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Long-term follow-up of patients with complex coronary artery disease treated with minimally invasive direct coronary artery bypass

Sandra Fraund-Cremer et al., MIDCAB in patients with complex CAD

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Abstract

Background: Patients with complex coronary artery disease (CAD) may benefit from surgical myocardial revascularization but weighing the risk of peri-operative complications against the expected merit is difficult. Minimally invasive coronary artery bypass (MIDCAB) procedures are less invasive, provide the prognostic advantage of operative revascularization of the left anterior descending artery and may be integrated in hybrid strategies. Herein, the outcomes between patients with coronary 1-vessel disease (1-VD) and patients with 2-VD and 3-VD after MIDCAB procedures were compared in this single-center study.

Methods: Between 1998 and 2018, 1363 patients underwent MIDCAB at the documented institution. 628 (46.1%) patients had 1-VD, 434 (31.9%) patients 2-VD and 300 (22.0%)

patients suffered from 3-VD. Data of patients with 2-VD, and 3-VD were pooled as multi-VD (MVD).
Results: Patients with MVD were older (66.2 ± 10.9 vs. 62.9 ± 11.2 years; $p < 0.001$) and presented with a higher EuroScore II (2.10 [0.4; 34.2] vs. 1.2 [0.4; 12.1]; $p < 0.001$). Procedure time was longer in MVD patients (131.1 ± 50.3 min vs. 122.2 ± 34.5 min; $p < 0.001$). Post-operatively, MVD patients had a higher stroke rate (17 [2.3%] vs. 4 [0.6%]; $p = 0.014$). No difference in 30-day mortality was observed (12 [1.6%] vs. 4 [0.6%]; $p = 0.128$). Survival after 15 years was significantly lower in MVD patients ($p < 0.01$). Hybrid procedures were planned in 295 (40.2%) patients with MVD and realized in 183 (61.2%) cases. MVD patients with incomplete hybrid procedures had a significantly decreased long-term survival compared to cases with complete revascularization ($p < 0.01$).
Conclusions: Minimally invasive coronary artery bypass procedures are low-risk surgical procedures. If hybrid procedures have been planned, completion of revascularization should be a major goal.
Keywords: coronary artery disease, minimally invasive direct coronary artery bypass, off-pump surgery, hybrid revascularization

INTRODUCTION

Operative myocardial revascularization may provide a prognostic benefit for patients with complex coronary artery disease compared to percutaneous coronary intervention (PCI). However, this advantage must be weighed against the risk of peri-operative complications and the need for a longer recovery phase especially in older patients with a limited life expectancy and reduced quality of life. Minimally invasive direct coronary bypass surgery (MIDCAB) enables arterial revascularization of the left anterior descending artery (LAD) via a small, antero-lateral thoracotomy [1]. It does not require extracorporeal circulation and most patients can be weaned off the ventilator while in the operating room (OR) [2, 3]. Therefore, the rate of complications usually associated with cardiac surgery is lower when MIDCAB procedures are performed [2, 4, 5]. Given the fact that a significant proportion of patients with complex coronary artery disease (CAD) are not ideal candidates for a complete operative revascularization due to age or comorbidities, MIDCAB surgery represents an attractive surgical option for these particular patients. While several individual centers have published promising short-term data concerning this approach, long-term data is scarce. The present institution has performed over 1.300 MIDCAB procedures since 1998 [6]. This report reveals the long-term outcome of all MIDCAB patients with a focus on a comparison between patients with single coronary artery disease and those with 2-vessel disease (2-VD) and 3-vessel disease (3-VD).

METHODS

Study population

From January 1998 to January 2021, 1,363 consecutive patients underwent MIDCAB at the current institution. Retrospective data analysis was performed. In addition to 30-day mortality, follow-up data was obtained. Data was collected by contacting respective patients by mail. In cases, where patients or relatives did not respond, their general practitioner was consulted. If their whereabouts remained unknown, the public records office was contacted. Median follow-up period of patients was 18.2 years, (95% confidence interval [CI] 16.5–19.9 years). Thirty-three patients were lost during the follow-up period (97.5% level of completeness). The study was approved by the institutional ethics review committee (number of ethic registration D497/13).

Patient selection for and time-point of hybrid procedures was made after discussing each individual case in the respective heart team conference.

