Clin Res Cardiol (2012) 101:885–893
DOI 10.1007/s00392-012-0472-y

ORIGINAL PAPER

Long-term clinical outcomes following sirolimus-eluting stent implantation in patients with acute myocardial infarction. A meta-analysis of randomized trials

Raffaele Piccolo · Salvatore Cassese · Gennaro Galasso · Tullio Niglio · Roberta De Rosa · Chiara De Biase · Federico Piscione

Received: 15 February 2012 / Accepted: 26 April 2012 / Published online: 16 May 2012

Abstract
Objectives The aim of this study was to perform a meta-analysis of randomized trials, evaluating the long-term outcomes of sirolimus-eluting stents (SES) versus bare-metal stents (BMS) in patients with ST-segment elevation myocardial infarction (STEMI).
Background Despite short-term outcomes of patients with STEMI undergoing primary percutaneous coronary intervention indicate a benefit of SES in terms of reintervention, several concerns remain on the long-term safety and efficacy of SES.
Methods A systematic literature search of electronic resources, through October 2011, was performed using specific search terms. Included trials were randomized studies comparing SES to BMS in STEMI patients, with a follow-up ≥3 years.
Results Seven trials were included, with a total of 2,364 patients. At a median follow-up of 3 years, SES significantly reduced the risk of target-vessel revascularization when compared with BMS [odds ratio (OR), 0.44; 95 % confidence interval (CI), 0.34–0.57; $p < 0.0001$], without increasing the risk of mortality (OR 0.78; 95 % CI, 0.57–1.08; $p = 0.14$), reinfarction (OR 0.91; 95 % CI, 0.61–1.35, $p = 0.64$) and early to late stent thrombosis (OR 0.77; 95 % CI, 0.49–1.20; $p = 0.25$). However after the first year, SES did not further reduce target-vessel revascularization (OR 1.06; 95 % CI, 0.64–1.74; $p = 0.83$) and increased the risk of very late stent thrombosis (OR 2.81; 95 % CI, 1.33–5.92; $p = 0.007$).
Conclusions At long-term follow-up, SES compared to BMS use in STEMI patients reduces the risk of target-vessel revascularization, without increasing the risk of death and reinfarction. However, the strong SES efficacy is counterbalanced by a significant risk of very late stent thrombosis.

Keywords Drug-eluting stent · Bare-metal stent · Primary PCI · Acute myocardial infarction · Meta-analysis

Introduction

When feasible, primary percutaneous coronary intervention (PCI) represents the preferred reperfusion strategy in patients with ST-segment elevation myocardial infarction (STEMI) because of its superiority in comparison with thrombolytic regimens [1]. In this setting, several randomized trials and meta-analyses demonstrated that sirolimus-eluting stent (SES) implantation, as compared to bare-metal stent (BMS), is associated with a 1-year reduction in the need for reintervention without increasing the incidence of safety endpoints [2]. However, there are conflicting data about the long-term effectiveness and safety of drug-eluting stent (DES) implantation during primary PCI. Particularly, several concerns have been raised about a higher risk of late death and stent thrombosis with DES use in STEMI patients [3, 4]. Meta-analysis has the potential to increase power and summarize results from different, but comparable, individual studies. Therefore, the aim of the current study was to perform a meta-analysis

Electronic supplementary material The online version of this article (doi:10.1007/s00392-012-0472-y) contains supplementary material, which is available to authorized users.

R. Piccolo · S. Cassese · G. Galasso · T. Niglio · R. De Rosa · C. De Biase · F. Piscione (✉)
Department of Clinical Medicine, Cardiovascular Sciences and Immunology, Federico II University,
Via S. Pansini, 5, 80131 Naples, Italy
e-mail: piscione@unina.it

of randomized trials evaluating the long-term clinical outcomes of SES as compared to BMS in STEMI patients undergoing primary PCI.

Methods

Search strategy and selection criteria

We searched Medline, EMBASE, the Cochrane Central Register of Controlled Trials (CENTRAL), scientific session abstracts in Circulation, Journal of the American College of Cardiology, European Heart Journal and The American Journal of Cardiology, and relevant websites (http://www.acc.org, http://www.americanheart.org, http://www.europcronline.com, http://www.escardio.org, http://www.clinicaltrialresults.org, http://www.tctmd.com and http://www.theheart.org), starting from previous databases on this field [2, 5–7]. The reference list of relevant studies was additionally scanned. No language, publication date, or publication status restrictions were imposed. The last search was run on 4th October, 2011. The following search terms were used: "randomized trial", "myocardial infarction", "ST-segment elevation", "percutaneous coronary intervention", "angioplasty", "primary angioplasty", "sirolimus-eluting stent", "drug eluting stent", "stent", "bare metal stent". To be included, the citation had to meet the following criteria: (1) random treatment allocation; (2) a mean follow-up period $\geq$3 years; and (3) the use of SES in the experimental arm. Exclusion criteria were: (1) ongoing studies and (2) irretrievable data.

Data collection and assessment of risk of bias

Two investigators (R.P. and S.C.) independently assessed reports for eligibility at title and/or at abstract level, with divergences resolved with a third reviewer (F.P.); studies that met inclusion criteria were selected for further analysis. The risk of bias was evaluated by the same two reviewer authors, in accordance with The Cochrane Collaboration methods [8] and considering the following methodological items: adequacy of sequence generation, adequacy of allocation concealment, blinding, incomplete data outcome, selective outcome reporting, other potential source of bias and sample size calculation. We did not use a quality score, since this practice has been previously discouraged [9].

