES), has fueled renewed interest in percutaneous treatment of LMCA disease.

Prognosis

As significant LMCA disease has long been considered an absolute indication for surgery, it is necessary to review literature from nearly 3 decades ago to learn about the prognosis of nonsurgically treated patients with this condition. In a study of 163 medically treated patients with LMCA stenoses greater than 50%, Conley and associates reported a 3-year survival rate of 50%.[3] Survival of patients with 50% to 70% stenosis (1- and 3-year survival of 91% and 66%, respectively) was better than for patients with a greater than 70% stenosis (1- and 3-year survivals of 72% and 41%).[3] In patients with greater than 70% LMCA stenosis, predictors of adverse outcome included chest pain at rest, ST-T wave changes on resting electrocardiogram, cardiomegaly on chest X-ray, a history of congestive cardiac failure, findings of left ventricular dysfunction at catheterization, and elevation of the arterial-mixed venous oxygen difference.

The Collaborative Study in Coronary Artery Surgery (CASS), including 1484 patients with LMCA disease, reported a 3-year survival of 69% for medically treated patients.[5] Independent predictors of mortality included low left ventricular score, congestive heart failure, age, hypertension, percent LMCA stenosis, and coronary artery dominance. The importance of left ventricular function in determining prognosis of LMCA disease is underlined by 15-year follow-up data from the CASS registry. Cumulative 15-year survival rates for patients with normal, mildly impaired, and severely impaired left ventricular systolic function were 51%, 38%, and less than 3%, respectively.[6]

Owing to the superiority of coronary artery bypass grafting over medical therapy in the treatment of LMCA disease in randomized trials conducted nearly 3 decades ago,[4,7] little data exists regarding the survival of medically treated patients in the *current era*, incorporating medications now considered standard of care for many patients with advanced coronary disease. These medications include statins, angiotensin-converting enzyme (ACE) inhibitors, and β-blockers. Such data, if available, would likely demonstrate improved survival for medically treated patients and would serve to recalibrate our understanding of the potential benefits of revascularization strategies in the current era.

Little data exists regarding the survival of medically treated patients in the current era, *incorporating medications now considered standard of care for many patients with advanced coronary disease.*

Surgery

Observational studies[5,8-10] and randomized trials[4,7,11-13] have consistently demonstrated a survival advantage for CABG over medical therapy for significant (≥ 50% stenosis) LMCA disease. In 1976, the Veterans Administration (VA) Cooperative Randomized trial reported a 3-year survival advantage of 82% for CABG versus 60% for medical therapy alone for LMCA disease, despite what would now be considered an extraordinarily high surgical mortality rate of 12%.[4] The European Coronary Surgical Study (ECSS) recruited lower risk patients than those of the VA Cooperative trial, with all patients enrolled being less than 65 years of age with good left ventricular function.[7] Not surprisingly, given a lower risk cohort, the 3-year survival benefit for CABG in ECSS was less than that observed for the VA study, at 91% for CABG versus 82% for medical therapy. Like the VA Cooperative trial, the CASS registry, incorporating almost 1500 patients with LMCA disease with a heterogenous surgical risk profile, reported an improved 4-year cumulative survival for CABG of 88%, versus 63% for medical therapy.[5] Data from the CASS study showed an overall 3.5% operative mortality for patients with LMCA disease.[5,14] In CASS, the CABG mortality rate increased with greater stenosis severity and with more myocardial territory in jeopardy (balanced and left dominant circulations).[15]

Long-term survival data (≥ 10 years) for LMCA disease patients in the VA Cooperative, ECSS, and CASS studies shed some light on the durability of benefit from CABG in LMCA disease. The 11-year cumulative survival of the 48 LMCA disease patients treated with CABG in the VA Cooperative trial was 59%.[11] No real comparison could be made with the medical group in this study as only 4 out of 43 patients initially assigned to medical treatment remained

