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ORIGINAL ARTICLE

Antithrombotic therapy after angioplasty of pulmonary vein stenosis due to atrial fibrillation ablation: A two-center experience and review of the literature

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Abstract

Background: Pulmonary vein stenosis (PVS) is a severe complication of atrial fibrillation (AF) ablation resulting in narrowing of affected pulmonary veins (PVs). Interventional treatment consists of angioplasty with or without PV stenting. The optimal postprocedural antithrombotic therapy is not known.

Study aims: To investigate the impact of antithrombotic medical therapy on recurrence of PVS after PV angioplasty.

Methods: A retrospective study of patients undergoing PV angioplasty with or without stent implantation in two German centers was performed. Postinterventional antithrombotic therapy consisted of either dual antiplatelet therapy (DAPT) or a combination of oral anticoagulation with single or dual antiplatelet therapy for 3–12 months after intervention. Angiographic follow-up was recommended 3, 6, and 12 months after intervention and in case of symptom recurrence.

Results: Thirty patients underwent treatment of 42 PVS. After intervention, twenty-eight patients received triple therapy and 14 patients received dual therapy/DAPT; restenosis occurred in 5/22 (22.7%) patients with triple therapy and 8/14 (57.1%) patients with dual therapy/DAPT PV ($p = .001$). Estimated freedom from PV restenosis after 500 days was 18.8 ± 15.8% (dual therapy/DAPT) and 76.2 ± 10.5% (triple therapy) ($p = .003$). Univariate regression analysis revealed postprocedural medication as a significant risk factor for restenosis ($p = .019$). No bleeding events occurred regardless of applied antithrombotic therapy.

Conclusion: Triple antithrombotic therapy after PV angioplasty is associated with less frequent restenosis as compared to dual antiplatelet therapy or a combination of

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anticoagulation and single antiplatelet therapy. No severe bleeding events occurred in patients on triple therapy. These findings need to be confirmed in larger patient cohorts.

KEYWORDS
anticoagulation, antiplatelet therapy, atrial fibrillation, pulmonary vein stenosis; restenosis, triple therapy

1 | INTRODUCTION

Catheter ablation of the pulmonary veins (PVs) has become an important therapeutic approach for the treatment of atrial arrhythmias since the landmark work of Haissaguerre et al. in 1998.[1] Pulmonary vein stenosis (PVS) is a rare but clinically relevant complication of atrial fibrillation (AF) ablation resulting in narrowing of the affected pulmonary veins (PVs). Clinical symptoms may include dyspnea, hemoptysis, cough, and recurrent pneumonia.[2–5] Long-term consequences are poorly understood. Despite being a rare complication, PVS will occur potentially more often in the future since AF ablation is performed extensively and in less experienced centers in recent years. The widespread adoption of catheter ablation as the main treatment modality for symptomatic AF will result in ablation procedures performed even in low-volume centers and will potentially lead to an increase in complications such as PVS.

Treatment of PVS includes percutaneous transluminal angioplasty (PTA) and stent implantation.[2,4–9] Mechanisms of PV restenosis development after initially successful recanalization are not fully understood. A combination of neointimal hyperplasia, fibrosis, and thrombus formation is thought to play a key role in restenosis development.[10] There are no prospective studies comparing different medical strategies after interventional PVS treatment yet. Thus, the optimal medical antithrombotic management in patients undergoing PV angioplasty is unknown. Usually, antiplatelet therapy or oral anticoagulation (OAC) is used to prevent neointimal hyperplasia and stent thrombosis.[2,4–8,11–14]

This study sought to assess the impact of postprocedural antithrombotic therapy on PV restenosis development in patients who were treated for PVS due to AF ablation in two German hospitals.