Outcomes variables

The primary endpoint of this meta-analysis was target-vessel revascularization (TVR) at the longest available follow-up. Secondary endpoints were: all-cause death, reinfarction and stent thrombosis (ST). All clinical endpoints were evaluated according to protocol definitions, while ST was evaluated according to Academic Research Consortium (ARC) criteria [10] (Supplementary Data Table 1). When not directly reported, very late ST was derived by subtracting early and late ST rate from the cumulative ST rate.

Statistical analysis

Statistical analysis was performed with RevMan software (Review Manager. Version 5.0.24 Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) and STATA 10 statistical software (STATA Corp, College Station, Texas, USA). The κ statistic was used to assess agreement between reviewers for study selection. Odds ratio (OR) and 95 % confidence intervals (95 % CI) were used as summary statistics. The pooled OR was calculated using the fixed effects Mantel-Hænzel model, while, in case of significant heterogeneity across studies, the random effects DerSimonian and Laird model was used instead. In case of statistical significance, the number needed to treat (NNT) or the number needed to harm (NNH) with relative CI was provided. The Breslow-Day Chi-squared test was calculated to test the statistical evidence of heterogeneity across the studies ($p < 0.1$). In addition, we used the I^2 statistic, which describes the percentage variation across studies that is due to heterogeneity rather than chance. As a guide, I^2 values <25 % indicated low, 25–50 % indicated moderate, and >50 % indicated high heterogeneity [11]. We assessed the possibility of small-study effects by visual inspection of funnel plot asymmetry. Because graphical evaluation can be subjective, we performed both Harbord [12] and Peters tests [13], as formal statistical tests for publication bias, using the metabias command. The Harbord test is a modified version of Egger test and has a type I error close to the nominal level in the absence of between-study heterogeneity. Differently, the Peter test is a minor modification of Macaskill test and gives a more balanced type I error rates in the tail probability areas as compared to the Egger test.

The study was realized in compliance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [14].

Results

Eligible studies

As shown in Fig. 1, we screened the title and/or the abstract of 1,499 potentially eligible publications. Of these, 1,431 citations were excluded since they were not relevant

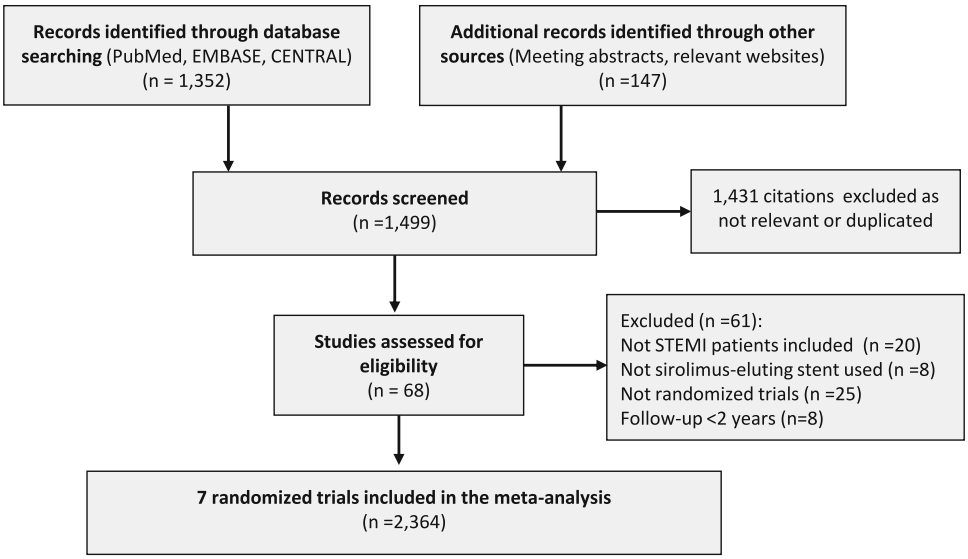

Fig. 1 Flow diagram of trial selection. STEMI, ST-segment elevation myocardial infarction

to this study or duplicated. Thus, 68 studies were assessed for eligibility and 61 studies were discarded since inclusion criteria were not met. Finally, 7 trials were included in the meta-analysis, enrolling a total of 2,364 patients (1,187 or 50.2 % randomized to SES and 1,177 or 49.8 % randomized to BMS) [15–21]. The inter-observer agreement for study selection was good, with a κ value of 0.87. Main characteristics of included studies were reported in Table 1. The number of participants in the trials ranged from 149 to 736. The duration of follow-up varied between 3 and 5 years [median 3 years, interquartile range 3–4.32]. Primary PCI was performed in all patients, with the exception of 57 patients of one trial, who underwent rescue PCI after failed thrombolysis [19]. A 300–600 mg loading dose of clopidogrel was used in all studies. The risk of bias among studies was reported in Table 2.

Clinical endpoints

TVR was needed in a total of 207 patients (12.99 %). As reported in Fig. 2, SES use was associated with a sustained reduction in TVR (8.59 vs. 17.42 %, SES versus BMS, respectively; OR 0.44; 95 % CI, 0.34–0.57; $p < 0.0001$). The NNT with a SES to prevent one TVR was 12 (95 % CI, 10–15). No heterogeneity was found among trials ($I^2 = 0$ %, $p_{het} = 0.67$). Visual inspection of funnel plot did not reveal a skewed distribution for TVR, suggesting the absence of small-study effects (Fig. 3). Moreover, both Harbord ($p = 0.86$) and Peters tests ($p = 0.71$) were not significant. Interestingly, there was no significant difference in the risk of TVR between SES and BMS after the first year (OR 1.06; 95 % CI, 0.64–1.74; $p = 0.83$) (Fig. 4).

