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Cover Page Footnote
Nil

ORIGINAL ARTICLE

Prevalence and Predictors of Venous Stenosis Following First Transvenous Cardiac Implantable Electronic Device Implantation

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Abstract

Objectives: **Very few studies have been done on Venous stenosis following the first transvenous cardiac device implantation. We aimed to assess the prevalence and predictors of Venous stenosis/Occlusion following the first transvenous cardiac device implantation with venous angiography at one year of follow-up.**

Methods: **This study was a single-center prospective, observational study. Demographic, clinical, procedural, and device data was collected. All patients underwent a preimplant contrast and repeated venography at twelve months to look for upper limb venous anatomy, obstruction, or collaterals.**

Results: **A total of 146 patients were included in the final analysis. 60 (41 %) patients developed some degree of venous stenosis. Most patients had mild to moderate stenosis, and almost all were asymptomatic. Among patient-related factors increasing age (64.66 ± 10.07 vs 60.91 ± 11.94 years p = 0.04), presence of hypertension (50.5 % vs19.6 % p = 0.0004), diabetes (73 % vs 29.6 % p = 0.000) and dyslipidemia (66.7 % vs 36.3 p = 0.009) were significantly associated with Venous stenosis/occlusion. Among procedure-related factors, larger total lead diameter (3.88 ± 1.09 vs. 3.50 ± 1.03 mm p = 0.03) and implantation of biventricular devices (p = 0.0037) seem to be significantly associated with venous obstruction. In logistic regression analysis, hypertension (p = 0.018), total lead diameter (p = 0.024), and use of CRT-P/CRTD/ICD (p = 0.03) remained significant predictors of severe venous stenosis.**

Conclusions: **Our study demonstrates venous obstruction in 40 % of cardiac implantable electronic device patients at one-year follow-up. Most patients have mild to moderate stenosis, and almost all are asymptomatic. Increasing age, hypertension, diabetes, dyslipidemia, larger total lead diameter, and implantation of biventricular devices are significantly associated with venous obstruction.**

Keywords: Venous stenosis, Cardiac implantable electronic devices, Prevalence, Lead diameter, Biventricular devices

1. Introduction

The number of cardiac implantable electronic devices (CIEDs) implanted worldwide continues to increase due to the aging population, expanding indications, and increasing access to health care. Each year more than one million CIEDs are implanted worldwide [1]. The implantation of transvenous leads represents a significant source of CIED complications, including dislocation, damage to the tricuspid valve, venous stenosis or occlusion (VSO), superior vena cava syndrome, and CIED infections. VSO is usually asymptomatic and often goes unnoticed due to the formation of collaterals providing venous drainage. However, it is of significant clinical importance if the patient needs to undergo implantation of additional leads, either in case of lead failure or upgradation to cardiac

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resynchronization therapy (CRT). Several mechanisms of VSO formation have been suggested, including thromboembolic phenomena and lead endothelization leading to narrowing or occlusion of veins [2–6]. Numerous studies have been conducted to determine the prevalence and predictors of VSO. However, most investigated the venous system during generator replacement, device upgradation, or transvenous lead extraction [7–9]. Few studies have been done on VSO following the first transvenous cardiac device implantation [10]. However, venous stenosis was diagnosed by doppler ultrasound and not contrast venography, which is the gold standard. Only one study [11] has done baseline venography. However, their follow-up period was only six months, with a small sample size. Therefore, we aimed to assess the prevalence and predictors of VSO following the first transvenous cardiac device implantation with venous angiography at one year of follow-up.

Abbreviations

CIEDs	Cardiac implantable electronic devices
VSO	Venous Stenosis/Occlusion
CRT	Cardiac resynchronization therapy
T2DM	Type 2 diabetes mellitus
EF	Ejection fraction
CRT-D	Cardiac resynchronization therapy Defibrillator
ICD	Implantable cardioverter defibrillator
SCPM	Single chamber pacemaker
DCPM	Double chamber pacemaker

2. Material and methods

2.1. Study sample

This study was a single-center prospective, observational study carried out at our tertiary care hospital for two years from 2019 to 2021 in the cardiology department. Patients undergoing CIED implantation for the first time were included. Demographic, clinical, procedural, and device data was collected. All patients were followed for twelve months. Variables examined for association with venous stenosis were age, sex, hypertension, type 2 diabetes mellitus (T2DM), dyslipidemia (defined as total cholesterol $\geq$200 mg/dl, or triglyceride $\geq$150 mg/dl, or LDL $\geq$130 mg/dl or HDL $\leq$40 mg/dl in men or $\leq$ 50 mg/dl in women) [12], smoking, number of leads, axillary versus subclavian vein, right versus left-sided implant, type of device, lead diameter, silicone versus polyurethane insulation, number of leads, and use of anticoagulant or antiplatelet therapy.

2.2. Inclusion criteria

Patients undergoing CIED implantation at our hospital and consenting for participation in the study.