Operative technique and postoperative management

Surgery was performed under general anesthesia with a double-lumen tube for temporary single-lung ventilation. Minimally invasive access was created by a small left-anterior thoracotomy in the fifth intercostal space. A second intercostal space was opened if necessary, depending on the optimal exposure of the LAD or for gaining additional left internal thoracic mammary artery (LITA) length. The LITA was harvested as far proximal and distal as possible to ensure maximal length. Exposition of the LAD was improved by placing felt-pledged sutures in the pericardial edges. Thereby, medial positioning of the LAD could be achieved. In addition, a mechanical stabilizer (Aesculap AG, Tuttlingen, Germany) was used to reduce local myocardial movement. Prior to performing the anastomosis, the LAD was temporarily occluded for 5 minutes to enable ischemic preconditioning followed by a 2-minute period of reperfusion. This step was left out in patients with chronic occlusion of the LAD. The anastomosis itself was performed using 8–0 prolene sutures without the use of intracoronary shunts. The distal LITA course was covered with an epi-pericardial fat tissue flap. Two transcostal stiches were placed to prevent lung herniation followed by routine wound closure. Most patients were extubated in the OR and transferred to the normal ward on the day of surgery after a short monitoring interval in the intensive care unit.

Statistical analysis

Nominal and ordinal data were described as absolute and relative frequencies and compared using the chi-squared test or the Fisher exact test, if one of the expected values in the 2 × 2 table was less than 5. The interval and ratio data were tested for normal distribution by the Kolmogorov-Smirnov test. Normally distributed demographic and clinical patient data are presented as mean and standard deviation and were compared using the two-sample t-test for independent samples. Non normally distributed data were described as median and 25th and 75th percentiles and compared using the Mann-Whitney U test. Covariates with significant univariate association to survival (log-rank test) were included into the Cox regression analysis to determine predictors for mid- and long-term survival. All tests were performed two-tailed at a significance level of 5%. Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS, Version 25).

RESULTS

Patient characteristics

Six hundred twenty-eight (46.1%) patients presented with 1-VD, 434 (31.9%) with 2-VD and 300 (22.0%) patients with 3-VD. Patients with multi-VD (MVD) were significantly older than patients with 1-VD (66.15 ± 10.98 years vs. 62.96 ± 11.21 years; $p < 0.001$) and presented more often with a severely reduced left ventricular function (30 [4.1%] vs. 9 [1.4%]; $p = 0.003$). More patients with MVD had already undergone PCI (311 [42.4%] vs. 167 [26.6%]; $p < 0.001$) and cardiac surgery (56 [7.6%] vs. 10 [1.6%]; $p < 0.001$) in the past. More patients with MVD had recently suffered from an acute myocardial infarction (302 [41.1%] vs. 177 [28.2%]; $p < 0.001$). Overall, MVD patients presented with a higher pre-operative risk profile with a median EuroScore II of 2.10 (0.35; 34.15) vs. 1.24 (0.35; 12.05); $p < 0.001$ (Tables 1, 2).

Intra-operative course

Mean procedure time was significantly longer in MVD compared to 1-VD patients (122.2 ± 34.47 min vs. 131.1 ± 50.3 min; $p < 0.001$). In 15 (1.1%) patients MIDCAB procedure could not be completed as scheduled due to intraoperative events (Table 3). In detail, conversion to full sternotomy was necessary in 6 patients with on-pump myocardial revascularization performed in 4 and off-pump in 2 cases. In 9 patients the procedure had to be aborted, either due to the fact that either the LAD could not be identified, reached or was too small. In 2 cases, the LITA could not be used. Graft elongation using venous bypass material was necessary in 1 case. No significant differences between patients with 1-VD and MVD were observed.

Post-operative course

85.2% (n = 1161) of all patients could be weaned off the ventilator while in the OR (Table 3). Overall, the cerebrovascular event rate was 1.5% (n = 21). However, patients with MVD had a higher incidence of stroke (17 [2.3%] vs. 4 [0.6%]; p = 0.014). A minority of patients (1.7%; n = 23) had to undergo re-thoracotomy due to bleeding with no differences between the groups. The overall rate of wound infections was 37 (2.7%) with 19 (3.0%) cases in the single-vessel disease (SVD)-group and 18 (2.5%) in the MVD group with no significant differences between the two groups (p = 0.617). The number of wound infections in need of surgical treatment was very low with 5 (0.3%) cases, 5 (0.1%) in the SVD-group and 3 (0.2%) in the MVD group (p = 1.000).

