Revascularization in ischemic heart failure with reduced left ventricular ejection fraction. The impact of complete revascularization

Łukasz Pyka, Michał Hawranek, Mariusz Gąsior

3rd Department of Cardiology, SMDZ in Zabrze, Medical University of Silesia in Katowice, Silesian Center for Heart Diseases, Zabrze, Poland

Kardiochirurgia i Torakochirurgia Polska 2017; 14 (1): 37-42

Abstract
Heart failure is a growing problem worldwide, with coronary artery disease being the underlying cause of over two-thirds of cases. Revascularization in this group of patients may potentially inhibit the progressive damage to the myocardium and lead to improved outcomes, but data in this area are scarce. This article emphasizes the role of qualification for revascularization and selection of method (percutaneous coronary intervention vs. coronary artery bypass grafting) and subsequently focuses on the issue of completeness of revascularization in this group of patients.

Key words: heart failure, coronary artery disease, complete revascularization.

Introduction
Heart failure (HF) is a growing problem for health care worldwide. It is currently estimated that 1–2% of all people living in the developed countries suffer from HF [1]. There is a clear relationship between socioeconomic development and ageing of societies and the occurrence of heart failure. Ischemia is the predominant etiologic factor of HF, accounting for over two-thirds of all HF cases [2]. With improved treatment – and reduced mortality – of acute coronary syndrome patients and the optimized care of stable coronary artery disease (CAD) patients, the number of patients with ischemic HF will inevitably grow.

The treatment of HF has improved over the years with the introduction of milestone forms of therapy, such as contemporary medical treatment (e.g. β-blockers) [3], orthotopic heart transplantation (OHT) or prevention of sudden cardiac death [4]. However, it seems that revascularization in ischemic HF was never recognized as one. In fact, despite common use of both percutaneous coronary interventions (PCI) and coronary artery bypass grafting (CABG) in ischemic heart failure, data supporting its role are still scarce [5].

Systolic ischemic heart failure
This review concentrates on treatment of heart failure with reduced ejection fraction (HFrEF), defined per the 2016 ESC heart failure guidelines as HF with left ventricular ejection fraction (LVEF < 40%) and ischemic etiology. Patients without significant impairment of LVEF with diagnosed heart failure form a completely different group (regarding treatment and prognosis) and are not the subject of this article.

Ischemia is the most frequent cause of systolic HF. Treatment of patients with this HF etiology differs from other forms of HF, as there is often an opportunity to remove or reduce the basic cause of myocardial damage – ischemia. Despite this fact, data on revascularization in this group of patients are limited. The guideline-based treatment in HF is generally based on a single scheme, consisting of medical treatment, prevention of sudden cardiac death and, finally, qualification for mechanical circulatory support or OHT. This form of treatment reflects the natural progression of HF, caused by a “vicious circle” mechanism. Myocardial damage leads to activation of the parasympathetic system and the renin-angiotensin-aldosterone axis, providing a short-term compensation of the circulatory system. In the long run,
Revascularization in ischemic heart failure with reduced left ventricular ejection fraction. The impact of complete revascularization

However, it causes deprivation of energetic resources. Subsequently, oxidative stress leads to further myocardial damage. Prolonged activation of these mechanisms causes electrolyte imbalance and arrhythmia [6]. Lack of medical intervention at this stage leads to inevitable progression of HF, a breakdown of compensation mechanisms, multi-organ failure and finally electrical instability of the heart and death [7, 8].

In the “vicious circle” mechanism the role of progression of underlying disease, i.e. long-term ischemia and hibernation of myocytes, is another, sometimes underestimated, mechanism leading to further myocardial damage. It can be an additional, alongside the neuro-hormonal, mechanism of HF progression. It seems that in ischemic HF insufficient attention is paid to the role of revascularization in stopping this mechanism.