As reported in Fig. 5, death was observed in a total of 166 patients (7.02 %) and there was no significant difference between SES and BMS (6.23 vs. 7.82 %, respectively; OR 0.78; 95 % CI, 0.57–1.08; $p = 0.14$). No significant heterogeneity was present across trials ($I^2 = 0$ %, $p_{het} = 0.81$). Consistently, the risk of death did not differ between SES and BMS after the first year (OR 1.05; 95 % CI, 0.66–1.69; $p = 0.83$).

As shown in Fig. 6, reinfarction was experienced by 108 patients (6.63 %) and there was no significant difference between SES and BMS (6.36 vs. 6.91 %, respectively; OR 0.91; 95 % CI, 0.61–1.35, $p = 0.64$). No significant heterogeneity was found among studies ($I^2 = 0$ %, $p_{het} = 0.66$). However, reinfarction rates tended to be higher in the SES group after the first year, albeit this difference was not significant (OR 1.44; 95 % CI, 0.75–2.75; $p = 0.27$) (Fig. 4).

ST occurred in a total of 115 patients (4.86 %). As represented in Fig. 7 (Panel A), the risk of early to late ST was not different between SES and BMS (2.95 vs. 3.82 %, OR 0.77; 95 % CI, 0.49–1.20; $p = 0.25$) and no heterogeneity was found ($I^2 = 0$ %, $p_{het} = 0.88$). Nevertheless, very late ST, occurring after the first year, was significantly increased with SES compared to BMS (OR 2.81; 95 % CI, 1.33–5.92; $p = 0.007$), with NNH = 75 (95 % CI, 28–403) (Fig. 7, panel B).

Discussion

In the current study, we performed a meta-analysis of seven randomized trials to evaluate the long-term safety and efficacy of SES compared with BMS in STEMI patients.

The main findings of this study can be summarized as follows: first, the use of SES is associated with a strong reduction in TVR at long-term follow-up as compared to BMS. Second, this reduction is achieved at the expense of

Table 1 Main characteristics of included trials

Trial	Study design	Multi-center	Mean age (years)	Length of follow-up (years)	Length of DAT[a] (months)	Routine angiographic follow-up	Gp IIb/IIIa inhibitors (%)	Type of Gp IIb/IIIa inhibitors	Symptoms duration to PCI (h)		Initial TIMI 3 flow (%)		Final TIMI 3 flow (%)		Period of enrollment
									SES	BMS	SES	BMS	SES	BMS	
BASKET-AMI [15]	SES ($n = 75$) versus BMS ($n = 74$)	No	62	3	6	No	67	n/r	n/r	n/r	n/r	n/r	n/r	n/r	2003–04
MISSION [16]	SES ($n = 158$) versus BMS ($n = 152$)	No	59	3	12	Yes	100	Abciximab	3	3.2	15.2	15.1	92.4	92.7	2004–06
MULTISTRATEGY [17]	SES ($n = 369$) versus BMS ($n = 367$)	Yes	64	3	3	No	100	Abciximab, tirofiban	3.1	3.4	21	21	95.7	91.8	2004–07
PASEO [18]	SES ($n = 90$) versus BMS ($n = 90$)	No	64	4.3	6	No	100	n/r	4	4.3	12.2	13.3	93.3	95.6	2003–04
SESAMI [19]	SES ($n = 157$) versus BMS ($n = 156$)	No	62	3	12	Yes	74.9	Abciximab	4.0	4.0	16	20.5	92.1	85.6	2003–04
STRATEGY[20]	SES ($n = 87$) versus BMS ($n = 88$)	No	63	5	3	Yes	100	Abciximab, tirofiban	3.0	3.0	13	11	96	93	2003–04
TYPHOON [21]	SES ($n = 251$) versus BMS ($n = 250$)	Yes	59	4	6	Yes	71.5	Abciximab[b]	4.5	4.4	13.5	17.3	96.3	95.4	2003–05

SES Sirolimus-eluting stent, *BMS* bare-metal stent, *PCI* percutaneous coronary intervention, *DAT* dual antiplatelet therapy, *Gp IIb/IIIa* inhibitors glycoprotein IIb/IIIa inhibitors, *TIMI* thrombolysis in myocardial infarction

[a] Aspirin therapy, with a dose ranging from 75 to 125 mg, was recommended indefinitely in all trials

[b] Abciximab was the most frequent glycoprotein IIb/IIIa inhibitor used

Table 2 Risk of bias assessment

Trial Name	Adequate sequence generation	Allocation concealment used	Blinding	Incomplete data outcome addressed	Free of selective reporting	Free of other sources of bias	Sample size calculation
BASKET-AMI [15]	Yes	Yes	No	Yes	Yes	Yes	No
MISSION [16]	Unclear	Unclear	Yes (patients, outcome assessors)	Yes	Yes	Yes	Yes
MULTISTRATEGY [17]	Yes	Yes	Yes (outcome assessors)	Yes	Yes	Yes	Yes
PASEO [18]	Yes	Yes	Yes (outcome assessors)	Yes	Yes	Yes	Yes
SESAMI [19]	Yes	Yes	No	Yes	Yes	Yes	Yes
STRATEGY [20]	Yes	Yes	Yes (outcome assessors)	Yes	Yes	Yes	Yes
TYPHOON [21]	Yes	Yes	Yes (patients)	Yes	Yes	Yes	Yes

