Red versus white thrombi in patients with ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention: clinical and angiographic outcomes

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Background Aspiration thrombectomy is used in primary percutaneous coronary interventions, but the importance of thrombus constituency has been scarcely investigated. The objective of this study was to evaluate thrombus constituency and its association with clinical, laboratory, and angiographic findings in patients with ST-segment elevation myocardial infarction.

Methods From April 2010 to May 2011, 562 patients with ST-segment elevation myocardial infarction undergoing primary percutaneous coronary interventions were considered for inclusion, and information on thrombi characteristics was available for 113 patients. Thrombus material were obtained and classified as white or red based on its constituency. Samples were analyzed by 3 independent pathologists blinded to clinical characteristics.

Results The mean age of patients was 58.6 ± 12.7 years, and 69% were men. White thrombi were present in 31% of cases, and red thrombi, in 69%. Patients with white thrombi had smaller vessels and lower ischemic times. All other clinical, angiographic, and laboratory characteristics did not differ. White thrombi were smaller and associated with fibrin infiltration, whereas red thrombi were associated with red blood cell infiltration. Thirty-day death rates were lower in patients with white thrombi than red (0% vs 10.1%, respectively; $P = .05$), as were 30-day major adverse cardiac event rates (4.2% vs 13.9%; $P = .10$). Total ischemic time was well correlated with fibrin infiltration ($R = –0.30$; $P < .01$), red blood cell infiltration ($R = 0.27$; $P < .01$), and thrombus volume ($R = 0.22$; $P = .02$).

Conclusions White thrombi were present in one-third of cases and were associated with lower ischemic times, higher fibrin infiltration, smaller thrombus volume, and lower mortality. These findings suggest that thrombus constituency may be a useful prognostic tool in this setting. (Am Heart J 2012;164:553-60.)

Primary percutaneous coronary intervention (pPCI) is the preferred reperfusion strategy in patients with ST-segment elevation myocardial infarction (STEMI).[1-3] Adjunctive aspiration thrombectomy lowers mortality when compared with the standard strategy[4] and has been increasingly performed at many centers. This new approach allows examination of the retrieved thrombi, and histological analysis has provided interesting insights into the pathophysiology of this disease.[5-10] It has been shown, for example, that older thrombi can occur with chest pain for only a few hours,[5] and the age of the thrombus is associated with worse ST-segment resolution[10] and poor prognosis.[6]

Histological analysis of thrombus composition in STEMI is an elegant and important research tool, and future studies will likely elucidate further aspects of this condition. However, it takes time to process and analyze material, making it difficult to use this information at the bedside. On the other hand, the macroscopic aspect of the retrieved thrombus is a piece of information that is readily available. Thrombi can be of different sizes, shapes, and colors. Coronary thrombi can be classified as red or white, but the clinical relevance of this aspect has scarcely been studied to date. Mizuno et al analyzed thrombus color by intracoronary angioscopy in 31 patients with acute coronary syndromes, and white

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thrombi were present only in patients with unstable angina but not STEMI.[11] In contrast, Abela et al identified white thrombi by angioscopy in several patients with STEMI.[12] Given these contradictory findings, the objective of this study was to evaluate clinical, angiographic, and laboratory correlates of thrombus constituency in patients with STEMI undergoing pPCI.

Methods

Patients

All consecutive patients with STEMI hospitalized at the Instituto de Cardiologia do Rio Grande do Sul, Fundação Universitária de Cardiologia, Porto Alegre, Brazil, between April 2010 and May 2011 were considered for inclusion. All patients enrolled in this study have provided written informed consent. STEMI was defined by resting chest pain lasting more than 30 minutes associated with (1) ST-segment elevation of at least 1 mm in 2 leads in the frontal plane or at least 2 mm in the horizontal plane, or (2) new left bundle branch block. Exclusion criteria were chest pain lasting for more than 12 hours, age <18 years, or refusal to participate. Patients had pPCI performed at the discretion of the attending physician, based on physician assessment and clinical need for reperfusion therapy. The study was approved by the institutional review board of the Instituto de Cardiologia do Rio Grande do Sul, Fundação Universitária de Cardiologia.

Clinical and angiographic characteristics

All patients were evaluated on hospital admission, and clinical, angiographic, and laboratory information was collected in a dedicated database. During the index hospitalization, patients were visited daily by one of the study investigators to assess in-hospital events. Delta-t was defined as the time between the onset of chest pain and hospital presentation. Door-to-balloon time comprised the time between hospital presentation and first inflation of the balloon inside the infarct related artery. Total ischemic time was the sum of these 2 periods.