2 | METHODS

2.1 | Study population

Patients who underwent treatment for symptomatic PVS or PV occlusion (PVO) after AF ablation between 2000 and 2018 at the Asklepios Klinik St. Georg, Hamburg, Germany and the University Hospital Lübeck, Lübeck, Germany were included in a retrospective analysis. The study was approved by the local ethics committee; it conforms to the Declaration of Helsinki. All patient information was anonymized for analysis. PVS was defined as a >75% vessel narrowing.[15] Patients underwent angioplasty without or with implantation of a coronary drug-eluting coronary stent (DES) or a self-expanding peripheral bare metal stent (BMS), as reported earlier.[5] All patients underwent first-time angioplasty after the initial diagnosis of PVS or PVO.

2.2 | Pulmonary vein angioplasty

All patients underwent preprocedural transoesophageal echocardiography (TEE) to exclude intracardiac thrombi. Procedures were performed under deep sedation with midazolam, propofol, and sufentanil. Left atrial access was obtained by transseptal puncture using a modified Brockenbrough technique. One or two 8.5F transseptal sheaths (SL1, St. Jude Medical, Inc.,) were inserted into the left atrium (LA) after a transseptal puncture with a BRK-1 needle (St. Jude Medical). After transseptal puncture, intravenous heparin was administered targeting an activated clotting time of ≥300 s. A stepwise balloon dilatation in 1 mm increments with balloon diameters of 2.5–10 mm and lengths of 15–40 mm was performed. Until 2003, patients underwent sole PTA. Afterward, stenting with DES or BMS was performed after angioplasty during the initial procedure or after documentation of restenosis. DES was used until November 2011 as the primary treatment option, then changed to BMS in large vessels and DES only in small vessels or PV bifurcations due to observed high rates of restenosis after DES implantation.[5]

2.3 | Postprocedural care and follow-up

After PVS intervention, oral anticoagulation (OAC) and/or dual antiplatelet therapy (DAPT) therapy was initiated at the discretion of the operator, based on the angiographic results, the $CHADS_2/CHA_2DS_2$-VASc score and the HASBLED score. In general, we recommended the use of DAPT or a combination of OAC and antiplatelet therapy for 3–12 months after stent implantation, then based on further results of the follow-up. Repeat PV angiography was recommended for all patients after 3, 6, and 12 months and in case of symptom recurrence. Restenosis was defined as >75% of vessel narrowing of the affected PV compared with the results of the end of the primary treatment procedure.[15]

2.4 | Statistical analysis

Continuous variables are described as means with standard deviations or as medians with interquartile range (IQR; first and third quartiles), as appropriate. Categorical data are presented as counts and proportions. Categorical variables were compared with the chi-square and Fisher's exact test. Univariate regression analysis on a per-patient basis was performed (ANOVA with bonferroin correction for groups). The Kaplan–Meier product-limit estimator was used to estimate freedom from PV restenosis. A log-rank test was performed to compare freedom from restenosis in patients with and without triple therapy. $p < .05$ was considered statistically significant.

3 | RESULTS

3.1 | Patient characteristics

A total of 30 patients with 42 high-degree PVS were studied. Fifteen patients had undergone the index catheter ablation before PVS formation at our center, the remaining 15 patients were referred for PVS treatment after ablation at external centers. The patients' baseline characteristics are summarized in Table 1. Mean patient age was 49.6 ± 10.8 years; the cohort comprised 7 women (24%). The underlying arrhythmia leading to catheter ablation prior to PVS formation was paroxysmal AF (PAF) in 23 cases (79%), persistent AF in 5 cases (17%), and left atrial tachycardia from the left pulmonary veins in 1 case. Patients had undergone a mean of 1.9 ± 1.1 ablation procedures before developing PVS. The most commonly affected PV was the LSPV (16 patients, 39% of all PV lesions).

TABLE 1 Baseline patient characteristics

N pts	30
Age	49.6 ± 10.8
Female gender	7 (23.3)
Underlying arrhythmia	
Paroxysmal AF	23 (76.7)
Persistent AF	6 (20.0)
Left atrial tachycardia (LPVs)	1 (3.3)
LA diameter, mm	41.3 ± 3.0
Normal left ventricular function	29 (96.7)
CHA_2DS_2-VASc score	1 [0; 1]
HASBLED score	1 [1; 1]
Number of ablation procedures prior to PTA	1.9 ± 1.1
AAD therapy	13 (43.3)
Type of AAD	
Class I	9 (30.0)
Class III	4 (13.3)
Total number of PV lesions	42
PV lesion location	
LSPV	16 (38.1)
LIPV	13 (31.0)
RSPV	6 (14.3)
RIPV	7 (16.7)
Number of pts with PV total occlusions (%)	11 (36.7)

Note: Variables are mean and standard deviation, median (first and third quartiles) or *n* (%).