Short-term mortality

Thirty-day mortality was 1.6% (n = 12) in patients with MVD and 0.6% (n = 4) in patients with 1-VD (p = 0.128; Table 3).

Long-term follow-up

Thirty-three patients were lost during the follow-up period (97.5% level of completeness). Overall, 1- , 5- , 10- , and 15-year survival rates were 96%, 85%, 73%, and 64%, respectively (Fig. 1). A post-operative angiography was carried out in 468 (39.2%) patients. In 454 (97%) cases, the LITA bypass was patent. No cases of significant shunts due to LITA collaterals was documented. MVD patients had a significantly reduced long-term survival.

Hybrid procedures

Hybrid procedures were planned in 295 (40.2%) of MVD patients. The vast majority of interventions was scheduled after surgery (80.3%). The right coronary artery was the target vessel in most cases (24.1%) followed by the circumflex coronary artery (20.3%). Overall, hybrid procedures were completed in 205 (69.8%) patients. The reasons for not completing PCI as planned included that the remaining lesions were not considered significant anymore (16.9%). In some cases, patients did not undergo a second coronary angiography because they were asymptomatic (13.5%; Table 4). Hybrid procedures that were not executed were associated with a significantly reduced survival ($p < 0.01$; Fig. 2).

DISCUSSION

Successful revascularization of the LAD is a key contributing factor to the benefits of both, interventional and surgical treatment of CAD [7, 8]. Today, the majority of left main and LAD stenoses are treated by PCI [9]. However, decision-making in more complex CAD with involvement of the left main or the LAD can still be a challenge [10–12]. Coronary lesion complexity plays an important role in these cases but the increasing rate of older patients with significant comorbidities and reduced life expectancy profoundly influences treatment selection nowadays. Given the prognostic importance of the LAD, optimal treatment of this lesion should ensure longevity of the result. MIDCAB procedures provide the advantages of surgical revascularization of the LAD using LITA as the most durable graft without the full surgical trauma after sternotomy or the inflammatory response induced by use of extracorporeal circulation resulting in shorter times of convalescence [13–15]. Due to this principle, MIDCAB is an interesting treatment option not only in patients with complex coronary 1-VD of the LAD but also in MVD patients who are not ideal candidates for coronary artery bypass grafting or sole PCI. These patients in particular could benefit from a hybrid solution with operative LAD revascularization and PCI. The present study data describes the outcome after MIDCAB surgery over 15 years in more than one thousand patients. The current focus was on a comparison between MIDCAB patients with coronary-1-VD and

patients with MVD. MVD patients were significantly older than 1-VD patients. They presented with a higher rate of severely reduced left ventricular function, prior myocardial infarction and had undergone cardiac surgery in the past more often. These findings reflect the growing rate of older CAD patients with significant comorbidities [16]. As a result, the EuroScore II was higher in MVD patients and 30-day mortality was increased with 1.6% in MVD patients compared to 0.6% in patients with 1-VD. The risk of a cerebrovascular event plays a pivotal role when discussing operative myocardial revascularization with patients. The present data indicate that MVD patients have a significantly higher risk of suffering a stroke post-operatively compared to patients with a less complex CAD. This difference may be partially explained by the higher incidence of risk factors in the MVD group, including severely reduced left ventricular function and previous myocardial infarction [17]. However, the overall rate of peri-operative complications that may prolong recovery and/or impair life expectancy proved to be low in both groups. These data are comparable to the results of other large MIDCAB centers and further underline the general safety of MIDCAB procedures. In the present center, 295 (40.2%) of MVD patients were planned to undergo hybrid procedures, most of them after surgery. Follow-up data indicated that not completing myocardial revascularization by PCI is associated with a significantly reduced long-term survival. Explanations for not performing PCI included that lesions were either found not to be significant in the post-surgery coronary angiography or that patients were symptom-free and therefore, did not undergo a second invasive work-up. Repossini et al. [2] provided the only other comparable MIDCAB publication integrating hybrid procedures in 2018 but their publication did not include patients where myocardial revascularization had not been completed. The current data implicate that incompletion of revascularization is associated with impaired survival. Therefore, MIDCAB patients intended for hybrid procedures should undergo a timely re-evaluation to decide whether further coronary interventions are still necessary.

