OBSERVATIONAL STUDY

OPEN

Impact of Time to Intervention on Catheter-Directed Therapy for Pulmonary Embolism

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OBJECTIVES: Cather-directed therapies (CDTs) are an evolving therapeutic option for patients with intermediate-risk pulmonary embolism (PE). Although many techniques have been studied, there is limited evidence for the impact of timing of intervention on patient outcomes. Our objective was to assess the association between time to CDT in patients presenting with PE on patient-related outcomes such as length of stay (LOS) and mortality.

DESIGN: Retrospective cohort study.

SETTING: Single academic center.

PATIENTS: We identified patients for which the PE response team had been activated from January 2014 to October 2021. Patients were split into two cohorts depending on whether they went to CDT less than 24 hours from admission (early) versus greater than 24 hours (late).

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Data on demographics, timing of interventions, pulmonary hemodynamics, and outcomes were collected. Sixty-four patients were included in analysis. Thirty-nine (63.8%) underwent their procedure less than 24 hours from admission, whereas 25 (36.2%) underwent the procedure after 24 hours. The time from admission to CDT was 15.9 hours (9.1–20.3 hr) in the early group versus 33.4 (27.9–41) in the late group ($p \leq 0.001$). There was a greater decrease in pulmonary artery systolic pressure after intervention in the early cohort (14 mm Hg [6–20 mm Hg] vs 6 mm Hg [1–10 mm Hg]; $p = 0.022$). Patients who received earlier intervention were found to have shorter hospital LOS (4 vs 7 d; $p = 0.038$) and ICU LOS (3 vs 5 d; $p = 0.004$). There was no difference in inhospital mortality between the groups (17.9% vs 12%; $p = 0.523$).

CONCLUSIONS: Patients who underwent CDT within 24 hours of admission were more likely to have shorter hospital and ICU LOS. The magnitude of change in LOS between the two cohorts was not fully explained by the difference in time to CDT. There were modest improvements in pulmonary hemodynamics in the patients who underwent CDT earlier.

KEY WORDS: endovascular procedures; fibrinolytic agents; mechanical thrombectomy; pulmonary embolism; venous thromboembolism

Pulmonary embolism (PE)—a leading cause of morbidity and mortality (1)—can be a clinically challenging condition to manage. Other thromboembolic or thrombotic diseases, such as myocardial infarction (MI) (2) or ischemic stroke (3) treatments, are time-sensitive as the mechanism for injury is ischemia and tissue death. PE, on the other hand, is related to cardiac stress. The right heart is extremely adaptive to volume and can often accommodate increases in pressure (4). The limit to this compensation, however, is difficult to assess (5). Given this importance, societies use the presence of right ventricular (RV) dysfunction to define higher risk groups that may benefit from more aggressive therapy than simple anticoagulation if the bleeding risks are

DOI: 10.1097/CCE.0000000000000828

KEY POINTS

- **Question**: Does timing of catheter-directed therapy (CDT) affect outcomes in patient with intermediate-risk pulmonary embolism?
- **Findings**: There was an association between patients who underwent CDT within 24 hours of admission and shorter hospital and intensive care length of stay, as well as more significant improvements in pulmonary hemodynamics than those who went to CDT 24 hours after admission.
- **Meaning**: Undergoing CDT within 24 hours of admission may lead to improved outcomes, though further study is warranted.

acceptable (6–8). Patients with intermediate-high and high-risk PE characteristically have RV dysfunction, and a small cohort within these two groups represents patients that can progress to obstructive/cardiogenic shock even with anticoagulation (9). Given the difference from other thrombotic syndromes such as stroke or MI, questions surround the optimal timing of catheter-directed interventions after initial diagnosis.

Catheter-directed therapy (CDT) has emerged as a novel therapy modality for PE patients at risk of clinical decompensation (10). These percutaneous techniques—which aim to reduce clot burden either through mechanical retrieval or local thrombolysis—are minimally invasive and can be safely performed even if patients are intolerant to systemic thrombolysis (11). Several studies (12–14) have reported CDT, yielding a reduction in RV strain as evidenced by improvements in pulmonary artery systolic pressure (PASP) and RV to left ventricle (LV) diameter ratio (RV:LV). Although improvements in these objective physiologic parameters are well documented, many questions remain regarding the optimization of CDT technique, such as when best to intervene on patients presenting with acute PE.