Angiographic analyses were performed in at least 2 different views by experienced operators with a previously validated digital caliper system (Siemens Axiom Artis, Munich, Germany), and intracoronary nitroglycerin was routinely given at a dose of 100 to 200 μg before measurements. Target vessel diameter was defined as the mean diameter of the luminal segments proximal and distal to the lesion, and the severity of stenosis was measured in 2 orthogonal views. Lesion length was measured "shoulder to shoulder," and longer lesions were considered a single lesion only when a normal segment <10 mm long lay between them. Coronary flow was assessed before and after the procedures according to the TIMI criteria.[13] Myocardial perfusion was evaluated by the myocardial blush score, as previously described by Gibson et al.[14]

Interventional procedures

Our institution is a high-volume tertiary referral center for interventional cardiology (2500 PCIs per year). Aspiration thrombectomy has been used in our institution for 2 years, and 3 different aspiration catheters are used: Export (Medtronic Vascular Inc, Santa Rosa, CA), Diver (INVATEC, Brescia, Italy), or Pronto (Vascular Solutions, Minneapolis, MN). In this study, the decision to perform thrombectomy was left to the discretion of the operator, as were technical aspects such as type and number of stents, use of any other devices, and glycoprotein IIb/IIIa use. In every case, aspiration was attempted before balloon dilatation (as in the TAPAS trial),[4] and several passages at the site of occlusion were performed. Aspirated blood and intracoronary material were collected in the filter. All patients were treated with 300 mg aspirin and 300 to 600 mg clopidogrel on hospital admission. Heparin (60-100 U/kg) was administered before coronary guide wire introduction, and all procedures were performed according to standard pPCI techniques.[15,16]

Thrombus analysis

All pathological analyses, including macro- and microscopic evaluation and thrombus color assessment, were done by 3 independent pathologists, blinded to the patient's characteristics and clinical outcomes. The intra- and interobserver agreement rates were assessed, and the kappa coefficient was 0.9.

All thrombi were classified as red or white based on their color by macroscopic evaluation. Those thrombi with both red and white constituents were classified according to the predominant color. The sample was placed in 10% formalin immediately after retrieval and fixed for 24 hours. The number of fragments recovered and the dimensions of each were recorded. Thrombus volume was defined as the product of its length, height, and thickness. The material was then embedded in paraffin, entirely cut in 3-micra serial sections, and stained with hematoxylin-eosin at ≥8 levels. On histopathological analysis, the thrombi were pathologically classified into 2 categories, as previously described[5]: (1) recent thrombus (<1 day), composed of layered patterns of platelets, fibrin, erythrocytes, and intact granulocytes; or (2) old thrombus (>1 day), characterized by areas of necrosis, apoptosis and karyorrhexis of leukocytes, and/or findings suggestive of organization (in-growth of smooth muscle cells, deposition of connective tissue, capillary in-growth). Thrombus material with a heterogeneous constituency was graded according to the age of the oldest part. In each case, the percentage of leukocytes, erythrocytes, and fibrin was recorded.

Clinical outcomes and follow-up

Patients were followed up during index hospitalization, and telephone contact was made 1 month after discharge to assess outcomes. Stent thrombosis was defined according to the Academic Research Consortium criteria.[17] Myocardial infarction was defined by recurrent chest pain with new elevation of serum biomarkers after the initial falling of the natural curve, with ST-segment elevation or new Q waves. Urgent revascularization was defined as an unplanned revascularization procedure in the first 30 days after the index STEMI, either by PCI or coronary artery bypass surgery, to treat recurrent myocardial ischemia.

Statistical analysis

Results are expressed as mean ± SD. For comparisons between categorical variables, the χ^2 or Fisher exact test was used. For comparisons between continuous variables, the t test was used. Mann-Whitney U test was used in the case of variables with non-normal distribution. Pearson coefficients were used to express correlation between total ischemic time and fibrin and red blood cells infiltration, and the Spearman coefficient was used to express correlation between total ischemic time and

thrombus volume. The intra- and interobserver correlations in pathological analyses were assessed by kappa coefficients. Statistical significance was considered if $P < .05$.

We did not have preliminary data to perform a precise and adequate sample size calculation. Instead, we decided to analyze data collected in a period of approximately 1 year because of the high volume of pPCI done by our center. This decision was also influenced by recent reports assessing histopathologic aspects of aspirated coronary thrombus, which included around 50 to 60 patients.[9,18]

The authors are solely responsible for the design and conduct of the study, all study analyses, the drafting and editing of the manuscript, and approval of its final contents. No extramural funding was used to support this study.