medically treated at 7 years—44% of patients had died while 47% had undergone CABG. In the ECSS trial, involving patients with normal left ventricular function, the 10-year survival of the 28 patients randomized to CABG and 31 patients randomized to medical treatment for LMCA disease was similar, at 64% and 61%, respectively.[13] Data from the CASS registry demonstrate a 15-year cumulative survival for patients initially treated with CABG of 37% versus 27% for patients initially treated medically (25% of all medically treated patients received CABG during follow-up).[6] Long-term survival patterns among CASS registry patients with LMCA disease demonstrated a convergence in surgical and medical group survival curves after 8 years as the result of a disproportionate increase in mortality in the surgical group. This late increase in mortality in the CABG group compared to medical treatment, a pattern also noted in both the VA Cooperative and ECSS studies, has been attributed to a combination of progression of native coronary artery disease and graft occlusion.[16] Despite the diminution of survival benefit in the CABG group over time in the CASS registry, the median survival of LMCA disease patients in the surgical group was 13.3 years compared with only 6.6 years in the medical group.[6] However CABG did not prolong the survival of LMCA disease patients in a number of subgroups, including those with: 1) LMCA stenosis of less than 60%; 2) normal left ventricular function; or 3) a nonstenotic (< 70%) right coronary artery.

Percutaneous Coronary Intervention

Early Experience With Balloon Angioplasty

In 1978, Andreas Gruentzig reported balloon dilatation of the LMCA in 2 of the first 5 patients to undergo percutaneous transluminal coronary angioplasty (PTCA).[17] However, owing to procedural difficulties and an early cardiac death involving 1 of the 2 LMCA cases, Gruentzig concluded that significant LMCA stenosis was a contraindication for balloon PTCA.[18] Over the following decade, further early reports of PTCA for LMCA disease did little to dissuade clinicians from Gruentzig's conclusion. In the largest series of PTCAs performed in LMCA reported during this period, O'Keefe and colleagues from the Mid-America Heart Institute reported the outcomes of 127 LMCA angioplasties grouped into 3 categories: elective protected cases (where a patent bypass graft to one or both major branches of the left coronary artery is present), elective unprotected cases (without a patent bypass graft), and acute patients (in the context of acute myocardial infarction).[19]

Whereas procedural and 3-year mortalities were 2.4% and 10%, respectively, in elective protected cases, they were a sobering 9.1% and 64% in elective unprotected patients, and 50% and 70% in the acute subgroup. These and other data[20] led to the conclusion that although elective PTCA of unprotected LMCA was technically feasible, the poor prognosis of these patients precluded its use, except as a "last resort" for those in whom surgical revascularization was not an option.

During the 1990s, the rapid growth of coronary stenting, with its improved outcomes against restenosis compared to balloon PTCA, led to a reappraisal of the role of PCI for unprotected LMCA disease.

Bare Metal Stenting

During the 1990s, the rapid growth of coronary stenting, with its improved outcomes against restenosis compared to balloon PTCA,[21] led to a reappraisal of the role of PCI for unprotected LMCA disease. Furthermore, the development of debulking techniques, such as directional and rotational atherectomy, which were also believed to potentially reduce residual stenosis and subsequent restenosis, also helped stimulate renewed interest in percutaneous treatment of LMCA disease.[22]

Single- and multicenter case series have shown that elective stenting, with or without adjunctive debulking techniques, for unprotected LMCA disease, is technically feasible with very high rates (> 95%) of early procedural success.[22-28] However, long-term follow-up of these patients has revealed high rates of angiographic restenosis and repeat revascularization, with a relatively high incidence of cardiac death in the first 6 months post-intervention, particularly among patients at high surgical risk.[23,27,28] As part of the ULTIMA (Unprotected Left Main Trunk Investigation Multicenter Assessment) registry, Ellis and coworkers reported the outcomes of 91 patients who underwent elective unprotected LMCA interventions.[23] In-hospital outcomes were strongly related to left ventricular function: when left ventricular ejection fraction (LVEF) was ≥ 40%, mortality was 1.7% but when LVEF was < 30%, mortality was 32%. Disturbingly, 10.6% of hospital survivors died of a presumed cardiac cause within the first 6 months. As the majority of these patients were treated with stents (in

conjunction with dual antiplatelet therapy), the authors postulated that these deaths may have been due to either stent thrombosis or severe restenosis of the LMCA with consequent heart failure or electrical instability.[23] In an updated report from the ULTIMA registry incorporating 279 elective and emergent LMCA PCI cases, 1-year rates of cardiac death, myocardial infarction, and repeat revascularization were 20.2%, 9.8%, and 33.6%, respectively. Independent predictors of mortality included LVEF less than 30%, mitral incompetence grades 3 or 4, presentation with myocardial infarction and shock, serum creatinine ≥ 2 mg/dL, and severe lesion calcification. Among a low-risk subset of patients in the registry (age < 65 years with LVEF $> 30\%$), there was no periprocedural mortality and 1-year mortality was only 3.4%.