In existing CDT studies, the intervention cutoff time varies significantly. For example, in the ULTIMA group (Randomized, Controlled Trial of Ultrasound-Assisted Catheter-Directed Thrombolysis for Acute Intermediate-Risk Pulmonary Embolism) (12), interventions were done within 4 hours of initial echocardiography. Conversely, in the OPTALYSE trial (A Randomized Trial of the Optimum Duration of Acoustic Pulse Thrombolysis Procedure in Acute Intermediate-Risk Pulmonary Embolism: The OPTALYSE PE Trial), interventions were done up to 48 hours after diagnostic CT angiography (15). Rawal et al (16) reviewed six prior studies on CDT in acute PE that included time to procedure. They reported a trend towards benefit with early interventions (<24–48 hr after presentation) compared with delayed intervention (>48 hr after presentation), with improvements in both echocardiographic and clinical outcomes. In a study of 41 patients with intermediate-high PE, Edla et al (17) found that early (<24 hr) CDT resulted in improved pulmonary hemodynamics and decreased length of stay (LOS) compared late (>24 hr) CDT. Although these findings may hint that a shorter time to interventions is beneficial, there is still limited literature on the optimal time of CDT. Hence, the objective of our study was to determine if early timing of CDT had benefit in patients with acute PE.

MATERIALS AND METHODS

This single-center, retrospective cohort study was approved by the local New York University Institutional Review Board (Pulmonary Embolism Response Team Outcomes Database; study number s21-01082; approved August 10, 2021). All procedures were followed in accordance with the Helsinki Declaration of 1975 and local institutional ethical standards on human experimentation. Given the retrospective nature of the study and lack of intervention, informed consent was waived by the local institutional review board. All consecutive patients for whom the pulmonary embolism response team (PERT) was activated from January 2014 through October 2021 and underwent CDT were screened. In all patients, PE was diagnosed using CT pulmonary angiography. Patients who had a cardiac arrest prior to intervention or patients who underwent CDT for a diagnosis other than PE were excluded. All eligible patients were included in analysis. The electronic medical record was reviewed to collect patient demographics, medical comorbidities, laboratory values, imaging reports, procedural details, and pharmacotherapy. If values were not available, patients with missing values were not included in analysis of that variable.

The selection process for patients referred for CDT involves a multidisciplinary discussion with PERT at our institution, which includes a pulmonary critical care attending, interventional radiology attending, and thoracic surgeon. Based on available data and this discussion, patients are referred for systemic thrombolysis, CDT, surgical embolectomy, or anticoagulation. At our institution, CDT is utilized in patients who have intermediate-high-risk PE who have a contraindication to systemic thrombolysis or at the clinical discretion of our PERT for patients who do not meet criteria for massive PE but still have concerning evidence of RV strain. Prior to referral for CDT, serologic and/or echocardiographic evidence of RV strain is required prior to procedure.

Data pertaining to date, time, and location of patient presentation (i.e., emergency department [ED] vs hospitalized inpatient), time since onset of symptoms attributable to PE, and time until initiation of anticoagulation and/or administration of systemic thrombolytics were recorded from the electronic medical record. CDT procedure notes were reviewed to record time from admission to procedure, method of sedation, device(s) used, use of mechanical techniques and/or pharmacologic thrombolysis, cumulative dose of thrombolytic agent delivered, and invasive physiologic parameter measurements (i.e., pulmonary artery pressures). Patients' clinical characteristics and data pertaining to PE risk stratification (i.e., vitals, supplemental oxygen, laboratory biomarkers, CT and echocardiography data, and vasopressor requirements) were recorded for the time periods pre-CDT (upon PE diagnosis) and post-CDT (24–48 hr post-CDT).