Results

Patients

During the study period, 562 patients presented to our center with a STEMI, and 168 patients (33%) underwent aspiration thrombectomy. Statistically significant differences between patients who did or did not undergo thrombus aspiration were age (58.8 ± 12.1 years vs 61.5 ± 11.6 years, respectively; $P < .01$), lesion length (18.8 ± 9.3 mm vs 16.9 ± 8.1 mm, respectively; $P < .01$), reference vessel diameter (3.3 ± 0.5 mm vs 3.1 ± 0.5 mm, respectively; $P < .01$), and TIMI risk scores (3.4 ± 2.3 vs 3.8 ± 2.4, respectively; $P = .01$).

Aspiration thrombectomy was successful in 70% (n = 118) of the patients. Statistically significant differences between patients who experienced a successful or unsuccessful aspiration were age (58.0 ± 12.1 vs 63.4 ± 11.0 years, respectively; $P = .01$), reference vessel diameter (3.4 ± 0.5 vs 3.2 ± 0.4 mm, respectively; $P < .01$), angiographically visible thrombus (74% vs 26%; $P < .01$), and TIMI risk scores (3.1 ± 2.0 vs 4.4 ± 2.8; $P < .01$).

Thrombi were available for analysis in 113 cases; the study flow chart is shown in Figure 1. The mean age of the sample was 58.6 ± 12.7 years, and 69% were men. White thrombi were present in 31% of cases, and red thrombi, in 69%. Macroscopic images of white and red thrombi are shown in Figure 2. Clinical and angiographic characteristics were generally similar (Table I), but patients with white thrombi had smaller vessels and a lower ischemic time when compared with patients with red thrombi. Laboratory evaluation was also generally similar between the 2 groups of patients (Table I).

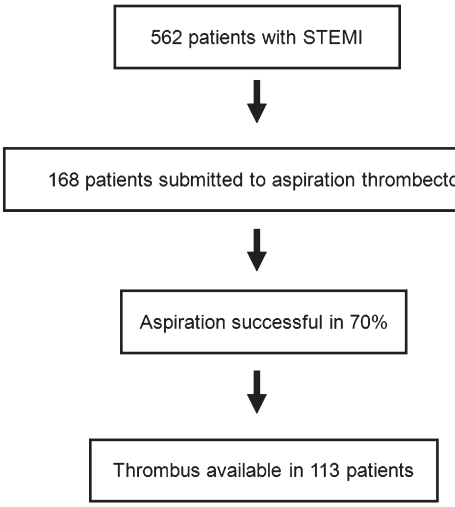
Regarding pharmacological treatment of both groups in the first 24 hours of hospital admission (Table II), we did not find significant differences regarding use of aspirin, clopidogrel, β-blockers, heparins, glycoprotein IIb/IIIa inhibitors, and other drugs.

Histological findings

The histopathologic analysis of the aspirated thrombi is shown in Figure 3, and comparisons between study groups are displayed in Table III. White thrombi were smaller, and fibrin infiltration was significantly higher, whereas red thrombi were associated with red blood cell infiltration. The frequency of recent thrombus according to previously defined criteria[5] was similar in both groups.

Total ischemic time was correlated with fibrin infiltration ($R = -0.30$; $P < .01$), red blood cell infiltration ($R = 0.70$; $P < .01$), and thrombus volume ($R = 0.22$; $P = .02$).

Figure 1



Study flow chart. STEMI, ST-segment elevation myocardial infarction.