2.3. Exclusion criteria

(1) Individuals with creatinine >1.5 mg/dl.
(2) Candidates that had known allergy to iodinated contrast media.
(3) Patients who had venous stenosis at baseline contrast venography.
(4) Those who declined to participate in the study.

The study was approved by the Institute Ethics Committee and informed consent was taken from all the patients. All the procedures followed were in accordance with the ethical standards of the Helsinki Declaration (1964, amended most recently in 2008) of the World Medical Association.

2.3.1. Venography

All patients underwent a pre-implant contrast venography using 10–20 ml of low osmolarity non-ionic iodinated radiographic contrast medium, which was injected through an intravenous cannula inserted into the medial antecubital vein ipsilateral to device side insertion. The contrast flow in axillary, subclavian, brachiocephalic, and superior vena cava was visualized. All the images were taken in anteroposterior view and recorded in cine angiography (Fig. 1). Patients were followed after twelve months with a similar procedure to look for upper limb venous anatomy, obstruction, or collaterals. Two experienced cardiologists reviewed the venograms. In freeze–frame images with complete opacification of the vessel lumen, the narrowest and widest luminal diameter for each venous segment was identified by visual inspection, and venous stenosis was categorized as absent-0%, mild-<50 %, moderate-50 %–74 %, severe 75 %–99 %, and occluded if 100 % stenosis.

2.4. Statistical analysis

Continuous variables are expressed as mean ± SD. Categorical variables are presented as the analyzed group's exact number and percentage. The student t-test tested differences between the two groups for continuous variables. The comparisons of categorical variables were analyzed using the π2 independence test. Two-way tables were assessed with the π2 test with Yates correction.