In a single-center study, Takagi and colleagues reported the outcomes in 67 patients who underwent unprotected LMCA intervention with a mean follow-up of 31 months.[27] Although there was no in-hospital mortality in this series, follow-up angiography in 85% of patients revealed a 31% restenosis rate, with 24% of patients undergoing repeat revascularization (7% by CABG) during the follow-up period. No benefit over stenting was observed in patients undergoing atherectomy. As with the ULTIMA registry results,[23] there was a high incidence of cardiac mortality in the first 6 months postprocedure, with 6 of 8 cardiac deaths during the entire follow-up period occurring during this time,[27] a pattern once again suggestive of LMCA stent thrombosis or fatal manifestation of restenosis.

As for the ULTIMA registry, outcomes were favorable for a subset of patients of low surgical risk (younger age, normal left ventricular function, and isolated left main disease) who had a 3-year mortality of only 4.2%. Other single center case series from Korean[22,24] and European centers[25,26] have also reported similarly favorable outcomes for LMCA PCI ($\leq 4\%$ 1-year mortality) among low-risk patient cohorts.

In summary, experience from case series has shown that although LMCA stenting is technically feasible, with high rates of early procedural success, patients undergoing unprotected LMCA PCI have high event rates because of frequent serious comorbidities. In a select proportion of low risk elective patients, bare metal stent (BMS) implantation for unprotected LMCA disease may provide outcomes that are comparable to CABG. However, high rates of restenosis with BMS, accompanied by high rates of repeat revascularization and cardiac events (including death) are a major problem, which precluded a more widespread adoption of PCI for LMCA stenosis during the BMS era.

Drug-Eluting Stents

Concerns about potentially fatal manifestations of severe in-stent restenosis involving the LMCA[23,27] have limited the more widespread use of PCI for LMCA disease. The recent introduction of drug-eluting stents (DES), either as sirolimus-eluting stent (SES) or paclitaxel-eluting stent (PES) systems, has resulted in dramatic reductions in in-stent restenosis rates compared to BMS.[29,30] Therefore, with the prospect of significantly lower rates of in-stent restenosis, interventional cardiologists have once again sought to reappraise the role of PCI for LMCA stenosis.

In a low surgical risk cohort with preserved left ventricular function (LVEF $> 40\%$), Park and associates compared the outcomes of 102 patients with *de novo* LMCA stenosis, treated with SES implantation, to outcomes of 121 historical controls, treated by BMS implantation.[31] At 6 months, angiographic restenosis rate in the SES group was significantly reduced to 7% compared to 30.3% in the BMS group. The very low rate of angiographic restenosis was observed in the SES group despite 70.6% of cases involving the bifurcation of the LMCA—an anatomic site that is associated with higher rates of restenosis. Figure 1 shows the 12-month event-free survival curves in the two groups. However, in keeping with a lower rate of restenosis in the SES group, the rate of target lesion revascularization at 12 months was much lower in the SES group (2%) compared to the BMS group (17.4%).

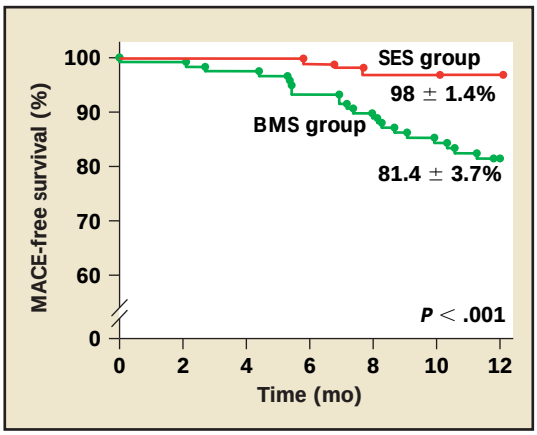
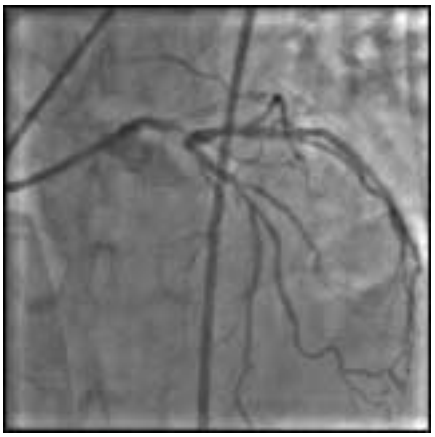
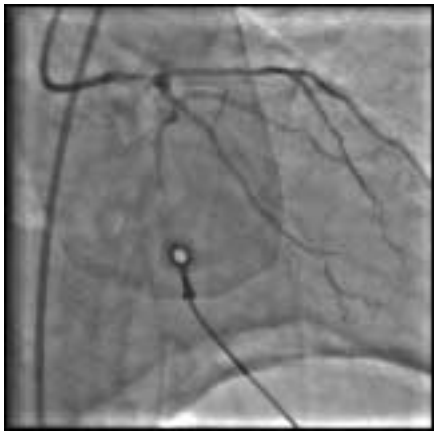