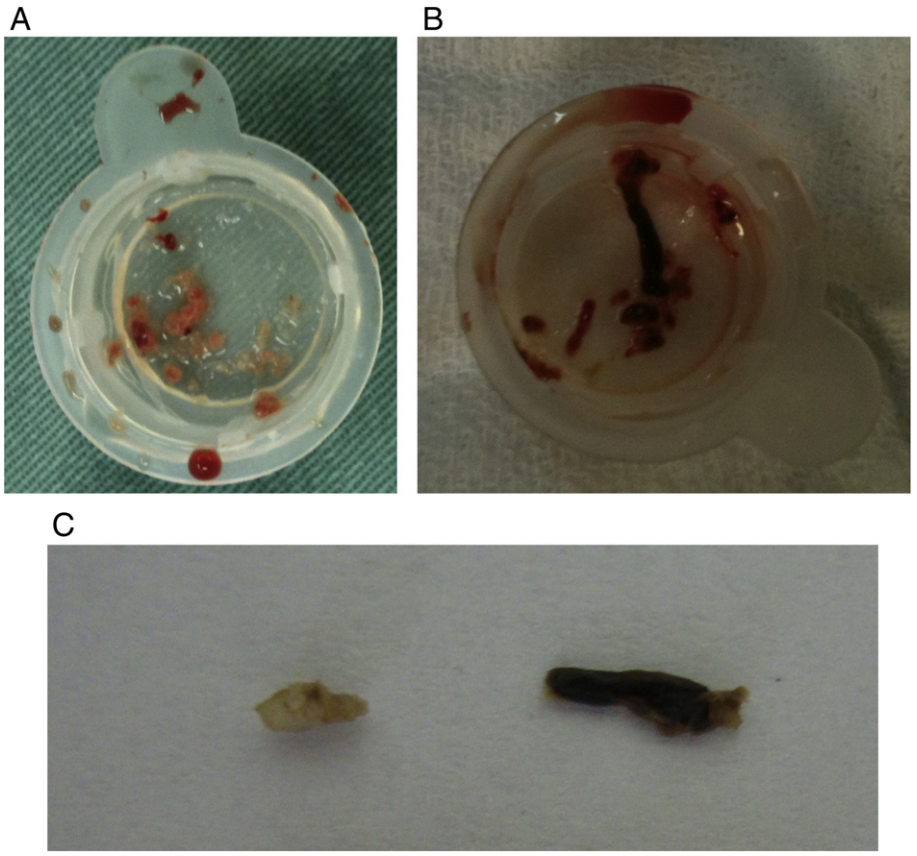
Clinical outcomes

Recurrent clinical events were less frequent in patients with white thrombi, as shown in Figure 4. Of note, death in the first 30 days occurred in 8 patients with red thrombi and in none of the patients with white thrombi (10.1% vs 0%; $P = .05$). Most patients died of cardiac causes: progressive congestive heart failure in 2 patients, refractory cardiogenic shock in 2 patients, definite/probable subacute stent thrombosis and MI in 2 patients, recurrent MI in 1 patient, and acute renal failure and sepsis in 1 patient. There was also a trend toward less frequent major adverse cardiovascular events (MACE) in patients with white thrombi than in those with red thrombi (4.2% vs 13.9%, respectively; $P = .10$). MACE rates over 30 days were similar for patients who underwent aspiration thrombectomy and those who did not (12% vs 14%, respectively; $P = .40$), as well as for those who did or did not experience successful aspiration (11% vs 15%, respectively; $P = .39$).

Discussion

Aspiration thrombectomy has gained widespread acceptance in recent years, and analyses of retrieved thrombi have provided interesting insights into the pathophysiology of STEMI. Most studies have focused on histological aspects of thrombus, whereas the

Figure 2



Macroscopic features of red and white thrombi. **A**. White thrombus immediately after retrieval. **B**. Red thrombus immediately after retrieval. **C**. White and red thrombi after formalin fixation.

importance of the gross macroscopic morphology has received less attention. This simpler approach could provide useful prognostic information during pPCI procedures, potentially guiding decision making regarding different antithrombotic and anticoagulants strategies, as well as other technical aspects of pPCI.

To the best of our knowledge, there are no studies reporting clinical, angiographic, laboratory, and histological correlates of the color of thrombi retrieved during pPCI in current practice. In the present analysis, we found that white thrombi composed approximately one-third of specimens retrieved during pPCI in a contemporary sample of patients from a high-volume referral center. White thrombi were smaller and mainly composed of fibrin. Patients with white thrombi had less ischemic time and had smaller vessels when compared with those with red thrombi. Other clinical, angiographic, and laboratory characteristics were generally similar between groups. More importantly, white thrombi were associated with less mortality and a trend toward less MACE than seen in patients with red thrombi.

The mechanisms by which white thrombi could have been associated with better outcomes in our study are not clear. However, most of the deaths that occurred in the patients with red thrombi were cardiac in origin. Patients with white thrombi had lower creatine kinase-MB (25 ± 37 vs 43 ± 76 ng/mL, respectively; $P = .11$) and troponin (911 ± 1,918 vs 1,997 ± 3,469 ng/mL; $P = .12$) peak levels compared with those having red thrombi, and higher postprocedural TIMI grade 3 (91% vs 87%; $P = .45$) and blush grade 3 (64% vs 61%; $P = .52$) rates, but these differences did not reach statistical significance. One possible explanation is that white thrombi could be associated with better coronary and myocardial perfusion and therefore smaller infarcts. White thrombi were smaller and with less cell content than red thrombi, and were also associated with lower ischemic time; these features may have contributed to lower distal embolization and better myocardial perfusion. However, additional research, including mechanistic studies, are needed to evaluate this issue.

