With current stent technology and guideline-based ACS management, stent thrombosis is rare

Coronary stent thrombosis in acute coronary syndromes

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Summary

Background: In ACS patients who are treated with a primary percutaneous coronary intervention (pPCI), stent thrombosis is a serious and potentially lethal complication. We analysed the occurrence, risk factors and outcomes of angiographically proven (definite) stent thrombosis in patients with ACS undergoing pPCI enrolled in the prospective multicentre Swiss Special Programme University Medicine (SPUM-ACS) registry.

Methods: The prospectively gathered data of consecutive patients with ACS, who were enrolled from December 2009 to October 2012, were analysed at 1 year regarding the primary outcome of definite stent thrombosis. An independent committee reviewed all the events. Baseline data of 2131 patients were considered for analysis. 2004 patients underwent pPCI, and 1843 had coronary stenting; of these, 1473 (79.9%) received a drug-eluting stent (DES), 338 (18.3%) a bare metal stent (BMS) and 30 (1.6%) both stent types.

Results: 20 of the 1843 patients (1.1%) had developed definite stent thrombosis at 1 year. Of the DESs that thrombosed, one was first-generation (sirolimus), 7 second-generation (5 everolimus, 2 zotarolimus) and 3 third-generation (biolimus). 7 thrombosed stents were BMS, and in 2 cases the affected stent type could not be determined. 11 DESs and 7 BMSs (0.7% and 2.1%, respectively) developed thrombosis (p = 0.03). There were 14 cases of early (<30 days) and 6 cases of late (30 days to 1 year) stent thrombosis. On average, early stent thromboses occurred 5.7 days and late ones 259.7 days after pPCI. Significant risk factors for stent thrombosis were female gender, presentation as a STEMI and anteroseptal infarction on ECG (p = 0.03, 0.01 and 0.02, respectively). Surprisingly, patients on clopidogrel prior to pPCI were also at higher risk for stent thrombosis (p = 0.048). Angiographically proven restenosis of a pre-existing stent, occlusion or thrombus at the site of stenting, insertion of more than two stents and residual stenosis distal to the implanted stent were further significant risk factors (p = 0.03, 0.01, 0.03, 0.048 and 0.03, respectively). Patients with stent thrombosis had a higher mortality rate than patients without thrombosis (15% compared to 3.7%; p = 0.01).

Conclusion: With current stent technology and guideline-based ACS management, stent thrombosis is rare, albeit associated with high mortality. (Study registered at ClinicalTrials.gov, no. NCT01000701.)

Key words: acute coronary syndromes; percutaneous coronary intervention; stent thrombosis; drug-eluting stent; bare metal stent

Introduction

Acute coronary syndrome (ACS) is known to be one of the major causes of mortality and morbidity in the western world [1]. Recent official data in Switzerland show that ACS is responsible for about 30% of deaths and 14% of hospitalisations in men, and about 34% and 9%, respectively, in women [2].

Timely primary percutaneous coronary intervention (pPCI) greatly reduces morbidity and mortality of ACS patients [3, 4]. One of the most important complications of PCI is thrombosis of the stent, leading to complete occlusion of the culprit coronary artery. Stent thrombosis is reported to occur in about 1–2% of patients with stent insertion because of either ACS or unstable or stable angina pectoris [5, 6].

Many risk factors for stent thrombosis have been described, with early discontinuation of dual antiplatelet therapy (DAPT), stenting in patients with ST-elevation myocardial infarction (STEMI), patient history of stent thrombosis and small target vessel / stent diameter being among the ones most often identified [7, 8]. Bare metal stents (BMSs) and drug eluting stents (DESs) are known to show different risk profiles for stent thrombosis [9, 10]. First-generation DESs (sirolimus- and paclitaxel-eluting stents) were at the highest risk of developing late stent thrombosis (i.e., more than 30 days after stenting); the risk dramatically decreased with second-generation DESs (zotarolimus- and everolimus-eluting stents) [11]. Large-scale trials showed lower rates of stent thrombosis and revascularisation for second-generation DESs compared with BMSs [10, 12].

Many international multicentre studies on stent thrombosis have been published, but differences in healthcare systems, patient demographics and cultural factors are well-known to result in differences in its occurrence in daily patient care [13].

