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Same-Day Discharge Following Outpatient Balloon Pulmonary Angioplasty: A Single-Center Experience

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ABSTRACT

Overnight inpatient monitoring is common following balloon pulmonary angioplasty (BPA) for chronic thromboembolic pulmonary hypertension (CTEPH). We describe our institutional experience in same-day discharge (SDD) after BPA. Across 78 BPA sessions, there were only 2 (2.6%) admissions for hemoptysis with no reperfusion lung injury or deaths at 30 days.

Balloon pulmonary angioplasty (BPA) is recommended in some patients with inoperable or persistent chronic thromboembolic pulmonary hypertension (CTEPH [1–3]. BPA-related adverse events occur in 4%–36% of cases and include hemoptysis, reperfusion lung injury, and rarely death [2–6]. BPA is therefore performed at experienced centers, and, in accordance with expert consensus, overnight in-hospital monitoring is common [1, 4, 7, 8]. However, new data suggest that < 24-h observation may be safe [9]. We describe here our experience since instituting same-day discharge (SDD) following BPA in 2020.

1 | Methods

1.1 | Patient Selection

All referred patients are established with a pulmonologist or heart failure cardiologist specializing in CTEPH. Comprehensive evaluation includes transthoracic echocardiogram, serologic testing, ventilation-perfusion scan, computed tomography (CT) angiography, and right heart catheterization with pulmonary angiography. Patients with at least World Health Organization (WHO) functional class II symptoms are discussed in a multidisciplinary committee for pulmonary thromboendarterectomy (PTE). If felt to be a poor surgical candidate, BPA evaluation is conducted jointly by the CTEPH provider and interventional cardiology concurrently with vasodilator therapy optimization.

1.2 | Procedural Characteristics

Patients are instructed to hold their chronic anticoagulation therapy as follows: warfarin, 5 days preoperatively; direct oral anticoagulants, 2 days; low molecular weight heparin, same-day. Moderate sedation is administered sparingly to ensure the patient can perform inspiratory breath holds for optimal angiography of the middle and lower lobar branches [10]. Common femoral venous access is obtained under ultrasound guidance using a 5-Fr Micropuncture kit (Cook Medical, Bloomington, IN) and then upsized to a 6- or 7-Fr sheath. Systemic anticoagulation is achieved with 5000 units of intravenous unfractionated heparin. Segmental arteries are cannulated using coronary guide catheters with guide extension support if needed. Digital subtraction angiography is utilized to optimize

visualization of stenotic lesions and pulmonary venous return. Intravascular ultrasound is used only for angiographically complex lesions.

Semi-compliant coronary balloons are delivered over a 0.014-inch workhorse guidewire to the lesion. We identify angiographically stenotic lesions supplying areas with poor pulmonary venous return. Low-pressure (4–8 atm), prolonged (30-s) inflations are performed using undersized balloons to minimize risk of vessel injury. Treatment efficacy is marked by brisk pulmonary venous return [11]. We perform unilateral revascularization each session to permit contralateral mainstem intubation in case of massive hemoptysis and limit treatments to two to four segments to reduce risk of reperfusion injury [12]. Contrast (mL) and radiation limits are three times estimated glomerular filtration rate (eGFR, mL/min/1.73 m^2) and 2 Gy, respectively.

1.3 | Post-BPA Management

Venous access is removed, and hemostasis is achieved with manual compression alone. The patient is transferred to the post-imaging recovery unit with telemetry monitoring. Postoperative anticoagulation with intravenous unfractionated heparin is immediately initiated at a fixed dose of 18 units/kg and continued for 6 h. Strict bedrest is enforced for 2 h. Routine postoperative chest imaging is not obtained. After completing unfractionated heparin, patients without new signs or symptoms concerning for complication are discharged. Outpatient anticoagulation is resumed the same evening. Repeat BPA is scheduled as soon as 2 weeks postprocedure depending on lesion burden, renal function, and patient preference.

1.4 | Data Collection

This retrospective analysis was approved by the University of Texas Southwestern Medical Center institutional review board with waiver of consent. SDD was instituted in June 2020, marking the start of our study period. Posttreatment hemodynamics are reported from the first catheterization following completion of all treatments or, if unavailable, from the final BPA session. Because thermodilution cardiac outputs were not routinely obtained, indirect Fick measurements were used. WHO functional class was determined from clinic documentation.