Abbreviations: AAD, antiarrhythmic drug; AF, atrial fibrillation; LA, left atrium; LIPV, left inferior pulmonary vein; LPV, left pulmonary veins; LSPV, left superior pulmonary vein; Pts, patients; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein; PTA, percutaneous transluminal angioplasty; PV, pulmonary vein.

3.2 | PV recanalization procedures

All 30 patients underwent successful angioplasty of their high-degree PVS. Angioplasty without stenting was performed during the first procedure in 4 PVS, angioplasty with DES implantation was performed in 12 PVS, angioplasty with BMS implantation was performed in 24 PVS, and angioplasty with DES and BMS implantation was performed in 2 bifurcation lesions in the same patient in the initial angioplasty procedure. There were 2 major complications (1 PV perforation and 1 pulmonary bleeding requiring endotracheal intubation) during recanalization procedures. No periprocedural thromboembolic complication occurred.

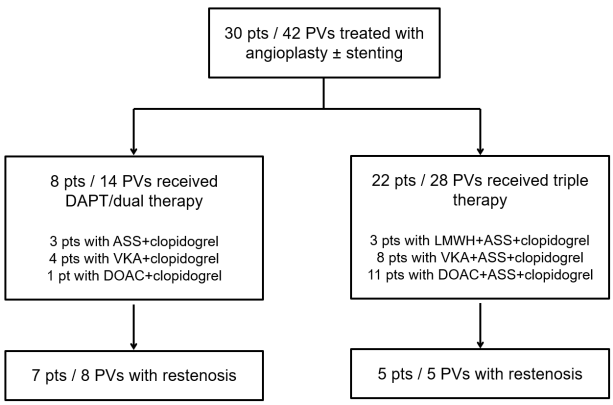

FIGURE 1 Study overview. DAPT, dual antiplatelet therapy; DOAC, direct oral anticoagulant; LMWH, low-molecular-weight heparin; PV, pulmonary vein; VKA, vitamin K antagonist.

3.3 | Medication after angioplasty

An overview of medical therapy after angioplasty is shown in Figure 1. Eight patients with 14 treated PVS received either DAPT or dual therapy. Three patients with 6 PVS were treated with DAPT consisting of acetylsalicylic acid (ASA) and clopidogrel for 12 months after angioplasty. Five patients with 8 PVS were treated with a dual therapy for 6 months consisting of vitamin K antagonists (VKA) and clopidogrel in 7 cases and rivaroxaban and clopidogrel in 1 case. The remaining 22 patients, in which 28 PVS were treated, received triple therapy for 3–12 months

(VKA, ASA, and clopidogrel treatment in 8 cases; a DOAC, ASA, and clopidogrel in 11 cases; and low-molecular-weight heparin [LMWH], ASA, and clopidogrel in 3 cases). After 3–6 months, ASA was discontinued, and dual therapy was continued until 12 months after angioplasty.