**Invasive diagnostics**

Even the qualification for coronary angiography (CA) in HF remains unclear. In everyday clinical practice de novo HF is considered an indication for invasive diagnostics, but guidelines do not support it. Currently two ESC guidelines undertake this issue:

1. The guidelines for treatment of stable coronary artery disease indicate that CA is indicated in all patients with impaired LVEF < 50% and angina pectoris. In absence of angina further non-invasive testing is required [9].
2. The 2016 Acute and Chronic Heart Failure Guidelines define angina pectoris, electrical instability and cardiac arrest as the basic indications for CA. In other cases, non-invasive stress testing should precede qualification [6].

However, there are clinical scenarios not reflected in the guidelines. Conditions such as further reduction of LVEF in ischemic HF commonly result in CA qualification, even without clear guideline support.

**Myocardial viability**

The presence of viable myocardium as a target for revascularization has become the gold standard ever since the Allman et al. meta-analysis in 2002, where a benefit of revascularization only in patients with myocardial viability was found [10]. Recently Inaba et al. published a meta-analysis confirming the results of the Allman study [11].

The reason for viability testing is to identify regions of hibernated myocardium (as opposed to tissue with no potential for improvement after reperfusion). The currently available methods of myocardial viability testing are:

1. Transthoracic resting echocardiography (indirectly, via assessment of parameters such as wall motion score index, measurement of wall thickness, etc.),
2. Echocardiographic stress testing (dobutamine or exercise induced),
3. Magnetic resonance imaging (MRI),
4. Single photon emission computed tomography (SPECT),
5. 18F-fluorodeoxyglucose positron emission tomography (18-FDG-PET).

Transthoracic resting echocardiography is an often-underappreciated method, but in everyday clinical practice its value is undeniable. Especially in numerous primary care centers where other methods are unavailable, the role of echocardiography prior to invasive or surgical procedures should be essential.

As for the other methods, numerous studies have been published since in this area. Entering the phrase “myocardial viability” in the pubmed.org search engine returns over 2200 results. The information mostly concerns the selection for the optimal myocardial viability testing method. It must be recognized that no significant advantages of any of the available viability testing methods have been proven.

Moreover, despite the very significant position of myocardial viability testing in current guidelines and clinical practice, there are no randomized data to support the influence of revascularization in viable myocardial segments on improved prognosis in HF patients; both the STICH trial [12] and the PARR-2 trial showed no real benefit of viability-guided revascularization [13]. It is also important that there are hypotheses that support revascularization in non-viable regions, especially regarding the question of electrical stability. Although studies such as an analysis by Brugada et al. have not proven the influence of revascularization on ventricular arrhythmia substrate modification [14], ischemia of the para-cicatrix region is considered as a potential arrhythmia trigger.

**Revascularization – coronary artery bypass grafting**

Contemporary evidence-based knowledge on revascularization in HF has been founded on the same clinical information for many years now. The cornerstone of this knowledge was published by Rahimtoola over 30 years ago. He stated that LV function in hibernated myocardium may be reversed with improvement of blood flow or reduction of oxygen demand [15]. The basis for implementation of viability-based revascularization was the aforementioned Allman analysis. However, the present position of surgical revascularization, represented by its status in the 2014 Myocardial Revascularization guidelines [5], is a result of the only contemporary randomized study on revascularization in ischemic heart failure, the STICH trial [12]. Even though it was an overall negative trial, failing to achieve its primary endpoint (death from any cause), subanalyses of all-cause mortality in a per protocol analysis as well as mortality from cardiovascular causes have shown a clear benefit for patients undergoing CABG with optimal medical treatment (OMT) versus OMT alone. It is worth mentioning that there is a general conviction that the STICH population is a “real” ischemic HF population, with significantly impaired LVEF and a significant proportion of comorbidities. However, the low prevalence of implantable cardioverter defibrillator (ICD) or cardiac resynchronization therapy defibrillator (CRT-D) in the STICH trial is a potential confounder of the results.

Due to conflicting recruitment, another randomized trial, the HEART study, was prematurely stopped and did not produce significant results [13]. An overview of available registries on patients undergoing CABG, providing informa-
tion on “real life” patient care, also shows a clear advantage of CABG over OMT, such as an analysis of the APPROACH registry. This analysis, however, bears a common limitation of utilizing a strictly clinical definition of HF, with no regard to LVEF. In this analysis of HF patients over 50% of subjects had an LVEF of > 50%. This does not change the fact that the role of CABG in ischemic HF is significant, with a strong position in contemporary guidelines.