Mizuno et al have analyzed thrombus color by intracoronary angioscopy in a sample of patients with unstable angina and STEMI.[11] Of the 29 patients with thrombi, those with unstable angina were frequently observed to have white thrombi (10 of 14, 71%), but none

Table I. Clinical, angiographic, and laboratory characteristics in white versus red thrombi

Characteristic	White thrombus (n = 34)	Red thrombus (n = 79)	*P*
Age, years	57.4 ± 12.9	58.7 ± 12.6	.63
Men, %	76	68	.43
Hypertension, %	64	59	.68
Diabetes mellitus, %	15	15	.99
Dyslipidemia, %	30	33	.78
Smoking, %	39	48	.49
Family history of CAD, %	27	30	.74
Medical history			
PCI, %	18	13	.44
CABG, %	0	2.5	1.00
Myocardial infarction, %	21	15	.48
Congestive heart failure, %	18	13	.48
Chronic renal failure, %	3	2.5	1.00
Anterior MI, %	51	38	.18
Delta T, hours	3.3 ± 2.2	4.5 ± 2.8	.01
Door-to-balloon time, hours	1.2 ± 0.5	1.6 ± 1.3	.19
Ischemic time, hours	4.5 ± 2.3	6.1 ± 3.1	.01
Three-vessel disease, %	3	16	.06
LAD involvement, %	48	37	.16
Reference vessel diameter, mm	3.2 ± 0.4	3.5 ± 0.6	.03
Lesion length, mm	18.5 ± 6.1	18.5 ± 10.3	.97
TIMI grade 3 flow			
Pre, %	6	8	.79
Post, %	91	87	.45
Blush grade 3			
Pre, %	3	5	.72
Post, %	64	61	.52
TIMI risk score	2.9 ± 1.9	3.5 ± 2.0	.18
Laboratory evaluation			
Glycemia, mg/dL	169 ± 82	167 ± 61	.88
Total cholesterol, mg/dL	203 ± 51	202 ± 49	.93
HDL cholesterol, mg/dL	40 ± 11	40 ± 12	.86
Triglycerides, mg/dL	181 ± 232	155 ± 148	.49
C-reactive protein, mg/dL"""	0.67 ± 0.71	1.01 ± 2.65	.49
Fibrinogen, mg/dL	219 ± 71	199 ± 54	.12
Hematocrit, %	41 ± 2.6	42 ± 4.4	.38
Hemoglobin, g/dL	13.6 ± 0.9	14.0 ± 1.6	.17
Leukocytes, mm^3	13,516 ± 5,339	13,687 ± 4,598	.86
Platelet, mm^3	261,892 ± 88,319	248,555 ± 66,533	.39
Creatinine, mg/dL	0.97 ± 0.3	1.03 ± 0.4	.36
Peak CK-MB, ng/mL	25 ± 37	43 ± 76	.11
Peak US troponin, ng/mL	911 ± 1,918	1,997 ± 3,469	.12

CABG, Coronary artery bypass grafting; *CAD*, Coronary artery disease; *CK-MB*, Creatine kinase-MB; *HDL*, high-density cholesterol; *LAD*, left anterior descending artery; *MI*, myocardial infarction; *PCI*, percutaneous coronary intervention; *TIMI*, thrombolysis in myocardial infarction; *US*, ultrasensitive.

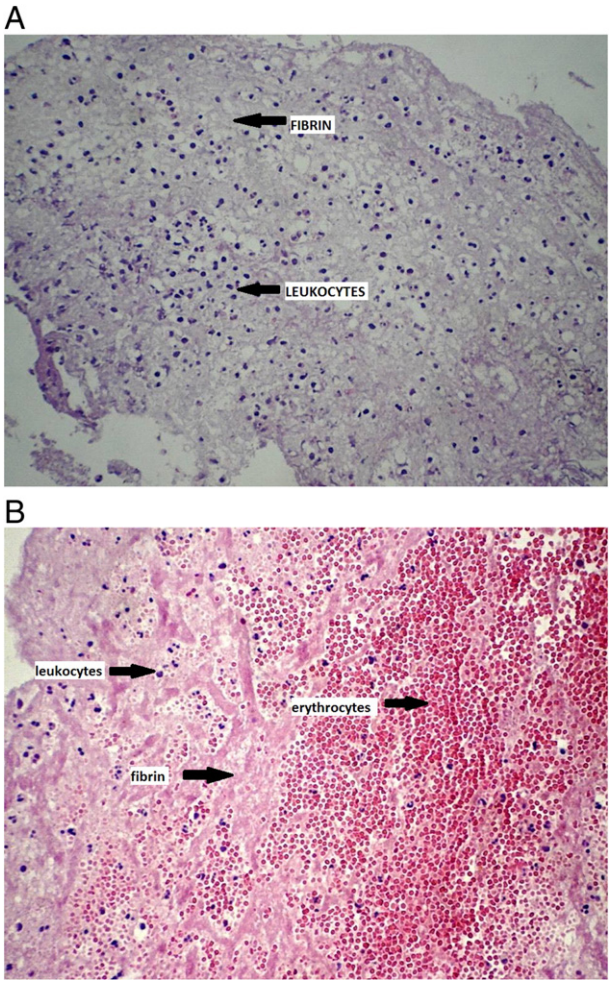
were found in the 15 patients with STEMI. The authors hypothesized that these differences in color probably reflected distinct composition of the thrombus, but histopathologic analyses were not performed. On the other hand, Abela et al also investigated STEMI patients with intracoronary angioscopy and found white thrombi to be frequent.[12] Our study reinforces the idea that white thrombi are relatively common in patients with STEMI.

