Myocardial revascularization in stable coronary artery disease in patients with and without diabetes

Abstract:

In chronic stable angina management, percutaneous or surgical revascularization could be adopted in addition to optimum medical treatment. Choice of the most suitable and beneficial strategies usually depends on appropriate clinical judgment, meticulous assessment by different contemporary investigatory tools and patient preference. In this review, we address the impact of contemporary investigatory and treatment equipment such as pressure wire, intravascular imaging, myocardial perfusion scans, cardiac magnetic resonance and new generations of drug eluting stents, on the outcome of myocardial revascularization among variable stable coronary artery disease patients' profiles; old age, multi-vessel, left main disease and diabetic patients.

Key words: Myocardial revascularization, Stable coronary artery disease, Coronary bypass graft, percutaneous coronary intervention

1. Introduction:

In chronic stable angina, the decision to continue medical treatment alone and the timing of invasive myocardial revascularization has been informed by several recent trials. The advantages of invasive therapy have to be one or both of significant improvement in ischemic symptoms or reduced major cardiac events (myocardial infarction, unplanned revascularization, stroke and death). These intended benefits should outweigh the expected complications.

2. The outcome of revascularization by Percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) in comparison to medical treatment in chronic stable angina:

2.1 Trials showed no difference

"A meta-analysis of 11 randomized clinical trials, 2950 patients with stable angina (one or more coronary vessel disease), reported no difference in overall mortality rate, cardiac death, myocardial infarction and unplanned revascularization". [1]

Similar findings were reported in "2287 patients at 50 centers over a 5 year follow up period from 1999 to 2004 comparing the prognostic outcome of PCI to medical treatment in stable coronary artery disease. The data showed no significant difference in the risk of mortality, myocardial infarction, unplanned revascularization, stroke and hospitalization between the two groups. It should be noted that this trial included only patients with single artery disease and most cases were managed with bare metal stents". [2]

"In 2012, a meta-analysis of 8 clinical trials involving 7229 patients also failed to demonstrate beneficial outcomes on mortality, non-fatal myocardial infarction or future revascularization in the percutaneous intervention arm". [3]

2.1 Some promising outcomes for the percutaneous or surgical revascularization strategies over optimum medical treatment alone

The BARI 2D trial was a randomized controlled trial conducted from 2001 to 2005 in 49 centers. This study recruited 2368 diabetic patients with stable coronary artery disease with all patients deemed suitable for both PCI and CABG. There was no significant difference in all-cause mortality between the medical group and revascularization group (including PCI and CABG). In comparison to the medical treatment only, the occurrence of major cardiac

events was not significantly different in the PCI group while CABG group showed a lower incidence of all major cardiac events in comparison to the medical treatment alone. [4]

In the **RITA-2 trial**, 1018 patients from 20 cardiovascular centers in the UK and Ireland were randomized to medical treatment or percutaneous coronary angioplasty reported a significantly higher rate of symptoms improvement in the PCI group, particularly in patients presenting with severe symptoms. In the RITA 2 trial, symptom improvement was assessed with angina grade and total exercise time on Bruce exercise protocol.[5] Recently, the same evidence of anginal symptoms reduction has been demonstrated in ORBITA trial secondary analysis, particularly in patients with focal coronary lesions. [6]

In contrast to the above, **a study of elderly patients (>75 years of age), the TIME trial**, randomized to medical treatment or PCI, and reported a significant reduction in major cardiac events in the PCI group. In addition, there was significant improvement the symptoms and the quality of the life after 6 months. [7]

In a large meta-analysis of 100 trials, reporting outcomes in 93533 patients, receiving any type of revascularization ; balloon, bare metal stents and different generations of drug eluting stents revealed coronary bypass graft surgery to have some survival benefits in comparison to medical treatment; in addition, PCI with new generations of drug eluting stents was associated with better survival rates (Everolimus: 0.75, C.I 0.59-0.96) and (Zatrolimus: 0.65, C.I. 0.42-1) while survival benefits with balloon angioplasty, bare metal stents and early generations of drug eluting stents (Paclitaxel, sirolimus) showed no benefit. The need for unplanned revascularization was reduced in CABG and all stent based angioplasty in comparison to medical treatment. [8]

A meta-analysis of three randomized clinical trials (Courage, FAME II and SWIS II), showed a significant survival benefit in the PCI group over the medical treatment only when PCI was guided , by coronary physiology or imaging guided ischemia such as by myocardial perfusion scans, invasive angiography with flow function reserve or exercise ECG treadmill test. [9]