However, many ischemic HF patients, especially with regard to age and profile of comorbidities, are considered unsuitable cardiac surgery candidates and are subsequently qualified for PCI.

Revascularization – percutaneous coronary intervention

The number of patients with ischemic HF patients qualified for PCI has equaled and exceeded the number of patients qualified for CABG [16, 17]. Despite the marginal role of PCI in the 2014 myocardial revascularization guidelines, a consequence of the lack of randomized data on PCI in HF, the role of percutaneous revascularization is growing, and one might argue that in real-life conditions it has already exceeded the role of CABG. The available data on PCI in HF are derived from comparisons to CABG. A paucity of randomized data is also clear, as shown in an analysis by Hlatky et al., where in an analysis of available randomized studies on PCI vs. CABG only 17% of patients had “abnormal left ventricular function” [18]. Therefore, available data are mostly based on registries. Again, a strictly clinical definition of heart failure is often utilized and a large proportion of subjects have preserved LVEF in these studies. The CREDO-Kyoto registry investigators concluded that in a large population of HF patients undergoing PCI the SYNTAX score was higher [19]. One could argue that such results are difficult to extrapolate to the systolic HF population. On the other hand, studies regarding the use of PCI in HF patients with a significant burden of comorbidities (larger than in the STICH population), along with a significant impairment of LVEF and complex coronary anatomy, concentrate on the use of mechanical circulatory support during high-risk PCI procedures, either with the use of the Impella device (PROTECT-II) or intra-aortic balloon pumping (BCIS-I). These studies show very good results of PCI in extremely difficult patient population, but are concentrated on immediate and short-term procedural success rather than long-term outcomes. The recently published long-term outcomes of the BCIS-1 trial show a benefit for patients treated with percutaneous support, but even for the authors this is difficult to rationalize [20, 21]. Moreover, the results of these studies again do not reflect everyday clinical practice. There is a great need for more data on PCI in HF.

Completeness of revascularization

While data on the role of CABG and, especially, PCI in HF are insufficient, the information on particular treatment strategies is even more lacking. Completeness of revascularization (CR) has been one of the “hot topics” in coronary revascularization for many years, and there is a general consensus that it should lead to improved results.

There is a hypothetical rationale to consider complete revascularization of utmost importance in HF patients, even more so than in patients with preserved LVEF. Restoring blood flow to regions of hibernated muscle may improve contractility and minimize adverse remodeling, leading to more pronounced benefits than in patients with preserved ventricular function. Protection from ventricular arrhythmia may also be of utmost importance, as persistent ischemia can be a trigger for arrhythmia [14].

The definition of CR itself is a point for discussion. At least three definitions are used: angiographic, physiological (FFR-based) and functional (viability-based).

Anatomical CR is achieved by stenting or grafting every angiographically significant lesion, usually with exclusion of small vessels (i.e. < 2 mm diameter). A strictly anatomical definition may be reasonable in HF and, due to the aforementioned rationale, is often used. In select cases, especially in presence of ventricular arrhythmia or in no-option advanced HF patients, decisions to revascularize based strictly on angiographic data are undertaken.

However, with data from the FAME and FAME-2 trials fractional flow reserve (FFR) assessment may add to the decision-making process, leading to achievement of “physiologically” complete revascularization – understood as revascularization of every vessel with significant stenosis in FFR [22]. There are, however, limitations to FFR in heart failure patients, such as the influence of higher left ventricular end diastolic pressure on the result, which may lead to inconsistent outcomes in select cases.

The third definition is functional, myocardial viability based [23]. In myocardial viability testing usually good improvement of contractility is assessed. In the aspect of complete revascularization, testing viability in regions supplied by particular coronary arteries should be performed. This may provide sufficient data to revascularize only in viable territories, while even angiographically significant lesions may be treated conservatively.

