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Vascular Complications After Venoarterial Extracorporeal Membrane Oxygenation Support: A CT Study

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OBJECTIVES: Vascular complications after venoarterial extracorporeal membrane oxygenation (ECMO) remains poorly studied, although they may highly impact patient management after ECMO removal. Our aim was to assess their frequency, predictors, and management.

DESIGN: Retrospective, observational cohort study.

SETTING: Two ICUs from a tertiary referral academic hospital.

PATIENTS: Adult patients who were successfully weaned from venoarterial ECMO between January 2021 and January 2022.

INTERVENTIONS: None.

PRIMARY OUTCOME: Vascular complications frequency related to ECMO cannula.

MEASUREMENTS AND MAIN RESULTS: A total of 288 patients were implanted with venoarterial ECMO during the inclusion period. One hundred ninety-four patients were successfully weaned, and 109 underwent a CT examination to assess for vascular complications until 4 days after the weaning procedure. The median age of the cohort was 58 years (interquartile range [IQR], 46–64 yr), with a median duration of ECMO support of 7 days (IQR, 5–12 d). Vascular complications were observed in 88 patients (81%). The most frequent complication was thrombosis, either cannula-associated deep vein thrombosis (CaDVT) ($n = 63$, 58%) or arterial thrombosis ($n = 36$, 33%). Nonthrombotic arterial complications were observed in 48 patients (44%), with 35 (31%) presenting with bleeding. The most common site of CaDVT was the inferior vena cava, occurring in 33 (50%) of cases, with 20% of patients presenting with pulmonary embolism. There was no association between thrombotic complications and ECMO duration, anticoagulation level, or ECMO rotation flow. CT scans influenced management in 83% of patients. In-hospital mortality was 17% regardless of vascular complications.

CONCLUSIONS: Vascular complications related to venoarterial ECMO cannula are common after ECMO implantation. CT allows early detection of complications after weaning and impacts patient management. Patients should be routinely screened for vascular complications by CT after decannulation.

KEYWORDS: arterial thrombosis; computed tomography; deep vein thrombosis; extracorporeal membrane oxygenation; limb ischemia; pulmonary embolism; vascular complications

Venoarterial extracorporeal membrane oxygenation (ECMO) is used for the management of patients with refractory cardiogenic shock. However, venoarterial ECMO may expose patients to a number of complications including ischemic events (stroke, leg ischemia), deep vein thrombosis (DVT), cannulation-related hemorrhage, and infections (1–8). The

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KEY POINTS

Question: Vascular complications after venoarterial extracorporeal membrane oxygenation (ECMO) are poorly studied, their risk factors are not clearly defined, and their management remains unknown.

Findings: Vascular complications frequency after venoarterial ECMO is high in this cohort study (81%), no risk factors were identified. CT scan findings modified therapeutic management in the majority of cases.

Meaning: CT should be discussed after weaning of venoarterial ECMO to allow early tailored medical or surgical management.

majority of the studies focused on cannula-associated deep vein thrombosis (CaDVT) in patients assisted with venovenous ECMO (ECMO). The prevalence of CaDVT has been reported to vary from 18% to 85% in this setting. While the risk factors for DVT are not clearly identified, higher body mass index and longer duration of ECMO appear to increase the risk of CaDVT (2–13). Data regarding vascular complications in patients assisted by venoarterial ECMO are scarce. In a recent cohort study of patients assisted with venoarterial ECMO, the prevalence of venous and arterial complications was 27% and 37%, respectively (14). Currently, there are no recommendations for routine diagnostic imaging after decannulation. CaDVT results from a combination of factors related to the patient, risk factors related to critical care, and the ECMO circuit, which triggers the coagulation cascade through contact of the blood with the synthetic surfaces of the cannula. Patients on venoarterial ECMO must be treated with unfractionated heparin (UFH) to prevent ischemia and DVT. However, this may also expose them to an increased risk of bleeding. Therefore, although thrombotic complications could potentially be reduced by an anticoagulation strategy, the latter can only be considered by taking into account the risk-benefit ratio, which accounts for all vascular complications. Therefore, the primary objective of this study was to assess the prevalence of CaDVT and arterial thrombosis after venoarterial ECMO weaning and to describe patient management using systematic CT. The secondary objective was to assess nonthrombotic arterial complications after venoarterial ECMO removal and identify risk factors of thrombosis with a particular focus on hemostasis parameters and anticoagulation management.

MATERIALS AND METHODS

Ethics Declaration

This observational study was approved by an Institutional Review Board (IRB) (Ethics Committee of the French Society of Anesthesiology and Critical Care Medicine on July 28, 2018, registration number: IRB 00010254-2018-099). According to the French Law on biomedical research, the IRB waived written consent. All patients were informed orally and in writing of their inclusion in the study and of their rights regarding data collection. The registry was declared to the French National Commission for Information Technology and Civil Liberties (CNIL registration number A#R2784212n). This report complies with the Strengthening the Reporting of Observational Studies in Epidemiology statement for transparent reporting of an observational study (15). Procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975.

Patient Population

Patients from two cardiac ICUs were screened for inclusion between January 2021 and January 2022. Patients were included after a systematic CT examination performed in a cardiothoracic imaging unit in the 96 hours following weaning from ECMO to screen for vascular complications. Patients who died while on venoarterial ECMO support or who were not eligible for CT were excluded.

Data Availability Statement

Data were retrospectively collected on a standardized, blinded form. We collected demographic variables, venoarterial ECMO-related variables (ECMO indication patient characteristics, complications), biological parameters with a focus on anticoagulation parameters and management, CT results, and patient outcomes (bleeding and arterial or venous thrombotic events,

sepsis, stroke, death). Because of the recording of various data and information, we declared registered data to the CNIL (registration number A#R2784212n).