Outcome measures included inhospital mortality, 30- and 90-day mortalities, ICU and hospital LOS, pulmonary artery pressures, subjective symptom assessment at 1–3-month outpatient PE clinic visit, and hospital readmission within 3 months. For bleeding complications related to CDT, the International Society on Thrombosis and Haemostasis definition was used for categorize major bleeding: hemoglobin drop greater than or equal to 2 g/dL, transfusion of greater than or equal to 2 units packed red blood cells, symptomatic bleeding in a critical area (such as intracranial, intraspinal, retroperitoneal, etc.), or fatal bleeding.

Patients who underwent CDT for their acute PE underwent catheter-directed thrombolysis and/or mechanical thrombectomy, with the particulars of each patient's CDT session reviewed and recorded from dictated procedure notes. In regard to catheter-directed-thrombolysis, our center utilized the Unifuse catheter (Angiodynamics, Latham, NY), a 4–5-F infusion catheter with varying infusion length, the Ekosonic Endovascular System (EKOS) device (Boston Scientific, Marlborough, MA), a catheter using low intensity ultrasound waves to facilitate thrombolysis, as well as the Bashir catheter (Thrombolex, New Britain, PA), a device with an expandable basket and multiple infusion holes utilized for thrombolytic therapy. For catheter-directed thrombectomy, the Indigo Penumbra system (Penumbra Inc, Alameda, CA), an 8-F vacuum assisted aspiration device, as well as the Inari FlowTriever (Inari Medical, Irvine, CA), a 20-F device with three expanding nitinol disks used to ensnare and aspirate the clot, were used. The Angiojet PE catheter (Boston Scientific, Marlborough, MA), a 6-F catheter using high-pressure saline jets to break up clot and an aspiration tip to remove the thrombus, was rarely used, and in the first year of our included cohort, given reported complications with its use in PE.

Statistical analysis was performed with SAS (SAS Institute, Cary, NC). Student *t* test and Mann-Whitney *U* test were used to compare continuous variables, and the chi-square test was used to compare categorical variables. Wilcoxon and log-rank tests were used to identify predetermined clinically relevant outcomes associated with timing of CDT. For all analyses, *p* values of less than 0.05 were considered significant. All continuous variables are reported with interquartile ranges unless otherwise noted.

RESULTS

A total of 64 patients who received CDT for PE were included in the analysis; no patients met exclusion criteria. Of the 64 patients, 39 (63.8%) underwent their procedure within 24 hours of admission to the ED, whereas 25 (36.2%) underwent their procedure after 24 hours. The average age of patients included in the study was 57 years old. There were no significant differences in age, sex, BMI, tobacco use, or comorbidities between the two groups. Full demographic data are included in **Table 1**.

Patients who received early CDT had higher heart rates (120 vs 113 bpm; $p = 0.043$) and required higher levels of oxygen supplementation on admission (**Table 2**). There were no differences in other markers of RV dysfunction, including troponin, lactate, BMI, RV/LV ratio on CT, or PESI scores. Echocardiographic

TABLE 1.
Patient Demographics

Variables	All (64)	Early Cohort (39)	Late Cohort (25)	*p*
n	64	39	25	
Age	57 (41–68)	51 (41–67)	57 (42–74)	0.203
Sex (male)	33 (51.5)	22 (56.4)	11 (44)	0.332
Race	*n* = 63	*n* = 38	*n* = 25	
African American	19 (30)	13 (33)	6 (24)	0.464
Caucasian	34 (54)	21 (54)	13 (52)	
Hispanic	6 (9)	2 (5)	4 (16)	
Asian	1 (2)	0 (0)	1 (4)	
Other	3 (5)	2 (5)	1 (4)	
BMI	*n* = 63	*n* = 38	*n* = 25	0.305
	32.2 (26.9–39.1)	33.7 (27.7–41.4)	31.6 (26.5–37.8)	
BMI category	*n* = 63	*n* = 38	*n* = 25	0.647
< 30	23 (37)	13 (34)	10 (40)	
≥ 30	40 (63)	25 (66)	15 (60)	
Tobacco use	13 (20)	8 (20.5)	5 (20)	0.96
Comorbidities				
Hypertension	28 (44)	15 (38.5)	13 (52)	0.287
Coronary artery disease	5 (8)	2 (5.1)	3 (12)	0.318
Cerebral vascular accident	3 (5)	2 (5.1)	1 (4)	0.835
Diabetes	17 (27)	12 (30.8)	5 (20)	0.341
Chronic kidney disease	3 (5)	1 (2.6)	2 (8)	0.315
Prior pulmonary embolism	*n* = 63	*n* = 38	*n* = 22	0.364
	8 (13)	6 (15.8)	2 (8)	
Prior deep vein thrombosis	14 (22)	9 (23.1)	5 (20)	0.771
Cancer	7 (11)	3 (7.7)	4 (16)	0.299
Recent surgery (within last 3 mo)	11 (17)	6 (15.4)	5 (20)	0.633