Table II. Medical treatment in the first 24 hours of hospitalization in white versus red thrombus

Treatment	White thrombus (n = 34)	Red thrombus (n = 79)	*P*
Aspirin, %	100	96	.55
Clopidogrel			
300 mg, %	16	15	1.00
600 mg, %	84	85	1.00
GP IIb/IIIa inhibitor, %	43	54	.33
Heparin, %	100	98	1.00
Statin, %	88	82	.58
β-Blocker, %	74	74	1.00
ACE inhibitor, %	75	75	1.00
Nitrates, %	40	38	.84

ACE, Angiotensin-converting enzyme; *GP*, glycoprotein.

Figure 3

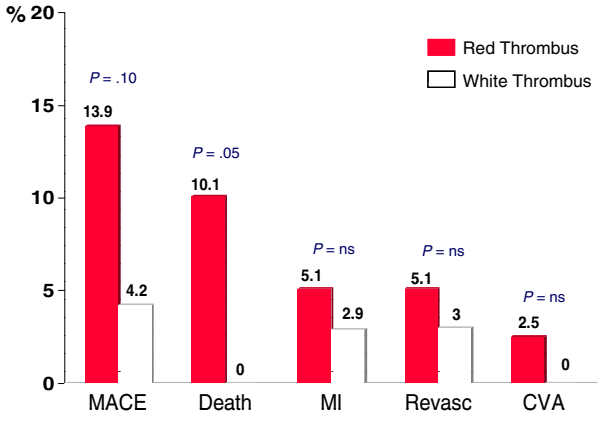


Histology of white and red thrombi. **A**. White thrombus displays predominant fibrin infiltration with few cellular elements. **B**. Red thrombus shows predominance of erythrocytes and lower fibrin infiltration.

Table III. Thrombus histology

Histology	White thrombus (n = 34)	Red thrombus (n = 79)	*P*
No. of fragments, n	3.3 ± 2.7	3.9 ± 3.4	.29
Dimension (largest), mm	0.4 ± 0.2	0.6 ± 0.4	<.001
Volume, μm^3	13 ± 12	25 ± 23	<.001
Red blood cells, %	12 ± 17	41 ± 21	<.001
White blood cells, %	20 ± 13	15 ± 9	.04
Fibrin, %	68 ± 19	44 ± 18	<.001
Recent thrombus, %	56	62	.59

Figure 4



One-month clinical outcomes according to thrombus color. *MACE*, Major adverse cardiovascular event; *MI*, myocardial infarction; *Revasc*, new revascularization; *CVA*, cerebrovascular accident; *NS*, non-significant.

Furthermore, we have confirmed that the color of the thrombus aspirated during pPCI is associated with a different histological architecture (eg, a higher fibrin infiltration than found in patients with red thrombi).

The process of thrombus formation was investigated by Uchida et al in an experimental model of coronary arteries isolated from cadavers and perfused with canine arterial blood.[19] In that study, white thrombi displayed a tight fibrin network and were older than red thrombi. On the contrary, we found that white thrombi were associated with less ischemic time than red thrombi. It has been shown that ischemic time is associated with thrombus burden and fibrin deposition, and our analyses confirm these findings. However, despite that white thrombi were generally composed of fibrin and had lower ischemic times in our study, we found that half of the white thrombi were old or organized. Silvain et al also investigated the composition of coronary thrombi retrieved by aspiration thrombectomy in a contemporary sample of patients using high-definition pictures taken with a scanning electron microscope.[9] The correlation between fibrin content of the thrombus and ischemic time in that sample was 0.38 (P = .01), similar to that found in our analysis (R = 0.30; P < .01).