In this study, we analysed data from the Special Programme University Medicine study (SPUM-ACS) on stent thrombosis and compared them with important studies and data from large-scale registries published in the literature.

Methods

Study population

The prospective multicentre Special Programme University Medicine (SPUM) – ACS Biomarker cohort [14, 15] recruited patients who were referred for coronary angiography with the diagnosis of ACS to one of the participating Swiss university hospitals (Zurich, Bern, Lausanne and Geneva) between December 2009 and October 2012. It featured consecutive patient recruitment, with follow-up at 30 days (telephone call) and 1 year (clinical visit). Female and male patients aged 18 years or older presenting within 5 days (preferably within 72 hours) after pain onset with the main diagnosis of STEMI, non-ST-elevation myocardial infarction (NSTEMI) or unstable angina were included. Within the consortium, a centralised electronic database provided comprehensive information on all patients. All adverse events occurring within 1 year after the index ACS event were ascertained at 30 days (telephone call) and 1 year (clinical visit) and adjudicated by an independent committee consisting of three experienced cardiologists (Lukas Kappenberger, Lausanne; Tiziano Moccetti, Lugano; Mathias E. Pfisterer, Basel).

Patient selection

Included patients had symptoms compatible with angina pectoris (chest pain, dyspnoea) and fulfilled at least one of the following criteria: (a) ECG changes such as persistent ST segment elevation or depression, T wave inversion or dynamic ECG changes, new left bundle-branch block; (b) evidence of positive (predominantly conventional) troponin according to local laboratory reference values; (c) known coronary artery disease, specified as status after myocardial infarction, or PCI or newly documented ≥50% stenosis of an epicardial coronary artery during the initial catheterisation. Exclusion criteria included severe physical disability, inability to comprehend study and less than 1 year of life expectancy for noncardiac reasons.

Medications

The protocol for medications during the hospital stay and follow-up was determined by consensus *a priori*. It comprised administration of aspirin and an additional platelet inhibitor (prasugrel, ticagrelor or clopidogrel) with prasugrel preferred for STEMI patients (loading dose of 60 mg, followed by 10 mg/d) and clopidogrel for NSTEMI patients (loading dose of 300 mg, followed by 75 mg/d) for 1 year after the ACS unless an indication for oral anticoagulation was present. Treating physicians were advised to administer a statin (rosuvastatin 20 mg/d), an angiotensin converting-enzyme inhibitor or angiotensin II receptor blocker, and a beta-blocker as soon after the ACS as they could be tolerated by the patient.

Heparin was routinely administered at angiography in all centres, but the dose was left to the discretion of the interventional cardiologist. Glycoprotein IIb/IIIa inhibitors were rarely used.

Laboratory testing

Routine tests were performed at laboratories of each institution. Because different assays were used for troponin, ratios of the result to the upper limit of the reference range were reported. Creatinine clearance was estimated with use of the Cockcroft–Gault equation in the current analysis.

Definitions

Stent thrombosis comprised either complete or partial stent occlusion as seen in angiography (angiographic findings were interpreted as described in the original report). An event occurring within the first 30 days of stent implantation was defined as early (sub-acute) stent thrombosis, whereas those occurring between 30 days and 1 year were considered late stent thrombosis. Cardiac death was defined as any death due to a proximate cardiac cause (e.g., myocardial infarction [MI], low-output failure, fatal arrhythmia), unwitnessed death and death of unknown cause, and all procedure-related deaths including those related to concomitant treatment were classified as cardiac death by the adjudication committee. Major adverse cardiac and cardiovascular events (MACCE) were defined in this analysis as a composite of all-cause mortality, cerebrovascular event, any repeat revascularisation and MI. Major adverse cardiac events (MACE) were defined as a composite of cardiac death, clinically indicated revascularisation and MI [16].

The presence of risk factors was determined either on the basis of the patient's history and drug use (many patients were taking cardiovascular drugs such as aspirin and statins, as well as antihypertensives and

antidiabetics) or on the diagnosis made during hospitalisation, according to published European Society of Cariology (ESC) guidelines [17, 18].