2.3 Myocardial revascularization versus medical treatment in multi-vessel disease:

Whilst the majority of studies have focused on single vessel disease, there have been studies looking at outcomes of revascularization in patients with multi-vessel disease. A meta-analysis of 12 studies comparing CABG versus PCI and another of 7 studies comparing CABG versus medical treatment (angiographic >50% narrowing) of unprotected left main stem,

revealed significant improvement in survival in both PCI and CABG groups in comparison to those on conservative medical treatment only. [10]

These findings were supported by findings from "a large study of 11661 patients with multi-vessel disease (defined as >70% angiographically narrowing in 2 or 3 major epicardial vessels or left main stem with narrowing more than 50% angiographically) over a 3 year-period. This study showed a significant 5-year survival improvement in CABG and PCI groups over the medical group". [11]

In one randomized clinical trial, conducted on 611 patients with multi-vessel disease randomized into PCI, CABG or medical treatment, the 10-year follow up showed that CABG led to a significant reduction in all major cardiac events (death, myocardial infarction and unplanned revascularization) in comparison to medical treatment. As in other studies, we saw consistent finding of the PCI group having a significantly higher incidence of revascularization and myocardial infarction in comparison to CABG. [12]

3. Investigatory tools usually help in myocardial revascularization decision making:

3.1 Coronary physiological assessment before myocardial revascularization:

The use of intracoronary physiology has facilitated the interrogation of coronary stenosis and allowed operators to identify significant flow limiting stenosis with greater accuracy than with angiography alone. This technology, by identifying significant lesions, has given hope to limiting invasive revascularization to only those lesions giving rise to significant ischemia and thereby avoiding unnecessary procedures.

In the DEFER study, 325 patients with moderate coronary stenosis had a functional flow reserve (FFR) assessment, 144 patients underwent PCI based on low FFR (<0.75), while those with functionally non-obstructing lesions were randomly assigned to either PCI (perform group) or medical treatment (defer group). The study revealed no significant difference in survival between the perform and defer groups over 5-years.[13]

The FAME study randomized 1005 either to angiographic guided PCI or FFR guided PCI with a cut-off value of 0.8. It showed a significant reduction in major cardiac events in the FFR guided PCI group up to 2 years but there was no significant difference between both groups from 2 to 5 years follow up. However, the number of stents was less in the FFR guided PCI. [14] In the subsequent FAME 2 trial, 888 patients with at least one significant lesion with FFR

<0.8 were assigned randomly into PCI plus medical treatment or medical treatment only. There was significant reduction in major cardiac events in the PCI arm in comparison to medical treatment, particularly in the rate of urgent revascularization due to myocardial infarction or evidenced myocardial ischemia. [15]

The role of FFR in changing strategy when compared to angiography alone was confirmed in the RIPCORD study of 200 patients. These patients with stable coronary artery disease had a plan based on coronary angiogram by an operator blinded to the FFR result. Following the FFR result, all patients had a plan guided by FFR and the study revealed a 26% change in the plan when compared to angiography alone with the lesions number and site of lesion changed in 32%.[16]

More recently, instantaneous wave free ratio (iwFR) has been introduced to measure coronary physiology with the advantage of not requiring intravenous vasodilators for measurement. This makes the procedure more comfortable for patients and easier for operators. A comparison between FFR and iwFR in a trial of 2492 patients were randomized to FFR and iwFR groups with treatment thresholds of 0.8 and 0.89, respectively. There was no significant difference in the survival rate between FFR guided decisions and iwFR which indicates non-inferiority of iwFR compared to FFR. [17] The absence of significant difference between PCI guided FFR and iwFR regarding the one year survival and major cardiac adverse events was observed in another trial done over 2037 patients who were randomized into FFR and iwFR guided PCI.[18]

The use of intracoronary physiology allows identification of culprit lesions and thereby successful execution of revascularization of the appropriate ischemia inducing vessel and lesion. This has the potential of reducing complications of performing revascularizations in non-culprit vessels.

