



Cath Lab Digest

CASE REPORT

Enhanced Augmentation of Cardiac Output for Different Counterpulsation Modes Using a New Intra-Aortic Balloon and Catheter

Catalin Boiangiu, MD, Fellow, Division of Cardiology, Newark Beth Israel Medical Center, Newark, NJ; and Marc Cohen, MD, Chief, Division of Cardiology; Director, Cardiology Fellowship, Newark Beth Israel Medical Center, Newark, New Jersey and Professor of Medicine, Mount Sinai School of Medicine, New York, New York

Abstract

We report the enhanced augmentation of cardiac output in a 60-year-old man who underwent percutaneous coronary intervention with drug-eluting stent implantation for a large anteroseptal ST-segment-elevation myocardial infarction. Because of persistent systemic hypotension during the procedure, a 50-cc, 8-Fr Mega™ intra-aortic balloon was inserted, used for 24 hours, and removed without complications. The use of this new balloon — with larger blood volume displacement but smaller caliber at the insertion site — significantly increased cardiac output in 1:1, 1:2, and 1:3 assist modes, by more than 15%, 9%, and 4%, respectively. These findings exceed the average augmentations reported for smaller-volume balloon catheters.

Introduction

The intra-aortic balloon pump (IABP) is the single most used cardiac-assist device for patients with impaired ventricular function, providing hemodynamic support in

patients with cardiogenic shock of various etiologies and those undergoing high-risk cardiac and noncardiac surgery. Balloon counterpulsation is also beneficial in refractory unstable angina, intractable ischemia-driven

ventricular arrhythmias, during percutaneous coronary interventions in high-risk patients, and in the setting of acute myocardial infarction (MI). Assistance of left ventricular function is achieved by augmenting coronary blood flow and decreasing myocardial oxygen consumption through reduction in ventricular afterload.¹ IAB counterpulsation also appears to improve diastolic function of the left ventricle as measured by changes in the transmitral filling pattern.²

The benefits of balloon counterpulsation also depend on several patient-specific factors. In particular, the balloon-to-aorta cross-sectional area ratio, aortic wall compliance,³ heart rate, and peripheral vascular resistance seem to significantly affect the efficacy of counterpulsation. The newly developed, improved, larger-volume balloon catheter (the Mega™ 50-cc catheter, Maquet Cardiovascular LLC, Mahwah, NJ) offers 25% more blood volume displacement with counterpulsation, with the added benefit of reducing vascular complications by using a smaller insertion point (an 8-Fr shaft).

Augmentation in cardiac output can be demonstrated using various methods. An excellent noninvasive way to assess the beneficial effect of counterpulsation is by Doppler echocardiography. In essence, pulsatile flow through the aortic valve generates variable individual velocities during ejection. The sum of these velocities is called the time-velocity integral (TVI) and equals the area under the Doppler velocity

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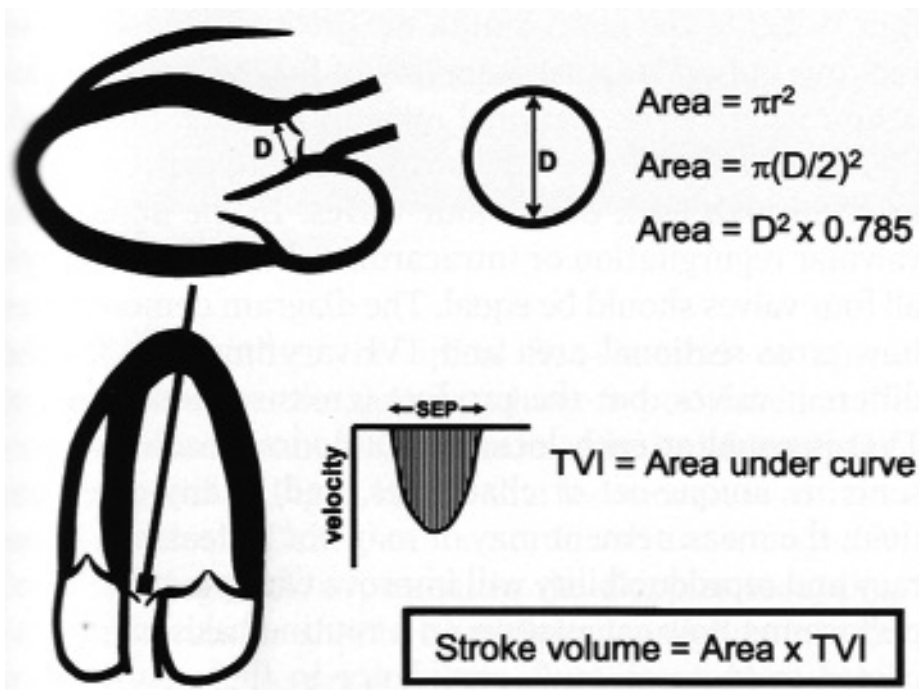