1.5 | Statistical Analysis

Categorical data are presented as n (%). Continuous variables are presented as mean ± standard deviation (SD) if normally distributed and median (interquartile range, IQR) if not, as determined by the Shapiro-Wilk test. Pre- and post-BPA hemodynamic data were compared using the Wilcoxon matched-pairs test. Statistical analyses were performed in Stata/IC 15.1 (StataCorp, College Station, TX). All tests were two-sided. A p-value < 0.05 was considered significant.

2 | Results

2.1 | Patient Characteristics

Between June 4, 2020, and October 31, 2023, 29 unique patients underwent 79 separate BPA procedures. SDD was intended in all but 1 patient, who underwent urgent BPA while inpatient and was excluded. The mean age was 64.6 ± 14.6 years, and 16 (57%) were women (Table 1). Disease burden was significant, with 22 (79%) reporting WHO functional class III–IV symptoms and 11 (41%) requiring supplemental oxygen. Twenty (71%) patients were inoperable due to distal lesions or prohibitive surgical risk.

2.2 | BPA Characteristics

Patients underwent 2.8 ± 1.4 (maximum 6) BPA sessions. Balloon diameters typically ranged from 2.0 to 4.0 mm, although two sessions utilized 5.0-mm balloons for more proximal lesions. Median radiation and mean contrast exposure were 291 mGy (IQR 186, 444) and 167 ± 51 mL, respectively, over a median fluoroscopy time of 25.6 min (IQR 21.4, 31.2).

2.3 | Hemodynamic Outcomes

The maximum pre-BPA pulmonary vascular resistance (PVR) was 12.9 Wood units. Seven (25%) patients had a mean pulmonary artery pressure (PAP) ≥ 40 mmHg, and 3 (10.7%) had a PVR ≥ 7 Wood units. Significant decreases were seen in mean PAP (32 [IQR 27, 40] to 28 [IQR 23, 33] mmHg, $p = 0.002$) and PVR (4.2 [IQR 2.8, 5.7] to 2.7 [IQR 2.1, 4.1] Wood units, $p = 0.004$). Right atrial, pulmonary capillary wedge pressures, and cardiac indices (3.1 [IQR 2.7, 3.6] to 3.5 [IQR 2.8, 3.8] L/min/m^2, $p = 0.151$) were unchanged.

2.4 | Complications

Complications occurred in 2 (2.6%) procedures requiring unplanned admission. One patient suffered massive hemoptysis due to vessel perforation requiring selective intubation and successful balloon tamponade. The patient was extubated within 24 h and discharged on hospital day 3. A second patient experienced approximately 15 mL of self-resolving, intraoperative hemoptysis with no angiographic evidence of vessel injury. The patient was admitted overnight for further observation. No episodes of reperfusion lung injury were observed. There were no procedure-related hospital readmissions or deaths within 30 days.

3 | Discussion

We present the first series of a true outpatient approach to BPA with SDD within 6 h postprocedure. In comparison, the shortest monitoring strategy previously described entailed 23-h monitoring in a postprocedure unit [9]. We observed complication rates similar to or lower than comparable single-center studies

TABLE 1 | Baseline patient characteristics.

	Participants ($n = 28$)
Age (years)	64.6 ± 14.6
Female	16 (57.1)
White race	26 (92.9)
Body mass index (kg/m^2)	28.4 (25.4, 33.2)
Hypertension	20 (71.4)
Coronary artery disease	3 (10.7)
Chronic obstructive pulmonary disease	5 (17.9)
Obstructive sleep apnea	10 (35.7)
Atrial fibrillation	5 (17.9)
Left heart diastolic failure	3 (10.7)
LVEF (%)	60.4 ± 8.9
LVEF < 50%	2 (7.1)
eGFR (mL/min/1.73 m^2)	59.3 ± 14.4
eGFR < 60 mL/min/1.73 m^2	14 (50.0)
Chronic hypoxic respiratory failure	11 (40.7)
Right ventricular systolic dysfunction ≥ moderate	10 (37.0)
Tricuspid regurgitation ≥ moderate	8 (30.8)
Anticoagulation	
Warfarin	5 (17.9)
Rivaroxaban	5 (17.9)
Apixaban	17 (60.7)
Dalteparin	1 (3.6)
6-min walk distance (m)	337.1 ± 121.0
World Health Organization functional class	
II	6 (21.4)
III	19 (67.9)
IV	3 (10.7)
Prior pulmonary thromboendarterectomy	6 (21.4)
Inoperable	20 (71.4)
Medication regimen	
Phosphodiesterase-5 inhibitor	4 (14.3)
Riociguat	16 (57.1)
Endothelin receptor antagonist	8 (28.6)
Prostacyclin	1 (3.6)
Pulmonary vasodilators	
0	9 (32.1)
1	10 (35.7)
2	8 (28.6)
3	1 (3.6)