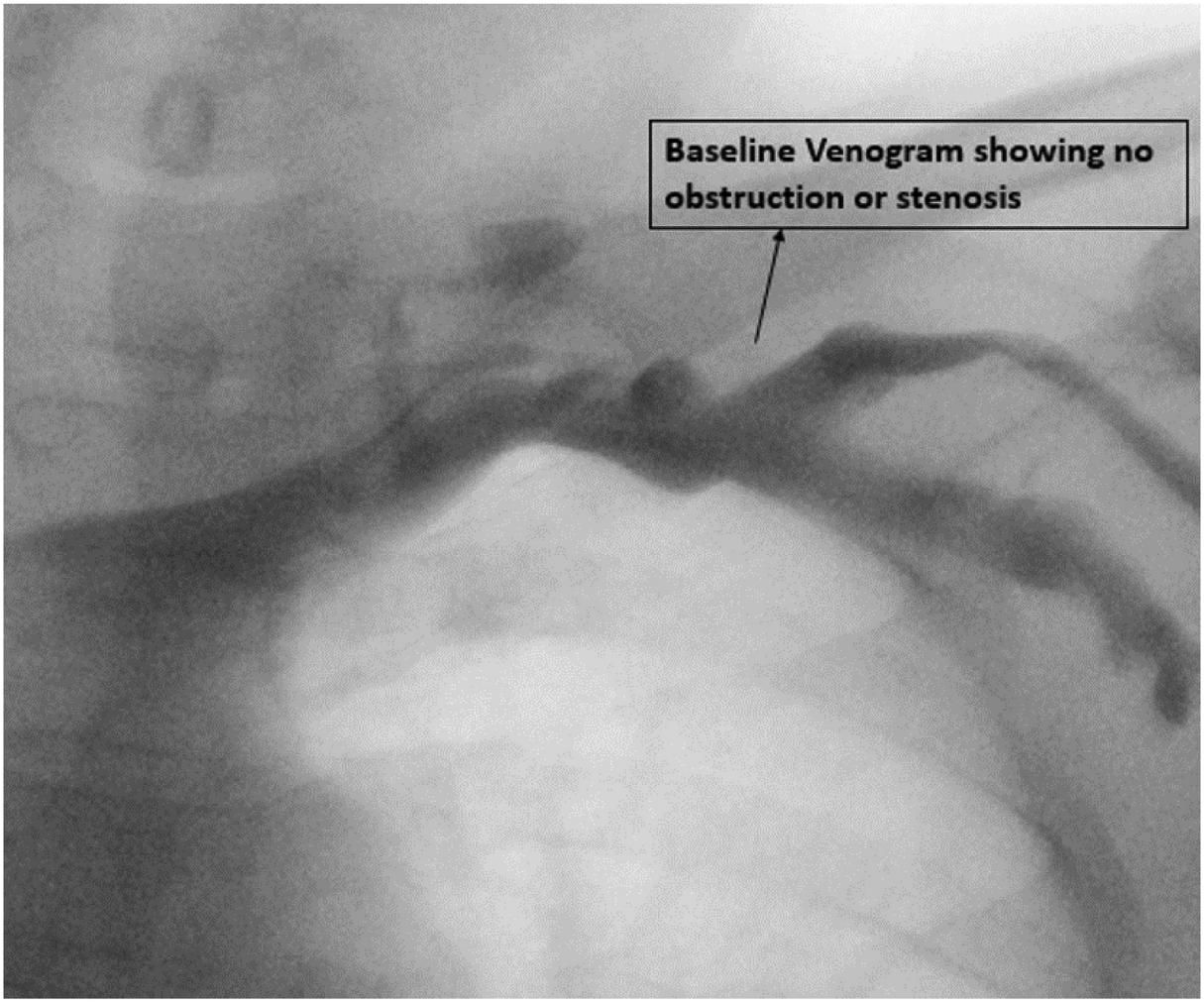

Fig. 1. Baseline venography in Anteroposterior view showing no obstruction or stenosis in axillary or subclavian vein.

Multivariate logistic regression analysis was performed to determine predictors of VSO by entering all predictors with p values < 0.1 in univariate analysis into a forward stepwise mode. Spearman's rank correlation coefficient was used to discover the strength of a link between two sets of data to exclude factors significantly correlated. A p-value <0.05 was defined as statistically significant.

3. Results

3.1. Baseline characteristics

A total of 164 consecutive patients were screened. Eight patients were excluded from the study because of history of renal dysfunction (serum creatinine >2 mg/dl, n = 6) and contrast medium hypersensitivity (n = 2). Ten patients were lost to follow-up. A total of 146 patients were included in the final analysis. The cohort's mean age was 62.78 ± 11.01 years, of which 100 (68.49 %) were males. Co-morbidities included hypertension in 99 (67.8 %), diabetes mellitus in 37 (25.3 %), dyslipidemia in 21 (14.38 %), smoking in 58 (39.72 %), ischemic heart disease in 3 (2.05 %), atrial fibrillation in 21 (14.38 %) and malignancy in 2 (1.36 %). 96 (65.75 %) patients had ejection fraction (EF) ≥ 50 %, 30 (20.5 %) patients had EF of 40–49 %, and 20 (13.69 %) patients had EF of less than 40 %. 19 (13.01 %) patients were on anticoagulation, 7 (4.79 %) were on antiplatelets, and 23 (15.75 %) patients were taking statins (Table 1).

3.2. Procedural characteristics

31 (21.2 %) patients underwent single chamber pacemaker, 95 (65.01 %) underwent dual chamber pacemaker, 11 (7.5 %) underwent Cardiac resynchronization therapy (CRT-P), 6 (4.1 %) underwent

Table 1. Characteristics of the study sample and comparison between patients with venous stenosis and those without venous stenosis.

Characteristic		All (146) Number (%)	Venous stenosis (60) Number (%)	No venous stenosis (86) Number (%)	P value
Male		100 (68.49 %)	44 (30.13 %)	56 (38.35 %)	P = 0.17
Age (years)		62.78 ± 11.01	64.66 ± 10.07	60.91 ± 11.94	P = 0.04
BMI, kg/m^2		27.4 ± 5.4	27.9 ± 5.6	27.1 ± 5.7	P = 0.8
Hypertension		99 (67.8 %)	50 (34.24 %)	49 (33.56 %)	P = 0.0004
Diabetes		37 (25.3 %)	27 (18.49 %)	10 (6.84 %)	P = 0.000
Dyslipidemia		21 (14.38 %)	14 (9.58 %)	7 (4.79 %)	P = 0.009
Smoking		58 (39.72 %)	27 (18.49 %)	31 (21.23 %)	P = 0.24
Antiplatelet		7 (4.79 %)	5 (3.42 %)	2 (1.36 %)	P = 0.09
Oral anticoagulant		19 (13.01 %)	7 (4.79 %)	12 (8.21 %)	P = 0.174
LVEF (%)	>50 %	96 (65.75 %)	38 (26.02 %)	58 (39.72 %)	P = 0.50
	40–50 %	30 (20.54 %)	11 (7.53 %)	19 (13.01 %)	
	<40 %	20 (13.69 %)	10 (6.84 %)	9 (6.16 %)	
Primary procedure site	Left	137 (93.83 %)	55 (37.67 %)	81 (55.47 %)	P = 0.81
	Right	9 (6.16 %)	4 (2.73 %)	5 (3.42 %)	
Primary procedure vein	Axillary	122 (83.56 %)	50 (34.24 %)	72 (49.31 %)	P = 0.82
	Subclavian	24 (16.43 %)	9 (6.16 %)	15 (10.27 %)	
Number of leads	One	33 (22.6 %)	11 (7.53 %)	22 (15.06 %)	P = 0.5
	Two	97 (66.43 %)	40 (27.39 %)	57 (39.04 %)	
	Three	16 (10.95 %)	8 (5.47 %)	8 (5.47 %)	
Total lead Diameter in mm		3.62 ± 1.06	3.88 ± 1.09	3.50 ± 1.03	P = 0.03
Diameter of leads	≥4 mm	66 (45.20 %)	46 (31.50 %)	20 (13.69 %)	P = 0.0001
	≤3.9 mm	80 (54.79 %)	13 (8.90 %)	67 (45.89 %)	
Primary procedure device	SCMP	31 (21.23 %)	8 (5.47 %)	23 (15.75 %)	P = 0.0037
	DCMP	95 (65.06 %)	37 (25.34 %)	58 (39.72 %)	
	CRT-P/CRTD/ICD	20 (13.69 %)	14 (9.58 %)	6 (4.1 %)	
Insulation material	Polyurethane	134 (91.78 %)	54 (36.98 %)	80 (54.79 %)	P = 1.0
	Silicon	12 (8.21 %)	5 (3.42 %)	7 (4.79 %)	