Limitations of the study

This is a retrospective analysis that covers a period of over 20 years. While the single-operator approach may ensure comparable technical operative results, patient population and peri-operative treatment approaches have changed over time. In addition, the initial decision to discuss a patient with complex CAD in the heart team is made by the referring cardiologist. Therefore, patient selection bias is inevitable.

CONCLUSIONS

Overall, the present data underline the value of MIDCAB procedures in the pursuit of optimal coronary artery revascularization concepts for a growing population of older CAD patients in need of individual treatment strategies. Therefore, this method should be actively integrated into the surgical spectrum of more institutions. The increased awareness and availability of this approach could not only broaden the discussion for treatment options for complex left main or LAD stenosis in the cath lab but, more importantly, improve patient outcome.

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Conflict of interest: None declared

References

1. Calafiore AM, Giammarco GD, Teodori G, et al. Left anterior descending coronary artery grafting via left anterior small thoracotomy without cardiopulmonary bypass. Ann Thorac Surg. 1996; 61(6): 1658–1665, doi: 10.1016/0003-4975(96)00187-7, indexed in Pubmed: 8651765.

2. Repossini A, Di Bacco L, Nicoli F, et al. Minimally invasive coronary artery bypass: Twenty-year experience. J Thorac Cardiovasc Surg. 2019; 158(1): 127–138.e1, doi: 10.1016/j.jtcvs.2018.11.149, indexed in Pubmed: 30739774.

3. Fraund S, Behnke H, Boening A, et al. Immediate postoperative extubation after minimally invasive direct coronary artery surgery (MIDCAB). Interact Cardiovasc Thorac Surg. 2002; 1(1): 41–45, doi: 10.1016/s1569-9293(02)00015-4, indexed in Pubmed: 17669955.

4. Thiele H, Oettel S, Jacobs S, et al. Comparison of bare-metal stenting with minimally invasive bypass surgery for stenosis of the left anterior descending coronary artery: a 5-year follow-up. Circulation. 2005; 112(22): 3445–3450, doi: 10.1161/CIRCULATIONAHA.105.578492, indexed in Pubmed: 16316966.

5. Deppe AC, Liakopoulos OJ, Kuhn EW, et al. Minimally invasive direct coronary bypass grafting versus percutaneous coronary intervention for single-vessel disease: a meta-analysis of 2885 patients. Eur J Cardiothorac Surg. 2015; 47(3): 397–406; discussion 406, doi: 10.1093/ejcts/ezu285, indexed in Pubmed: 25100715.

6. Fraund S, Herrmann G, Witzke A, et al. Midterm follow-up after minimally invasive direct coronary artery bypass grafting versus percutaneous coronary intervention techniques. Ann Thorac Surg. 2005; 79(4): 1225–1231, doi: 10.1016/j.athoracsur.2004.08.082, indexed in Pubmed: 15797053.

7. Conley MJ, Ely RL, Kisslo J, et al. The prognostic spectrum of left main stenosis. Circulation. 1978; 57(5): 947–952, doi: 10.1161/01.cir.57.5.947, indexed in Pubmed: 639216.

8. 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(4): 765–777, doi: 10.1016/0002-9149(81)90156-9, indexed in Pubmed: 7025604.

9. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. Considerations for the choice between coronary artery bypass grafting and percutaneous coronary intervention as revascularization strategies in major categories of patients with stable multivessel coronary artery disease: an accompanying article of the task force of the 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J. 2019; 40(2): 204–212, doi: 10.1093/eurheartj/ehy532, indexed in Pubmed: 30165435.

10. Stone GW, Kappetein AP, Sabik JF, et al. Five-Year outcomes after PCI or CABG for left main coronary disease. N Engl J Med. 2019; 381(19): 1820–1830, doi: 10.1056/NEJMoa1909406, indexed in Pubmed: 31562798.

11. Holm NR, Mäkikallio T, Lindsay MM, et al. Percutaneous coronary angioplasty versus coronary artery bypass grafting in the treatment of unprotected left main stenosis: updated 5-year outcomes from the randomised, non-inferiority NOBLE trial. Lancet. 2020; 395(10219): 191–199, doi: 10.1016/S0140-6736(19)32972-1, indexed in Pubmed: 31879028.

12. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J. 2019; 40(2): 87–165, doi: 10.1093/eurheartj/ehy394, indexed in Pubmed: 30165437.

13. Blazek S, Holzhey D, Jungert C, et al. Comparison of bare-metal stenting with minimally invasive bypass surgery for stenosis of the left anterior descending coronary artery: 10-year follow-up of a randomized trial. JACC Cardiovasc Interv. 2013; 6(1): 20–26, doi: 10.1016/j.jcin.2012.09.008, indexed in Pubmed: 23347858.

14. Diegeler A, Thiele H, Falk V, et al. Comparison of stenting with minimally invasive bypass surgery for stenosis of the left anterior descending coronary artery. N Engl J Med. 2002; 347(8): 561–566, doi: 10.1056/NEJMoa013563, indexed in Pubmed: 12192015.

15. Hoffmann G, Friedrich C, Barrabas M, et al. Short- and long-term follow-up after minimally invasive direct coronary artery bypass in octogenarians. Interact Cardiovasc Thorac Surg. 2016; 23(3): 377–382, doi: 10.1093/icvts/ivw149, indexed in Pubmed: 27209534.

16. Hulme WJ, Sperrin M, Martin GP, et al. Temporal trends in relative survival following percutaneous coronary intervention. BMJ Open. 2019; 9(2): e024627, doi: 10.1136/bmjopen-2018-024627, indexed in Pubmed: 30782913.

17. Stamou SC, Hill PC, Dangas G, et al. Stroke after coronary artery bypass: incidence, predictors, and clinical outcome. Stroke. 2001; 32(7): 1508–1513, doi: 10.1161/01.str.32.7.1508, indexed in Pubmed: 11441193.

Table 1. Pre-operative patient characteristics

Parameter	**All patients**	**MIDCAB (SVD)**	**MIDCAB (MVD)**	**P: MVD vs. SVD**
Age [years]	64.68 ± 11.20	62.96 ± 11.21	66.15 ± 10.98	< 0.001
Sex (female)	387 (28.4)	199 (31.7)	188 (25.6)	0.014
Body mass index	27.21 (14.36; 47.84)	27.30 (16.66; 44.44)	27.13 (14.36; 47.84)	0.450
IDDM	98 (7.2)	37 (5.9)	61 (8.3)	0.093
Arterial hypertension	1034 (75.9)	481 (76.6)	553 (75.3)	0.611
Hyperlipidemia	912 (67.0)	401 (63.9)	511 (69.6)	0.024
Smoking	361 (26.5)	168 (26.8)	193 (26.3)	0.854
COPD	102 (7.5)	55 (8.8)	47 (6.4)	0.121
PAD	159 (11.7)	50 (8.0)	109 (14.9)	< 0.001
Renal insufficiency	23 (1.7)	6 (1.0)	17 (2.3)	0.059
RRT	13 (1.0)	3 (0.5)	10 (1.4)	0.160
Stroke	45 (3.3)	16 (2.5)	29 (4.0)	0.172
LV function < 30%	39 (2.9)	9 (1.4)	30 (4.1)	0.003
EuroScore II	1.70 (0.35; 34.15)	1.24 (0.35; 12.05)	2.10 (0.35; 34.15)	< 0.001
Prior AMI	479 (35.2)	177 (28.2)	302 (41.1)	< 0.001
Prior AMI < 4 weeks	144 (10.6)	56 (8.9)	88 (12.0)	0.077
Prior cardiac surgery	66 (4.8)	10 (1.6)	56 (7.6)	< 0.001

Data are presented as mean ± standard deviation or median (range); MIDCAB — minimally invasive coronary artery bypass; SVD — single-vessel disease; MVD — multi-vessel disease; IDDM — insulin-dependent diabetes mellitus; COPD — chronic obstructive pulmonary disease; PAD — peripheral arterial disease; LV — left ventricular; RRT — renal replacement therapy; AMI — acute myocardial infarction