Primary outcome

The primary outcome in our study was stent thrombosis at 1-year follow-up.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), or median and 25th/75th interquartile range for skewed variables. They were compared using one-way analysis of variance (ANOVA), student's t-test or the Mann Whitney U-test as appropriate. Categorical data are presented as frequencies (percentages) and were compared using the Fisher exact or the chi-square tests.

All p-values and confidence intervals were two-sided. A p-value of <0.05 was considered significant, and all tests were two-tailed. All analyses were performed with SPSS version 21.0 software (SPSS Inc., Chicago, Ill).

Results

Patient population

Of the 2168 patients originally enrolled, 37 (1.7%) either withdrew from the study or were lost to follow-up. Baseline data of the 2131 patients who were included in the analysis are shown in table 1.

Overall, 2004 of the 2131 patients underwent PCI, of whom 1843 had insertion of a coronary stent: 1473 patients (79.9%) received a DES, 338 (18.3%) a BMS and 30 (1.6%) both stent types.

Stent thrombosis

Overall, 20 of the 1843 patients (1.1%) developed definite stent thrombosis (table 2). In two cases, the stent type could not be determined from the study documentation as these patients (numbers 2 and 9) had a history of both DES and BMS insertion in the same target vessel. Neither case was included in the statistical comparison of the two stent types, whereas all 20 patients were included in the analysis of risk factors for stent thrombosis.

Table 1: Baseline data of study patients.

	ST	Early ST	Late ST	No ST	All
Demographic data					
Number of patients	20	14	6	1823	2131 (1843 with stent)
Age [years]	65 ± 6.4	66.6 ± 5.5	61.2 ± 3.3	63.1 ± 25.0	63.7 ± 12.5
Male gender	12 (60%)	8 (57.1%)	4 (66.7%)	1449 (79.5%)	1682 (78.9%)
BMI	27.5 ± 2.7	27.9 ± 2.3	26.6 ± 1.4	26.7 ± 10.6	27.1 ± 4.3
Past medical history					
CAD	6 (30%)	3 (21.4%)	3 (50%)	451 (24.7%)	539 (25.3%)
Myocardial infarction	4 (20%)	1 (7.1%)	3 (50%)	232 (12.7%)	314 (14.7%)
PCI	6 (30%)	2 (14.3%)	4 (66.7%)	281 (15.4%)	367 (17.2%)
Smoker	13 (65%)	8 (57.1%)	5 (83.3%)	1136 (62.3%)	1312 (61.6%)
Diabetes	6 (30%)	4 (28.6%)	2 (33.3%)	311 (17.1%)	390 (18.3%)
Hypertension	8 (40%)	6 (42.9%)	2 (33.3%)	1031 (56.7%)	1231 (57.8%)
Dyslipidaemia	12 (60%)	6 (42.9%)	6 (100%)	1122 (61.6%)	1322 (62%)
Malignoma	3 (15%)	1 (7.1%)	2 (33.3%)	136 (7.5%)	165 (7.7%)
Medication					
Aspirin	6 (30%)	4 (28.6%)	2 (33.3%)	538 (29.5%)	689 (32.3%)
Clopidogrel	4 (20%)	2 (14.3%)	2 (33.3%)	127 (7.0%)	178 (8.4%)
Statin	7 (35%)	4 (28.6%)	3 (50%)	489 (26.8%)	634 (29.8%)
ACE inhibitor	3 (15%)	2 (14.3%)	1 (16.7%)	296 (16.2%)	367 (17.2%)
AT2 inhibitor	3 (15%)	2 (14.3%)	1 (16.7%)	314 (17.2%)	388 (18.2%)
Beta-blocker	4 (20%)	1 (7.1%)	3 (50%)	420 (23%)	533 (25%)
Nitrate	2 (10%)	1 (7.1%)	1 (16.7%)	68 (3.7%)	95 (4.5%)
Diuretic	4 (25%)	2 (14.3%)	2 (33.3%)	286 (15.7%)	355 (16.7%)
Insulin	1 (5%)	0	1 (16.7%)	89 (4.9%)	111 (5.2%)
OAD	5 (20%)	4 (28.6%)	1 (16.7%)	203 (11.1%)	256 (12%)

ST: stent thrombosis; BMI: body mass index; CAD: coronary artery disease; PCI: percutaneous coronary intervention; ACE: angiotensin converting-enzyme: AT2: angiotensin II; OAD: oral antidiabetic drug

Table 2: Overview of patients with stent thrombosis.