ECMO Implantation, Anticoagulation, and Weaning

The ECMO management protocol describing implantation and weaning is described in the **Supplementary Appendix** (http://links.lww.com/CCM/H607) (14–17). CT angiography was performed in the both departments systematically within 4 days of weaning from venoarterial ECMO.

Outcomes

The primary objective of this study was to describe the frequency and types of vascular complications related to the ECMO cannula following venoarterial ECMO weaning. The primary outcome was the incidence of CaDVT and arterial thrombosis complications. The secondary objective was to describe the arterial nonthrombotic complications and to identify potentially risk factors regarding hemostasis parameters. Secondary outcomes included the frequency of arterial nonthrombotic complications, the management of vascular complications, and in-hospital mortality. Vascular complications were diagnosed by CT angiography performed up to 4 days after ECMO weaning. Two radiologists from the cardiovascular imaging department conducted a prospective analysis to determine the presence or absence of vascular complications. These complications could include any arterial or venous thrombosis, CaDVT, pseudoaneurysm, active bleeding, arterial dissection, hematoma, or arteriovenous fistula. A specific roadmap was employed for the screening of vascular complications. DVT was defined as a partial or complete filling defect on at least two consecutive axial images, which were then confirmed, if necessary, by centerline vascular reconstructions. CaDVT was defined as DVT at the cannulation sites.

Management

After confirming the presence of a thrombus on CT imaging, anticoagulation with continuous UFH infusion was initiated in the ICU. This was then switched to oral anticoagulation at the discretion of the physician. To ascertain the persistence of the thrombus, vascular ultrasounds were conducted in the ICU or follow-up CT scans were performed at the discretion of the medical team caring for the patient. Anticoagulation was discontinued for up to 6 weeks in the absence of any other indication for anticoagulation. In the event of a clinically suspected complication after decannulation, such as an arterial thrombotic event, the surgical team was consulted to determine the most appropriate treatment. This could include surgical intervention, endovascular treatment, and systemic anticoagulation.

Statistical Analyses

Quantitative continuous results were expressed as median (interquartile range [IQR]), qualitative data as count (%). Univariable comparisons were analyzed using Student *t* test or the Mann-Whitney *U* test according to variable's distribution, normal or not, for continuous variables, and chi-square test or Fisher exact test for qualitative variables.

For the primary outcome, only univariable analyses were conducted, as a multivariable analysis on inverse and sometimes competing complications was not relevant.

For the secondary objective, several variables with repeated measures (activated partial thromboplastin time [aPTT] ratio, anti-Xa activity, fibrinogen values, and ECMO flow rate) were analyzed using a mixed model with a random effect on subject identification. A multivariable logistic regression model was used to examine the association between thrombotic complications and patients' characteristics or ICU events. Risk factors of thrombotic complications were determined using a multivariable logistic regression model including variables previously reported as strongly associated with thrombotic complications (age, Simplified Acute Physiology Score II, duration of venoarterial ECMO support) and variables of interest regarding hemostasis management (number of days with a daily dose of UFH < 10,000 international units, number of days with aPTT ratio < 2, number of days with fibrinogen > 4 g/dL) (2–5, 12). The R software (for Macintosh, GNU GPL [general public license], "The R Foundation for Statistical Computing," Vienna, Austria) and the R Studio interface (R, Version 4.1.1) were used to perform the statistical analyses. Bilateral statistical tests were used, and a *p* value of less than 0.05 was considered statistically significant.

RESULTS

Patient Characteristics

A total of 288 patients underwent venoarterial ECMO between January 2021 and January 2022. Of these, 94 patients died while on ECMO, 194 patients were successfully weaned, and 109 patients were included in the study. The flow chart is described in **Figure 1**. The median patient age was 58 years (IQR, 46–64 yr), and the median ECMO support time was 9 days. The median time from ECMO weaning to CT examination was 2 days (IQR, 1–3 d). The primary indication for venoarterial ECMO was refractory cardiogenic shock in 90 patients (82%), of whom 42 patients (38%) had undergone cardiac surgery. Left ventricular (LV) venting was employed in 50 patients (46%), comprising 41 intra-aortic balloon pump (IABP), eight Impella, and one cannula through the LV apex.

The principal characteristics are presented in **Table 1**, while the features of venoarterial ECMO are outlined in **Table 2**.

CaDVT and Arterial Complications

The primary vascular complication was CaDVT, observed in 63 of 109 patients (58%). Eleven patients (10%) exhibited simultaneous venous and arterial thrombosis. The primary site of CaDVT was the inferior vena cava (IVC) in 33 of 63 patients (50%). Thirteen patients (20%) exhibited pulmonary embolism, 11 of 63 (17%) demonstrated right atrial thrombosis, and six of 63 (9%) exhibited superior vena cava thrombosis.

Arterial thrombosis was observed in 36 of 109 patients (33%). The majority of arterial thrombi were localized in the femoral artery (24/36, 67% of cases), followed by the iliac artery (17/36, 47% of cases) and the aorta (2/36, 6% of cases). A total of seven patients (19%) exhibited multiple thrombosis sites. In the majority of cases, arterial thrombosis occurred at the cannulation site. In 17% of cases, thrombosis occurred at the LV venting site (IABP or Impella [Abiomed, Danvers, MA]). The data are presented in **Figure 2**, ***A*** and ***B***.

