Cardiogenic Shock in Thyroid Storm: A Biventricular Impella (Bi-Pella) Approach

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July 21, 2020

Abstract

A 31 year old man with a past medical history of hyperthyroidism presented to the hospital in thyroid storm and cardiogenic shock. He was found to be in severe biventricular failure and with the use of biventricular impella support had a full recovery without significant comorbidity.

History of Presentation:

A 31-year-old man with a history of hyperthyroidism presented with five days of lower extremity swelling and shortness of breath. He had been on methimazole as an outpatient for several years, but had not taken it for several weeks due to loss of his insurance. On admission he had an irregular heart rhythm with rates up to 200bpm and a blood pressure of 110/70. An EKG was done showing rapid atrial fibrillation.

Laboratory data was consistent with thyroid storm. He was initiated on propranolol, PTU and hydrocortisone with admission to the ICU. Heart rates continued to be elevated and he was started on an esmolol drip. With rate control he became confused, lethargic, cold and hypotensive.

A bedside echocardiogram was performed showing 4 chamber dilatation and bi-ventricular failure with an ejection fraction of 5%. Laboratory data showed developing shock (table 1). He was started on norepinephrine and taken to the cath lab for invasive hemodynamic evaluation.

2) Case Series:

Management/Interventions:

A right heart catheterization was performed (figure I, table II). The initial pulmonary artery pulsatility index (PAPi) was 0.535 and his cardiac power output was 0.47 consistent with severe biventricular failure. An impella CP was placed via the right femoral artery. He was monitored in the cath lab for 30 minutes and repeat right heart catheterization was performed (figure II):

Repeat PAPi was 0.73 demonstrating minimal improvement in RV function with LV offloading. The RA:PCWP was 1.04 which was unchanged from the initial measurement prior to impella CP placement and the RV stroke work index (RVSWI) improved modestly from 3.2 to 4.5, but was still significantly reduced, indicative of severe RV dysfunction. At that point an RP impella was placed and repeat hemodynamics showed improved biventricular function (figure III, table II) with an improved PAPi of 1.04 and an RA: PCWP of 0.88. He was then transferred to the CCU for further management.

In the CCU, he was placed on PTU, hydrocortisone, cholestyramine, lugol's solution, and propranolol for management of his hyperthyroidism and rate control.

Over the course of 3 days his lactate, renal and hepatic function normalized. He developed mild hemolysis, hematuria, and thrombocytopenia, all of which resolved shortly after device weaning (table I).

On hospital day 3 echocardiograhy showed modest improvement in the right ventricular function prompting removal of the RP impella. He was aggressively diuresed and on hospital day 4 the impella CP was weaned off and removed.

Diuresis and uptitration of guideline directed medical therapy for heart failure were continued over several days. On hospital day 8 he underwent successful TEE/DCCV. Prior to discharge repeat echocardiogram showed marked improvement with an ejection fraction of 35% and normal right ventricular function by TAPSE. On discharge he was taking metoprolol succinate, lisinopril, furosemide, apixaban, and methimazole.

Clinical Follow up: Three months later he was asymptomatic and had an echocardiogram that showed normalized cardiac function.

3) Discussion:

In hyperthyroidism the increased serum concentration of T3 up-regulates several cardiac-specific genes enhancing contractility, improving cardiac relaxation, lowering SVR, increasing blood volume, and elevating baseline heart rate (1). In the setting of prolonged, severe hyperthyroidism, sustained tachycardia impairs left ventricular contractility and increases atrial-filling pressures leading to heart failure. Ultimately, an untreated high-output state may lead to ventricular dilatation and persistent tachycardia resulting in cardiogenic shock (2). 6% of patients with thyrotoxicosis develop symptoms of heart failure, but less than 1% develop a dilated cardiomyopathy and impaired systolic function (3). Of these patients with impaired systolic function cardiogenic shock is rare, but with mortality rates that approach 30% (4).

The above case illustrates how rapid recognition of the severity of illness accompanied by aggressive management with mechanical circulatory support can result in a good outcome and avoid serious comorbidities. On presentation our patient appeared relatively stable, which is likely due to his young age and ability to significantly increase his SVR despite a thyrotoxic state. However when his SVR dropped, his poor cardiac output led to rapid clinical decline and laboratory evidence of multi-organ hypo-perfusion. While it is not possible to delineate whether his ventricular dysfunction was due to prolonged tachyarrhythmia or thyrotoxicosis, this difference did not affect management as he required support while the underlying disorder was treated.