3.4 | Restenosis-free survival

Follow-up results are depicted in Table 2. All patients underwent at least one invasive follow-up investigation. A complete invasive 12-month follow-up including 3 angiographies was available for 19 of 30 patients (63.3%). Further invasive follow-up was performed only in patients with documented restenosis who underwent repeat angioplasty. There was 1 patient with restenosis without symptoms who underwent 1 repeat angiography and further follow-up based on computed tomography angiography which detected asymptomatic restenosis. The patient refused further invasive diagnostic and therapeutic approaches. Restenosis occurred in 13/42 PVs (31.0%) after a median invasive angiographic follow-up of 873 ± 181 days after initial PV angioplasty. Restenosis occurred in 5/28 cases (17.9%) receiving triple therapy after intervention and in 8/14 (57.1%) cases receiving dual therapy/DAPT after intervention ($p = .015$) (Figure 2A). Estimated freedom from PV restenosis in patients with and without triple therapy was 81.7 ± 8.3% and 59.3 ± 12.9% after 500 days post-PV angioplasty ($p = .001$) (Figure 2B). Patients with restenosis suffered from dyspnea in all except one case (12 of 13 patients with restenosis). There were no cases of pneumonia or hemoptysis associated with restenosis. One patient with complete stent occlusion was not affected by any clinical symptom. Restenosis occurred in 2/6 RSPV (33.3%), 2/7 RIPV (28.6%), 4/16 LSPV (25.0%), and 5/13 LIPV (38.5%).

In a per-patient analysis of individuals receiving either triple therapy or dual therapy /DAPT, restenosis was angiographically documented in 5/22 patients (22.7%) receiving triple therapy and in 7/8 patients (87.5%) receiving dual therapy/DAPT ($p = .003$) (Figure 2C). The mean time span from angioplasty to invasive documentation of restenosis differed significantly between patients with triple therapy (837 ± 714 days) and patients with dual therapy/DAPT (216 ± 65 days) ($p = .017$). Estimated freedom from PV restenosis in patients with and without triple therapy was 76.2 ± 10.5% and 18.8 ± 15.8% after 500 days post-PV angioplasty (log-rank $p = .003$) (Figure 2D).

Univariate regression analysis was performed to assess predictors of restenosis. Analysis revealed postprocedural medication as the only significant factor for restenosis ($p = .019$ for DAPT, dual therapy or triple therapy after angioplasty, Table 3). No other parameter was significantly associated with the occurrence of restenosis.

4 | DISCUSSION

4.1 | Main findings

We report on the impact of antithrombotic and anticoagulative therapy on the occurrence of restenosis after interventional treatment of iatrogenic PVS. We found that treatment with triple therapy was associated with a significantly lower frequency of restenosis as compared to treatment with antiplatelet therapy or dual therapy. We did not observe severe bleeding events in patients with any therapy regime. This study is the first systematic analysis of postprocedural medication after PVS treatment.

4.2 | Impact of postprocedural medical therapy on restenosis development

PVS treatment is challenging and is limited by a high restenosis rate.[2,3,7–9,13] Therapeutic approaches are further challenged by the

TABLE 2 Follow-up data

Parameter	All pts	Pts with triple therapy	Pts with DAPT/ dual therapy
n pts	30	22	8
n PVs	42	28	14
Treatment strategy			
n PVs with sole PTA	4 (9.5)	0 (0.0)	4 (28.6)
n PVs with DES implantation	12 (28.6)	8 (28.6)	4 (28.6)
n PVs with BMS implantation	24 (57.1)	18 (64.3)	6 (42.9)
n PVs with DES + BMS implantation	2 (4.8)	2 (7.1)	0 (0.0)
Duration of FU (days)	873 ± 181	720 ± 204	897 ± 484
Time to restenosis (days)	489 ± 272	837 ± 714	216 ± 65
n repeat PTA, mean	0.44 ± 0.98	0.75 ± 0.31	0.36 ± 0.20
n pts with major bleeding events	0 (0)	0/0	0/0

Note: Values are median (first and third quartiles), *n* or *n* (%).

Abbreviations: BMS, bare metal stent; DAPT, dual antiplatelet therapy; DES, drug-eluting stent; FU, follow-up; OAC, oral anticoagulation; PV, pulmonary vein; Pts, patients; PTA, percutaneous transluminal angioplasty.