Patient	Age (yr)	Gender	Stent	Early/late ST	Days after PCI
1	68	Female	DES	Early	0
2*	80	Female	Both	Late	38
3	64	Male	DES	Early	6
4	60	Male	BMS	Late	470
5	81	Male	BMS	Early	5
6	69	Female	DES	Early	7
7	53	Male	DES	Early	0
8	56	Male	DES	Early	9
9*	50	Male	Both	Late	327
10	55	Female	DES	Early	13
11	78	Male	BMS	Early	0
12	57	Male	BMS	Late	452
13	84	Female	BMS	Early	4
14	55	Male	DES	Early	6
15	75	Female	BMS	Early	4
16	61	Male	DES	Late	195
17	59	Female	DES	Late	76
18	56	Female	DES	Early	4
19	84	Male	DES	Early	21
20	54	Male	BMS	Early	1

* Patients 2 and 9 were not included in the statistical comparison of stent types. Female average age 68.3 ± 11.0 years, male average age 62.8 ± 11.7 years (p = 0.31)

Eleven DESs and seven BMSs (0.7% of 1473 and 2.1% of 338, respectively) developed thrombosis (p = 0.03). In the subgroups of early and late thrombosis, the two stent types showed no statistically significant difference (table 3). Among the DESs that thrombosed, one was first-generation (sirolimus), seven second-generation (five everolimus, two zotarolimus) and three third-generation (biolimus). The average stent length in cases of stent thrombosis was 20.2 mm (range 8–30), and the average diameter 3.1 mm (range 2.25–4.5).

There were 14 cases of early and 6 cases of late stent thrombosis (70 and 30%, respectively). On average, early stent thrombosis occurred 5.7 days and late stent thrombosis 259.7 days after pPCI.

The rate of BMS insertion was highest in 2010, with 28% of patients receiving a BMS (compared with 15, 16 and 10% for 2009, 2011 and 2012 respectively). Accordingly, the stent thrombosis rate was higher in 2010 than in later years (1.4% of 829, 0.6% of 513 and 0.8% of 503 patients for 2010, 2011 and 2012, respectively). There was one case of stent thrombosis in 26 patients in 2009 (3.8%), which is difficult to interpret statistically owing to the low number of case.

Table 3: Stent thrombosis risk was higher in bare metal stents (BMSs) than drug-elutin stents (DESs) (hazard ratio 2.8, CI 1.1–7.1). The subgroups of early and late thrombosis showed no significant difference.

	BMS (n = 338)	DES (n = 1473)	p-value
Stent thrombosis	7 (2.1%)	11 (0.7%)	0.03*
Early stent thrombosis	5 (1.5%)	9 (0.5%)	0.16
Late stent thrombosis	2 (0.6%)	2 (0.1%)	0.16

*) p <0.05 was considered statistically significant

Risk factors for stent thrombosis

Clinical risk factors: Significant risk factors for stent thrombosis were female gender, presentation as a STEMI and anteroseptal infarction on ECG (p = 0.03, 0.01 and 0.02, respectively; table 4). Patients already on clopidogrel prior to pPCI also were at a higher risk to develop stent thrombosis (p = 0.048).

Procedure-related risk factors: Angiographically proven restenosis of a pre-existing stent, occlusion or thrombus at the site of stenting, insertion of more than two stents and stenosis distal to the implanted stent were significant risk factors of later stent thrombosis (p = 0.03, 0.01, 0.03, 0.048 and 0.03, respectively; table 5).

Clinical outcomes of stent thrombosis

Stent thrombosis was associated with a higher risk of lethal outcome (three patients, 15%) compared with the overall population undergoing PCI with stenting (68 of 1823 patients, 3.7%; p = 0.01). Death occurred 6, 43 and 277 days after PCI in cases of stent thrombosis (fig. 1).