Figure 1. *Rates of survival, free from major adverse coronary events (MACE), in sirolimus-eluting stent (SES)-treated patients with left main coronary artery stenosis and preserved left ventricular function (LVEF $> 40\%$) versus historical controls treated with bare-metal stent (BMS) implantation. Reproduced with permission from Park et al.*[31]

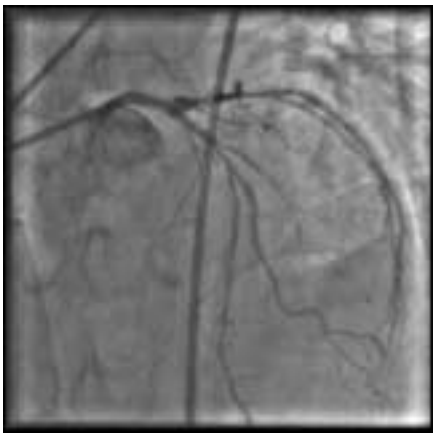


(A)

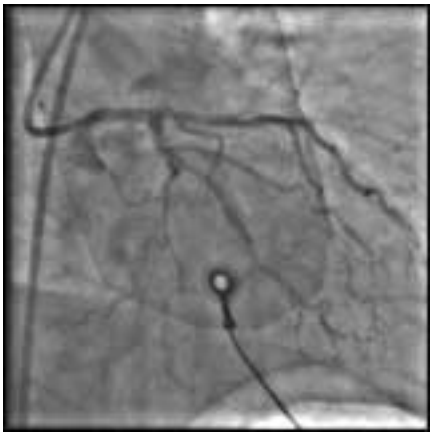


(B)

Figure 2. *Imaging of a 52-year-old man with a history of hyperlipidemia but not of diabetes. He develops angina on exertion and a stress test showed significant ischemia in the anterior-lateral region. Coronary angiography reveals a significant ostial and distal left main stenosis (***A** *and* **B***).*

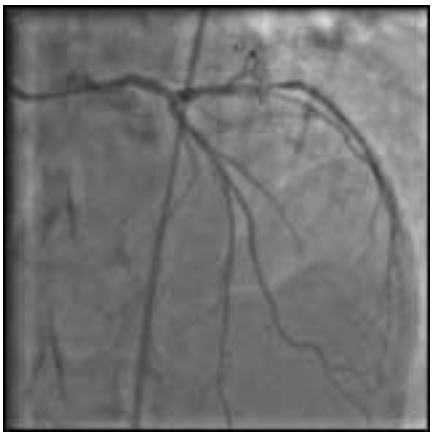


(A)

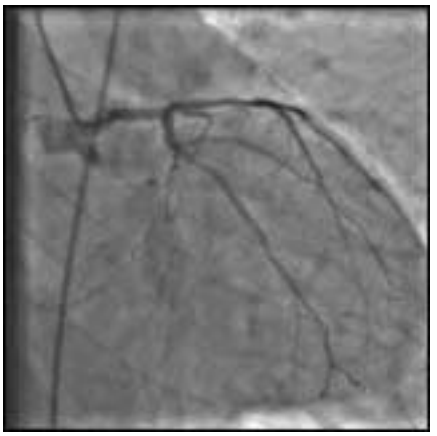


(B)

Figure 3. *The patient was seen by several cardiac surgeons and refused coronary artery bypass surgery. He underwent left main stenting with a drug-eluting stent from the ostial opening of the left main to the left anterior descending artery, covering the non-diseased ostial opening of the circumflex (***A** *and* **B***).*



(A)



(B)