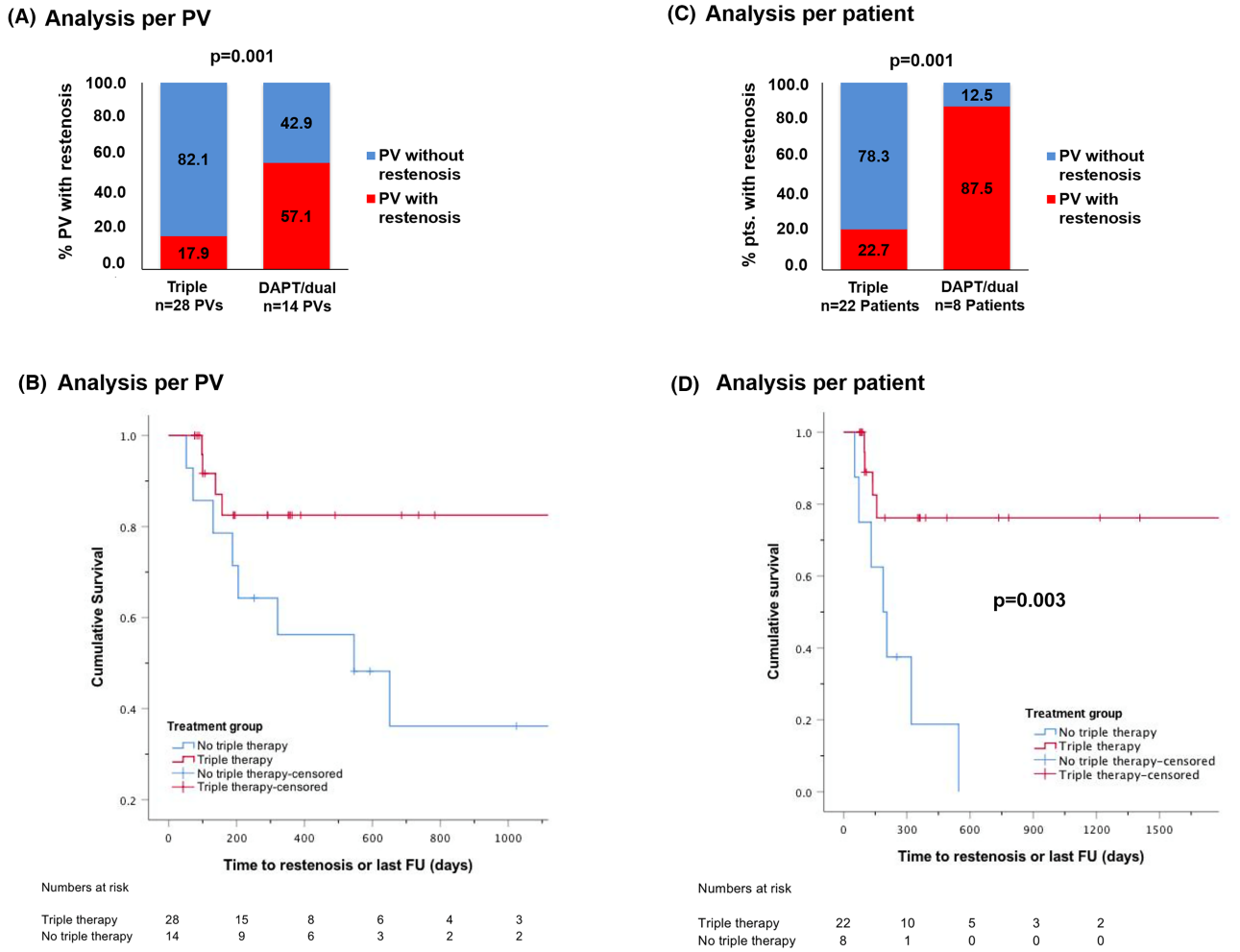

FIGURE 2 Incidence of restenosis in relation to postprocedural medication. (A, B) show analysis per treated PV; restenosis occurred in 8/14 PVs (57.1%) of patients with DAPT/dual therapy and 5/28 PVs of patients (17.9%) with triple therapy ($p = .001$). The estimated freedom from PV restenosis with and without triple therapy after 500 days was 59.3 ± 12.9% (DAPT/dual therapy) and 81.7 ± 8.3% (triple therapy) (B). (C, D) show analysis on a per-patient basis. Restenosis occurred in 7/8 patients (87.5%) with DAPT/dual therapy and 5/22 of patients (22.7%) with triple therapy ($p = .001$). Estimated freedom from PV restenosis with and without triple therapy after 500 days was 18.8 ± 15.8% (DAPT/dual therapy) and 76.2 ± 10.5% (triple therapy) (D) ($p = .003$). The analysis is based on the Chi-square test (A, C) and Kaplan–Meier method (B, D). DAPT, dual antiplatelet therapy; FU, follow-up; PV, pulmonary vein.