BMI = body mass index.

parameters of RV dysfunction were also similar between the groups, including RA/RV gradient, PASP, and tissue Doppler of the tricuspid valve. Both cohorts demonstrated signs of RV dysfunction on imaging modalities including elevated RV/LV ratio and decreased tissue Doppler of the tricuspid valve. A full summary of clinical characteristics is included in Table 2.

The average time from admission to the ED to start of CDT was 15.9 hours (9.1–20.3 hr) in the early group vs 33.4 (27.9–41) in the late group ($p \leq 0.001$). Patients in the early cohort did have a quicker time to initiation of anticoagulation (113 min [84–202 min] vs 226 min [125.5–309.5 min]; $p = 0.019$). This did not lead to a difference in time to therapeutic Ax level (9.9 hr [8–15.6 hr] vs 11.5 hr [9.9–16.3 hr]; $p = 0.313$). There was no difference in time from symptom onset to ED presentation (72 hr [5–168 hr] vs 72 hr [24–120 hr]; $p = 0.761$). There was a greater decrease in PASP after intervention in the early cohort versus the late (14 mm Hg [6–20 mm Hg] vs 6 mm Hg [1–10 mm Hg]; $p = 0.022$) (**Fig. 1**). The change in mean pulmonary artery pressure (mPAP) was not statistically significant (8 mm Hg [5.5–14 mm Hg] vs 6 mm Hg [3–9 mm Hg]; $p = 0.12$). There was no difference in inhospital mortality between the early and late cohorts (17.9% vs 12%; $p = 0.523$). Of these