In the event of a CT diagnosis of CaDVT, anticoagulation was continued. All patients diagnosed with CaDVT were asymptomatic. In 53 of the 63 patients (84%), there was no indication of anticoagulation prior to the initiation of ECMO. The in-hospital mortality rate was comparable between patients with and without CaDVT, as was the incidence of arterial thrombosis. With regard to the outcomes of arterial

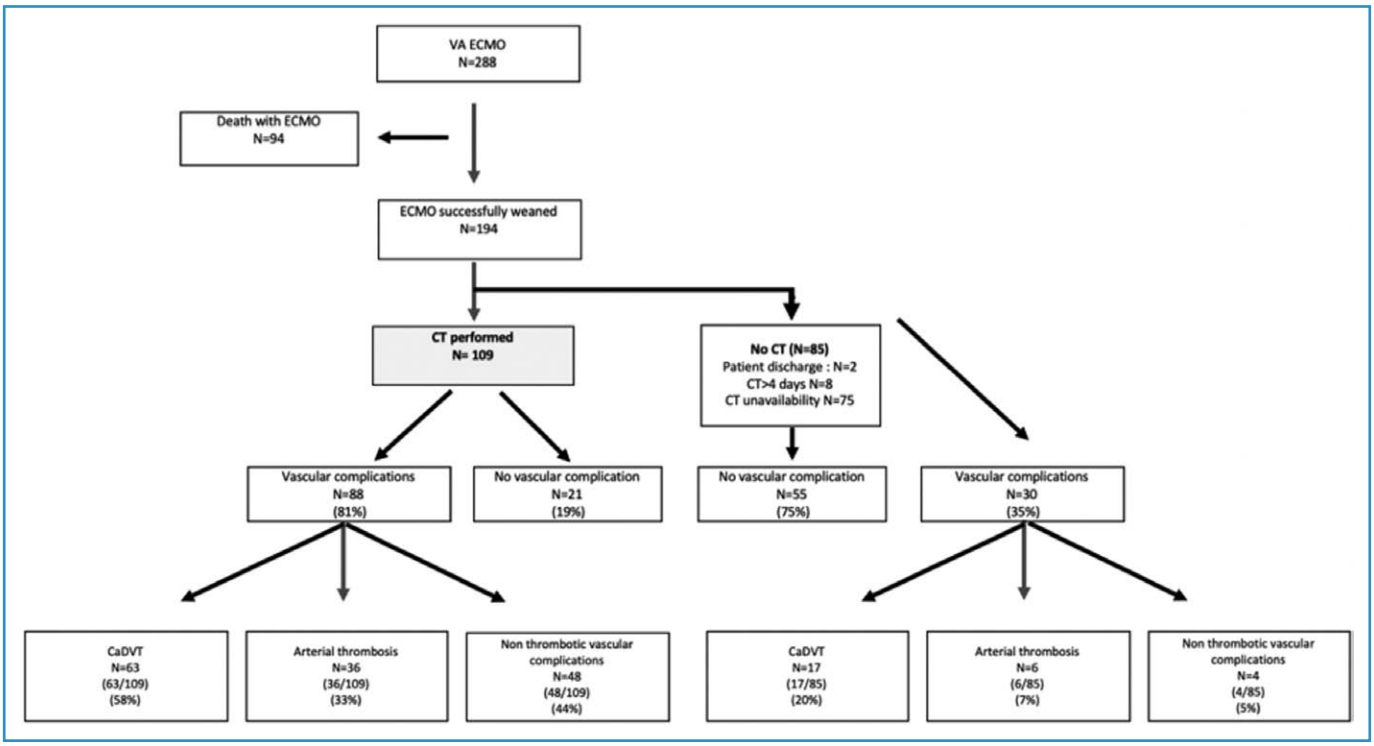

Figure 1. Flow chart. Data are shown as nominal *n* (%). CaDVT = cannula-associated deep vein thrombosis, ECMO = extracorporeal membrane oxygenation, VA = venoarterial.

TABLE 1.
Cannula-Associated Deep Vein Thrombosis and Arterial Thrombosis Groups—Baseline Characteristics