Parameter	**All patients**	**MIDCAB (SVD)**	**MIDCAB (MVD)**	**P: MIDCAB MVD vs. SVD**
Coronary anatomy				
1-VD	628 (46.1)	628 (46.1)	0 (0.0)	
2-VD	434 (31.9)	0 (0.0)	434 (59.1)	< 0.001
3-VD	300 (22.0)	0 (0.0)	300 (40.9)	< 0.001
LM stenosis	190 (14.0)	0 (0.0)	190 (25.6)	NA
LAD occlusion	338 (24.8)	182 (29.0)	156 (21.3)	0.001
Prior PCI	478 (35.1)	167 (26.6)	311 (42.4)	< 0.001
- LAD	478 (35.1)	153 (24.4)	160 (21.8)	0.272
Medication				
DAPT	316 (23.1)	88 (14.0)	228 (31.1)	< 0.001

Table 2. Coronary angiography

MIDCAB — minimally invasive coronary artery bypass; SVD — single-vessel disease; MVD — multi-vessel disease; VD — vessel disease; LM — left main; LAD — left anterior descending artery; PCI — percutaneous coronary intervention; DAPT — dual anti-platelet treatment

Parameter	All patients	MIDCAB (SVD)	MIDCAB (MVD)	P: MIDCAB MVD vs. SVD
Procedure time [min]	127.2 ± 43.8	122.2 ± 34.47	131.1 ± 50.3	< 0.001
Conversion	15 (1.1)	7 (1.1)	8 (1.0)	1.000
Stroke	21 (1.5)	4 (0.6)	17 (2.3)	0.014
PCI post-operatively	1 (0.5)	0 (0.0)	1 (0.1)	1.000
Myocardial infarction	3 (0.2)	1 (0.2)	2 (0.3)	1.000
Rethoracotomy	23 (1.7)	10 (1.6)	13 (1.8)	0.836
Wound infections	37 (2.7)	19 (3.0)	18 (2.5)	0.617
Wound infections with surgical revision	5 (0.3)	2 (0.1)	3 (0.2)	1.000
Extubation OR	1161 (85.2)	536 (85.4)	625 (85.1)	1.000
LOS	7.98 (2.00; 41.00)	7.98 (2.00; 41.00)	8.41 (1.00; 39.00)	0.014
30-day mortality	16 (1.2)	4 (0.6)	12 (1.6)	0.128

Table 3. Post-operative course

Data are presented as mean ± standard deviation or median (range); MIDCAB — minimally invasive coronary artery bypass; SVD — single-vessel disease; OR — operating room; PCI — percutaneous coronary intervention; LOS — length of stay