TABLE 2.
Clinical Characteristics on Admission

Variables	All	Early Cohort	Late Cohort	*p*
Heart rate	117 (109–126)	120 (110–130)	113 (105–122)	***0.043***
Systolic BP	128 (106–144)	121 (105–146)	136 (107–144)	0.804
Diastolic BP	81 (71–91)	82 (68–89)	80 (75–93)	0.413
Respiratory rate	24 (20–28)	24 (20–28)	22 (19–26)	0.222
Oxygen use	64 (64)	22 (56.4)	19 (76)	0.11
Supplemental oxygen				
Nasal cannula	28 (44)	12 (30.8)	16 (64)	***0.041***
Nonrebreather	4 (6)	4 (10.3)	0 (0)	
High-flow nasal cannula	7 (10)	6 (15.4)	1 (4)	
Noninvasive ventilation	1 (2)	0 (0)	1 (4)	
Invasive ventilation	1 (2)	0 (0)	1 (4)	
Oxygen saturation (%)	95 (93–97)	96 (94–97)	95 (93–96)	0.144
Troponin (ng/mL)	*n* = 63	*n* = 38	*n* = 25	0.91
	0.18 (0.08–0.35)	0.18 (0.10–0.33)	0.17 (0.07–0.36)	
Lactate (mmol/L)	*n* = 49	*n* = 31	*n* = 18	0.11
	2.4 (1.4–3.45)	2.5 (1.5–3.6)	1.5 (1.2–3.1)	
Brain natriuretic peptide (pg/mL)	*n* = 57	*n* = 33	*n* = 24	0.891
	389 (139–1,258)	389 (117–1,205)	370 (138.2–1,426.3)	
Right ventricle/left ventricle ratio	*n* = 60	*n* = 35	*n* = 25	0.33
	1.49 (1.22–1.73)	1.5 (1.3–1.7)	1.4 (1.1–1.8)	
Pulmonary embolism severity index	107 (78–121)	109 (78–121)	94 (80–143)	0.685
Preprocedure echocardiogram				
Pulmonary artery systolic pressure	*n* = 53	*n* = 32	*n* = 21	0.764
	49 (40–61)	53 (42–60)	47 (37–64)	
Right ventricular/right atrium gradient	*n* = 50	*n* = 30	*n* = 20	0.851
	42 (33–53)	44 (30–51)	40 (33–55)	
Tricuspid value S′	*n* = 37	*n* = 21	*n* = 16	0.371
	9 (8–10)	9 (8–10)	8.8 (7.7–10.3)	
Clinical timing				
Symptom onset to admission (hr)	72 (17.2–168)	72 (5–168)	72 (24–120)	0.761
Admission to heparin initiation (min)	*n* = 61	*n* = 39	*n* = 22	***0.019***
	171 (102–270)	113 (84–202)	226 (125.5–309.5)	
Admission to procedure (hr)	21.2 (10.4–29.2)	15.9 (9.1–20.3)	33.4 (27.9–41)	***< 0.001***
Admission to therapeutic Xa (hr)	*n* = 58	*n* = 36	*n* = 22	0.313
	10.9 (8.3–15.1)	9.9 (8–15.6)	11.5 (9.9–16.3)	

$p < 0.05$ were considered significant and are italicized and boldface.