absence of specific angioplasty balloons and stents which are suitable for PV anatomy. We report acceptable results with restenosis occurring in about 30% of patients compared with other patient cohorts.

There are no data from prospective studies comparing medical therapy after interventional PVS treatment yet. We summarize available data on postinterventional medical treatment in published patient cohorts with PVS treatment in Table 4. A total of 7 studies reported on medical therapy after PVS angioplasty.[2,3,7–9,12,16,17]

Success rates after PV angioplasty range from only 27% to 100%.[2,3,7–9,12,16,17] Neumann et al. reported on a patient cohort that was treated with postinterventional DAPT.[7,9] Restenosis was 73% in patients undergoing PTA alone and improved significantly after the performance of PV stenting.[7,9] Packer and Fender reported on a large cohort of patients treated for iatrogenic PVS in which a combination of Warfarin and Clopidogrel was recommended after PV angioplasty.[2,3] Treatment consisted of sole PTA in 96 cases or stenting in 85 cases and restenosis occurred in 37% of patients.[2,3] Prieto et al. report on patients being on Warfarin therapy without additional antiplatelet therapy; frequency of restenosis in this small patient cohort was 12.5%.[12] Schoene et al. describe a patient cohort which was treated with sole PV angioplasty and triple therapy for 4 weeks.[8] They found restenosis in about 53% of the patients.[8] Another study using triple antithrombotic therapy found restenosis in only 11% of patients after concomitant angioplasty and stenting.[16]

The impact of postprocedural medication in this context is poorly understood. The main factor with regard to restenosis-free survival seems to be the type of treatment strategy chosen. A study by Widmer found that stenting instead of sole PTA was an independent predictor of restenosis-free survival.[17] Additionally, there might be a different outcome depending on the type of stent (DES or BMS).[5] In our patient cohort, the majority of patients were treated with PV stenting. The distribution of DES and BMS implantation was comparable

TABLE 3 Univariate regression analysis of predictors of restenosis

Factor	Level	No restenosis	Restenosis	*p* value
n pts		18	12	
PV total occlusion		7 (39%)	6 (50%)	.71
Stent type	PTA only	0 (0%)	2 (17%)	.12
	DES[a]	5 (28%)	5 (42%)	
	BMS	13 (72%)	5 (42%)	
Re-ablation after PVS formation		9 (50%)	6 (50%)	1.00
Arrhythmia recurrence		10 (56%)	7 (58%)	1.00
Medication after angioplasty	DAPT	0 (0%)	3 (25%)	**.019**
	Dual therapy	1 (6%)	4 (33%)	
	Triple therapy	17 (94%)	5 (42%)	
Age (years), mean (SD)		53.3 (10.7)	45.5 (11.3)	.065
Time causal ablation to angioplasty (days), mean (SD)		721.9 (1132.5)	261.0 (345.7)	.18
n ablation procedures before angioplasty, mean (SD)		1.7 (1.1)	1.9 (1.1)	.63
LA diameter (mm), mean (SD)		41.1 (4.0)	41.3 (2.0)	.82
Minimal stent diameter (mm), mean (SD)		7.9 (2.6)	6.5 (2.3)	.18
Mean stent diameter (mm), mean (SD)		8.2 (2.4)	6.7 (2.1)	.097
Multiple stents		7 (39%)	2 (17%)	.25
Maximum balloon diameter (mm), mean (SD)		7.0 (2.6)	5.4 (2.0)	.084
Procedure duration (min), mean (SD)		187.7 (80.0)	171.2 (80.2)	.64
Flouroscopy time (min), mean (SD)		46.8 (23.1)	35.3 (17.5)	.21

Note: Univariate regression analysis was performed on 18 patients without restenosis and 12 patients with restenosis.