Despite many rationales to aim for CR, evidence-based data are not unanimous and in HF particularly are scarce. The most important randomized data, suggesting a benefit resulting from complete revascularization, or rather a burden resulting from incomplete revascularization, are derived from the SYNTAX and FAME trials [22, 24]. These studies, however, did not incorporate significant proportions of HFrEF patients (FAME – mean LVEF 57.1% in angiography group, SYNTAX – 1.8% with HF and LVEF < 30%). A summary of available data on CR with special regard to HFrEF patients is presented in Table I. These studies show that complete revascularization is generally related to improved results, although it is often achieved in pa-
**Tab. I.** Data on complete revascularization with special regard to patients with heart failure and impaired left ventricular ejection fraction (LVEF)

| Study name                        | Study type     | Number of patients | Method of revascularization | Percentage of patients with impaired LVEF | Benefit of CR                                           | Benefit of CR in impaired LVEF |
|-----------------------------------|----------------|--------------------|------------------------------|------------------------------------------|-------------------------------------------------------|--------------------------------|
| CASS (Bell et al.) [25]           | Observational  | 3372               | CABG                         | 4.3%                                     | Only CCS III/IV, especially LVEF < 35%               | Improved 6-year survival in patients with CCS III/IV angina |
| NHLBI (Bourassa et al.) [30]      | Observational  | 757                | PCI                          | N/A (21% with LVEF < 50%)                | Reduced late occurrence of CABG                      | N/A                            |
| Bell et al. [31]                  | Observational  | 867                | PCI                          | N/A (23% with LVEF ≤ 50%)                | No difference                                        | N/A                            |
| BARI (Kip et al.) [32]            | Observational  | 2047               | PCI                          | N/A (73.9% with LVEF < 50%)              | Reduced need for CABG                                | N/A                            |
| BARI (Vander Salm et al.) [33]    | Observational  | 1507               | CABG                         | N/A (8% with HF, mean LVEF 61 ±13%)     | No difference                                        | N/A                            |
| Scott et al. [34]                 | Observational  | 2067               | CABG                         | N/A (“severe LV dysfunction” in 2% of subjects) | Improved survival                                  | None; LV dysfunction correlated with more IR           |
| Ijselmuiden et al. [35]           | Randomized     | 219                | PCI                          | N/A                                      | No difference                                        | N/A                            |
| Kleisli et al. [36]               | Observational  | 1034               | CABG                         | N/A (29% with LVEF < 50%)                | No difference after adjustment for risk factors      | None reported                     |
| NYS (Hannan et al.) [37]          | Observational  | 21945              | PCI                          | 10.2% LVEF < 40%                        | Improved survival                                    | No benefit                       |
| APPROACH (McLellan et al.) [38]   | Observational  | 1956               | PCI                          | 5% LVEF ≤ 30%                           | Less need for CABG, trend towards better survival    | N/A                            |
| Kozower et al. [39]               | Observational  | 500                | CABG                         | N/A (mean LVEF 46%)                     | Improved survival (octogenarians only)               | N/A                            |
| NYS (Hannan et al.) [40]          | Observational  | 11294              | PCI                          | 11% LVEF < 40%                          | Improved survival                                    | No benefit                       |
| Valenti et al. [41]               | Observational  | 486                | PCI                          | 34.3% LVEF < 40%                        | Improved survival                                    | N/A                            |
| Rastan et al. [42]                | Observational  | 8806               | CABG                         | 4.8% LVEF < 30%                         | No difference                                        | No difference                    |
| Mohr et al. [43]                  | Randomized/observational | 1541               | CABG                         | 3.3% LVEF < 30%                         | Less repeat revascularization                        | N/A                            |
| Aziz et al. [44]                  | Observational  | 580                | CABG                         | N/A (mean LVEF = 45%)                   | Improved survival (octogenarians only)               | N/A                            |
| Lehmann et al. [45]               | Observational  | 679                | PCI                          | 18.4% LVEF ≤ 30%                        | Improved survival                                    | N/A                            |

CABG – coronary artery bypass grafting, PCI – percutaneous coronary intervention, N/A – not available, CR – completeness of revascularization.
tients with a smaller burden of comorbidities and favorable coronary anatomy. Nonetheless, it is important to note that patients with reduced LVEF have either been excluded from these studies or formed a small subset of analyzed patients. Often the results in this subgroup have not been separately assessed. Only in an analysis from the CASS registry by Bell et al. were patients with an LVEF of 35% or less identified as those who benefit most from complete revascularization by CABG [25].