Figure 4. *At 9-month follow-up, the patient remains asymptomatic and has a normal stress test. Follow-up angiography reveals a left main stent without restenosis (***A** *and* **B***).*

Valgimigli and colleagues compared the outcomes of 95 patients with LMCA stenosis (19 protected LMCAs) treated with DES (either SES or PES) with the outcomes from 86 historical controls (15 protected LMCA) in a single-center study.[32] Unlike the study by Park and associates,[31] this study incorporated patients at both low and high procedural risk—for example, 19% of PCIs were undertaken in the context of acute myocardial infarction. Approximately two thirds of PCIs in both DES and BMS groups involved the LMCA bifurcation. After a median follow-up of 503 days, lower rates of myocardial infarction (4% for DES vs. 12% for BMS) and target vessel revascularization (6% for DES vs. 23% for BMS) were observed in the DES group. Mortality was similar between DES (14%) and BMS (16%) groups. Independent predictors of major adverse cardiovascular events included distal LMCA location of lesion, Parsonnet classification of surgical risk, troponin level at entry, use of DES, and reference vessel diameter.[32]

In another single center study, Chieffo and coworkers compared the outcomes of 85 patients undergoing elective DES (either SES or PES) implantation for *de novo,* unprotected LMCA disease with 64 historical controls treated with BMS.[33] In comparison to patients receiving BMS, patients treated with DES had poorer left ventricular function, a higher incidence of diabetes mellitus, and more frequent involvement of the distal LMCA bifurcation. There was no in-hospital mortality in either group. Despite a higher preponderance of high risk features, the incidence of major adverse cardiac events (cardiac death, myocardial infarction, or repeat revascularization)

at 6-month follow-up was lower in the DES group than in the BMS group (20% vs. 35.9%, respectively). Cardiac deaths occurred in 3 patients (3.5%) in the DES group, as compared with 6 (9.3%) in the BMS group, a difference that was not statistically significant. Interestingly, restenosis rates were also not significantly different between DES (19%) and BMS (31%) groups, although restenoses in the DES group occurred exclusively at the LMCA bifurcation and were focal in nature.

In summary, DES left main stenting has medium-term acceptable outcome rates, especially if the left main stenosis does not include the bifurcation of the left anterior descending artery and circumflex artery.

DES left main stenting has medium-term acceptable outcome rates, especially if the left main stenosis does not include the bifurcation of the left anterior descending artery and circumflex artery.

Percutaneous Coronary Intervention Versus Surgery for Left Main Coronary Disease—Time for a Randomized Trial?

In an effort to establish a contemporary benchmark for CABG outcomes in the context of LMCA disease, Ellis and colleagues described the surgical outcomes of 1585 consecutively treated LMCA disease patients at the Cleveland Clinic Foundation.[34] Overall in-hospital mortality in this study was 2.3%, with a 1-year mortality of 11.3%. Independent predictors of adverse outcome included renal dysfunction, age, and New York Heart Association (NYHA) Class III or IV heart failure. Among patients at low surgical risk (age < 65 years and NYHA Class $\leq$ II heart failure), 1-year mortality was 5.7%.[28,34]

Recent outcomes for LMCA PCI in the DES era compare favorably with most surgical series,[6,34,35] particularly with respect to in-hospital mortality, which was 0% in the studies by Park and coworkers[31] and Chieffo and associates.[33] Moreover, published outcomes for DES out to 6 to 12 months post-procedure, in both low-risk[31] and higher-risk[33] patients, appear to be favorable compared to those reported for CABG. In light of these data, a randomized trial comparing CABG with DES placement for unprotected LMCA disease may now be warranted.

Conclusions

Severe stenosis of the LMCA is a manifestation of coronary artery disease of critical prognostic importance. As