Abbreviations: BMS, bare metal stent; DAPT, dual antiplatelet therapy; DES, drug-eluting stent; LA, left atrium; PTA, percutaneous transluminal angioplasty; Pts, patients; PV, pulmonary vein.

[a]Two patients with DES + BMS implantation.

Significances < .05 are depicted in bold values.

among different groups of postprocedural antithrombotic treatment. Univariate risk factor analysis of PV restenosis did not show any association between the type of interventional treatment and the occurrence of restenosis. In our cohort, we found improved restenosis-free survival when triple therapy was used. Additionally, we found a longer time span from angioplasty to the development of restenosis in patients treated with triple therapy compared with patients on dual therapy/DAPT. Although assessed in a relatively small patient cohort, our results point to a beneficial role of triple antithrombotic therapy after PV angioplasty. In our cohort, 4 PVs in 3 patients were treated with PTA alone, and two of these developed restenosis. Due to limited patient numbers, we were not able to differentiate between patients with sole PTA and different stent types in our analysis. Nevertheless, the incidence of restenosis was not higher in patients with PTA alone and patients undergoing stent implantation with dual therapy. Our results have to be confirmed in larger patient cohorts.

Triple therapy was associated with the occurrence of significantly more common bleeding events in patients undergoing percutaneous coronary intervention (PCI) compared with dual therapy.[18–21] In our study cohort, we did not observe such an excess of bleeding complications in either treatment cohort. Differences between patients with PCI and PVS treatment may be a result of different patient characteristics since investigated PVS patients are generally of younger age (mean age < 50 years in this study and about 70 years in all randomized multicenter PCI trials on triple versus dual antithrombotic therapy[18–21]) and with less pronounced comorbidity compared with typical patients undergoing PCI. Triple therapy over a longer period of time is rarely been used in recent clinical practice of PCI patients. Nevertheless, our findings may indicate use for triple therapy in PVS patients since these patients may be less prone to bleeding events.

4.3 | Recommendations for medication after angioplasty

There are no data available from prospective studies comparing different medical treatment strategies after interventional PVS treatment. Medical therapy aims at antithrombotic therapy after angioplasty or stenting as well as prevention of restenosis, which most likely occurs due to intimal hyperplasia and fibrosis. Previous studies adopted medical approaches used for coronary angioplasty and used for venous

TABLE 4 Overview on available studies on antithrombotic medication after PV angioplasty

Study	N pts	N PVs	Intervention	% PVs with restenosis	FU duration	Postprocedural antithrombotic therapy	Duration of antithrombotic therapy
Neumann 2005[7]	12	15	PTA (15 PVs), BMS stenting (11 PVs with restenosis)	73.0 (PTA), 0.0 (stenting)	12 months	ASS + Clopidogrel	Unknown
Neumann 2009[9]	10	13	PTA, BMS stenting	23.0	47.7 months	ASS + Clopidogrel	Unknown
Prieto et al. 2010[12]	7	8	PTA (7 PVs), stenting (1 PV)	12.5	11.3 months	Warfarin	12 months (large stents), indefinitely (small stents/PVs)
Packer et al. 2005[3]	23	34	PTA (20 PVs), DES or BMS stenting (14 PVs)	41.1	18 months	Warfarin + Clopidogrel	Indefinitely
Fender et al. 2016[2]	113	182	PTA (96 PVs), DES stenting (4 PVs), BMS stenting (82 PVs)	37.0	3 years	Warfarin + Clopidogrel	Indefinitely
Iversen et al. 2017[16]	9	11	BMS stenting	11.0	64 months	ASS, Clopidogrel or OAC	3 months
Schoene et al. 2018[8]	39	61	PTA (68 procedures), BMS stenting (16 procedures)	53.0	6 months	Triple and dual therapy	Triple 4 weeks, then dual 5 months
Fink et al. 2019[17]	30	42	PTA (4 PVs), DES stenting (12 PVs), BMS stenting (24 PVs)	31.7	29.1 months	DAPT, dual therapy or triple therapy	DAPT (6–12 months), dual therapy or triple therapy (3–12 months)