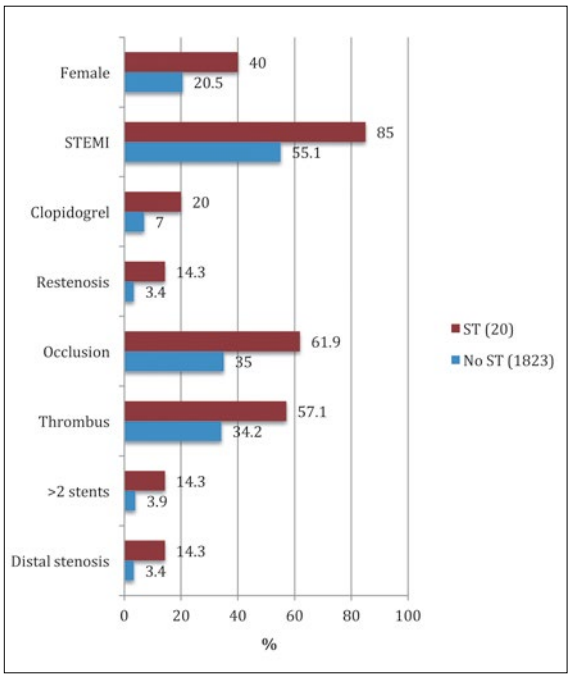

Figure 1: Comparison of patient groups with and without stent thrombosis (ST).

Table 4: Significant risk factors of stent thrombosis were female gender, presentation as ST segment elevation myocardial infarction (STEMI) or anteroseptal infarction on ECG and baseline clopidogrel therapy.

	Stent thrombosis	No stent thrombosis	p-value
Total	20	1823	
Gender / initial presentation			
Female	8 (40%)	374 (20.5%)	0.03*
STEMI	17 (85%)	1005 (55.1%)	0.01*
Anteroseptal infarction (ECG)	4 (20%)	102 (5.6%)	0.02*
Past medical history			
CAD	6 (30%)	451 (24.7%)	0.59
Smoker	13 (65%)	1136 (62.3%)	0.81
Diabetes	6 (30%)	311 (17.1%)	0.13
Diabetes/OAD	5 (25%)	206 (11.3%)	0.07
Diabetes/insulin	1 (5%)	88 (4.8%)	1.0
Hypertension	8 (40%)	1031 (56.6%)	0.14
Dyslipidaemia	12 (60%)	1122 (61.6%)	0.89
Malignoma	3 (15%)	136 (7.5%)	0.19
Baseline medication			
Aspirin	6 (30%)	538 (29.5%)	1.000
Clopidogrel	4 (20%)	127 (7%)	0.048*
Statin	7 (35%)	489 (26.8%)	0.45
ACE inhibitor	3 (15%)	296 (16.2%)	1.0
Beta blocker	4 (20%)	420 (23%)	1.0
OAD	5 (20%)	203 (11.1%)	0.07

* p <0.05 was considered statistically significant. ACE: angiotensin converting-enzyme; CAD: coronary artery disease; OAD: oral antidiabetic drug

Discussion

In this large prospective Swiss real-world ACS cohort referred for primary PCI for ACS we found a very low rate of stent thrombosis of 1.1%. The low rate of stent thrombosis is well in line with the findings of other "real-world" registries, such as the large Swedish SCAAR registry with a stent thrombosis rate of 1.2% [5]. Stent thrombosis risk was lower in a DES than in a BMS, which matches the results of a recent meta-analysis [19].

As patients with ACS, particularly those with STEMI, have a large thrombus burden at the site of coronary narrowing or occlusion, the risk of stent thrombosis was initially considered much higher than in patients with stable angina undergoing elective PCI. The very low stent thrombosis rate of 1.1% reflects the impressive progress that has been achieved over recent decades in stent design and implantation technique. The higher risk of stent thrombosis in patients presenting with STEMI is known and reflects the importance of intracoronary thrombus load for the development of such an event [20]. In STEMI patients platelet activity is markedly elevated and endothelial healing delayed, thereby exposing naked thrombogenic stent struts to the circulating blood [21]. Of note, patients with stent thrombosis had been implanted with stents 20 mm in length, which may have contributed to delayed or incomplete healing, which in turn may have increased the risk of such an event.

Table 5: Factors associated with later stent thrombosis were restenosis of pre-existing stent, complete occlusion or thrombus in target vessel, implantation of more than two stents and stenosis distal to stented lesion, as seen on baseline coronary angiography.