Note: Continuous data are presented as mean ± SD if normally distributed or median (IQR). Categorical data are presented as *n* (%).
Abbreviations: eGFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction.

despite reduced postprocedure observation time [4, 6, 7, 9]. Intended SDD was achieved in 97.4% of cases, including first-time BPA with mean PAP ≥ 40 mmHg. There were no procedure-related readmissions or deaths within 30 days. The complications that did occur were all immediately apparent intraoperatively.

The safety of our approach is multifactorial. The importance of an experienced, multidisciplinary team in patient selection and optimization is well recognized [1, 13]. BPA techniques have undergone continuous refinement, and we have incorporated such considerations as undersizing balloons, low-pressure inflations, and limiting lesions treated per procedure. We also preferentially treat web and ring lesions over chronic occlusive disease, which is associated with higher complication risk [14, 15]. Operator experience is also critical, as seen from historic decreases in complications over time at other institutions [16, 17]. We concur with prior studies that abbreviated post-procedure monitoring strategies should not be immediately implemented at centers without first building sufficient experience in BPA [9].

Reperfusion lung injury is an important complication of both PTE and BPA and is characterized by acute radiographic pulmonary edema and hypoxia [11, 13]. However, subclinical reperfusion injury may be underrecognized, with chest CT demonstrating subclinical parenchymal densities post-BPA in 57% of procedures in one study [17]. Importantly, no patients in our cohort developed new or worsening postprocedure hypoxia. Clinically significant reperfusion injury was therefore avoided.

SDD has several potential advantages. At the institutional level, SDD can help optimize inpatient resource utilization. Moreover, as an accredited PH Care Center, we receive multiple BPA referrals from neighboring states. SDD may facilitate access to treatment while reducing patient cost and cumulative travel time without apparent harm.

This study is limited by its retrospective design. Many patients did not have 6-min walk distance remeasured, so functional improvement could not be assessed. Observed decreases in mean PAP and PVR were lower than prior studies [18]. This likely reflects the non-standardized timing of post-BPA hemodynamic assessments, most of which were actually performed immediately preceding the final treatment session. Moreover, sample size precluded multivariable analyses adjusting for pulmonary vasodilator therapy. However, the objective of this study was to assess SDD safety, not BPA efficacy, and vasodilator therapy was optimized before proceeding with BPA.

In conclusion, SDD following BPA was successfully implemented at our large academic center without an adverse safety signal. As cumulative experience in BPA continues to grow, prospective, multicenter data will be invaluable in more definitively evaluating the safety of SDD at select, high-volume centers.

Author Contributions

Amit Saha: writing—original draft, visualization, validation (lead), software (lead), methodology (lead), formal analysis (lead), investigation

(supporting), data curation (lead). **Jeffrey P. Chidester:** writing—review and editing (equal), investigation (supporting), validation (supporting), methodology (supporting), data curation (supporting), software (supporting), formal analysis (supporting). **Hurst M. Hall:** writing—review and editing (equal), supervision (supporting), project administration (supporting). **Trushil Shah:** writing—review and editing (equal), supervision (supporting). **Kelly M. Chin:** writing—review and editing (equal), supervision (supporting). **Sonja D. Bartolome:** writing—review and editing (equal), supervision (supporting). **Thomas P. Koshy:** writing—review and editing (equal), validation (supporting), supervision (lead), resources (lead), methodology (supporting), project administration (lead), conceptualization.

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Ethics Statement

This retrospective analysis was approved by the University of Texas Southwestern Medical Center institutional review board with waiver of consent.

Conflicts of Interest

The authors declare no conflicts of interest.

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