Main Points

- As significant left main coronary artery (LMCA) disease has long been considered an absolute indication for surgery, it is necessary to review literature from nearly 3 decades ago to learn about the prognosis of nonsurgically treated patients with this condition.
- Little data exists regarding the survival of medically treated patients in the current era, incorporating medications now considered standard of care for many patients with advanced coronary disease, including statins, angiotensin-converting enzyme inhibitors, and β-blockers. Data on the use of these agents would likely demonstrate improved survival for medically treated patients and serve to recalibrate our understanding of the potential benefits of revascularization strategies.
- Data from early studies of balloon angioplasty in LMCA led to the conclusion that although elective PTCA of unprotected LMCA was technically feasible, the poor prognosis of these patients precluded its use, except as a "last resort" for those in whom surgical revascularization was not an option.
- Experience from case series has shown that although LMCA stenting is technically feasible with bare metal stents and provides high rates of early procedural success, patients undergoing unprotected LMCA PCI have high event rates because of frequent serious comorbidities.
- Left main stenting utilizing currently available drug-eluting stents (DES) has shown acceptable medium-term outcome rates, especially if the left main stenosis does not include the bifurcation of the left anterior descending artery and circumflex artery.
- In light of these data regarding DES in left main disease, a randomized trial comparing coronary artery bypass grafting with DES placement for unprotected LMCA disease may now be warranted.

a consequence of the survival advantage conferred by CABG over medical therapy, lesions in the LMCA have been considered a standard indication for CABG for nearly 3 decades. Initial attempts to treat LMCA disease percutaneously, by balloon angioplasty, resulted in poor clinical outcomes, leading many to regard significant LMCA disease as a contraindication for PCI. However, the development and refinement of coronary stenting over the last 15 years, followed by the recent introduction of DES has fueled renewed interest in percutaneous treatment of LMCA disease. Outcomes of recent studies using SES and/or PES for treatment of LMCA disease have yielded rates of in-hospital and 1-year mortality that compare favorably with most surgical series. These data have established a context for head-to-head comparisons between CABG and DES approaches for the treatment of LMCA disease. The results of such studies may ultimately lead to a paradigm shift in the treatment of LMCA disease. ■