Variable	All (*n* = 109)	No CaDVT (*n* = 46)	CaDVT (*n* = 63)	*p*	No AT (*n* = 73)	AT (*n* = 36)	*p*
Baseline							
Age	58 (46–64)	58 (46–67)	56 (44–63)	0.183	58 (47–64)	53 (30–62)	0.052
Male sex	80 (73)	34 (74)	46 (73)	1.000	58 (79)	22 (61)	0.071
Body mass index	26 (23–28)	26 (23–29)	25 (23–28)	0.429	26 (23–28)	25 (23–28)	0.774
Severity score							
Sequential Organ Failure Assessment	12 (10–15)	12 (10–15)	11 (8–15)	0.301	12 (10–15)	11 (8–15)	0.301
Simplified Acute Physiology Score II	56 (42–69)	63 (50–73)	53 (40–66)	0.042	61 (49–71)	46 (35–65)	0.004
Comorbidities, *n* (%)							
Hypertension	35 (32)	16 (35)	19 (30)	0.762	25 (34)	10 (28)	0.644
Chronic obstructive pulmonary disease	4 (4)	2 (4)	2 (3)	1.000	3 (4)	1 (3)	1.000
Peripheral artery disease	5 (5)	2 (4)	3 (5)	1.000	4 (5)	1 (3)	0.883
Diabetes	21 (19)	8 (17)	13 (20)	0.859	14 (19)	7 (19)	1.000
Ischemic cardiomyopathy	35 (32)	12 (26)	23 (36)	0.346	21 (29)	14 (39)	0.397
Dilated cardiomyopathy	43 (39)	15 (33)	28 (44)	0.294	28 (39)	15 (42)	0.901
Restrictive cardiomyopathy	14 (13)	8 (17)	6 (9)	0.356	10 (14)	4 (11)	0.940
Hypertrophic cardiomyopathy	3 (3)	1 (2)	2 (3)	1.000	1 (1)	2 (6)	0.526
Valvular heart disease	18 (16)	8 (17)	10 (16)	1.000	10 (14)	8 (22)	0.394
Cancer	6 (5)	1 (2)	5 (8)	0.380	3 (4)	3 (8)	0.643
COVID-19+	4 (3.7)	2 (4.3)	2 (3.2)	0.747	3 (4)	0 (0)	0.541
Deep vein thrombosis < 3 mo	3 (3)	3 (6)	0 (0.0)	0.144	2 (2.7)	2 (5.5)	0.462
Therapeutic anticoagulation	36 (33)	19 (41)	17 (27)	0.173	25 (34)	11 (31)	0.866
Antiplatelet agent	27 (25)	13 (28)	14 (23)	0.653	19 (26)	8 (22)	0.814
Left ventricular ejection fraction	40 (25–50)	42 (30–50)	37 (24–50)	0.259	40 (25–50)	50 (25–50)	0.472
Extracorporeal membrane oxygenation indication, *n* (%)				0.537			0.628
Cardiac arrest	19 (17)	8 (17)	11 (17)		12 (16)	7 (19)	
Medical causes	48 (44)	21 (45)	27 (43)		31 (42)	17 (47)	
Post-cardiotomy	21 (19)	8 (17)	13 (21)		13 (18)	8 (22)	
Post-transplantation	21 (19)	9 (20)	12 (19)		17 (23)	4 (11)	
Ventricular dysfunction, *n* (%)				0.145			0.045
Biventricular	63 (58)	31 (67)	32 (51)		48 (66)	15 (42)	
Right ventricular failure	6 (5)	3 (6)	3 (5)		4 (5)	2 (6)	
Left ventricular failure	40 (37)	12 (26)	28 (44)		21 (29)	19 (53)	

(*Continued*)

TABLE 1. (*Continued*)
Cannula-Associated Deep Vein Thrombosis and Arterial Thrombosis Groups—Baseline Characteristics

Variable	All (*n* = 109)	No CaDVT (*n* = 46)	CaDVT (*n* = 63)	*p*	No AT (*n* = 73)	AT (*n* = 36)	*p*
Biological parameters at implantation							
Lactate level (mmol/L)	4.5 (3.5–5.5)	3.3 (2.1–6.5)	3.4 (1.9–5.5)	0.549	3.6 (2.1–6.5)	3.1 (1.8–5.1)	0.336
Creatinine (mg/dL)	1.67 (1.02–2.04)	1.57 (1.01–1.97)	1.21 (0.90–1.75)	0.153	1.51 (1.09–2.09)	1.14 (0.85–1.37)	0.005
Leukocyte (G/L)	14 (11–18)	15 (12–19)	13 (9–15)	0.034	13 (9–17)	14 (11–18)	0.373

AT = arterial thrombosis, CaDVT = cannula-associated deep vein thrombosis.
Quantitative results were expressed as median (interquartile range), qualitative data as nominal *n* (%).

thrombosis, lower limb ischemia was observed in nine of 36 patients (25%), and 16 of 36 (44%) required surgical or endovascular intervention.

Nonthrombotic Arterial Complications

Nonthrombotic arterial complications were the second most frequent vascular complications, occurring in 48 of the 109 patients (44%). The primary cause was arterial dissection at the insertion point in the common femoral artery, occurring in 26 of 48 patients (54% of cases). Hematoma was the second most common cause, affecting 14 of 48 patients (30% of cases). Other causes included pseudoaneurysm (8/48 patients, 17% of cases), arterial bleeding (2/48 patients, 4% of cases), and arteriovenous fistula (1/48 patients, 2% of cases).

With regard to nonthrombotic complications, 13 of 48 patients (27%) required further surgical or endovascular intervention following a diagnosis made on CT. The majority of these patients presented with arterial dissection or pseudoaneurysm. The aforementioned data are presented in **Figures 2*C*** and **3**.

CaDVT Risk Factors

No risk factors were identified in the univariate or multivariate analyses. Indeed, no significant discrepancy was observed in the duration of heparin-free periods across the groups. The median duration of heparin-free periods was 31 hours in the CaDVT group and 29 hours in the no CaDVT group (p = 0.802). Similarly, no significant difference was observed in the median ECMO flow, with a median of 2.8 L/min in the CaDVT group and 2.9 L/min in the no CaDVT group (p = 0.09). For the CaDVT group, baseline characteristics, ECMO features and complications, and transfusion during venoarterial ECMO support are summarized in **Tables 1–3**. The anticoagulation features and ECMO flow rates are presented in Table 2; and **Supplemental Figure 1*A–D*** (http://links.lww.com/CCM/H607). The results of the multivariate analysis are provided in **Supplemental Table 1** (http://links.lww.com/CCM/H607).

Arterial Thrombosis Risk Factors

In regard to the risk factors of arterial thrombosis, no risk factors were identified in the univariate or multivariate analyses. Baseline characteristics, ECMO features, and transfusion are summarized in Tables 1–3. The anticoagulation features are described in **Supplemental Figure 2*A–C*** (http://links.lww.com/CCM/H607) while the multivariate analysis is detailed in **Supplemental Table 2** (http://links.lww.com/CCM/H607).