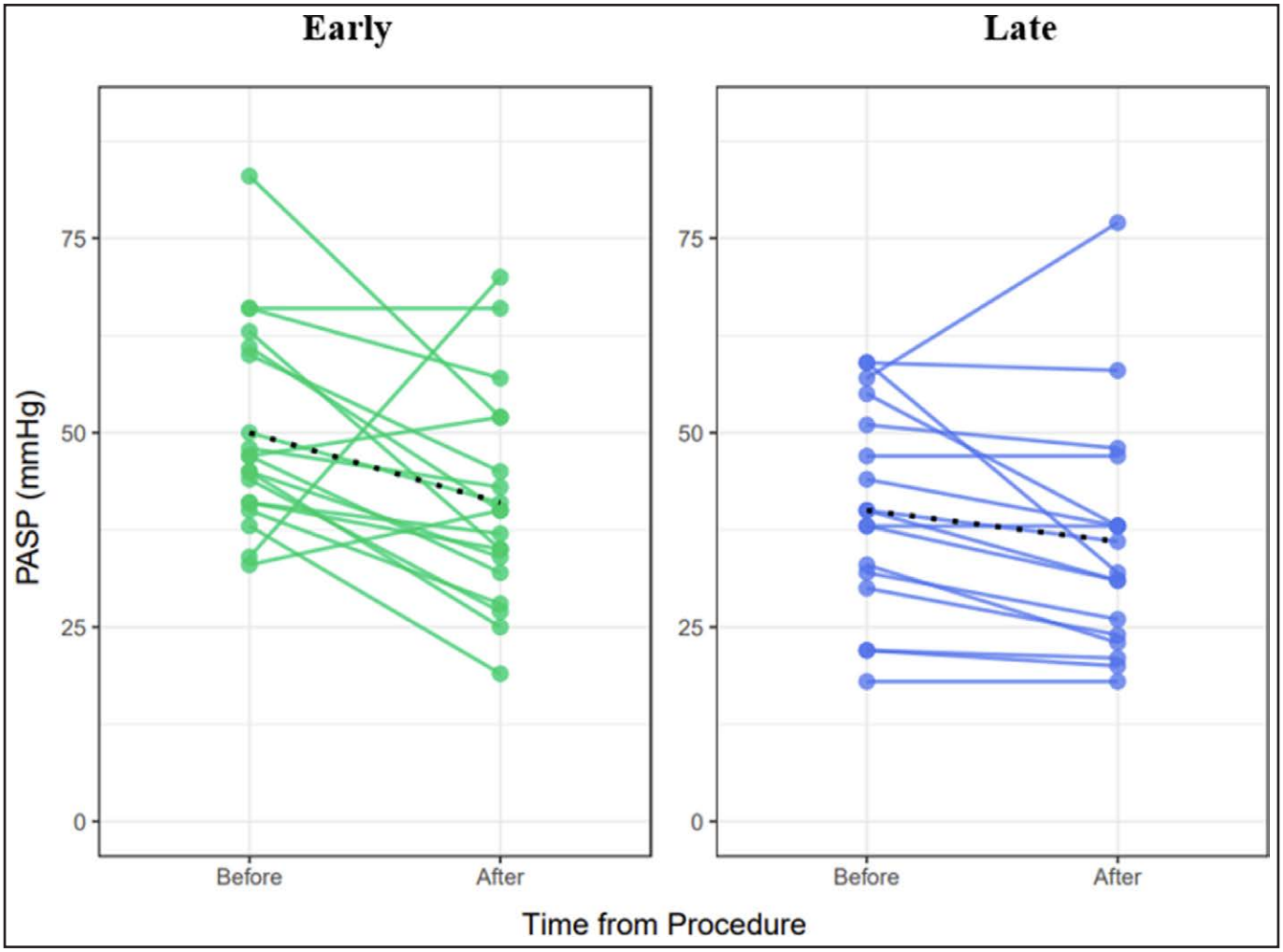

Figure 1. Difference in pulmonary artery systolic pressure (PASP) before and after catheter-directed therapy, as measured by pulmonary artery catheterization. Each *line* represents one patient. Seventeen patients included from the early cohort, and 15 from the late cohort.

patients who died after intervention, seven were in the early cohort and three in the late cohort. Three of these 10 patients were given systemic thrombolysis after cardiac arrest, two in the early cohort and one in the late cohort. None were referred for surgical thrombectomy. There was discussion regarding placing one of the patients in the early cohort on venoarterial extracorporeal membrane oxygenation (VA-ECMO); however, due to prolonged cardiac arrest, cannulas were not placed. There was one additional patient in the early cohort who was placed on VA-ECMO after cardiac arrest during the procedure, who ultimately survived to hospital discharge with good neurologic outcome.

Patients who received earlier intervention were found to have both shorter hospital LOS (4 vs 7 d; $p = 0.038$) and ICU LOS (3 vs 5 d; $p = 0.004$) (**Table 3**). There was no difference in the rate of rehospitalization. At 1–3-month follow-up ($n = 49$), there was no difference in the subjective reporting of chest pain, shortness of breath, or palpitations.

Most patients underwent a bilateral procedure (75%), and there were no differences in laterality between the early and late groups. Patients in the early cohort were more likely to have undergone catheter-directed thrombolysis when compared with the late cohort (76.2% vs 48%; $p = 0.037$), whereas patients in the late cohort were more likely to have undergone mechanical thrombectomy (17.9% vs 48%; $p = 0.037$). Data for types of devices were available for 60 patients total. There were no differences in the type of catheters used between the early and late cohorts. None of the 64 patients required surgical embolectomy after CDT or received systemic thrombolysis prior to CDT. Two patients required both catheter-directed thrombolysis