3.2 Myocardial viability assessment before revascularization in patients with left ventricular systolic dysfunction:

In the viability sub-study of the Surgical Treatment for Ischemic Heart failure (STICH) trial, 618 of 1212 randomized patients had their viability assessment with stress Echocardiography or SPECT before their surgical revascularization (CABG). Regardless the adopted treatment plans, patients with myocardial viability evidence showed a better survival outcome in comparison to those with inviable myocardium (37% versus 51%; HR 0.64, 95% CI 0.48 to 0.86). At 10-year follow up, patient who had CABG showed a better

survival rate in comparison to those who have been managed with medical treatment only, in the whole cohort [61% (182 of 298) versus 69% (209 of 303), HR 0.73, 95% CI 0.6 to 0.9). Importantly, there was no significant interaction between viability results and outcome of CABG plus medical therapy over medical therapy alone on mortality outcome (P=0.34 for interaction). In other words, CABG in addition to optimum medical therapy had obvious benefits in both viable and non-viable myocardium and the magnitude of benefits was comparable in those two settings. [19]

"On the other hand, Revived- BCIS2 trial, conducted on 700 patients with severe left ventricular systolic dysfunction (EF ≤35%), extensive coronary disease and viability evidence, the patients were randomized into either PCI plus medical treatment or medical treatment only. The trial showed no significant difference between two arms regarding to all-cause mortality and hospitalization for heart failure reasons". [20]

"In a meta-analysis of 3088 coronary artery disease patients with left ventricular systolic dysfunction, there was a significant reduction in mortality only in patients with viable myocardium who underwent revascularization. Nevertheless, there was no significant difference in mortality between revascularization and medical groups in the non-viable myocardium patients. So, this meta-analysis highlighted the importance of myocardial assessment viability in the appropriately selecting patients for revascularization in the presence of left ventricular systolic dysfunction".[21]

3.3 Documented ischemia (with myocardial perfusion scan) before myocardial revascularization outcome:

In COURAGE, 314 patients underwent serial myocardial perfusion scan before and after the treatment. It showed higher rate of documented reduced myocardial ischemia (defined as more than 5% myocardial ischemia reduction) in the revascularization plus medical treatment group in comparison to the medical treatment, especially in the patient with moderate to severe baseline ischemia (defined as having more than 10 % ischemic myocardial segments. In addition, patients with reduced ischemia showed lower risk of death and myocardial infarction. [22] In another trial, 10627 consecutive patients with stable coronary artery disease patients received either medical treatment or underwent revascularization after they had stress myocardial perfusion scan. A significant survival benefit was seen in the revascularization group over the medical treatment in case of

moderate or high documented ischemia in myocardial perfusion scan (ischemic segment greater than 10% of the total segments). [23]

3.4 Rule of intravascular ultrasound (IVUS) in the left main artery revascularization:

In a study conducted on 975 patients with unprotected diseased left main re-vascularized with angiography guided PCI (219) or IVUS guided PCI (756). Analysis of 145 matched patients, who had undergone PCI with drug eluting stents, revealed better 3 year survival outcome in the IVUS group in comparison to the angiography guided PCI. [24]

4. Myocardial revascularization in complex coronary lesions:

4.1 Myocardial revascularization in multi-vessel disease and or left main disease

In the trial, 1800 patients with three vessel coronary artery disease or left main lesions were randomized to PCI with drug eluting stents or CABG. Approximately one quarter of the enrolled patients were diagnosed with diabetes mellitus. In addition, the surgical risk of the patients on both groups, based on euro SCORE assessment, was not significantly different. After 1 year follow up, the major adverse cardiac events and unplanned revascularization were significantly higher in the PCI group whilst the CABG arm showed higher stroke incidence in non-diabetic patients. Analysis based on subgrouping the sample on Syntax scores (low (0-22), intermediate (from 23-32) and high (≥33)) revealed the difference in major cardiac events between PCI and CABG was statistically significant only in the high Syntax subgroup. [25]

The 5 years follow up data confirmed that CABG was better in complex lesions (three vessel disease and left main) than PCI (only Paclitaxel eluting stents used) in terms of mortality, myocardial infarction, major cardiac events and unplanned revascularization and without the higher rate of stroke seen in 1 year follow up. In the left main subgroup, the MACE incidence was higher in PCI in comparison to CABG only in higher syntax group (≥32). In multi-vessel disease, the MACE rate was higher in the PCI group in both intermediate and high SYNTAX score.[26] The 10 year follow up revealed no significant difference in all-cause mortality in the whole sample but only in two subgroups; multi-vessel disease and higher syntax score (≥33). [27]

The follow-on Syntax II study attempted to address some of the shortcomings of Syntax I, with thin struts bio-resorbable polymer drug eluting stents used when indicated following lesion physiological assessment and IVUS image interrogation. A total of 454 of 708 de novo

three vessel disease patients (not including left main lesions) were selected to have PCI and one year follow up was compared with predefined PCI cohort group from the Syntax I trial. The rate of myocardial infarction, unplanned revascularization and in-stent thrombosis was significantly lower in the in SYNTAX II in comparison to the rate in PCI group in SYNTAX I, driven largely by use of newer generation stent and appropriate revascularization after lesion interrogation. [28]