Note: Percentages mentioned are of total study population. BMI (Body Mass Index), LVEF (Left ventricular Ejection fraction), SCPM (Single chamber pacemaker), DCMP (Double chamber pacemaker), CRT-P (Cardiac Resynchronization therapy), CRT -D (Cardiac Resynchronization therapy with defibrillator), ICD (Implantable cardioverter defibrillator).

CRT-D and 3 (2.05 %) underwent implantable cardioverter defibrillator (ICD) implantation. Among 9 patients of CRT D and ICD, four patients had dual coil ICD. 137 (93.8 %) patients underwent left sided CIED implantation. 9 (6.16 %) underwent right sided implantation. The reasons for right sided implant included persistent left SVC in two patients, left sided breast Carcinoma in two patients, left sided venous obstruction in one patient and operator preference in four patients.

122 (83.5 %) had axillary puncture while as 24 (16.4 %) patients had subclavian puncture for CIED implantation (Table 1).

3.3. Venography analysis

In our study, 60 (41.09 %) patients developed some degree of venous stenosis. 16 (26.66 %) had mild stenosis, 12 (20 %) had moderate stenosis, 22 (36.67 %) had severe stenosis, and 10 (16.67 %) had occluded veins. The most common site of obstruction was the subclavian vein which was obstructed in 25 (41.66 %) patients. Other sites of obstruction were the axillary vein in 10 (16.66 %), the brachiocephalic vein in 13 (21.66 %), and simultaneous in 12 (20 %) patients. Twenty patients (33.33 %) had collateral circulation (Figs. 1 and 2). Only one patient developed mild pain and swelling of upper limb. He had complete venous occlusion but well-developed collaterals. His symptoms gradually improved over time and he did not require any intervention at one year of follow up (see Fig. 3).

3.4. Factors affecting venous stenosis

3.4.1. Patient characteristics

The mean age of those who developed venous obstruction was significantly higher (64.66 ± 10.07 years) compared to those who did not (60.91 ± 11.94 years). (p = 0.04). The prevalence of VSO was 73 % (27 out of 37) in diabetes vs 29.35 % (32 out of 109) in non-diabetics (p = 0.001), 50.5 % (50 out of 99) in hypertensives vs 19.14 % (9 out of 47) in non-hypertensives (p = 0.0004) and 66.67 % (14 out of 21) in those with dyslipidemia vs 36 % (45 out of 125) (p = 0.009) in those without dyslipidemia. There was no significant difference in gender, ejection fraction,