Indications for complete revascularization are a different issue than its feasibility. Head et al. on the basis of the SYNTAX trial population identified the reasons for lack of complete revascularization [24]:

1. For CABG:
   a. Main reason: diffuse disease of small vessels (HR = 2.1; 95% CI: 1.51–2.93; p < 0.001).
   b. Other reasons: peripheral vascular disease, unstable angina, higher EuroSCORE, higher SYNTAX score, presence of total occlusion, bifurcation, higher number of lesions.

2. For PCI:
   a. Main reason: presence of total occlusion (HR = 2.45; 95% CI: 1.81–3.39; p < 0.001).
   b. Other reasons: diabetes, insulin treatment, fasting glucose > 110 mg/dl, hyperlipidemia, higher SYNTAX score, diffuse disease or small vessels, bifurcation, high number of lesions.

In an ischemic HF population a significant proportion of patients suffer from chronic total occlusions (CTO). The presence of CTO is one of the major factors limiting the possibility to achieve complete revascularization, especially percutaneously. Moreover, it has recently been shown that the presence of CTO is related to inferior outcomes in this patient population [26]. Even with progressing experience of operators with management of CTO, the frequency of CTO recanalization remains low, in all-comer registries reaching not more than 10% [27]. Especially in the high-risk HF patient population there is no agreement on CTO management. Current guidelines for managing HF and stable CAD and for myocardial revascularization, as well as the EuroCTO Club consensus, do not provide recommendations on occlusion recanalization in the ischemic HF subpopulation [5, 9, 28].

This overview of difficulties in achievement of complete revascularization is the basis of the “reasonable incomplete revascularization” concept, presented by Dauermann. It was argued that it is acceptable not to revascularize for certain anatomical (small vessel lesion, asymptomatic side-branch closure), functional (non-viable myocardium segments, less than 5% of myocardium with ischemia) or physiological (FFR > 0.8) reasons. This concept, although theoretically attractive, has not yet been validated in a systematic HF population [29].

With all this information in mind, it is important to remember that ischemic HF patients comprise a group with the most advanced form of CAD. Often, even after careful selection of indications for PCI or CABG, due to the complexity of coronary lesions or presence of CTO, complete revascularization remains an optimal, but impossible goal.

**Conclusions**

The decision on revascularization in ischemic HF very often cannot be made solely on the basis of current guidelines. A personalized approach towards every patient is mandatory, and therefore the role of a Heart Failure Team in this process with regard to the patient’s medical history, clinical status and coronary anatomy is vital. These decisions should also be undertaken with regard to the possibility of achieving complete revascularization, with the consideration that in certain conditions it may not be feasible.

**Disclosure**

Authors report no conflict of interest.

**References**

1. Ambrosy AP, Fonarow GC, Butler J, Chioncel O, Greene SJ, Vadugananathan M, Nodari S, Lam CS, Sato N, Shah AN, Gheorghiade M. The global health and economic burden of hospitalizations for heart failure: lessons learned from HHF registries. J Am Coll Cardiol 2014; 63: 1223-1313.

2. Mosterd A, Hoes AW. Clinical epidemiology of heart failure. Heart 2007; 93: 1137-1146.

3. CIBIS Investigators and Committees. A randomized trial of beta-blockade in heart failure. The Cardiac Insufficiency Bisoprolol Study (CIBIS). Circulation 1994; 90: 1765-1773.

4. Moss AJ, Hall WJ, Cannon DS, Daubert JP, Higgins SL, Klein H, Levine JH, Saksena S, Waldo AL, Wilber D, Brown MW, Heo M. Improved survival with an implanted defibrillator in patients with coronary disease at high risk for ventricular arrhythmia. Multicenter Automatic Defibrillator Implantation Trial Investigators. N Engl J Med 1996; 335: 1933-1940.