"In the CARDia trial, 510 diabetic patients, with either 3 vessel disease or single complex coronary lesion were randomized to PCI (with bare metal stent or a sirolimus drug eluting stent) or CABG. At one year the rate of all-cause mortality, myocardial infarction, stroke or unplanned revascularization was significantly higher in the PCI group". [29]

The Freedom trial enrolled 1900 diabetic patients with multi-vessel disease (angiographic significant narrowing in two or more major epicardial vessels excluding the left main lesions). The patients were randomized to PCI (with Sirolimus or Paclitaxel drug eluting stents) or CABG. The 5-year all-cause mortality, nonfatal MI or nonfatal stroke was higher in the PCI group. [30] And a longer follow up (median 7.5 years) in a subset of 943 patients d also confirmed higher all-cause mortality in the PCI group. [31] "In the Freedom trial, subsequent analysis based on Syntax scores showed it to be an independent risk factor for higher major cardiac events rate in the PCI group but not the CABG group".[32]

"A pooled analysis from 3 trials, SYNTAX, PRECOMPACT and BEST trials, revealed the impact of SYNTAX score on patients with multi-vessel coronary disease. The result revealed that the rate of death, stroke or myocardial infarction, but not revascularization, was not significantly different between PCI and CABG in the subgroup of low or intermediate SYNATX (<33) but was significant in high SYNTAX scores". [33]

In a meta-analysis of 68 trials in diabetic patients with multi-vessel disease, patients who underwent, PCI with Paclitaxel or Sirolimus carried a significant higher rate of mortality and higher repeated revascularization compared to the CABG arm. However, patients undergoing PCI with a cobalt-chromium everolimus drug eluting stents showed no significant difference in mortality rate compared to CABG. Although the number of repeated revascularization was higher in the PCI with chromium cobalt everolimus stent arm, strokes were numerically higher in the CABG group but neither was statistically non-significant. [34]

In a registry, the short- and long-term outcome of PCI (with everolimus eluting stent) versus CABG was assessed on 8096 diabetic patients with multi-vessel disease. In the 30 days

outcome, the PCI group revealed significant reduction of stroke and death. Nevertheless, in the long-term outcome, PCI with everolimus eluting stent showed higher rate of myocardial infarction and repeat revascularization. Of note, the difference in myocardial infarction was not observed in the subgroup that underwent complete PCI revascularization. Consequently, staged or incomplete revascularization via PCI may be one of the causes of the usually observed better CABG outcome in multi-vessel disease. [35]

In another registry of multi-vessel disease analysis of 9223 patients who underwent PCI and 9223 patients CABG, the myocardial infarction and unplanned revascularization was significantly higher in the PCI group while the stroke incidence was higher in the CABG. Interestingly, the myocardial infarction incidence was not statistically significant in group of who underwent complete PCI revascularization. [36]

4.2 Impact of new generation stents on outcomes after percutaneous coronary intervention:

A study of 1830 diabetic patients and coronary artery disease showed that PCI with everolimus stents carries a lower rate of one year target vessel failure, stent thrombosis, repeated revascularization and myocardial infarction in comparison to paclitaxel eluting stents. [37] Qualitatively similar findings were seen in 3687 patients where patients receiving everolimus eluting stents had less target lesion failure (including death, myocardial infarction, and target lesion revascularization and stent thrombosis) in comparison to Paclitaxel in the diabetic subgroup. [38]

A meta-analysis of 3389 patient from four randomized trials studying the new bio-absorbable stent platform revealed no significant difference between the cobalt chromium and bio-absorbable stents in one year all cause death, cardiac mortality rate, all myocardial infarction and repeated revisualization; however, the rate of target vessel related myocardial infarction was significantly higher in the bioresorbable vascular scaffold group. [39]

“In the LEADERS trial, 1707 patients from 10 centers were randomized to a biodegradable polymer biolimus eluting stents and sirolimus eluting stents. There was a significantly lower rate of all death cause, myocardial infarction, revascularization in the biodegradable polymer stents with a significant lower rate of very late stent thrombosis (after 1-5 years) in the group of the biodegradable polymer stents”. [40]