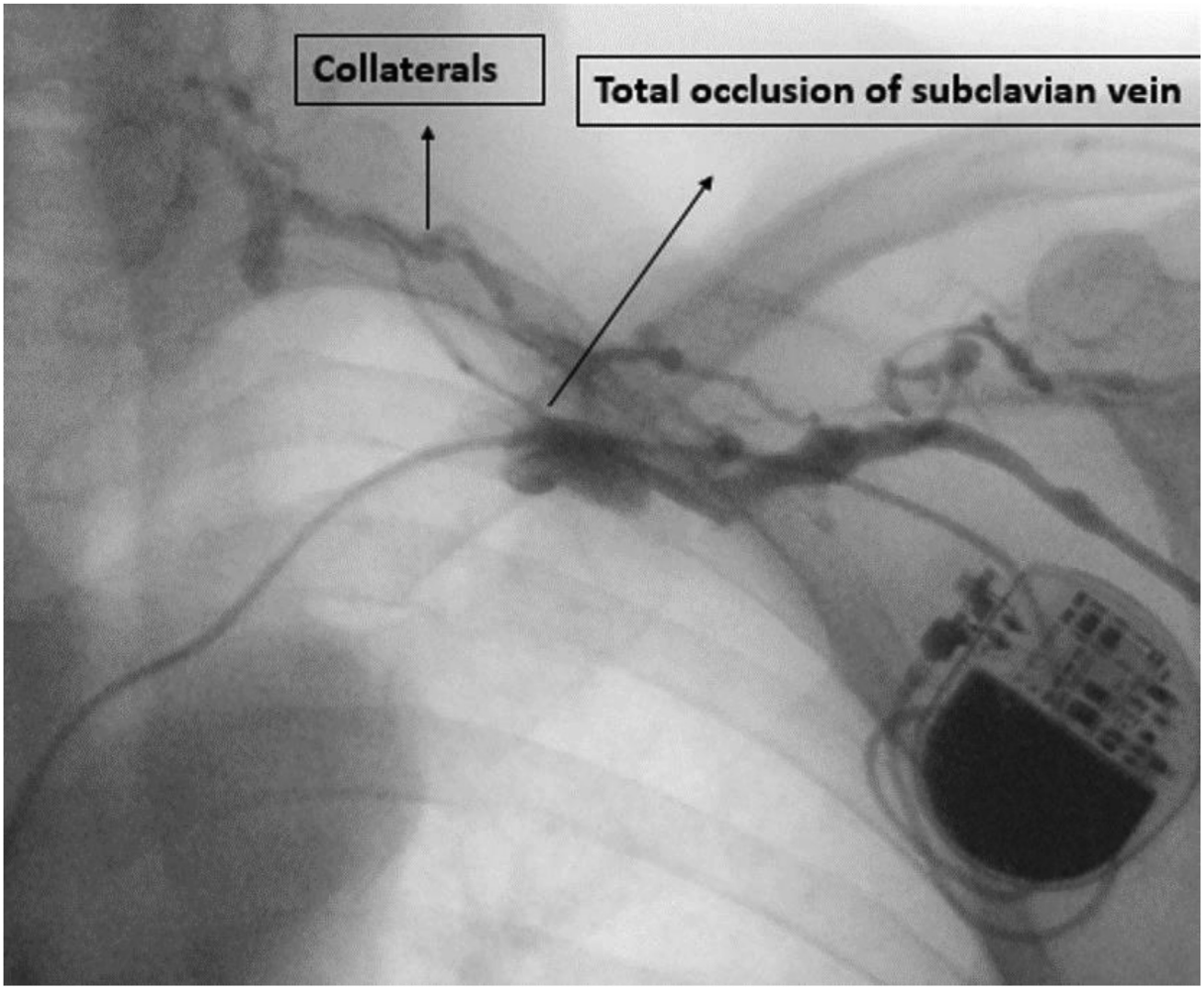

Fig. 2. Venography at 12 months showing complete occlusion of origin of subclavian vein with extensive collaterals.

primary procedure site, primary procedure vein, antiplatelet use, and anticoagulant use for venous stenosis (Table 1).

3.4.2. Procedural factors

Venous stenosis was significantly higher in patients in whom total lead diameter was ≥4 mm. 66 patients had lead diameter of ≥ 4 mm, of whom 46 (69.69 %) developed venous stenosis. 80 patients had lead diameter ≤3.9 mm, of whom 13 (16.25 %) developed venous stenosis. ($p = 0.0001$). The total lead diameter in those with venous stenosis was significantly higher than those without (3.88 ± 1.09 vs 3.50 ± 1.03 mm $p = 0.03$). Venous stenosis was numerically higher with the increasing number of leads implanted. Single lead was implanted in 33 patients, of which 11 (33.33 %) had venous obstruction. Double leads were implanted in 97 patients, of whom 40 (41.23 %) patients had venous obstruction. Three leads were implanted in 16 patients of whom 8 (50 %) developed venous obstruction. However, the difference was not statistically significant ($p = 0.5$). VSO was significantly higher in those with CRT-P/CRTD/ICD than those with single or double-chamber pacemakers ($P = 0.0037$). The lead diameter was more in those with CRT-P/CRTD/ICD as compared to single and dual chamber pacemaker patients. (4.6 ± 0.7 vs 3.3 ± 0.8 mm $p = 0.01$). Among four patients with dual coil ICD lead (with additional SVC coil), three developed VSO. There was no relation of venous stenosis with lead insulation material (Table 1).

3.4.3. Prevalence of severe venous stenosis (>75 %) and factors affecting it

Out of 146 patients, 22 (15.06 %) had venous stenosis over 75 %. Severe venous stenosis was significantly higher in diabetics, hypertensives, and those with dyslipidemia (Table 2). The total lead diameter was also significantly higher in those with severe stenosis. (4.08 ± 1.05 vs 3.53 ± 1.05 mm respectively $p = 0.027$). Severe VSO was significantly higher in those with CRT-P/CRTD/ICD as compared to those