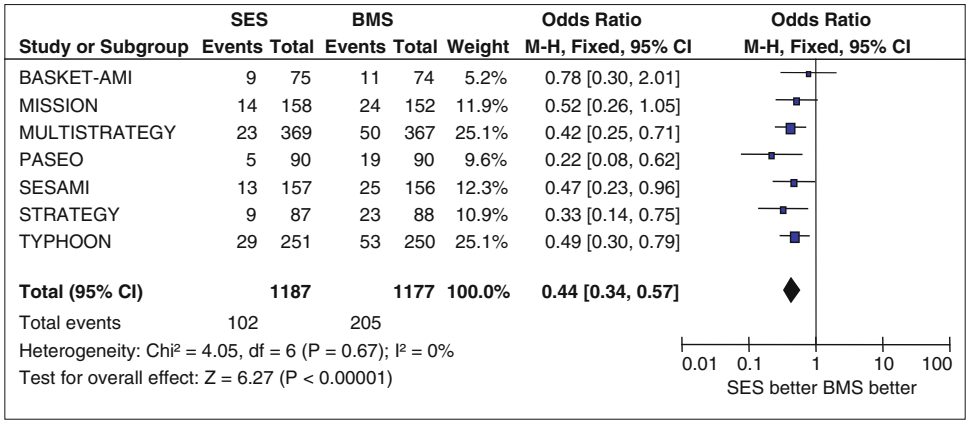

Fig. 2 Odds ratio of target-vessel revascularization associated with sirolimus-eluting stent (SES) versus bare-metal stent (BMS). The *squares* and the *horizontal lines* indicate the OR and the 95 % CIs for each trial included; the size of each square is proportional to the statistical weight of a trial in the meta-analysis; diamond indicates the effect estimate derived from meta-analysis, with the centre indicating the point estimate and the left and the right ends the 95 % CI. *M-H* Mantel-Hænzel model

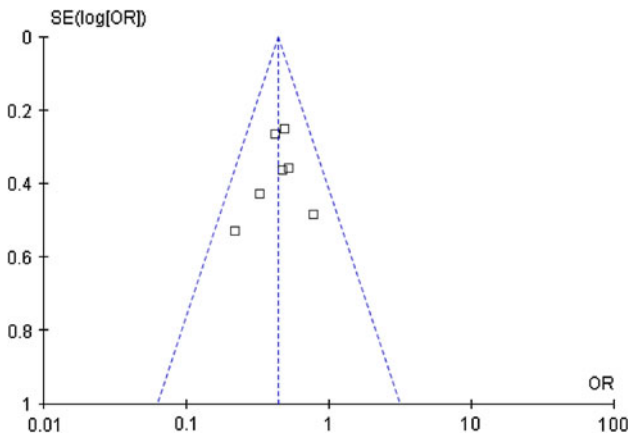

Fig. 3 Funnel plot of all studies included in the meta-analysis. The standard error (SE) of the ln odds ratio (OR) was plotted against the OR for target-vessel revascularization

higher very late ST rates in patients treated with SES, despite the cumulative risk of early to late ST is comparable between SES and BMS. Third, the long-term risk of death, as well as reinfarction, is similar between SES and BMS.

SES was the first commercially available DES: its introduction represented a "revolution" among revascularization strategies for patients with coronary artery disease, due to the potent inhibition of neointima proliferation and restenosis as compared to BMS. However, the long-term efficacy of DES in reducing TVR has been challenged, especially in the setting of primary PCI. In fact, a 6-year follow-up analysis from the Rapamycin-Eluting Stent Evaluated at Rotterdam Cardiology Hospital (RESEARCH) and Taxus-Stent Evaluated at Rotterdam Cardiology Hospital (T-SEARCH) registries showed that DES usage was no longer superior to BMS in terms of TVR