The combination of his deteriorating clinical status, laboratory data and the abnormal echocardiogram, led us to proceed with invasive hemodynamics. In the lab, there was clear evidence of severely impaired left ventricular function by CPO. Several hemodynamic measurements including PAPi, RA:PCWP ratio, and RVSWI were indicative of severe right ventricular dysfunction (table II). Previous studies to evaluate the most effective management of bi-ventricular failure have yielded mixed results (5). Given the limited options for medical therapy, the use of acute mechanical circulatory support has grown as Impella, TandemHeart, and VA-ECMO have been used with increased frequency over the last 15 years (6).

The decision to place an impella CP was made based on what we identified as a reversible cause of cardiogenic shock. The use of impella over ECMO was based on the concept of ventricular unloading to allow the ventricle time to recover as the underlying cause of heart failure was treated. Following placement of the impella CP the patient was monitored in the cath lab to see if the right ventricular function improved with off-loading of the left ventricle. This resulted in a slight improvement of his PAPi and RVSWI, however both were still severely reduced and his RA:PCWP ratio was unchanged and severely elevated. Prior studies have indicated that a reduced RVSWI is an independent predictor for biventricular support requirement in patient undergoing LVAD placement (7) and that an increased RA:PCWP ratio is associated with reduced RV function and adverse outcomes in advanced heart failure (8). Given this previous data, combined with hemodynamic findings and minimal clinical improvement, we determined that RV support, in addition to LV support, was necessary to allow for treatment of his underlying disorder. Prior evidence indicates that biventricular impella (Bi-Pella) is a feasible approach that improves cardiac output and may be associated with improved outcomes in patients with bi-ventricular failure (9). Thus following the Recover Right Trial, an RP impella was placed (10) which showed an improvement in his PAPi and RA:PCWP ratio, (table II), and more importantly a significant improvement in his mental status.

What followed was rapid improvement in his overall clinical status. Multi-organ failure was reversed within 48 hours of mechanical support and the need for other advanced supportive care was avoided. By 48 hours there was significant improvement in bi-ventricular function. With resolution of clinical cardiogenic shock and evidence of hemolysis (table I) the RP impella was discontinued. Following this the hemolysis improved and the impella CP was discontinued shortly thereafter.

This case illustrates that the use of Bi-Pella may have a significant impact on mortality in patients with acute, reversible causes of cardiogenic shock. The short-term use of the support device likely limited our device related complications to mild hemolysis and thrombocytopenia. In this situation the benefits of left and right ventricular offloading significantly outweighed device complications. This leads us to believe that Bi-Pella has a "sweet spot" for duration of support where a mortality benefit can be gleaned. Further studies should be done to determine the balance between duration of support and degree of ventricular recovery that will have the greatest benefit in patient care.

One limitation in our case is that for our cardiac output we utilized the Fick equation with nomogram-derived estimates of O2 consumption. In a thyrotoxic state this may underestimate true O2 consumption and lead to an underestimation of cardiac output and an overestimation of SVR. However, the patient had severe tricuspid regurgitation by echocardiogram and in his clinically low-flow state thermodilution likely would yield similar limitations. Second, given his degree of illness, full hemodynamics were not performed at every stage, but only as necessary to direct management.

4) Conclusion:

Our case demonstrates that rapid diagnosis and aggressive mechanical intervention in acute, reversible cardiogenic shock with Bi-Pella can improve clinical outcomes without significant co-morbidity. Further studies are needed to determine the ideal balance between ventricular offloading and duration of support so as to derive a mortality benefit with this device.

Author Contribution

Evan Caruso: Background data collection and analysis of hemodynamics. Primary author of manuscript development.

Elias Iliadis: Primary investigator, physician who managed patient and performed cardiac catheterization. Provided significant authorship in the development of manuscript.

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Figure I: Initial Right Heart Hemodynamics prior to impella insertion

Demonstrates the right atrial, right ventricular, pulmonary artery, and left ventricular waveforms prior to impella insertion. This shows a very narrow PA pulse pressure, significantly elevated right atrial pressure, and elevated RA:PCWP ratio demonstrating the severity of RV failure.

Figure II: Right Heart hemodynamics on Impella CP

Repeat waveforms of the right atrium and pulmonary artery after impella CP placement. The elevated right-sided filling pressures and a narrow PA pulse pressure indicate minimal improvement in RV function after 30 minutes of LV unloading, consistent with intrinsic RV failure.

Figure III: RA and PA Waveforms following placement of RP impella

Repeat waveforms of the right atrium and pulmonary artery demonstrate widening of the PA pulse pressure with brisk down-stroke, and improved RA pressures consistent with improved RV output.