References

1. Herrick J. Clinical features of sudden obstruction of the coronary arteries. *JAMA*. 1912;59: 2015-2020.
2. Conti CR, Selby JH, Christie LG, et al. Left main coronary artery stenosis: clinical spectrum pathophysiology and management. *Prog Cardiovasc Dis*. 1979;22:73-106.
3. Conley MJ, Ely RL, Kisslo J, et al. The prognostic spectrum of left main stenosis. *Circulation*. 1978;57:947-952.
4. Takaro T, Hultgren HN, Lipton MJ, Detre KM. The VA cooperative randomized study of surgery for coronary arterial occlusive disease: II. subgroup with significant left main lesions. *Circulation*. 1976;54:III-107-III-116.
5. Chaitman BR, Fisher LD, Bourassa MG, et al. Effect of coronary bypass surgery on survival patterns in subsets of patients with left main coronary artery disease: report of the Collaborative Study in Coronary Artery Surgery (CASS). *Am J Cardiol*. 1981;48:765-777.
6. Caracciolo EA, Davis KB, Sopko G, et al. Comparison of surgical and medical group survival in patients with left main coronary artery disease. Long-term CASS experience. *Circulation*. 1995;91:2325-2334.
7. European Coronary Surgery Study Group. Prospective randomized study of coronary artery bypass in stable angina pectoris. *Lancet*. 1980;2:491-495.
8. Cohen MV, Gorlin R. Main left coronary artery disease: clinical experience from 1964-1974. *Circulation*. 1975;52:275-285.
9. Talano JV, Scanlon PJ, Meadows WR, et al. Influence of surgery on survival in 145 patients with left main coronary artery disease. *Circulation*. 1975;52(2 Suppl):I105-I111.
10. Oberman A, Kouchoukos NT, Harrell RR, et al. Surgical versus medical treatment in disease of the left main coronary artery. *Lancet*. 1976;2: 591-594.
11. The Veterans Administration Coronary Artery Bypass Surgery Cooperative Study Group. Eleven-year survival in the Veterans Administration randomized trial of coronary bypass surgery for stable angina. *N Engl J Med*. 1984; 311:1333-1339.
12. European Coronary Surgery Study Group. Long-term results of a prospective randomized study of coronary artery bypass surgery in stable angina pectoris. *Lancet*. 1982;2:1173-1180.
13. Varnauskas E, for European Coronary Surgery Study Group. Twelve-year follow-up of survival in the randomized European Coronary Surgery Study. *N Engl J Med*. 1988;319:332-337.
14. Kennedy JW, Kaiser GC, Fisher LD, et al. Clinical and angiographic predictors of operative mortality from the Collaborative Study in Coronary Artery Surgery (CASS). *Circulation*. 1981;63:793-802.
15. Chaitman BR, Rogers WJ, Davis K, et al. Operative risk factors in patients with left main coronary artery disease. *N Engl J Med*. 1980;303:953-957.
16. Bourassa MG, Enjalbert M, Campeau L, Lesperance J. Progression of atherosclerosis in coronary arteries and bypass grafts: ten years later. *Am J Cardiol*. 1984;53:102C-107C.
17. Gruentzig AR. Transluminal dilatation of coronary artery stenosis. *Lancet*. 1978;1:263.
18. Gruentzig AR, Senning A, Siegenthaler WE. Nonoperative dilatation of coronary artery stenosis. *N Engl J Med*. 1979;301:61-67.
19. O'Keefe JHJ, Hartzler GO, Rutherford BD, et al. Left main coronary angioplasty: early and late results of 127 acute and elective procedures. *Am J Cardiol*. 1989;64:144-147.
20. Tommaso CL, Vogel JHK, Vogel RA. Coronary angioplasty in high risk patients with left main coronary stenosis: Results from the National Registry of Elective Supported Angioplasty. *Cathet Cardiovasc Diagn*. 1992;25:169-173.
21. Serruys PW, de Jaegere P, Kiemeneij F, et al. A comparison of balloon-expandable-stent implantation with balloon angioplasty in patients with coronary artery disease. Benestent Study Group. *N Engl J Med*. 1994;331:489-495.
22. Park SJ, Hong MK, Lee CW, et al. Elective stenting of unprotected left main coronary artery stenosis. Effect of debulking before stenting and intravascular ultrasound guidance. *J Am Coll Cardiol*. 2001;38:1054-1060.
23. Ellis SG, Tamai H, Nobuyoshi M, et al. Contemporary percutaneous treatment of unprotected left main coronary stenoses initial results from a multicenter registry analysis 1994–1996. *Circulation*. 1997;96:3867-3872.
24. Park SJ, Park SW, Hong MK, et al. Stenting of unprotected left main coronary artery stenoses: immediate and late outcomes. *J Am Coll Cardiol*. 1998;31:37-41.
25. Silvestri M, Barragan P, Sainsous J, et al. Unprotected left main coronary artery stenting: immediate and medium-term outcomes of 140 elective procedures. *J Am Coll Cardiol*. 2000; 35:1543-1550.
26. Black A, Cortina R, Bossi I, et al. Unprotected left main coronary artery stenting: correlates of midterm survival and impact of patient selection. *J Am Coll Cardiol*. 2001;37:832-838.
27. Takagi T, Stankovic G, Finci L, et al. Results and long-term predictors of adverse clinical events after elective percutaneous interventions on unprotected left main coronary artery. *Circulation*. 2002;106:698-702.
28. Tan WA, Tamai H, Park SJ, et al. Long-term clinical outcomes after unprotected left main trunk percutaneous revascularization in 279 patients. *Circulation*. 2001;104:1609-1614.
29. Morice MC, Serruys PW, Sousa JE, et al. A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization. *N Engl J Med*. 2002;346:1773-1780.
30. Stone GW, Ellis SG, Cox DA, et al. A polymer-based, paclitaxel-eluting stent in patients with coronary artery disease. *N Engl J Med*. 2004; 350:221-231.
31. Park SJ, Kim YH, Lee BK, et al. Sirolimus-eluting stent implantation for unprotected left main coronary artery stenosis: comparison with bare metal stent implantation. *J Am Coll Cardiol*. 2005;45:351-356.
32. Valgimigli M, van Mieghem CA, Ong AT, et al. Short- and long-term clinical outcome after drug-eluting stent implantation for the percutaneous treatment of left main coronary artery disease: insights from the Rapamycin-Eluting and Taxus Stent Evaluated At Rotterdam Cardiology Hospital registries (RESEARCH and T-SEARCH). *Circulation*. 2005;22:1383-1389.
33. Chieffo A, Stankovic G, Bonizzoni E, et al. Early and mid-term results of drug-eluting stent implantation in unprotected left main. *Circulation*. 2005;111:791-795.
34. Ellis SG, Hill CM, Lytle BW. Spectrum of surgical risk for left main coronary stenoses: benchmark for potentially competing percutaneous therapies. *Am Heart J*. 1998;135 (2 Pt 1):335-338.
35. d'Allonnes FR, Corbineau H, Le Breton H, et al. Isolated left main coronary artery stenosis: long term follow up in 106 patients after surgery. *Heart*. 2002;87:544-548.