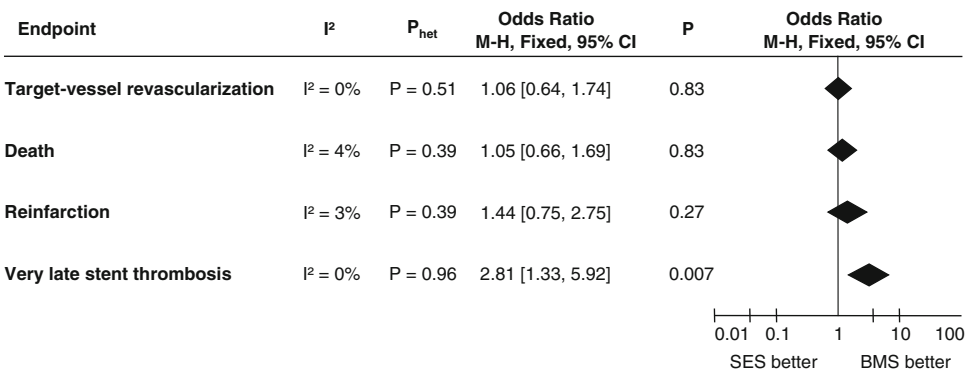

Fig. 4 Odds ratio for clinical outcomes after the first year

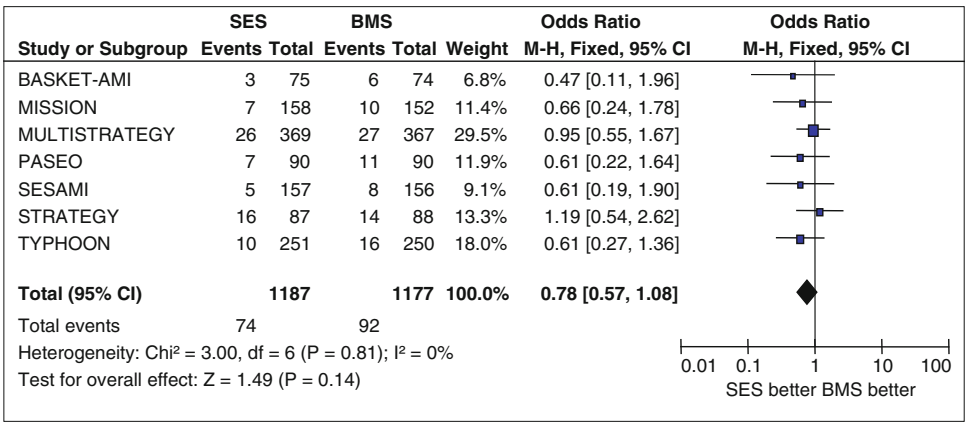

Fig. 5 Odds ratio of death associated with sirolimus-eluting stent (SES) versus bare-metal stent (BMS)

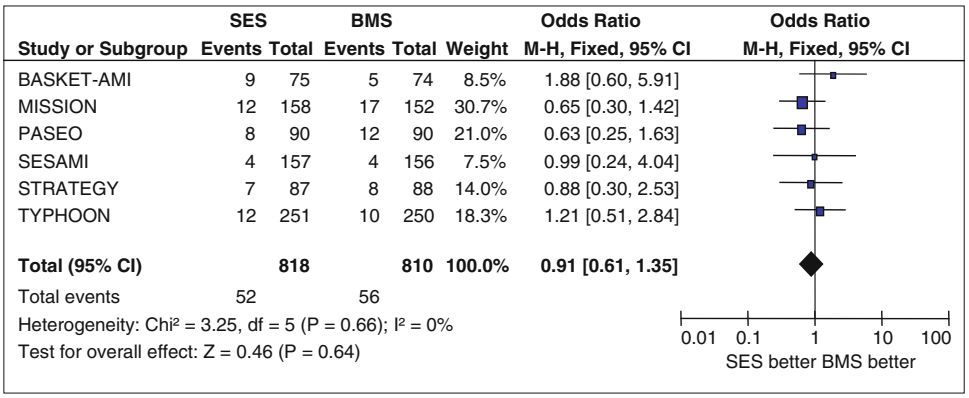

Fig. 6 Odds ratio of reinfarction associated with sirolimus-eluting stent (SES) versus bare-metal stent (BMS)

[22]. On the other hand, several larger registries demonstrated the long-term efficacy of DES in patients undergoing primary PCI [23, 24]. Accordingly, in this meta-analysis we found a 56 % reduction in the odds of TVR in favour of SES, with only 12 patients needed to be treated with a SES to prevent one TVR. Importantly, the magnitude of this reduction is similar to that observed in previous 1-year follow-up meta-analyses investigating the use of SES versus BMS in STEMI patients [2, 25], suggesting that the "catch-up phenomenon" may not be inherent in this setting. Indeed, after the first year SES did not narrow its anti-restenotic effect (Fig. 4).

Nevertheless, the reduction in TVR with SES was counterbalanced by a higher risk of very late ST, although the overall risk of ST did not differ between SES and BMS. This finding is consistent with registries and meta-analysis of randomized trials, reporting a slight but significant increase in DES-related ST after the first year from PCI [26–28]. At this regard, several pathophysiological mechanisms have been proposed to explain the higher incidence of late ST observed with DES. In autopsy studies, a delayed stent struts endothelialization, persistent fibrin deposition and inflammation have been associated with stent thrombosis [29]. Furthermore, stent underexpansion