DISCUSSION

In this observational study based on systematic CT performed less than 96 hours after venoarterial ECMO weaning, vascular complications after ECMO weaning were found to occur in the majority of patients, either thrombotic, hemorrhagic, or parietal and interesting both arteries and veins. CT proved to be useful, leading to major changes in the management of patients. Most of the data looking for vascular complications were during the ECMO support time (18). As far as we know our study is the first to describe vascular complications using systematic CT after venoarterial ECMO decannulation. Parzy et al (19) in 2020 used CT after ECMO decannulation,

TABLE 2.
Cannula-Associated Deep Vein Thrombosis and Arterial Thrombosis Groups—Extracorporeal Membrane Oxygenation Features

Variable	Overall (*n* = 109)	No CaDVT (*n* = 46)	CaDVT (*n* = 63)	*p*	No AT (*n* = 73)	AT (*n* = 36)	*p*
Percutaneous implantation (%)	93 (85)	36 (78)	57 (90)	0.132	60 (82)	33 (92)	0.304
Femoral venous cannulation (%)	108 (99)	46 (100)	62 (98)	1.000	73 (100)	35 (97)	0.717
Arterial cannula localization (%)				0.479			0.173
Axillary	3 (3)	2 (4)	1 (2)		3 (4)	0 (0)	
Femoral	105 (96)	44 (96)	61 (97)		70 (96)	35 (97)	
Central	1 (1)	0 (0)	1 (2)		0 (0)	1 (3)	
Vein cannula size (%)				0.776			0.183
25-Fr	85 (78)	35 (76)	50 (79)		59 (81)	26 (72)	
< 25-Fr	8 (7)	3 (6)	5 (8)		3 (4)	5 (14)	
> 25-Fr	16 (15)	8 (17)	8 (13)		11 (15)	5 (14)	
Arterial cannula size (%)				0.891			0.873
17-Fr	83 (76)	34 (74)	49 (78)		56 (77)	27 (75)	
< 17-Fr	2 (2)	1 (2)	1 (2)		1 (1)	1 (3)	
> 17-Fr	24 (22)	11 (24)	13 (21)		16 (22)	8 (22)	
ECMO brand (%)				0.621			
Heart-Lung Support set	25 (23)	11 (24)	14 (22)		20 (27.8)	5 (13.9)	
Medos	16 (15)	6 (13)	10 (16)		12 (16.7)	4 (11.1)	
Pump lung support set	59 (55)	23 (51)	36 (57)		35 (49)	24 (67)	
Sorin	8 (7)	5 (11)	3 (5)		5 (7)	3 (8)	
ECMO flow (L/min)	3 (2.6–3.9)	2.9 (2.5–4)	2.8 (2.7–3.1)	0.148	3.2 (2.6–4)	2.9 (2.5–3.6)	0.089
Hours with ECMO flow < 2 L/min	37 (22–45)	43 (31–49)	31 (20–43)	0.090	35 (22–48)	38 (24–47)	0.084
Femoral closure device (%)	77 (71)	28 (61)	49 (77)	0.060	50 (68)	27 (75)	0.482

AT = arterial thrombosis, CaDVT = cannula-associated deep vein thrombosis, ECMO = extracorporeal membrane oxygenation. Quantitative results were expressed as median (interquartile range), qualitative data as nominal *n* (%).

but in a venovenous ECMO population, they reported a frequency of 71.4% of CaDVT. In our series, CT appears more sensitive for the detection of vascular complications. Concerning vascular complications after decannulation we previously found in a venoarterial ECMO population a frequency of 41% of CaDVT and 14% of arterial complications using ultrasounds (20). Recently, Fisser et al (14) in 2022 show in a larger venoarterial ECMO population a frequency of 27% of CaDVT and 37% of arterial thrombosis; however, CT and ultrasound Doppler were used to screen for these complications. Our results appear to be in agreement with these previous studies. No comparative data is available to show which imaging test is most reliable in this context. Doppler ultrasound is usually performed in studies for the detection of CaDVT, and recommended for the diagnosis of catheter-related thrombosis (CRT) and lower limb DVT, but it is however inefficient for the detection of central and iliocaval vein thrombosis and pulmonary embolism (21–24). In our study, 50% of CaDVT was in the IVC, this localization could be underestimated with ultrasounds and the performance of CT venography in the detection of DVT is high and similar to ultrasounds in several studies in non-ICU populations (25–27). CT changed patient management in 53 patients (84%) when the diagnosis of CaDVT was made. In two retrospective studies with venovenous ECMO population,