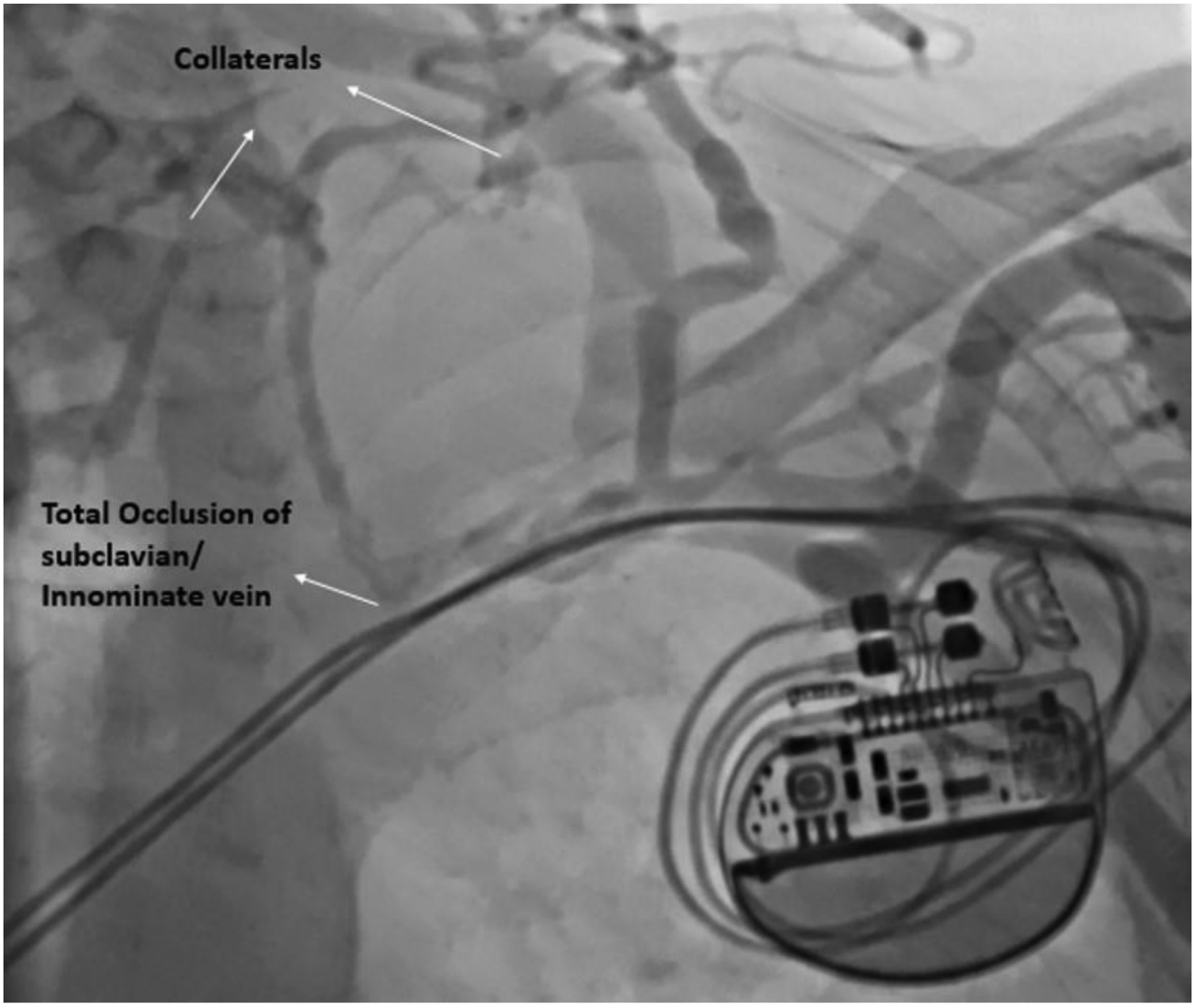

Fig. 3. Venography at 12 months showing complete occlusion of subclavian and innominate vein with collaterals in a patient with double chamber pacemaker.

with single or double chamber pacemakers (P = 0.0001) (Table 2).

3.4.4. Logistic regression analysis

In logistic regression analysis, hypertension (p = 0.018), total lead diameter (p = 0.024), and use of CRT-P/CRTD/ICD (p = 0.03) remained significant predictors of severe venous stenosis.

4. Discussion

In our study, we observed venous obstruction in 40.2 % of patients with CIED, in line with reports in the literature [12–15]. The main findings of our study were: (1) Most venous obstructions are clinically silent; (2) Among clinical factors, increasing age, diabetes, hypertension, and dyslipidemia are essential factors associated with venous obstruction; (3) Among procedure-related factors, increasing lead diameter and implantation of CRT-P/CRT D are associated with venous obstruction.

Most of the studies done prior were performed only after pacing lead implantation. Therefore, there is a possibility of overestimating the incidence of venous obstruction induced by pacing leads. In our study, we did baseline venography in all patients before lead implantation and excluded patients with any venous obstruction from the study. We found venous obstruction in 40 % of patients during the follow-up period of one year. The incidence of VSO in different studies varies from 25 % to 40 % [13–19]. The high incidence (>60 %) [3,20] in some studies may be due to different definitions used to define VSO and different methods of venous visualization. Besides, the absence of a baseline venogram may overestimate the incidence of VSO. We found that subclavian and brachiocephalic veins are the most commonly affected veins, as found in other studies

Table 2. Comparison between patients with severe venous stenosis (more than 75 %) and those without severe venous stenosis.