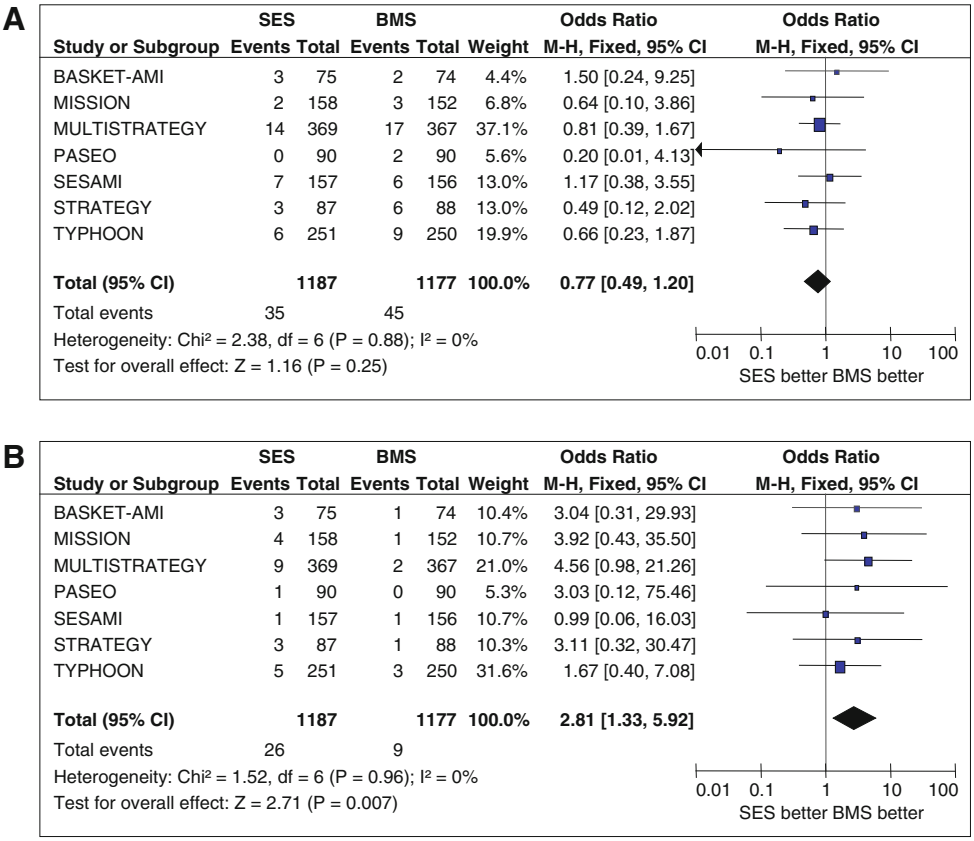

Fig. 7 Odds ratio of early to late (a) and very late (b) stent thrombosis associated with sirolimus-eluting stent (SES) versus bare-metal stent (BMS)

and residual stenosis, which might be more frequent after primary PCI, have been identified as predictors of SES thrombosis [30]. However, the mechanisms underlying DES and BMS very late ST may differ. Indeed, an intravascular ultrasound study by Lee et al. [31] found that stent malapposition plays a key role in DES-related very late ST, whereas neoatherosclerosis with plaque rupture plays a key role in BMS-related ST. Therefore, the risk of late acquired stent malapposition, significantly higher after DES than BMS implantation [32], may contribute to explain the higher very late ST rates observed with SES. However, in our study, the higher very late ST risk did not translate in an increased mortality and reinfarction in SES patients, although, after the first-year, there was a greater but not significant risk for reinfarction (Fig. 7, Panel B).

The similar mortality rates among treatment arms (Fig. 5) jars the findings from the GRACE (Global Registry of Acute Coronary Events) registry [3], reporting an increased risk-adjusted late mortality in DES treated patients. Conversely, we found almost identical risk for death after 1 year between SES and BMS (Fig. 4), consistent with other observational studies [33, 34].

As final remark, clinicians should carefully weigh the benefit from SES implantation in terms of anti-restenotic efficacy against the possible risk of ST, reserving SES use in patients at higher risk for restenosis, such as those with diabetes, small vessels or long lesions [35].

This meta-analysis presents some limitations. This is a meta-analysis at the study level, and we could not properly assess the role of confounding factors. Although we acknowledge the superiority of patient-level based studies, the reported analyses were based on published data only. Second, some trials were underpowered to detect significant differences between interventions in the main outcomes; however, this reinforces the necessity of the present study. Third, SES is a first-generation DES and the use of second-generation DES is expected to improve clinical outcomes [36]. In fact, a recent meta-analysis demonstrated, across a broad spectrum of patients undergoing PCI, a significant risk reduction of definite stent thrombosis associated with everolimus-eluting stents as compared to SES [37].

In conclusion, the results of the current study indicate that at long-term follow-up SES implantation in STEMI patients reduces the risk of TVR compared with BMS, without increasing the risk of death and reinfarction. Nevertheless, the use of SES during STEMI is associated with a higher risk of very late ST when compared with BMS.

Acknowledgments There was no funding source for this study.