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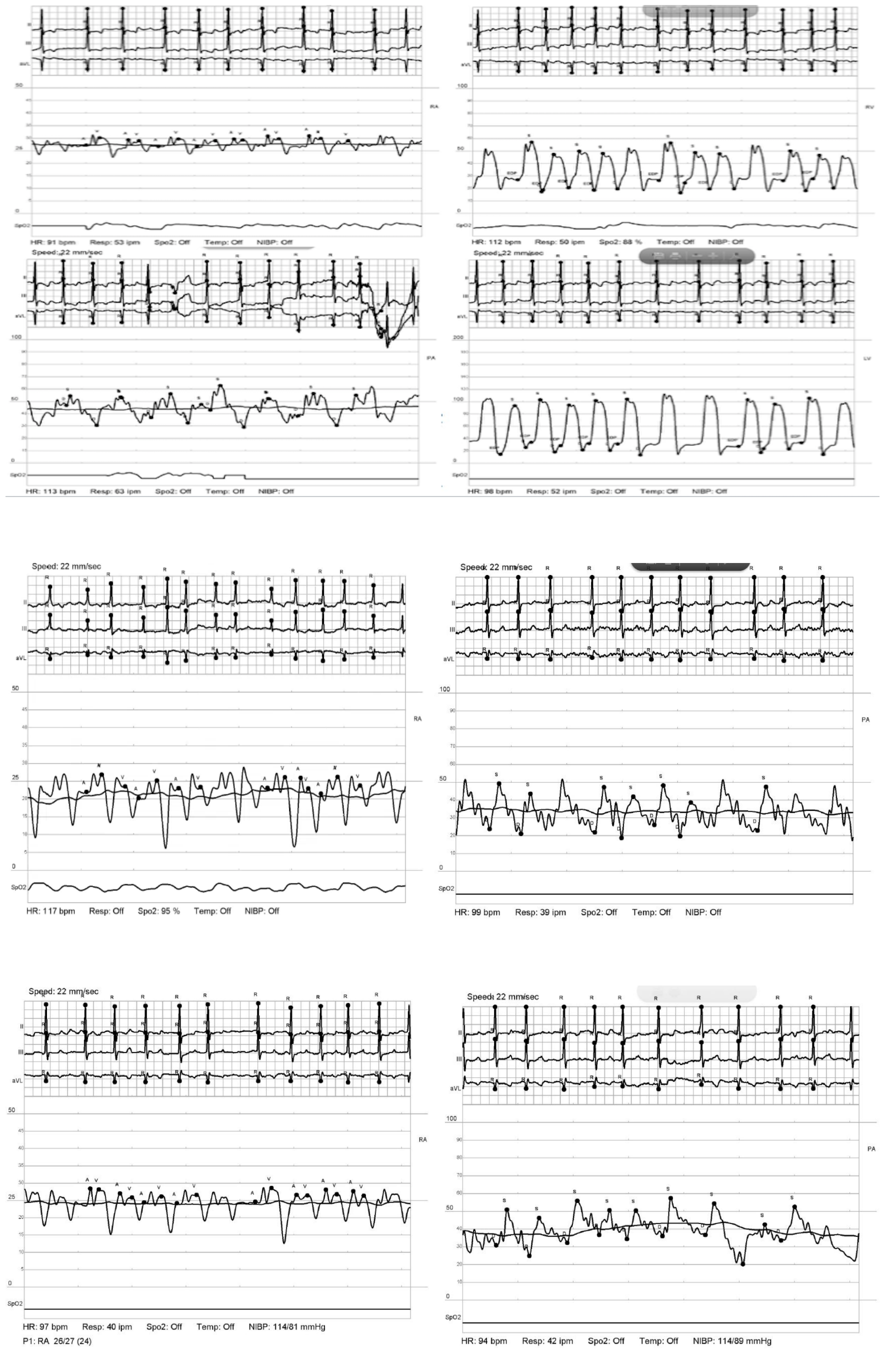
`Table II.docx` available at https://authorea.com/users/344917/articles/471272-cardiogenic-shock-in-thyroid-storm-a-biventricular-impella-bi-pella-approach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RV
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PA
HR: 113 bpm Resp: 63 ipm Spo2: Off Temp: Off NIBP: Off
Speed: 22 mm/sec
LV
HR: 98 bpm Resp: 52 ipm Spo2: Off Temp: Off NIBP: Off
Speed: 22 mm/sec
RA
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Speed: 22 mm/sec
PA
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Speed: 22 mm/sec
RA
HR: 97 bpm Resp: 40 ipm Spo2: Off Temp: Off NIBP: 114/81 mmHg
P1: RA 26/27 (24)
Speed: 22 mm/sec
PA
HR: 94 bpm Resp: 42 ipm Spo2: Off Temp: Off NIBP: 114/89 mmHg