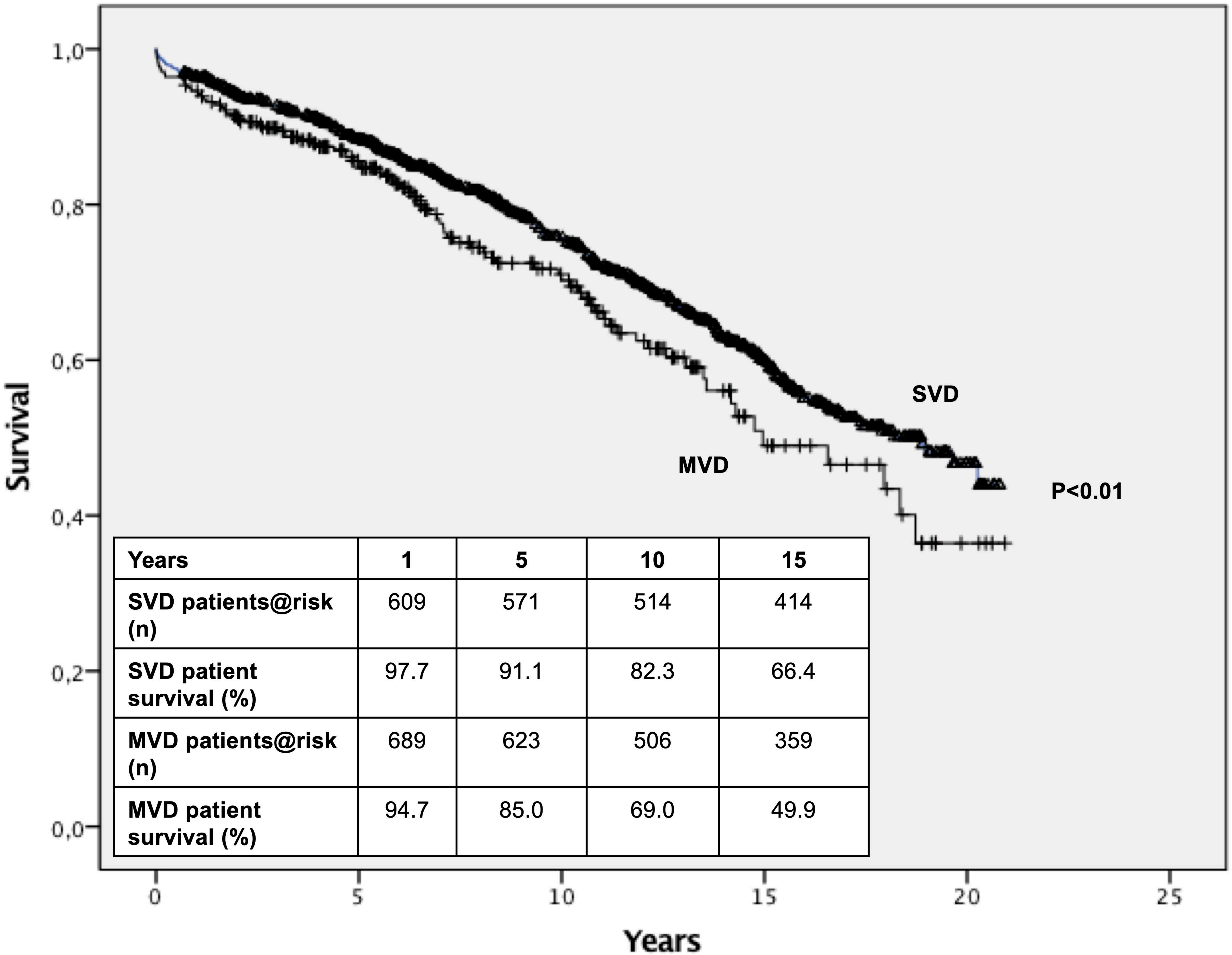
Parameter	All patients	MIDCAB (SVD)	MIDCAB (MVD)	P: MIDCAB MVD vs. SVD
Hybrid procedure planned	295 (21.7)	0 (0)	295 (40.2)	NA
Hybrid prior to MIDCAB	58 (4.3)	0 (0)	58 (7.9)	NA
Hybrid target vessel:				
RCA	71 (24.1)	0 (0)	71 (24.1)	NA
RCX	60 (20.3)	0 (0)	60 (20.3)	NA
LM	17 (5.8)	0 (0)	17 (5.8)	NA
RCX + RCA	19 (6.4)	0 (0)	19 (6.4)	NA
RD	7 (2.4)	0 (0)	7 (2.4)	NA
RIM, RCX, RCA	2 (0.7)	0 (0)	2 (0.7)	NA
SVB	2 (0.7)	0 (0)	2 (0.7)	NA
Hybrid procedures not performed	89 (30.2)	0 (0)	89 (30.2)	NA
PCI not necessary	15 (16.9)	0 (0)	15 (16.9)	NA
No symptoms	12 (13.5)	0 (0)	12 (13.5)	NA