5. Kolh P, Windecker S, Alfonso F, Collet JP, Crameri R, Falk V, Filippatos G, Hammad C, Heid S, Jünemann P, Kappetein AP, Kato K, Kaduji J, Landmesser U, Lauffer G, Neumann FJ, Richter DJ, Schauerer P, Sousa Uva M, Stefanini G, Taggart DP, Torracca L, Valgimigi M, Wijns W, Witkowski A. 2014 ESC/EACTS Guidelines on myocardial revascularization. Eur J Cardiothorac Surg 2014; 46: 517-592.

6. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JG, Coats AJ, Filippatos G, Hamm C, Hiort O, Kober L, Katus H, Mancini JM, Marwick TH, McMurray JJ, Nihoyannopoulos P, PARISIS IT, Piecki R, Riley JP, Rosano GM, Rutgeerts IM, Ruschitzka F, Rutten FH, van der Meer P. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J 2017; 38: 2219-2290.

7. Kuzminska-Pakula M. Terapia niewydolności serca – nowe cele i perspektywy. Przrzew Lek 2007; 10: 17-22.

8. Korewicz J, Zieliński T, Leszek R. Niewydolność serca [w:] Interna. Januszewicz W, Kolek F. (eds.), PZWL, Warsaw 2006: 49-82.

9. Montalescot G, Sechtem U, Achenbach S, Andreotti F, Arden C, Budaj A, Bugiardini R, Crea F, Cuxi T, Di Gioia P, Ferreira IR, Gersh B, Gitt AK, Hu- lot JS, Marx N, Opie LH, Pfisterer M, Prescott E, Rutschitzka F, Sabaté M, Se- nior R, Taggart DP, van der Wall EE, Vrints CJ. 2013 ESC guidelines on the management of stable coronary artery disease. Eur Heart J 2013; 34: 2949-3003.

10. 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: 1151-1158.

11. Inaba Y, Chen JA, Berrman SR. Quantity of viable myocardium required to improve survival with revascularization in patients with ischemic cardiomyopathy: a meta-analysis. J Nucl Cardiol 2010; 17: 646-654.

12. Velaquez EJ, Lee KL, Deja MA, Jain A, Sopko G, Manchonko A, Ali JS, Po- host G, Gradinac S, Abraham WT, Yli M, Prabhakaran D, Sadow H, Ferrazzi P, Pe- trie MC, O’Connor CM, Panchavinni P, She L, Bonow RO, Rankin GR, Jo- nes RH, Rouleau JL. Coronary-artery bypass surgery in patients with left ventricular dysfunction. N Engl J Med 2011; 364: 1607-1616.

13. Beanlands RS, Nichol G, Huszt E, Humen D, Racine N, Freeman M, Gulevych KY, Garrard L, de Kemp R, Guo A, Rudy TD, Bernard F, Lamy A, Iwanochko RM.
Revascularization in ischemic heart failure with reduced left ventricular ejection fraction. The impact of complete revascularization

F-18-fluorodeoxyglucose positron emission tomography imaging-assisted management of patients with severe left ventricular dysfunction and suspected coronary disease: a randomized, controlled trial (PARR-2). J Am Coll Cardiol 2007; 50: 2002-2012.

Brugada J, Aguinaldo L, Mont L, Bebrui A, Mulet J, Sans G. Coronary artery revascularization in patients with sustained ventricular arrhythmias in the chronic phase of a myocardial infarction: effects on the electrophysologic substrate and outcome. J Am Coll Cardiol 2001; 37: 529-533.

Rahimtoola SH. Coronary bypass surgery for chronic angina—1981. A perspective. Circulation 1982; 65: 225-241.

Nieminen MS, Brutsaert D, Dickstein K, Drexler H, Follath F, Harjola VP, Ho- chadel K, Kajander M, Lassus I, Lopez-Sendon JL, Ponikowski P, Tavazzi L. EuroHeart Failure Survey II (EHFS II): a survey on hospitalized acute heart failure patients: description of population. Eur Heart J 2006; 27: 2725-2734.