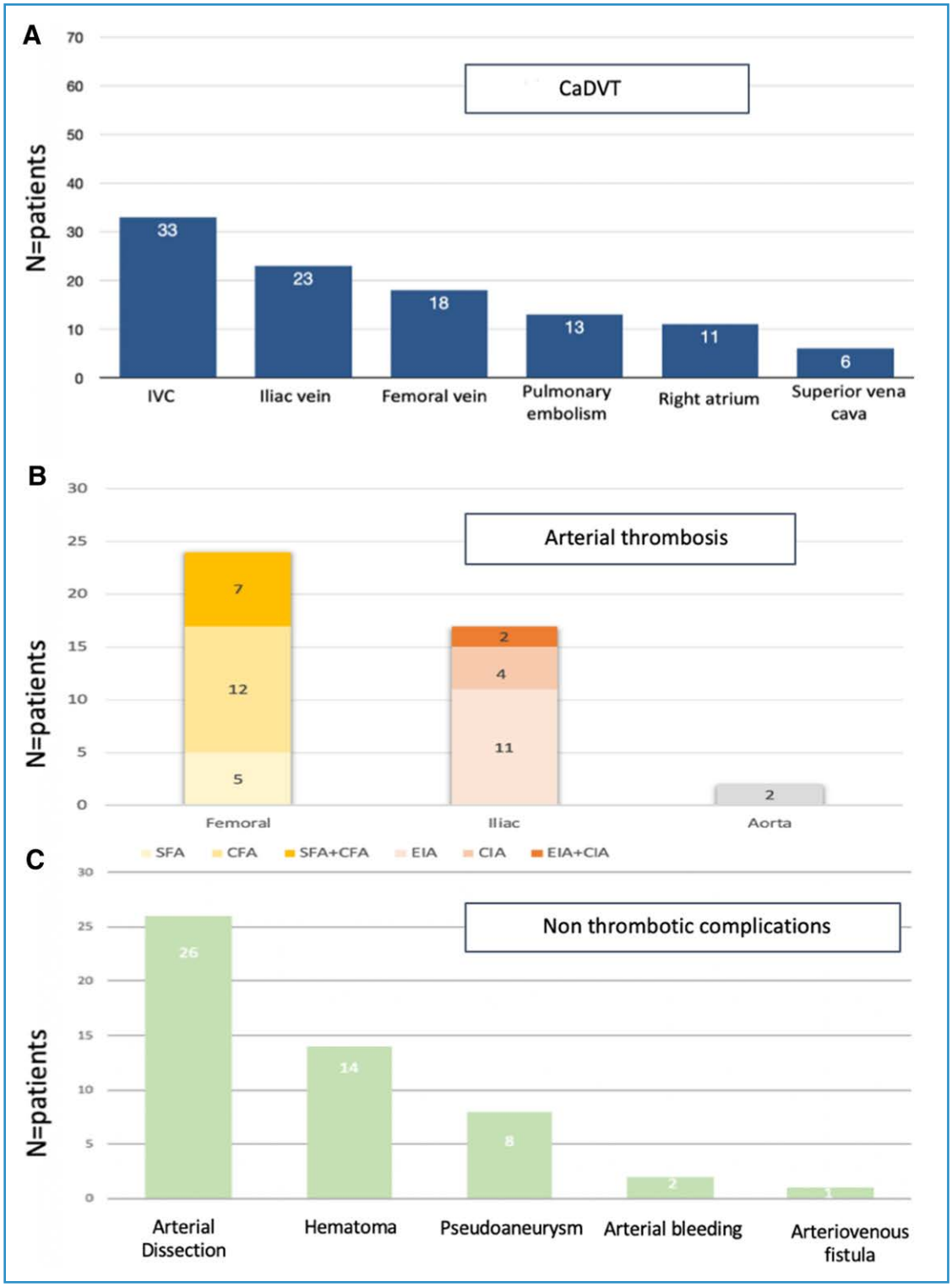

Figure 2. Vascular complications localization after venoarterial extracorporeal membrane oxygenation. **A**, Ccannula-associated deep vein thrombosis (CaDVT). **B**, Arterial thrombosis. **C**, Nonthrombotic complications. Data are shown as nominal *n* (%). CFA = common femoral artery, CIA = common iliac artery, EIA = external iliac artery, IVC = inferior vena cava, SFA = superficial femoral artery.

CTs were performed only in 20.7% and 3.5% of cases to assess the frequency of CaDVT (28, 29). Despite the absence of impact of vascular complications concerning in-hospital morbidity and mortality, we may recommend to realize a CT examination for early detection of vascular complications. Recently, a study carried out in our surgical ICU department revealed that venoarterial ECMO weaning-related shock represents 38% of cases, and right heart failure concerned 12.5% of cases potentially related to CaDVT (30).

No risk factors were found whereas previously in a venoarterial ECMO population using Doppler ultrasound after venoarterial ECMO weaning, the age and ECMO duration appears to be risk factors for CaDVT and prior anticoagulation therapy appeared to be protective (20).

The frequency of vascular complications is high and the level of anticoagulation therapy and the daily heparin doses were low but similar to that in the study by Bidar et al (20). This low level of anticoagulation is explained