"In a pooled meta-analysis from 11 clinical trials, conducted on 12644 patients, revealed no significant difference in the major cardiac events between biodegradable polymer drug eluting stents and second generation durable polymer drug eluting stents (evirolimus and Zatrolimus)". [41]

4.3 Myocardial revascularization outcome in left main artery disease:

In the Procombat trial, 600 patients with diseased unprotected left main artery were randomized to PCI with sirolimus eluting stent or CABG. After 5 years follow up, there was no significant difference in the major cardiac events apart from a higher rate of unplanned revascularization in the PCI group. [42]

In the NOBLE trial, 1201 patients with left main lesion (>50% angiographic narrowing or fractional flow reserve < 0.8) were randomized to CABG and PCI with drug eluting stents. In the PCI group, proximal and mid left main lesions were managed with a single stent while distal left main was managed with two stents with the Culotte technique preferred and proximal optimization technique along with final kissing done in most cases. This study revealed that PCI for left main cannot be considered as non-inferior to CABG because 5-year major cardiac events, all-cause mortality, non-procedural myocardial infarction and repeat revascularization were significantly higher in the PCI group. [43]

In contrast, the EXCEL trial of low or intermediate complex left main stem lesions complexity was assessed with SYTAX score, (low complexity ≤22, intermediate 23-32) revealed that PCI was non inferior to CABG in the primary end points including all-cause mortality, stroke or myocardial infarction over a 3 year follow up period. On the other hand, for predefined secondary end points, the rate of death, stroke or myocardial infarction in first 30 days was significantly higher in CABG than PCI, 7.9% and 4.9%, respectively. In addition, the major cardiac events (death, myocardial infarction, stroke or unplanned revascularization) in the PCI group, over 3 year follow up period, was non inferior to CABG group, 23.1% and 19.1%, respectively. [44]

5. Conclusion:

This review addresses the evolution of coronary revascularization and analyses major trials that have advanced our understanding of the management of atherosclerotic cardiovascular disease. In order to achieve optimal outcomes for the treatment of atherosclerotic cardiovascular disease, a balanced decision must be made between optimal medical

therapies, percutaneous or surgical revascularization. This decision should be guided by patient symptoms, objective evidence of ischemia severity, myocardial viability, lesion complexity and of course, patient preference. Recent trials confirm the successful role of optimal medical therapy in successfully managing patients with stable angina symptoms. The availability of new generation drug eluting stents has led to improved outcomes and the increasing value of lesion interrogation to limit revascularization in culprit lesions only, has improved outcomes from percutaneous revascularization. Numerous studies show the benefit of surgical revascularization in patients with complex multi-vessel disease with good long-term outcomes, particularly in patients receiving an internal mammary graft to the left anterior descending artery.

References:

[1] Katritsis DG, Ioannidis JPA. Percutaneous coronary intervention versus conservative therapy in nonacute coronary artery disease: A meta-analysis. Circulation 2005;111:2906–12. https://doi.org/10.1161/CIRCULATIONAHA.104.521864.

[2] Boden WE, O'Rourke RA, Teo KK, Hartigan PM, Maron DJ, Kostuk WJ, et al. Optimal Medical Therapy with or without PCI for Stable Coronary Disease. N Engl J Med 2007;356:1503–16. https://doi.org/10.1056/nejmoa070829.

[3] Stergiopoulos K, Brown DL. Initial coronary stent implantation with medical therapy vs medical therapy alone for stable coronary artery disease: Meta-analysis of randomized controlled trials. Arch Intern Med 2012;172:312–9. https://doi.org/10.1001/archinternmed.2011.1484.

[4] Frye RL, August P, Brooks MM, Hardison RM, Kelsey SF, MacGregor JM, et al. A Randomized Trial of Therapies for Type 2 Diabetes and Coronary Artery Disease. N Engl J Med 2009;360:2503–15. https://doi.org/10.1056/nejmoa0805796.

[5] Pocock S. Coronary angioplasty versus medical therapy for angina: the second Randomised Intervention Treatment of Angina (RITA-2) trial. Lancet 1997;350:461–8. https://doi.org/10.1016/S0140-6736(97)07298-X.

[6] Rajkumar C, Shun-Shin M, Seligman H, Ahmad Y, Warisawa T, Cook C, et al. TCT CONNECT-385 Placebo-Controlled Efficacy of Percutaneous Coronary Intervention for Focal and Diffuse Patterns of Stable Coronary Artery Disease: A Secondary Analysis From ORBITA. J Am Coll Cardiol 2020;76:B165. https://doi.org/10.1016/j.jacc.2020.09.407.