The finding that white thrombi are smaller than red thrombi is also of relevance because thrombus burden is an established predictor of complications during PCI with or without stents.[20,21] In the TAPAS study, the erythrocyte-rich thrombi were also moderate to large.[4] Abela et al have previously demonstrated that red thrombi were associated with large filling defects detected by angiography, whereas white thrombi generally presented as hazy lesions.[12] Although these authors did not measure thrombus size, these findings also suggest that white thrombi were smaller than red thrombi. There are several factors associated with thrombus size, such as the intensity of anticoagulant and antithrombotic therapy,[22,23] the age of the thrombus,[5,7] and the presence of flow in the infarct-related artery before pPCI.[11] In this report, we did not find significant differences regarding pharmacological treatment or preprocedural TIMI 3 flow among the 2 groups of patients. However, total thrombus burden was found to be significantly associated with total ischemic time.

The extrapolation of our findings to the entire spectrum of patients with acute coronary syndromes has to be evaluated with caution in light of the limited sample. In fact, one-third of the patients who presented to our center with a STEMI in the study period underwent aspiration thrombectomy, which is similar to contemporary data reported by other reference centers.[9,24,25] Despite receiving a class IIa recommendation in the recently published 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention,[15] the use of aspiration thrombectomy in our study was low, similarly to what is observed in the real world practice. In our study, patients who underwent thrombus aspiration were younger than those who did not undergo this treatment, with longer lesions, larger vessels, and lower TIMI risk scores, and presented similar MACE rates. The rate of unsuccessful aspiration occurred in 30% of those who submitted to this procedure. Patients who experienced an unsuccessful aspiration were older, had higher TIMI risk scores, smaller vessels, and less frequently an angiographically visible thrombus. Outcomes between patients with successful and unsuccessful aspiration thrombectomy were also not statistically different. These findings are similar to those recently reported by Vink et al.[24]

Strengths and limitations

Potential limitations of this study include the relatively small number of patients, which precludes an appropriate multivariable analysis to assess whether thrombus color is an independent predictor of death by itself. White thrombi were also associated with decreased ischemic time, and therefore a definite cause-and-effect relationship between thrombus color and outcomes cannot be

established. There are few studies to date analyzing histopathological correlates of retrieved thrombi, and our sample size compares favorably with the most recent reports, which included only around 50 to 60 patients.[9,18] This is an exploratory study and the first to demonstrate the potential of using thrombus color after aspiration in daily practice as a prognostic tool, and our results deserve validation by a multicenter study adequately powered for clinical outcomes. Rittersma et al,[5] Kramer et al,[6,7] and Verouden et al[10] published histopathological analyses of thrombi with larger sample sizes, but these studies were limited by including patients with older pharmacological regimens and different types of thrombectomy devices. Another criticism that has been made of the analysis of specimens retrieved by aspiration thrombectomy during pPCI is that it may not represent the whole thrombotic burden inside the coronary artery. However, given the dynamic characteristics of thrombosis and the importance of a number of clinical, angiographic, and pharmacological variables in this setting, we believe that the investigation of thrombus characteristics in vivo and in real-world clinical practice is an important aspect of our study. In the present study, thrombus color was assessed by the pathologist. This fact may be considered a limitation when extrapolating these results to daily practice, where the interventional cardiologist will have to rely on his or her own assessment of thrombus color. However, one strength of our study was that 3 pathologists evaluated all samples, and there was an excellent correlation among their final classification. Lastly, we did not have information on left ventricular ejection fraction for all patients.

Conclusion

In conclusion, our exploratory study showed that white thrombi occurred in one-third of cases and were associated with lower death rates, lower ischemic time, higher fibrin infiltration, and smaller thrombus volume when compared with red thrombi. Our findings deserve validation and suggest that thrombus constituency might be a useful prognostic tool in the setting of acute MI.