Manani A, Kimura T, Nishikawa N, Komiya T, Hanyu M, Shiomi H, Tanaka S, Sakata R. Three-year outcomes after percutaneous coronary intervention and coronary artery bypass grafting in patients with heart failure: from the CREDO-Kyoto percutaneous coronary intervention/coronary artery bypass graft registry cohort-2. Eur J Cardiothorac Surg 2015; 47: 316-321.

Hlatky MA, Boothroyd DB, Bravata DM, Boersma E, Booth J, Brooks MM, Carrell D, Clayton TC, Danchin N, Flather M, Hamm CW, Hube WA, Kähler J, Kelsey SF, King SB, Kosinski AS, Lopes N, McDonald K, Rodríguez A, Serruys P, Sigwart U, Stables RH, Owms DK, Pocock SJ. Coronary bypass surgery compared with percutaneous coronary interventions for multivessel disease: a collaborative analysis of individual patient data from ten randomised trials. Lancet. 2009; 373: 1190-1197.

Tsuynki RT, Shrive FM, Galbraith PD, Knudtson ML, Graham MM. Revascularization in patients with heart failure. CMAJ 2006; 175: 361-365.

Pereira D, Stables R, Clayton T, De Silva K, Lumley M, Clack L, Thomas M, Redwood S. Long-term mortality data from the Balloon Pump-Assisted Coronary Intervention Study (BCIS-1): a randomized, controlled trial of elective balloon counterpulsation during high-risk percutaneous coronary intervention. Circulation 2013; 127: 207-212.

O’Neill WW, Kleiman NS, Moses J, Henrichs JP, Dixon S, Massaro J, Piacentini G, Christiansen EH, Gershlick A, Carlino M, Karlas A, Konstantinidis NV, Tijnissen JG, Kiemeneij F, Slagboom T, van der Weiken R, Tangelder G, Serruys PW, Laarman G. Complete versus culprit vessel percutaneous coronary intervention in multivessel disease: a randomized comparison. Am Heart J 2004; 148: 467-474.

Klesiński T, Cheng W, Jacobs MJ, Mirocha J, Derobertis MA, Kass RM, Blanche C, Fontana GP, Raissi SS, Magliato KE, Trento A. In the current era, complete revascularization improves survival after coronary artery bypass surgery. J Thorac Cardiovasc Surg 2005; 129: 1283-1291.

Hannan EL, Raz C, Holmes DR, King SB 3rd, Walford G, Ambrose JA, Sharma S, Katz S, Clark LT, Jones RH. Impact of completeness of percutaneous coronary intervention revascularization on long-term outcomes in the stent era. Circulation 2006; 113: 2404-2412.

McLellan CS, Ghali WA, Labinaz M, Davis RB, Galbraith PD, Southern DA, Shrive FM, Knudtson ML, Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) Investigators. Association between completeness of percutaneous coronary intervention and post-procedure outcomes. Am Heart J 2005; 150: 800-806.

Kozower BD, Moon MR, Barber HB, Moazami N, Lawton JS, Pasque MK, Damiano RJ Jr. Impact of complete revascularization on long-term survival after coronary artery bypass grafting in octogenarians. Ann Thorac Surg 2005; 80: 112-6.

Hannan EL, Wu C, Walford G, Holmes DR, Jones RH, Sharma S, King SB 3rd. Incomplete revascularization in the era of drug-eluting stents: impact on adverse outcomes. JACC Cardiovasc Interv 2009; 2: 17-25.

Valentí R, Millorós AI, Siguori P, Urcroga V, Parodi G, Carabba N, Cerisano G, Antonucci D. Impact of complete revascularization with percutaneous coronary intervention on survival in patients with at least one chronic total occlusion. Eur Heart J 2008; 29: 2336-2342.

Rastan AI, Walther T, Fahl V, Kempff J, Merk D, Lehmann S, Holzhey D, Mahr FW. Does reasonable incomplete surgical revascularization affect early or long-term survival in patients with multivessel coronary artery disease receiving left internal mammary artery bypass to left anterior descending artery? Circulation 2009; 120: 70-77.

Mahr FW, Rastan AI, Serruys PW, Kappetein AP, Holmes DR, Pomar JL, Westafer S, Vander Salm TJ, Kardiochirurgia i Torakochirurgia Polska