	Stent thrombosis	No stent thrombosis	p-value
Baseline PCI findings			
LAD lesion	8 (38.1%)	949 (36.7%)	0.90
RCA lesion	7 (33.3%)	829 (32.1%)	0.90
RCX lesion	1 (4.8%)	340 (13.2%)	0.51
Restenosis	3 (14.3%)	87 (3.4%)	0.03*
Occlusion	13 (61.9%)	905 (35%)	0.01*
Thrombus	12 (57.1%)	884 (34.2%)	0.03*
AHA/ACC type A lesion	2 (9.5%)	311 (12.%)	1.00
AHA/ACC type B1 lesion	6 (28.6%)	1007 (38.9%)	0.38
AHA/ACC type B2 lesion	4 (19.1%)	421 (16.3%)	0.77
AHA/ACC Type C Lesion	2 (9.5%)	288 (15%)	1.00
Bifurcation lesion	3 (14.3%)	229 (8.9%)	0.43
>1 stent	6 (28.6%)	524 (20.3%)	0.35
>2 stents	3 (14.3%)	100 (3.9%)	0.048*
Stent overlap	5 (23.8%)	522 (20.2%)	0.60
Distal stenosis	3 (14.3%)	87 (3.4%)	0.03*
TIMI score <3 after PCI	2 (9.5%)	74 (2.9%)	0.12

* p <0.05 was considered statistically significant. AHA: American Heart Association; ACC: American College of Cardiology; LAD: left anterior descending artery; RCA: right coronary artery; RCX: right circumflex artery; TIMI: Thrombosis in Myocardial Infarction

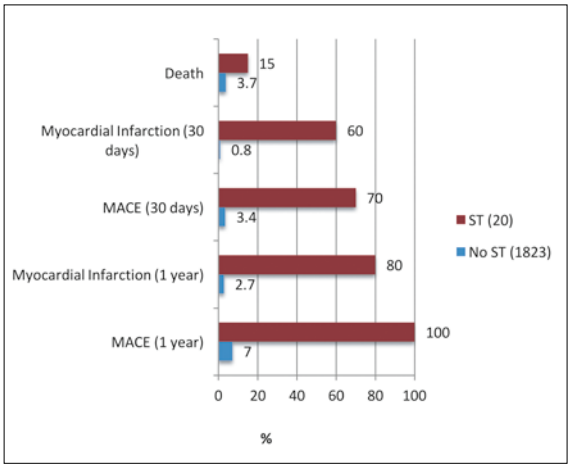

Figure 2: Outcomes of patient groups with and without stent thrombosis.

The (at first glance) surprising finding of a higher stent thrombosis risk in women has already been reported by others [22]. It is probably attributable to the smaller coronary arteries in women; stent diameter is known to be inversely associated with the risk of stent thrombosis [23].

Nonadherence to DAPT has been repeatedly found to be one of the most important risk factors for stent thrombosis, especially in the first 30 days after PCI [8]. All our patients with stent thrombosis started DAPT upon admission, if they were not already on DAPT. Unfortunately, compliance with antiplatelet therapy lacks a useful biomarker and is therefore difficult to assess objectively. In the current cohort it was not investigated in detail and therefor may be one of the factors involved in early stent thrombosis. Data on medication compliance in this study population at 1-year follow up after PCI has been published previously [17], with 96.7% of patients still on aspirin and 81.9% on P2Y12 inhibitors at follow-up (at discharge 99.3 and 100%, respectively). Most frequently, the medication was stopped by the patients' physicians.

Surprisingly, in our study patients already on clopidogrel prior to primary PCI had a higher risk of stent thrombosis. A possible explanation might be that these patients might generally have been considered at high ischaemic risk by their treating physicians and therefore were left on this P2Y12 inhibitor for prolonged periods of time. As previous reports have mentioned, there may be a benefit of an additional loading dose of prasugrel in patients pretreated with clopidogrel [24].

Premature cessation of DAPT is known as one of the strongest risk factors for early stent thrombosis, but the pathophysiology of late thrombosis is complex. Delayed arterial healing, with inflammatory responses in the vessel wall persisting after stent implantation and delayed endothelial coverage of the stent, has been described as an underlying cause [25]. The risk was highest in first-generation DESs (sirolimus- or paclitaxel-eluting stents), and was greatly reduced with the introduction of second-generation DESs (everolimus- or zotarolimus-eluting stents) [11], as already mentioned in the introduction. Furthermore, neoatherosclerosis may develop within the stent and be responsible for late stent thrombosis [26]. The sample size of our study was, however, too small to allow differentiation between different types of DES.