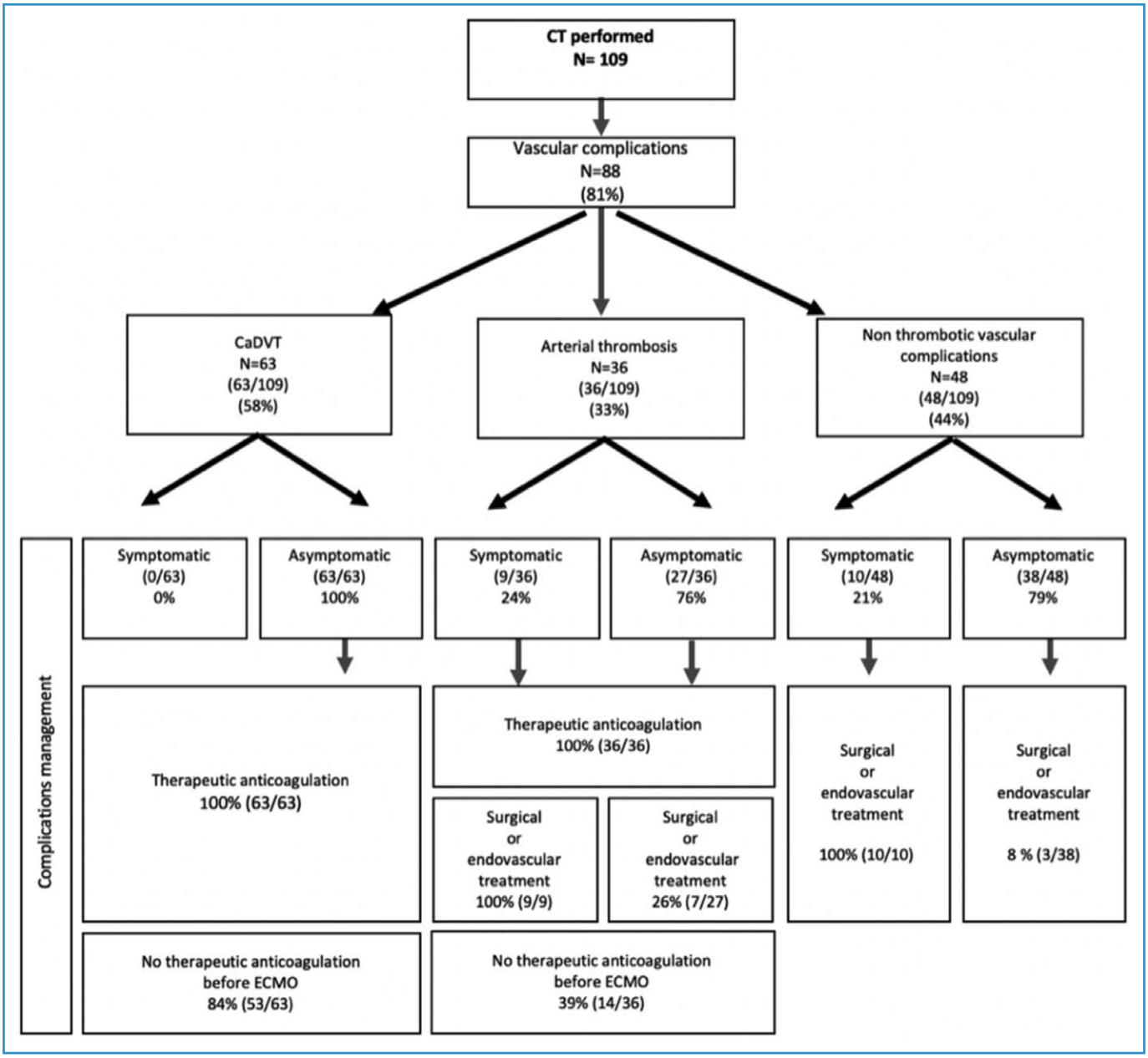

Figure 3. Flow chart of vascular complications management. Data are shown as nominal *n* (%). CaDVT = cannula-associated deep vein thrombosis, ECMO = extracorporeal membrane oxygenation.

by the hemorrhagic risk in this context, 32% of the patients needed a revision surgery for bleeding and 5% of patients had hemorrhagic stroke. Despite recommendations of Extracorporeal Life Support Organization targeting a level of anticoagulation under venoarterial ECMO with an anti-Xa ratio between 0.3 and 0.6 UI/mL, there is few data to correlate the degree of anticoagulation with vascular complications (12, 18, 28, 31–33). The high frequency of vascular complications did not allow to identify risk factors in our study. It would appear difficult to justify higher anticoagulation targets to prevent these vascular complications in view of the bleeding risk. Vascular complications after ECMO weaning have no impact on short-term patient prognosis, but early detection and treatment may be justified to avoid further or longer-term complications. The absence of higher mortality in the group with CaDVT, and arterial complications could also be explained by the early therapeutic management of complications detected by systematic imaging, and also this may be because most complications are asymptomatic.

TABLE 3.

Cannula-Associated Deep Vein Thrombosis and Arterial Thrombosis Groups—Complications, Transfusion, and Hemostasis Parameters During Venoarterial Extracorporeal Membrane Oxygenation

Variable	Overall (*n* = 109)	No CaDVT (*n* = 46)	CaDVT (*n* = 63)	*p*	No AT (*n* = 73)	AT (*n* = 36)	*p*
Bleeding with surgical revision (%)	35 (32)	14 (30)	21 (33)	0.678	25 (34)	10 (28)	0.656
Limb ischemia (%)	10 (9)	5 (11)	5 (8)	0.851	4 (5)	6 (17)	0.121
Left ventricular venting (%)	50 (46)	17 (37)	33 (52)	0.098	31 (42)	19 (53)	0.538
Intra-aortic balloon pump	41 (82)	12 (70)	29 (87)	0.130	26 (84)	15 (79)	0.660
Impella	8 (16)	4 (23)	4 (13)	0.290	4 (13)	4 (21)	0.445
Left ventricular apex	1 (2)	1 (7)	0 (0)	0.159	1 (3)	0 (0)	0.429
Hemorrhagic stroke (%)	6 (5)	3 (6)	3 (5)	1.000	4 (5)	2 (5)	0.567
Ischemic stroke (%)	13 (12)	6 (13.0)	7 (11)	0.993	9 (12)	4 (11)	0.099
Infection during ECMO (%)	56 (51)	26 (56)	30 (48)	0.469	37 (51)	19 (53)	0.999
Continuous venovenous hemodiafiltration (%)	29 (27)	14 (30)	15 (24)	0.580	23 (31)	6 (17)	0.156
Duration (d)							
ECMO duration	7 (5–12)	7.5 (5–11)	7 (4–13)	0.897	7 (4–11)	8 (5–13)	0.055
ICU length of stay	37 (23–68)	36 (27–68)	40 (20–63)	0.388	18 (10–30)	16 (12–35)	0.639
Mechanical ventilation	5 (2–14)	5 (2–15)	5 (2–10)	0.534	5 (2–14)	5 (2–11)	0.957
Hospital length of stay	37 (23–68)	36 (27–68)	40 (20–63)	0.388	36 (20–68)	41 (25–64)	0.842
Mortality (%)							
ICU mortality	19 (17)	10 (22)	9 (14)	0.449	15 (20)	4 (11)	0.341
Hospital mortality	19 (17)	10 (22)	9 (14)	0.843	8 (11)	2 (6)	0.585
Transfusion > 1 packed RBC unit							
During ECMO support	81 (74)	38 (83)	43 (68)	0.141	54 (74)	27 (75)	1.000
Transfusion > 1 fresh frozen plasma unit							
During ECMO support	44 (40)	19 (41)	25 (40)	1.000	30 (41)	14 (39)	0.989
Transfusion > platelet concentrate unit							
During ECMO support	43 (39)	16 (35)	27 (43)	0.513	30 (41)	13 (36)	0.770
Transfusion > 1 g of fibrinogen							
During ECMO support	19 (17)	6 (13)	13 (21)	0.438	9 (12)	10 (28)	0.083