References

1. Keeley EC, Boura JA, Grines CL (2003) Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. Lancet 361(9351):13–20
2. Piscione F, Piccolo R, Cassese S, Galasso G, Chiariello M (2009) Clinical impact of sirolimus-eluting stent in ST-segment elevation myocardial infarction: a meta-analysis of randomized clinical trials. Catheter Cardiovasc Interv 74(2):323–332
3. Steg PG, Fox KA, Eagle KA, Furman M, Van de Werf F, Montalescot G, Goodman SG, Avezum A, Huang W, Gore JM (2009) Mortality following placement of drug-eluting and bare-metal stents for ST-segment elevation acute myocardial infarction in the Global Registry of Acute Coronary Events. Eur Heart J 30(3):321–329
4. Kukreja N, Onuma Y, Garcia-Garcia HM, Daemen J, van Domburg R, Serruys PW (2009) The risk of stent thrombosis in patients with acute coronary syndromes treated with bare-metal and drug-eluting stents. Jacc 2(6):534–541
5. Piccolo R, Cassese S, Galasso G, De Rosa R, D'Anna C, Piscione F (2011) Long-term safety and efficacy of drug-eluting stents in patients with acute myocardial infarction: a meta-analysis of randomized trials. Atherosclerosis 217(1):149–157
6. Piccolo R, Cassese S, Galasso G, De Rosa R, D'Anna C, Piscione F (2011) Sirolimus- versus paclitaxel-eluting stents in patients with acute myocardial infarction: a meta-analysis of randomized trials. Int J Cardiol 146(2):234–236
7. Piscione F, Piccolo R, Cassese S, Galasso G, De Rosa R, D'Andrea C, Chiariello M (2010) Effect of drug-eluting stents in patients with acute ST-segment elevation myocardial infarction undergoing percutaneous coronary intervention: a meta-analysis of randomised trials and an adjusted indirect comparison. EuroIntervention 5(7):853–860
8. Higgins JP (2008) Green Se Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.2 (updated September 2009). The Cochrane Collaboration. http://www.cochrane-handbook.org
9. Juni P, Witschi A, Bloch R, Egger M (1999) The hazards of scoring the quality of clinical trials for meta-analysis. JAMA 282(11):1054–1060
10. Cutlip DE, Windecker S, Mehran R, Boam A, Cohen DJ, van Es GA, Steg PG, Morel MA, Mauri L, Vranckx P, McFadden E, Lansky A, Hamon M, Krucoff MW, Serruys PW (2007) Clinical end points in coronary stent trials: a case for standardized definitions. Circulation 115(17):2344–2351
11. Higgins JP, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ (Clinical research ed) 327(7414):557–560
12. Harbord RM, Egger M, Sterne JA (2006) A modified test for small-study effects in meta-analyses of controlled trials with binary endpoints. Stat Med 25(20):3443–3457
13. Peters JL, Sutton AJ, Jones DR, Abrams KR, Rushton L (2006) Comparison of two methods to detect publication bias in meta-analysis. JAMA 295(6):676–680
14. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151(4):264–269 W264
15. Leibundgut G, Nietlispach F, Pittl U, Brunner-La Rocca H, Kaiser CA, Pfisterer ME (2009) Stent thrombosis up to 3 years after stenting for ST-segment elevation myocardial infarction versus for stable angina—comparison of the effects of drug-eluting versus bare-metal stents. Am Heart J 158(2):271–276
16. Atary JZ, van der Hoeven BL, Liem SS, Jukema JW, van der Bom JG, Atsma DE, Bootsma M, Zeppenfeld K, van der Wall EE, Schalij MJ (2010) Three-year outcome of sirolimus-eluting versus bare-metal stents for the treatment of ST-segment elevation myocardial infarction (from the MISSION! Intervention Study). Am J Cardiol 106(1):4–12
17. Valgimigli M, Campo G, Gambetti S, Bolognese L, Ribichini F, Colangelo S, de Cesare N, Rodriguez AE, Russo F, Moreno R, Piva T, Sheiban I, Penzo C, Prati F, Nazzaro MS, Diaz Fernandez JF, Vassanelli C, Parrinello G, Ferrari R (2011) Three-year follow-up of the MULTIcentre evaluation of single high-dose bolus TiRofiban versus abciximab with sirolimus-eluting STEnt or bare-metal stent in acute myocardial infarction StudY (MULTISTRATEGY). Int J Cardiol. [Epub ahead of print]
18. Di Lorenzo E, Sauro R, Varricchio A, Carbone G, Cortese G, Capasso M, Lanzillo T, Manganelli F, Mariello C, Siano F, Pagliuca MR, Stanco G, Rosato G, De Luca G (2009) Long-Term outcome of drug-eluting stents compared with bare metal stents in ST-segment elevation myocardial infarction: results of the paclitaxel- or sirolimus-eluting stent versus bare metal stent in Primary Angioplasty (PASEO) Randomized Trial. Circulation 120(11):964–972
19. Violini R, Musto C, De Felice F, Nazzaro MS, Cifarelli A, Petitti T, Fiorilli R (2010) Maintenance of long-term clinical benefit with sirolimus-eluting stents in patients with ST-segment elevation myocardial infarction: 3-year results of the SESAMI (sirolimus-eluting stent versus bare-metal stent in acute myocardial infarction) trial. J Am Coll Cardiol 55(8):810–814
20. Tebaldi M, Arcozzi C, Campo G, Percoco G, Ferrari R, Valgimigli M (2009) The 5-year clinical outcomes after a randomized comparison of sirolimus-eluting versus bare-metal stent implantation in patients with ST-segment elevation myocardial infarction. J Am Coll Cardiol 54(20):1900–1901
21. Spaulding C, Teiger E, Commeau P, Varenne O, Bramucci E, Slama M, Beatt K, Tirouvanziam A, Polonski L, Stella PR, Clugston R, Fajadet J, de Boisgelin X, Bode C, Carrie D, Erglis A, Merkely B, Hosten S, Cebrian A, Wang P, Stoll HP, Henry P (2011) Four-year follow-up of TYPHOON (trial to assess the use of the CYPHer sirolimus-eluting coronary stent in acute myocardial infarction treated with BallOON angioplasty). Jacc 4(1):14–23
22. Simsek C, Magro M, Boersma E, Onuma Y, Nauta S, Daemen J, Gaspersz M, van Geuns RJ, van der Giessen W, van Domburg R, Serruys P (2011) Comparison of six-year clinical outcome of sirolimus- and paclitaxel-eluting stents to bare-metal stents in patients with ST-segment elevation myocardial infarction: an analysis of the RESEARCH (rapamycin-eluting stent evaluated at Rotterdam cardiology hospital) and T-SEARCH (taxus stent evaluated at Rotterdam cardiology hospital) registries. J Invasive Cardiol 23(8):336–341
23. Jensen LO, Maeng M, Thayssen P, Kaltoft A, Tilsted HH, Bottcher M, Lassen JF, Hansen KN, Krusell LR, Rasmussen K, Pedersen KE, Pedersen L, Paaske Johnsen S, Sorensen HT, Thuesen L (2008) Clinical outcome after primary percutaneous coronary intervention with drug-eluting and bare metal stents in patients with ST-segment elevation myocardial infarction. Circ Cardiovasc Interv 1(3):176–184
24. Mauri L, Silbaugh TS, Garg P, Wolf RE, Zelevinsky K, Lovett A, Varma MR, Zhou Z, Normand SL (2008) Drug-eluting or bare-metal stents for acute myocardial infarction. New Engl J Med 359(13):1330–1342
25. Dibra A, Tiroch K, Schulz S, Kelbaek H, Spaulding C, Laarman GJ, Valgimigli M, Di Lorenzo E, Kaiser C, Tierala I, Mehilli J, Campo G, Thuesen L, Vink MA, Schalij MJ, Violini R, Schomig A, Kastrati A (2010) Drug-eluting stents in acute myocardial infarction: updated meta-analysis of randomized trials. Clin Res Cardiol 99(6):345–357