[7] Pfisterer M. Trial of invasive versus medical therapy in elderly patients with chronic symptomatic coronary-artery disease (TIME): A randomised trial. Lancet 2001;358:951–7. https://doi.org/10.1016/S0140-6736(01)06100-1.

[8] Windecker S, Stortecky S, Stefanini GG, DaCosta BR, Rutjes AW, Di Nisio M, et al. Revascularisation versus medical treatment in patients with stable coronary artery disease: Network meta-analysis. BMJ 2014;348. https://doi.org/10.1136/bmj.g3859.

[9] Gada H, Kirtane AJ, Kereiakes DJ, Bangalore S, Moses JW, Généreux P, et al. Meta-Analysis of Trials on Mortality After Percutaneous Coronary Intervention Compared With Medical Therapy in Patients With Stable Coronary Heart Disease and Objective Evidence of Myocardial Ischemia. Am J Cardiol 2015;115:1194–9. https://doi.org/10.1016/j.amjcard.2015.01.556.

[10] Bittl JA, He Y, Jacobs AK, Yancy CW, Normand S-LT. Bayesian Methods Affirm the Use of Percutaneous Coronary Intervention to Improve Survival in Patients With Unprotected Left Main Coronary Artery Disease. Circulation 2013;127:2177–85. https://doi.org/10.1161/CIRCULATIONAHA.112.000646.

[11] Dzavik V, Ghali WA, Norris C, Mitchell LB, Koshal A, Saunders LD, et al. Long-term survival in 11,661 patients with multivessel coronary artery disease in the era of stenting: A report from the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) Investigators. Am Heart J 2001;142:119–26. https://doi.org/10.1067/mhj.2001.116072.

[12] Hueb W, Lopes N, Gersh BJ, Soares PR, Ribeiro EE, Pereira AC, et al. Ten-Year Follow-Up Survival of the Medicine, Angioplasty, or Surgery Study (MASS II). Circulation 2010;122:949–57. https://doi.org/10.1161/CIRCULATIONAHA.109.911669.

[13] Pijls NHJ, van Schaardenburgh P, Manoharan G, Boersma E, Bech JW, van't Veer M, et al. Percutaneous Coronary Intervention of Functionally Nonsignificant Stenosis. 5-Year Follow-Up of the DEFER Study. J Am Coll Cardiol 2007;49:2105–11. https://doi.org/10.1016/j.jacc.2007.01.087.

[14] Van Nunen LX, Zimmermann FM, Tonino PAL, Barbato E, Baumbach A, Engstrøm T, et al. Fractional flow reserve versus angiography for guidance of PCI in patients with multivessel coronary artery disease (FAME): 5-year follow-up of a randomised controlled trial. Lancet 2015;386:1853–60. https://doi.org/10.1016/S0140-6736(15)00057-4.

[15] Gonçalves P de A. Co[1] Bangalore S, Guo Y, Samadashvili Z, Blecker S, Xu J, Hannan EL. Everolimus Eluting Stents Versus Coronary Artery Bypass Graft Surgery for Patients With Diabetes Mellitus and Multivessel Disease. Circ Cardiovasc Interv 2015;8. https://doi.org/10.1161. Rev Port Cardiol (English Ed 36:967–9. https://doi.org/10.1016/j.repce.2017.12.009.

[16] Curzen N, Rana O, Nicholas Z, Golledge P, Zaman A, Oldroyd K, et al. Does routine pressure wire assessment influence management strategy at coronary angiography for diagnosis of chest pain? the ripcord study. Circ Cardiovasc Interv 2014;7:248–55. https://doi.org/10.1161/CIRCINTERVENTIONS.113.000978.

[17] Davies JE, Sen S, Dehbi H-M, Al-Lamee R, Petraco R, Nijjer SS, et al. Use of the Instantaneous Wave-free Ratio or Fractional Flow Reserve in PCI. N Engl J Med 2017;376:1824–34. https://doi.org/10.1056/NEJMoa1700445.

[18] Götberg M, Christiansen EH, Gudmundsdottir IJ, Sandhall L, Danielewicz M, Jakobsen L, et al. Instantaneous Wave-free Ratio versus Fractional Flow Reserve to Guide PCI. N Engl J Med 2017;376:1813–23. https://doi.org/10.1056/NEJMoa1616540.