Characteristic		All (146) Number (%)	More than 75 % Venous stenosis (22) Number (%)	Less than 75 % venous stenosis (124) Number (%)	P value
Male		100 (68.49 %)	18 (12.32 %)	82 (56.16 %)	P = 0.138
Age (years)		62.78 ± 11.01	64.27 ± 10.19	62.10 ± 11.5	P = 0.4
BMI, kg/m^2		27.4 ± 5.4	28.5 ± 5.5	27.7 ± 5.4	P = 0.8
Hypertension		99 (67.8 %)	19 (13.01 %)	80 (54.79 %)	P = 0.048
Diabetes		37 (25.3 %)	13 (8.9 %)	24 (16.43 %)	P = 0.000
Dyslipidemia		21 (14.38 %)	7 (4.79 %)	14 (9.58 %)	P = 0.0012
Smoking		58 (39.72 %)	11 (7.53 %)	47 (32.19 %)	P = 0.299
Antiplatelet		7 (4.79 %)	5 (3.42 %)	2 (1.36 %)	P = 0.09
Oral anticoagulant		19 (13.01 %)	2 (1.36 %)	17 (11.64 %)	P = 0.174
LVEF (%)	>50 %	96 (65.75 %)	38 (26.02 %)	58 (39.72 %)	P = 0.50
	40–50 %	30 (20.54 %)	11 (7.53 %)	19 (13.01 %)	
	<40 %	20 (13.69 %)	10 (6.84 %)	9 (6.16 %)	
Primary procedure site	Left	137 (93.83 %)	20 (13.69 %)	117 (80.13 %)	P = 0.54
	Right	9 (6.16 %)	2 (1.36 %)	7 (4.79 %)	
Primary procedure vein	Axillary	122 (83.56 %)	20 (13.69 %)	102 (69.86 %)	P = 0.34
	Subclavian	24 (16.43 %)	2 (1.4 %)	22 (14.5 %)	
Number of leads	One	33 (22.6 %)	3 (2.05 %)	30 (20.54 %)	P = 0.39
	Two	97 (66.4 %)	16 (10.95 %)	81 (55.47 %)	
	Three	16 (10.95 %)	4 (2.73 %)	12 (8.21 %)	
Total lead Diameter in mm		3.62 ± 1.06	4.08 ± 1.05	3.53 ± 1.05	P = 0.027
Diameter of leads	≥4 mm	66 (45.20 %)	50 (34.24 %)	16 (10.95 %)	P = 0.0001
	≤3.9 mm	80 (54.79 %)	12 (8.21 %)	68 (46.57 %)	
Primary procedure device	SCMP	31 (21.23 %)	2 (1.36 %)	29 (19.86 %)	P = 0.0001
	DCMP	95 (65.01 %)	9 (6.16 %)	86 (58.90 %)	
	CRT-P/CRTD/ICD	20 (13.69 %)	11 (7.53 %)	9 (6.16 %)	

Note: Percentages mentioned are of total study population. BMI (Body Mass Index), LVEF (Left ventricular Ejection fraction), SCPM (Single chamber pacemaker), DCMP (Double chamber pacemaker), CRT-P (Cardiac Resynchronization therapy), CRT -D (Cardiac Resynchronization therapy with defibrillator), ICD (Implantable cardioverter defibrillator).

[21]. One study [11] showed that stenosis developed at the same point where the vessel was narrowest already before lead implantation.

We found that almost all patients with VSO were clinically asymptomatic. Only one patient developed mild symptoms which gradually improved over time and he did not require any intervention. Previous reports also show very low rates of symptomatic venous obstruction ranging from 0 to 2 % [22]. The lack of symptoms of VSO may be due to the slow progression of venous obstruction that permits the development of adequate collateral circulation. In our study, 20 patients (33.33 %) had collateral circulation.

Despite many decades of experience with CIED, no studies have identified apparent risk factors that lead to venous stenosis [13,19,20]. Although the number of males in the VSO group was higher numerically {100 (68.5 %)} than the non-VSO group, it was not statistically significant. This is consistent with the data from the other studies [10,14]. Although age has not been clearly defined as the risk factor for VSO, we found higher age to be significantly associated with the development of VSO. We found hypertension to be significantly higher in those who developed venous stenosis. Hypertension was our study population's most frequent comorbidity (70 %). In both bivariate and multivariate analyses, we found that hypertension was significantly associated with the development of severe venous stenosis. This is a novel finding in our study. Although hypertension is a well-established factor for the development of venous thrombosis, the link between hypertension and VSO after CIED implantation has received little attention to date. In our study, many patients had hypertension which was not present in other studies. The mechanisms underlying the association between hypertension and venous thrombosis are not yet fully clear but involve various interrelated pathways, including endothelial dysfunction, inflammation & coagulation imbalance, and altered hemodynamics that promote stasis and turbulence, which are known contributors to thrombus formation [23]. Our finding has important clinical implications as hypertension is an easily modifiable risk factor, and optimal blood pressure control can decrease VSO. However, we acknowledge that we do not have data on control of blood pressure in our study group and our results are hypothesis generating which require to be validated in further studies. We also noted diabetes to be significantly associated with VSO.