Previous reports have described diabetes, in particular in patients requiring insulin, and persistent smoking as having a major influence on stent thrombosis risk [27, 28]. Neither finding could be reproduced in our population, possibly as patients with diabetes were under a strict dietary regimen and treated with oral antidiabetic drugs or insulin. Furthermore, the number of patients with diabetes was quite low, which reduced statistical power to detect such a relationship. The percentage of smokers was high, but equal in patients with or without stent thrombosis.

Previously reported angiographic risk factors such as bifurcation lesions, stent overlap or lesion complexity according to American Heart Association / American Collece of Cardiology (AHA/ACC) criteria [11, 29] did not affect the risk of stent thrombosis in our patients. In contrast, the use of more than two stents, which might be a surrogate marker for overall lesion burden, was associated with an increased risk of stent thrombosis. Furthermore, in-stent restenosis and coronary lesions distal to the stent increased the risk of stent thrombosis. Thus, it appears that during the procedure stenosis distal to the culprit lesion should be treated appropriately to further reduce the risk of stent thrombosis.

Many other intervention-related factors, such as mismatch of stent and vessel size, stent underexpansion or stent length, are well known risk factors for stent thrombosis [30]. The data acquired in our study did not allow a thorough analysis of these important aspects, as the registry was not designed to allow a detailed investigation of technical factors. Imaging-assisted PCI with the use of intravascular ultrasound (IVUS) or optic coherence tomography (OCT) has shown promising results in reducing the rates of stent thrombosis [31]. Neither IVUS nor OCT were, however, routinely used in our study population, which reflects the clinical practice of four major cardiac centres in Switzerland.

The enrolled patients had characteristics similar to those of larger European studies [32, 33] in terms of demographics, medical history and cardiovascular risk profile. The percentage of patients with a history of a

prior PCI was slightly higher in our study: 17 compared with 13% in the European Heart Study [32] and in FAST-MI [33]. This might be related to the affordable and accessible healthcare system open to all patient groups in Switzerland, with a low intervention threshold. Indeed, as published reports show, patients with clinical signs of coronary artery disease or documented ischaemia are more likely to undergo PCI in Switzerland than in some neighbouring countries [34].

Limitations

One of the limitations of this study is that the current secondary analysis was retrospective and not predefined, albeit the data were gathered prospectively. Furthermore, one of the most important risk factors for stent thrombosis, premature discontinuation of DAPT, was not specifically examined as it was not part of the original study protocol. We acknowledge that data from larger registries when published are always behind technical improvements and recent developments in interventional patient care. As a common issue in studies where large amounts of data are collected, information on, for example, patient history or laboratory results was incompletely acquired and/or documented in a couple of cases. Predictors of stent thrombosis were not evaluated by multivariate analysis. Nevertheless, our results are well in line with the mentioned similar-sized registries and meta-analyses.

Conclusions

Stent thrombosis remains a serious complication, as shown by the high mortality of 15% associated with this event. However, its occurrence is rare even in patients with ACS, especially with the use of DESs and guideline-based management. Future developments such as imaging-assisted PCI might further decrease the risk of stent thrombosis in patients with ACS.

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Conflicts of interest

FM has received research grants to the institution from Amgen, AstraZeneca, Boston Scientific, Biotronik, Medtronic, MSD, Eli Lilly and St. Jude Medical including speaker or consultant fees. TFL received research grants to the institution from AstraZeneca, Bayer Healthcare, Biosensors, Biotronik, Boston Scientific, Eli Lilly, Medtronic, MSD, Merck, Roche and Servier, including speaker fees by some of them. CMM received research grants to the institution from Eli Lilly, AstraZeneca, Roche, Amgen and MSD including speaker or consultant fees. LR received speaker fees and research grants to the institution from St. Jude Medical. MR received institutional research grants by Terumo, Biotronik, Boston Scientific, Medtronic, and Abbott Vascular. All other authors have nothing to disclose.

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