[19] Bonow RO, Maurer G, Lee KL, Holly TA, Binkley PF, Desvigne-Nickens P, et al. Myocardial Viability and Survival in Ischemic Left Ventricular Dysfunction. N Engl J Med 2011;364:1617–25. https://doi.org/10.1056/NEJMoa1100358.

[20] Perera D, Clayton T, Petrie MC, Greenwood JP, O'Kane PD, Evans R, et al. Percutaneous Revascularization for Ischemic Ventricular Dysfunction: Rationale and Design of the REVIVED-BCIS2 Trial: Percutaneous Coronary Intervention for Ischemic Cardiomyopathy. JACC Hear Fail 2018;6. https://doi.org/10.1016/j.jchf.2018.01.024.

[21] Allman KC, Shaw LJ, Hachamovitch R, Udelson JE. Myocardial viability testing and impact of revascularization on prognosis in patients with coronary artery disease and left ventricular dysfunction: A meta-analysis. J Am Coll Cardiol 2002;39:1151–8. https://doi.org/10.1016/S0735-1097(02)01726-6.

[22] Shaw LJ, Berman DS, Maron DJ, Mancini GBJ, Hayes SW, Hartigan PM, et al. Optimal medical therapy with or without percutaneous coronary intervention to reduce ischemic burden: results from the Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial nuclear substudy. Circulation 2008;117:1283–91. https://doi.org/10.1161/CIRCULATIONAHA.107.743963.

[23] Hachamovitch R, Hayes SW, Friedman JD, Cohen I, Berman DS. Comparison of the Short-Term Survival Benefit Associated With Revascularization Compared With Medical Therapy in Patients With No Prior Coronary Artery Disease Undergoing Stress Myocardial Perfusion Single Photon Emission Computed Tomography. Circulation 2003;107:2900–7. https://doi.org/10.1161/01.CIR.0000072790.23090.41.

[24] Park S, Kim Y, Park D. Impact of Intravascular Ultrasound Guidance on Long-Term Mortality in Stenting for Unprotected Left Main. Circ Interv 2009;2:167–77. https://doi.org/10.1161/CIRCINTERVENTIONS.108.799494.

[25] Serruys PW, Morice M-C, Kappetein AP, Colombo A, Holmes DR, Mack MJ, et al. Percutaneous Coronary Intervention versus Coronary-Artery Bypass Grafting for Severe Coronary Artery Disease. N Engl J Med 2009;360:961–72. https://doi.org/10.1056/NEJMoa0804626.

[26] Mohr FW, Morice M-C, Kappetein AP, Feldman TE, Ståhle E, Colombo A, et al. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. Lancet 2013;381:629–38. https://doi.org/10.1016/S0140-6736(13)60141-5.

[27] Thuijs DJFM, Kappetein AP, Serruys PW, Mohr F-W, Morice M-C, Mack MJ, et al. Percutaneous coronary intervention versus coronary artery bypass grafting in patients with three-vessel or left main coronary artery disease: 10-year follow-up of the multicentre randomised controlled SYNTAX trial. Lancet 2019;394:1325–34. https://doi.org/10.1016/S0140-6736(19)31997-X.

[28] Escaned J, Collet C, Ryan N, Luigi De Maria G, Walsh S, Sabate M, et al. Clinical outcomes of state-of-the-art percutaneous coronary revascularization in patients with de novo three vessel disease: 1-year results of the SYNTAX II study. Eur Heart J 2017;38:3124–34. https://doi.org/10.1093/eurheartj/ehx512.

[29] Kapur A, Hall RJ, Malik IS, Qureshi AC, Butts J, de Belder M, et al. Randomized Comparison of Percutaneous Coronary Intervention With Coronary Artery Bypass Grafting in Diabetic Patients. 1-Year Results of the CARDia (Coronary Artery Revascularization in Diabetes) Trial. J Am Coll Cardiol 2010;55:432–40. https://doi.org/10.1016/j.jacc.2009.10.014.

[30] Farkouh ME, Domanski M, Sleeper LA, Siami FS, Dangas G, Mack M, et al. Strategies for Multivessel Revascularization in Patients with Diabetes. N Engl J Med 2012;367:2375–84. https://doi.org/10.1056/NEJMoa1211585.

[31] Farkouh ME, Domanski M, Dangas GD, Godoy LC, Mack MJ, Siami FS, et al. Long-Term Survival Following Multivessel Revascularization in Patients With Diabetes. J Am Coll Cardiol 2019;73:629–38. https://doi.org/10.1016/j.jacc.2018.11.001.