(*Continued*)

TABLE 3. (*Continued*)
Cannula-Associated Deep Vein Thrombosis and Arterial Thrombosis Groups—Complications, Transfusion, and Hemostasis Parameters During Venoarterial Extracorporeal Membrane Oxygenation

Variable	Overall (*n* = 109)	No CaDVT (*n* = 46)	CaDVT (*n* = 63)	*p*	No AT (*n* = 73)	AT (*n* = 36)	*p*
Hemostasis parameters							
Daily UFH dose, international unit	17,900 (13,700–25,500)	18,000 (13,000–27,000)	14,500 (13,000–17,000)	0.804	16,200 (13,500–19,500)	18,000 (14,500–26,000)	0.789
Days with anti-Xa activity < 0.25	6 (2.0–9.0)	6.5 (2.2–9.0)	5 (2.0–9.5)	0.522	7 (3.0–9.0)	5 (2.0–8.5)	0.522
Hours without UFH treatment	30 (18–40)	29 (17–36)	31 (20–42)	0.802	30 (15–41)	29 (15–36)	0.812
Days with activated partial thromboplastin time ratio < 2	5.3 (3.2–9.3)	6 (4.0–9.7)	5 (3.0–9.0)	0.503	6 (4–9.0)	5 (2.0–9.0)	0.503

AT = arterial thrombosis, CaDVT = cannula-associated deep vein thrombosis, ECMO = extracorporeal membrane oxygenation, UFH = unfractionated heparin.
Quantitative results were expressed as median (interquartile range), qualitative data as nominal *n* (%).

Management of CaDVT with ECMO is unclear. Guidelines recommend 3 months of anticoagulation for an incidental finding in the general population, whereas 6 weeks of anticoagulation may be sufficient for management of CRT (21–23). No hemorrhagic complication occurred during the anticoagulation time. Menaker et al (12) reexamined patients 2 weeks after the diagnosis and observed residual thrombosis in 75% of patients. In addition, thrombosis was not observed after 6 weeks treatment following venoarterial ECMO removal in a case series (13). Hence, it may be reasonable to systematically perform CT after decannulation and treat CaDVT for 6 weeks.

Our study has several limitations. First, as a retrospective observational study, selection and attrition biases may impact our results. Second, the high frequency of thromboses may be induced by our low level of anticoagulation, but no specific risk factors were identified. Third, 194 patients were weaned from venoarterial ECMO but only 109 patients performed a CT examination. A total of 85 patients did not undergo a CT scan following weaning from ECMO. Upon reexamination of the data, it was observed that the rate of vascular complications among the 85 patients was 35% vs. 81% in the CT scan group. For CaDVT, the incidence was 20%, all asymptomatic, discovered on cardiac ultrasound, vs. 58% in the group of patients who underwent a CT scan. With regard to thrombotic arterial complications, 7% of cases were found, with the majority of these cases (66%) being discovered after the clinical event. The in-hospital mortality rate was 20.5% in the group without a CT scan and 21% in the group with a CT scan. No significant differences were identified between the two groups. Nevertheless, the incidence of vascular complications remains high, and the complication rate appears to be lower in the group without a CT scan. Many patients could not have a CT within 96 hours because of CT unavailability. Furthermore, it is more difficult to organize and move an ICU ventilated patient for CT, and bedside Doppler ultrasound may be more feasible. CT scan appears to be more efficient in the diagnosis of vascular complications, but there was no direct comparison with ultrasounds in this study. Finally, the impact of such vascular complications, the most effective means of managing them, and the efficacy of their treatment remain unknown due to a lack of comparative data. The use of systematic CT scans has been shown to enhance

the awareness of vascular complications associated with ECMO. An integrated noninvasive diagnostic approach, potentially based on a stepwise approach of CT (deep and central vessels) after a negative ultrasound (cannulation sites), may allow for the development of personalized patient management strategies. These strategies could identify the risk of vascular complications and facilitate discussions regarding the potential benefits of preventive anticoagulation, which appears to be the only protective factor in our study.

CONCLUSIONS

This study presents the first description of vascular complications following venoarterial ECMO weaning, utilizing a systematic CT approach. The incidence of vascular complications related to venoarterial ECMO is high, although not associated with in-hospital mortality. No specific risk factors for thrombotic complications were identified. Given the high prevalence of vascular complications, CT should be employed following venoarterial ECMO weaning to facilitate early, tailored medical or surgical management. Nevertheless, the efficacy of this approach should be evaluated in a future randomized prospective study.

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