26. Kastrati A, Mehilli J, Pache J, Kaiser C, Valgimigli M, Kelbaek H, Menichelli M, Sabate M, Suttorp MJ, Baumgart D, Seyfarth M, Pfisterer ME, Schomig A (2007) Analysis of 14 trials comparing sirolimus-eluting stents with bare-metal stents. New Engl J Med 356(10):1030–1039
27. Wenaweser P, Daemen J, Zwahlen M, van Domburg R, Juni P, Vaina S, Hellige G, Tsuchida K, Morger C, Boersma E, Kukreja N, Meier B, Serruys PW, Windecker S (2008) Incidence and correlates of drug-eluting stent thrombosis in routine clinical practice. 4-year results from a large 2-institutional cohort study. J Am Coll Cardiol 52(14):1134–1140
28. Brodie B, Pokharel Y, Fleishman N, Bensimhon A, Kissling G, Hansen C, Milks S, Cooper M, McAlhany C, Stuckey T (2011) Very late stent thrombosis after primary percutaneous coronary intervention with bare-metal and drug-eluting stents for ST-segment elevation myocardial infarction: a 15-year single-center experience. Jacc 4(1):30–38
29. Nakazawa G, Finn AV, Joner M, Ladich E, Kutys R, Mont EK, Gold HK, Burke AP, Kolodgie FD, Virmani R (2008) Delayed arterial healing and increased late stent thrombosis at culprit sites after drug-eluting stent placement for acute myocardial infarction patients: an autopsy study. Circulation 118(11):1138–1145
30. Fujii K, Carlier SG, Mintz GS, Yang YM, Moussa I, Weisz G, Dangas G, Mehran R, Lansky AJ, Kreps EM, Collins M, Stone GW, Moses JW, Leon MB (2005) Stent underexpansion and residual reference segment stenosis are related to stent thrombosis after sirolimus-eluting stent implantation: an intravascular ultrasound study. J Am Coll Cardiol 45(7):995–998
31. Lee CW, Kang SJ, Park DW, Lee SH, Kim YH, Kim JJ, Park SW, Mintz GS, Park SJ (2010) Intravascular ultrasound findings in patients with very late stent thrombosis after either drug-eluting or bare-metal stent implantation. J Am Coll Cardiol 55(18):1936–1942
32. Hassan AK, Bergheanu SC, Stijnen T, van der Hoeven BL, Snoep JD, Plevier JW, Schalij MJ, Wouter Jukema J (2010) Late stent malapposition risk is higher after drug-eluting stent compared with bare-metal stent implantation and associates with late stent thrombosis. Eur Heart J 31(10):1172–1180
33. Shishehbor MH, Amini R, Oliveria LP, Singh IM, Kelly P, Bhatt DL, Kapadia SR, Ellis SG, Whitlow PL, Brener SJ (2008) Comparison of drug-eluting stents versus bare-metal stents for treating ST-segment elevation myocardial infarction. Jacc 1(3):227–232
34. Brodie BR, Stuckey T, Downey W, Humphrey A, Nussbaum M, Laurent S, Bradshaw B, Metzger C, Hermiller J, Krainin F, Juk S, Cheek B, Duffy P, Simonton CA (2008) Outcomes with drug-eluting stents versus bare metal stents in acute ST-elevation myocardial infarction: results from the Strategic Transcatheter Evaluation of New Therapies (STENT) Group. Catheter Cardiovasc Interv 72(7):893–900
35. Stone GW, Parise H, Witzenbichler B, Kirtane A, Guagliumi G, Peruga JZ, Brodie BR, Dudek D, Mockel M, Lansky AJ, Mehran R (2010) Selection criteria for drug-eluting versus bare-metal stents and the impact of routine angiographic follow-up: 2-year insights from the HORIZONS-AMI (Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction) trial. J Am Coll Cardiol 56(19):1597–1604
36. Cassese S, Piccolo R, Galasso G, De Rosa R, Piscione F (2011) Twelve-month clinical outcomes of everolimus-eluting stent as compared to paclitaxel- and sirolimus-eluting stent in patients undergoing percutaneous coronary interventions. A meta-analysis of randomized clinical trials. Int J Cardiol 150(1):84–89
37. de Waha A, Cassese S, Park DW, Burzotta F, Byrne RA, Tada T, King LA, Park SJ, Schomig A, Kastrati A (2012) Everolimus-eluting versus sirolimus-eluting stents: an updated meta-analysis of randomized trials. Clin Res Cardiol. [Epub ahead of print]