[32] Esper RB, Farkouh ME, Ribeiro EE, Hueb W, Domanski M, Hamza TH, et al. SYNTAX Score in Patients With Diabetes Undergoing Coronary Revascularization in the FREEDOM Trial. J Am Coll Cardiol 2018;72:2826–37. https://doi.org/10.1016/j.jacc.2018.09.046.

[33] Cavalcante R, Sotomi Y, Mancone M, Whan Lee C, Ahn J-M, Onuma Y, et al. Impact of the SYNTAX scores I and II in patients with diabetes and multivessel coronary disease: a pooled analysis of patient level data from the SYNTAX, PRECOMBAT, and BEST

trials. Eur Heart J 2017;38:1969–77. https://doi.org/10.1093/eurheartj/ehx138.

[34] Bangalore S, Toklu B, Feit F. Outcomes With Coronary Artery Bypass Graft Surgery Versus Percutaneous Coronary Intervention for Patients With Diabetes Mellitus. Circ Cardiovasc Interv 2014;7:518–25. https://doi.org/10.1161/CIRCINTERVENTIONS.114.001346.

[35] Bangalore S, Guo Y, Samadashvili Z, Blecker S, Xu J, Hannan EL. Everolimus Eluting Stents Versus Coronary Artery Bypass Graft Surgery for Patients With Diabetes Mellitus and Multivessel Disease. Circ Cardiovasc Interv 2015;8. https://doi.org/10.1161/CIRCINTERVENTIONS.115.002626.

[36] Bangalore S, Guo Y, Samadashvili Z, Blecker S, Xu J, Hannan EL. Everolimus-Eluting Stents or Bypass Surgery for Multivessel Coronary Disease. N Engl J Med 2015;372:1213–22. https://doi.org/10.1056/NEJMoa1412168.

[37] Kaul U, Bangalore S, Seth A, Arambam P, Abhaichand RK, Patel TM, et al. Paclitaxel-Eluting versus Everolimus-Eluting Coronary Stents in Diabetes. N Engl J Med 2015;373:1709–19. https://doi.org/10.1056/NEJMoa1510188.

[38] Stone GW, Rizvi A, Newman W, Mastali K, Wang JC, Caputo R, et al. Everolimus-Eluting versus Paclitaxel-Eluting Stents in Coronary Artery Disease. N Engl J Med 2010;362:1663–74. https://doi.org/10.1056/nejmoa0910496.

[39] Stone GW, Gao R, Kimura T, Kereiakes DJ, Ellis SG, Onuma Y, et al. 1-year outcomes with the Absorb bioresorbable scaffold in patients with coronary artery disease: a patient-level, pooled meta-analysis. Lancet 2016;387:1277–89. https://doi.org/10.1016/S0140-6736(15)01039-9.

[40] Serruys PW, Farooq V, Kalesan B, De Vries T, Buszman P, Linke A, et al. Improved safety and reduction in stent thrombosis associated with biodegradable polymer-based biolimus-eluting stents versus durable polymer-based sirolimus-eluting stents in patients with coronary artery disease: Final 5-year report of the LEADERS (limus. JACC Cardiovasc Interv 2013;6:777–89. https://doi.org/10.1016/j.jcin.2013.04.011.

[41] Pandya B. Biodegradable polymer stents vs second generation drug eluting stents: A meta-analysis and systematic review of randomized controlled trials. World J Cardiol 2016;8:240. https://doi.org/10.4330/wjc.v8.i2.240.

[42] Ahn J-M, Roh J-H, Kim Y-H, Park D-W, Yun S-C, Lee PH, et al. Randomized Trial of Stents Versus Bypass Surgery for Left Main Coronary Artery Disease. J Am Coll Cardiol 2015;65:2198–206. https://doi.org/10.1016/j.jacc.2015.03.033.

[43] Mäkikallio T, Holm NR, Lindsay M, Spence MS, Erglis A, Menown IBA, et al. Percutaneous coronary angioplasty versus coronary artery bypass grafting in treatment of unprotected left main stenosis (NOBLE): a prospective, randomised, open-label, non-inferiority trial. Lancet 2016;388:2743–52. https://doi.org/10.1016/S0140-6736(16)32052-9.

[44] Stone GW, Sabik JF, Serruys PW, Simonton CA, Généreux P, Puskas J, et al. Everolimus-Eluting Stents or Bypass Surgery for Left Main Coronary Artery Disease. N Engl J Med 2016;375:2223–35. https://doi.org/10.1056/NEJMoa1610227.