Table 4. Hybrid procedures

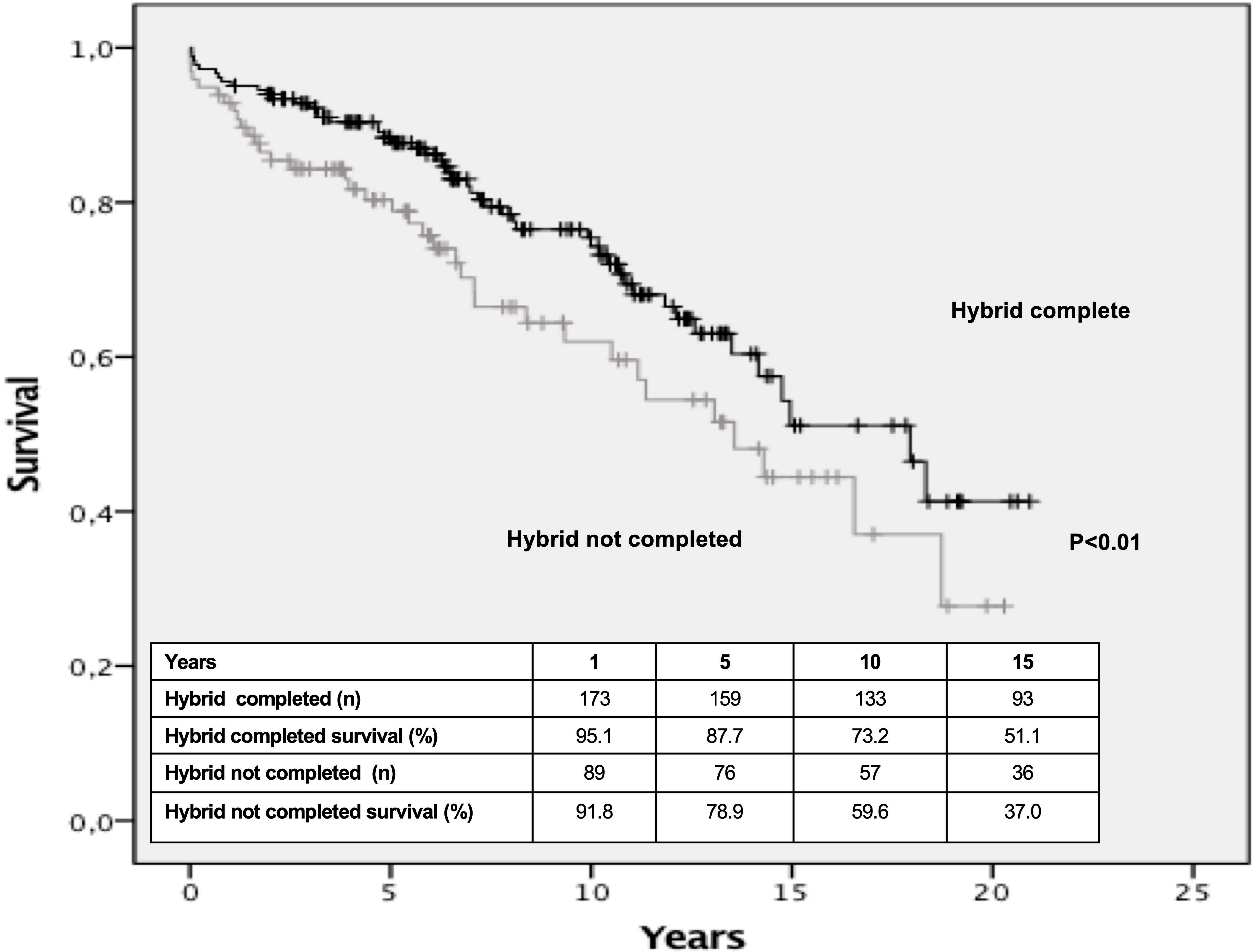
MIDCAB — minimally invasive coronary artery bypass; SVD — single-vessel disease; MVD — multi-vessel disease; VD — vessel disease; RCA — right coronary artery; RCX — ramus circumflex; LM — left main; RD — ramus diagonalis; RIM — ramus intermedius; SVB — saphenous venous graft; PCI — percutaneous coronary interventions

Figure 1. Long-term survival after minimally invasive coronary artery bypass (MIDCAB) surgery of patients with coronary multi-vessel (MVD) and single-vessel disease (SVD). Kaplan-Meier analysis of survival over 15 years demonstrated a significantly reduced survival of patients with MVD compared to patients with SVD.

Figure 2. Long-term survival after hybrid procedures. Kaplan-Meier analysis of survival over 15 years demonstrated a significantly reduced survival of patients with completed hybrid procedures compared to patients who did not undergo complete revascularization.



Years	1	5	10	15
SVD patients@risk (n)	609	571	514	414
SVD patient survival (%)	97.7	91.1	82.3	66.4
MVD patients@risk (n)	689	623	506	359
MVD patient survival (%)	94.7	85.0	69.0	49.9



Years	1	5	10	15
Hybrid completed (n)	173	159	133	93
Hybrid completed survival (%)	95.1	87.7	73.2	51.1
Hybrid not completed (n)	89	76	57	36
Hybrid not completed survival (%)	91.8	78.9	59.6	37.0