TABLE 3.
Outcomes

Variables	All	Early Cohort	Late Cohort	*p*
Inhospital mortality	10 (16)	7 (17.9)	3 (12)	0.523
Hospital LOS (d)	5 (3–8)	4 (3–7)	7 (5–9)	***0.038***
ICU LOS (d)	4 (3–5)	3 (2–4)	5 (3–7)	***0.004***
Difference in pulmonary artery systolic pressure after procedure (by catheterization)	*n* = 32 8 (4–18)	*n* = 17 14 (6–20)	*n* = 15 6 (1–10)	***0.022***
Difference in pulmonary artery mean after procedure (by catheterization)	*n* = 24 7 (4–10)	*n* = 13 8 (5.5–14)	*n* = 11 6 (3–9)	0.12
Rehospitalization within 3 mo	5 (9)	2 (6)	3 (14)	0.596
1-mo follow-up symptoms	*n* = 49	*n* = 30	*n* = 19	
Dyspnea	8 (16)	5 (12.8)	3 (12)	0.933
Chest pain	3 (6)	3 (7.7)	0 (0)	0.155
Palpitations	0 (0)	0 (0)	0 (0)	-

LOS = length of stay.
$p < 0.05$ were considered significant and are italicized and boldface.

TABLE 4.
Procedure Characteristics

Variables	All	Early	Late	*p*
Device	*n* = 60	*n* = 39	*n* = 21	
Angiojet	3 (5)	0 (0)	3 (14.3)	0.070
Bashir	6 (10.0)	4 (10.2)	2 (9.5)	
Ekosonic Endovascular System	11 (18.3)	10 (25.6)	1 (4.8)	
Inari FlowTriever	5 (8.3)	3 (7.7)	2 (9.5)	
Inari FlowTriever, Unifuse[a]	2 (3.3)	2 (5.1)	0 (0)	
Indigo Penumbra	9 (15.0)	4 (10.2)	5 (23.8)	
Unifuse	24 (40)	16 (41)	8 (38.1)	
Type of procedure				
Mechanical thrombectomy	19 (29.7)	7 (17.9)	12 (48)	***0.037***
Cather-directed therapy	42 (65.6)	30 (76.9)	12 (48)	
Both	3 (4.7)	2 (5.1)	1 (4)	
Procedure side				
Unilateral–right	12 (18.8)	5 (12.8)	7 (28)	0.106
Unilateral–left	4 (6.3)	4 (10.3)	0 (0)	
Bilateral	48 (75)	30 (76.9)	18 (72)	

[a]Two patients underwent both catheter-directed thrombolysis and thrombectomy during the same procedure.
$p < 0.05$ was considered significant and is italicized and boldface.

and mechanical thrombectomy. Three patients required systemic thrombolysis peri- or postprocedurally due to cardiac arrest, two in the early cohort, and one in the late. In regard to bleeding complications, three patients had major bleeding complications after CDT, including one intracranial hemorrhage. Two of these, including the patient with intracranial hemorrhage, occurred in the early cohort. A full description of the procedural characteristics used can be found in **Table 4**.

DISCUSSION

Management of intermediate-high-risk PE is an evolving field. Although CDT has been actively studied, the effect of timing of CDT on patient outcomes remains unclear. Our study of 64 patients looked specifically at the effect of CDT timing on outcomes of PE. In our analysis, we found that early intervention was associated with shorter hospital and ICU LOS and improved PASP postprocedure, but with no mortality difference at 1–3-month follow-up.

Current guidelines on management of PE are limited in recommendations surrounding CDT and do not provide guidance on optimal timing of these advanced therapies given limited prior data (7). The American College of Chest Physicians has two guideline statements. The first suggests patients with acute PE undergo systemic thrombolytic therapy using a peripheral vein over CDT (weak recommendation, low-certainty evidence). The second focuses on patients who are at high bleeding risk, failed systemic thrombolysis, or are in shock without sufficient time for thrombolytic therapy to work. In an appropriately resourced setting, they suggest catheter-assisted thrombus removal over no such intervention (weak recommendation, low-certainty evidence) (8, 18). The American Society of Hematology remarks that the paucity of data surrounding CDT drives them to recommend systemic thrombolysis over CDT (very low certainty). Although they cite possible differences in locations, they do not discuss the timing of clot or decompensation surrounding the use of therapy. (6) The European Society of Cardiology recommends that percutaneous catheter-directed treatment should be considered when systemic thrombolysis is contraindicated or has failed, but again does not give guidance on timing of CDT (7).