Abbreviations: BMS, bare metal stent; DES, drug-eluting stent; dual, Clopidogrel, oral anticoagulation; FU, follow-up; OAC, oral anticoagulation; PTA, percutaneous transluminal angioplasty; Pts, patients; PV, pulmonary vein; Triple, ASS, Clopidogrel, oral anticoagulation.

stenting. While the cornerstone of antithrombotic therapy for the treatment of coronary artery lesions is antiplatelet therapy, its counterpart in venous disease and PVS is not clear yet. The venous location of vessel lesions suggests a potential role for anticoagulative therapy in thrombosis prevention. Additional deployment of stents may result in the need for platelet inhibition to prevent stent thrombosis. Two retrospective studies on larger patient cohorts found no association of antithrombotic regimes with the frequency of restenosis after superior vena cava stenting.[22,23] A single study associated the presence of antiplatelet therapy with improved restenosis-free survival after iliocaval vein stenting.[24] A recent expert consensus on antithrombotic therapy following venous stenting led to the recommendation of anticoagulative therapy after venous stenting but did not reach a consensus on a recommendation regarding the use of antiplatelet therapy.[25] Consequently, the potential roles of both antiplatelet therapy and anticoagulation in PVS treatment have to be evaluated in further studies. The main concern of triple therapy is the occurrence of bleeding events, which was frequently observed in studies investigating triple therapy after coronary angioplasty.[18–21] We did not observe major bleeding events in our study cohort, which is mainly related to the characteristics of investigated patients with relatively young age and low comorbidity as reflected by low CHA_2DS_2-VASc and HASBLED scores. Our patient group is comparable to most published patient cohorts, which are typically younger and without severe comorbidity. Based on our findings, we recommend the use of triple therapy in all patients after PV angioplasty which do not have a contraindication to medical therapy which is associated with risks of bleeding. Recommendation of triple therapy for at least 3 months seems to be reasonable after individual risk assessment with regard to the high risk of restenosis and the need to undergo repeat angioplasty in patients suffering from PVS. Further studies are needed to better define the role of medical therapy and to give better recommendations based on empiric findings in patients with PVS treatment.

4.4 | Limitations

This study was a retrospective study with a limited number of patients and its typical limitations. Conclusions on the mechanisms of restenosis in patients with differing antithrombotic therapy cannot be drawn from this analysis. Nevertheless, to our knowledge, this is the first systematic descriptive analysis of the influence of postprocedural medication on restenosis development after PVS angioplasty/stenting. There were 4 PVs treated with sole PTA in 3 patients which might have a potential influence on the study results. Nevertheless, the univariate analysis did not detect differences between types of angioplasty in patient outcomes.

5 | CONCLUSION

Triple antithrombotic therapy after PV angioplasty is associated with less frequent restenosis compared with dual antiplatelet therapy or the combination of anticoagulation and single antiplatelet therapy without

the occurrence of excessive bleeding events. A potential role for triple therapy in PVS patients needs further investigation in larger studies.

FUNDING INFORMATION

No sources of funding.

CONFLICT OF INTEREST

Dr Kuck reports having received consulting fees/honoraria from Biosense Webster, Medtronic, Boston Scientific, and Abbott. Dr Metzner reports having received speaker's honoraria from Medtronic. Dr Tilz reports having received research grants from St. Jude Medical; speaker's honoraria from Biosense Webster, Biotronik, Pfizer, Topera, Bristol-Myers Squibb, Bayer, and Sanofi Aventis. The other authors report no relevant conflicts of interest.

ETHICAL STATEMENT

The study was approved by the local ethics committee (Hamburger Ärztekammer, file number WF/15–16). All patients signed written consent for the procedure. There is no further trial registration.

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