Although some studies [10] have shown a protective effect of diabetes on VSO development, our observation was the opposite. Several studies have demonstrated an increased risk of venous thrombosis with diabetes [24,25]. Diabetes induces chronic proinflammatory and procoagulant states besides causing endothelial dysfunction, all promoting venous thrombosis and stenosis. However, further dedicated studies are needed to assess the effect of hyperglycaemia on the development of VSO. We also noted dyslipidemia to be significantly associated with the development of VSO. The association of dyslipidemia with venous thrombosis needs to be better established. Total serum cholesterol has been observed to be a significant risk factor for pulmonary embolism [26]. There needs to be more data on the association of dyslipidemia with VSO after CIED. Circulating lipids appear to have both procoagulant and endothelium-altering properties. Animal studies have shown a higher rate of thrombi and greater platelet activation in hyperlipidaemic compared to normolipidemic rates [27]. Our finding has important clinical implications, as lowering cholesterol may help decrease VSO. However, further more extensive studies are needed to validate this association. Although antiplatelet and oral anticoagulant use, implant on the right side, have been weakly associated with reduced VSO [7,14,18], our study found no association.

Among the device factors, we found lead diameter to be significantly associated with VSO, a result that was consistent with other studies. Although the lead number was numerically higher in those with VSO, it did not reach statistical significance [28]. The residual lumen of the vein becomes less by increasing the number and diameter of leads, which may lead to the development of stenosis. Multiple leads cause mechanical stress due to rubbing each other, resulting in endothelial injury. They also cause flow turbulence, thus promoting thrombosis, inflammation, and fibrosis. Besides, the trauma induced by a puncture at the veinous entry site induces inflammation and may also contribute to the pathogenesis of venous stenosis [29]. However, some studies are still conflicting and found no association between the number of leads with VSO [7,9]. We also found that CRT-P/CRT-D and ICD device implantation was significantly associated with VSO. Multiple factors were thought to responsible for high prevalence of VSO in these patients. Implantation of CRT-P/CRT-D can be challenging. The manipulation of guiding catheters during the procedure can damage the vessel wall. Elevated central venous pressure and reduced blood flow in these patients due to left ventricular failure also increase the propensity for thrombosis and fibrosis. Furthermore, heart failure itself is a hypercoagulable state [30–32]. ICD leads could lead to more VSO because of the second shocking coil in the superior vena cava, which can lead to thrombosis and fibrosis. Out of four patients with dual coil ICD leads three developed VSO. The lead diameter was more in these patients as compared to single and dual chamber pacemaker patients. (4.6 ± 0.7 vs 3.3 ± 0.8 mm $p = 0.01$). Besides, multiple leads in biventricular devices lead to mechanical irritation and VSO development Although lead number was not statistically significant but numerically, higher lead number was associated with higher VSO. This could also have been contributory for development of VSO in these patients. The lead composition was non-contributory in venous obstruction in our study, as reported previously [33].

5. Limitations

It was a single-center study. We only analyzed the cine angiography in a single plane (anterior posterior) to detect venous obstruction. Our search for predisposing factors might have been hampered by our population's relatively small sample size. We did not have data about how many patients had controlled hypertension, diabetes or dyslipidemia. However, our findings are hypothesis generating and require further studies to prove that controlling hypertension, hyperglycemia or dyslipidemia could decrease VSO. Follow up period was only one year. However, patients enrolled are strictly being followed at the pacemaker clinic in our hospital. The follow up is however, only clinical.

6. Conclusions

Our study demonstrates that venous obstruction is common (40 % of patients) in CIED patients. Most patients have mild to moderate stenosis, and almost all are asymptomatic. Among patient related factors increasing age, hypertension, diabetes, and dyslipidemia were significantly associated with VSO. Among procedure-related factors, larger total lead diameter and implantation of biventricular devices are significantly associated with venous obstruction. Further multicentre studies with larger sample sizes are needed to confirm our findings and detect other predictors of venous stenosis.

Author contributions

Conception and design of Study: QY, AR, IH, HR, IS, AHM, SAM, AL. Literature review: QY, AR, IH, HR, IS, AHM, SAM, AL. Acquisition of data: QY,

AR, IH, HR, IS, AHM, SAM, AL. Analysis and interpretation of data: QY, AR, IH. Research investigation and analysis: QY, AR, IH. Data collection: QY. Drafting of manuscript: AR. Revising and editing the manuscript critically for important intellectual contents: AR. Data preparation and presentation: AR. Supervision of the research: AR. Research coordination and management: AR. Funding for the research: AR.

Disclosure of any funding to the study

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Conflicts of interest

None declared.

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