Smaller studies investigating proper timing have suggested potential benefit in some hemodynamic parameters such as cardiac index and pulmonary vascular resistance (17). The ULTIMA trial also demonstrated early intervention with ultrasound-assisted thrombolysis within 4 hours of baseline echocardiography led to improvement in RV/LV ratio, an important predictor of mortality (12). In our study, although we found no difference in mPAP postprocedure, there was a significant improvement in PASP between the early versus late cohorts. Elevated PASP is one of the initial pathophysiologic factors that drive RV dysfunction and, therefore, mortality in acute PE. Additionally, recent studies have suggested that PASP measurements, in conjunction with left ventricular stroke volume, may be an important predictor of mortality in PE (19). Although our study did not demonstrate a definitive mortality benefit given its small size, this finding of improvement in PASP may be an important factor in considering early versus late interventions. At 1–3 months follow-up, however, there was no difference in outcomes, bringing the durability of these benefits into question.

There was a significant decrease in both hospital LOS and ICU LOS in the early cohort, by 3 and 2 days, respectively. These findings reflect those of prior studies demonstrating similar improvements in LOS (16). The severity of PE, as demonstrated by PESI scores, serologic testing, and imaging risk stratification parameters, was also similar across the two groups. This suggests the decrease in LOS may be related to earlier intervention. The simplest explanation is that earlier intervention led to shorter hospital stay simply by expediting therapy for PE patients. The absolute difference in mean time to intervention between the two cohorts was only about 17 hours, however, which on its own does not account for the magnitude of decrease in LOS in our study. Although this difference in LOS between groups is likely multifactorial, earlier intervention may lead to quicker improvement in clinical status compared with later intervention and, therefore, quicker discharge. Patients who wait longer for intervention also may have experienced a clinical decompensation prior to intervention, leading to prolonged hospital courses.

There are limitations to our study. First, the retrospective nature of our study limits the conclusions we can make about the associations in our cohort. Furthermore, our data set is incomplete in regard to postintervention hemodynamic parameters as only some patients underwent pulmonary pressure

measurement. Second, although we utilized a cutoff of 24 hours to distinguish between the early and late groups, it is unclear at what time point patients may benefit. Some studies have defined early intervention as less than 24 hours (17), whereas others have looked at time points ranging from less than 12 hours to 24–48 hours (20). An optimal timing window requires further investigation. Additionally, although our study looked at CDT broadly, a range of potential interventions were performed in our cohort, ranging from catheter-directed thrombolysis and ultrasound-assisted thrombolysis to mechanical thrombectomy. Additionally, there is variability among interventionalists in how to carry out CDT for PE. For example, the range of thrombolytics used during the procedure ranged from 6–36 mg. The effects of these different therapeutic techniques on clinical outcomes are unclear. Finally, although our study did include patients with high-risk intermediate PE based on relatively high PESI scores and signs of RV dysfunction, our data are only from a single center, limiting generalizability.

CONCLUSIONS

The optimal timing window for CDT in the management of PE is unclear. In our study, advanced intervention less than 24 hour from presentation was associated with improvements in hemodynamic parameters and shorter ICU and hospital LOS when compared with interventions greater than 24 hours without differences in outcomes 1–3 months after event.

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Drs. Lehr and Brosnahan were involved in conceptualization, data curation, methodology, project administration, writing of the original draft, as well as review and editing. Drs. Guichet and Garimella were involved in data curation and writing of the original draft. Ms. Krolikowski was involved in formal analysis of the data. Dr. Sista was involved in conceptualization and revision of the article. Dr. Amoroso was involved in revision of the article. The article has been read and approved by all authors for submission.

Dr. Sista serves an unpaid position on the advisory board of Thrombolex as well as the clinical events committee of the Acute Pulmonary Embolism Extraction Trial with the AlphaVac System (APEX-AV) trial for Angiodynamics. The remaining authors have disclosed that they do not have any potential conflicts of interest.

Funding for study provided from the Stony Wold–Herbert Foundation and the New York University Doris Duke Fund. For information regarding this article, E-mail: andrew.lehr@nyulangone.org

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