Disclosures

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References

1. Grines CL, Browne KF, Marco J, et al. A comparison of immediate angioplasty with thrombolytic therapy for acute myocardial infarction—the Primary Angioplasty in myocardial Infarction Study Group. N Engl J Med 1993;328:673-9.
2. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. Lancet 2003;361:13-20.
3. Van de Werf F, Bax J, Betriu A, et al. ESC Committee for Practice Guidelines. Management of acute myocardial infarction in patients presenting with persistent ST-segment elevation: the task force on the management of ST-segment elevation. Eur Heart J 2008;29: 2909-45.
4. Svilas T, Vlaar PJ, van der Horst IC, et al. Thrombus aspiration during primary percutaneous coronary intervention. N Eng J Med 2008; 358:557-67.
5. Rittersma SZ, van der Wal AC, Koch KT, et al. Plaque instability frequently occurs days or weeks before occlusive coronary thrombosis: a pathological thrombectomy study in primary percutaneous coronary intervention. Circulation 2005;111:1160-5.
6. Kramer MC, van der Wal AC, Koch KT, et al. Presence of older thrombus is an independent predictor of long-term mortality in patients with ST-elevation myocardial infarction treated with thrombus aspiration during primary percutaneous coronary intervention. Circulation 2008;118:1810-6.
7. Kramer MC, van der Wal AC, Koch KT, et al. Histopathological features of aspirated thrombi after percutaneous coronary intervention in patients with ST-elevation myocardial infarction. PLoS One 2009;4:e5817.
8. Kramer MC, Rittersma SZ, de Winter RJ, et al. Relationship of thrombus healing to underlying plaque morphology in sudden coronary death. J Am Coll Cardiol 2010;55:122-32.
9. Silvain J, Collet JP, Nagaswami C, et al. Composition of coronary thrombus in acute myocardial infarction. J Am Coll Cardiol 2011;57: 1359-67.
10. Verouden NJ, Kramer MC, Li X, et al. Histopathology of aspirated thrombus and its association with ST-segment recovery in patients undergoing primary percutaneous coronary intervention with routine thrombus aspiration. Catheter Cardiovasc Interv 2011;77:35-42.
11. Mizuno K, Satomura K, Miyamoto A, et al. Angioscopic evaluation of coronary-artery thrombi in acute coronary syndromes. N Eng J Med 1992;326:287-91.
12. Abela GS, Eisenberg JD, Mittleman MA, et al. Detecting and differentiating white from red coronary thrombus by angiography in angina pectoris and in acute myocardial infarction. Am J Cardiol 1999;83:94-7.
13. The TIMI Study Group. The Thrombolysis in Myocardial Infarction (TIMI) trial: phase I findings. N Engl J Med 1985;312:932-6.
14. Gibson CM, Cannon CP, Murphy SA, et al. Relationship of TIMI myocardial perfusion grade to mortality after administration of thrombolytic drugs. Circulation 2000;101:125-30.
15. Levine GN, Bates ER, Blankenship JC, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. J Am Coll Cardiol 2011;58:44-122.
16. Holmes Jr DR, Hirshfeld Jr J, Faxon D, et al. ACC expert consensus document on coronary artery stents. Document of the American College of Cardiology. J Am Coll Cardiol 1998;32:1471-82.
17. Cutlip DE, Windecker S, Mehran R, et al. Academic Research Consortium. Clinical end points in coronary stent trials: a case for standardized definitions. Circulation 2007;115:2344-51.
18. Barba I, Garcia del Blanco B, Abdul-Jawad O, et al. MRI discriminates thrombus composition and ST resolution after percutaneous coronary intervention in patients with ST-elevation myocardial infarction. PLoS One 2011;6:e18459.

19. Uchida Y, Mauo M, Tomary T, et al. Fiberoptic observation of thrombosis and thrombolysis in isolated human coronary arteries. Am Heart J 1986;112:691-6.
20. Mabin TA, Holmes DR, Smith HC, et al. Intracoronary thrombus: role in coronary occlusion complicating percutaneous transluminal coronary angioplasty. J Am Coll Cardiol 1985;5:198-202.
21. Sianos G, Papafaklis MI, Daemen J, et al. Angiographic stent thrombosis after routine use of drug-eluting stents in ST-segment elevation myocardial infarction: the importance of thrombus burden. J Am Coll Cardiol 2007;50:573-83.
22. Niccoli G, Spaziani C, Marino M, et al. Effect of chronic aspirin therapy on angiographic thrombotic burden in patients admitted for a first ST-elevation myocardial infarction. Am J Cardiol 2010;105: 587-91.
23. Goto S. Propagation of arterial thrombi: local and remote contributory factors. Arterioscler Thromb Vasc Biol 2004;24: 2201-8.
24. Vink MA, Kramer MC, Li X, et al. Clinical and angiographic predictors and prognostic value of failed thrombus aspiration in primary percutaneous coronary intervention. JACC Cardiovasc Interv 2011;4:634-42.
25. Fröbert O, Lagerqvist B, Kreutzer M, et al. Thrombus aspiration in ST-elevation myocardial infarction in Sweden: a short report on real world outcome. Int J Cardiol 2010;145:572-3.