Figure 1. Schematic depiction of the method for estimating transvalvular flow using Doppler echocardiography. D = diameter; TVI = time-velocity integral. Reprinted from Armstrong et al.,⁴ with permission.

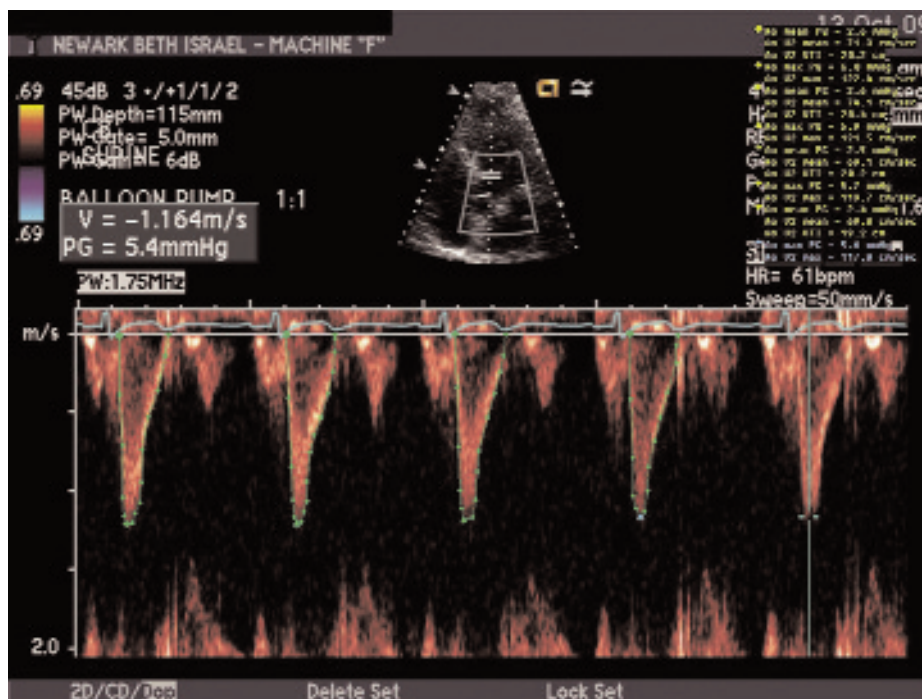


Figure 2. Pulsed-wave-mode Doppler showing time-velocity integral of the flow across the aortic valve in 1:1 assist mode (measurements depicted).

profile (Figure 1).⁴ The product of TVI and cross-sectional area of the aortic annulus equals the stroke volume (in the absence of shunts or regurgitation). We used the TVI

analysis to assess augmentation in cardiac output associated with the new balloon catheter in various assist modes.

Case Presentation

A 60-year-old man presented to the emergency room of a satellite hospital with typical retrosternal chest pain and was diagnosed with a large anteroseptal ST-elevation MI. He was given aspirin 325 mg and clopidogrel 600 mg orally, as well as intravenous heparin. Because the hospital lacked the capability to perform primary percutaneous coronary intervention (PCI), thrombolysis with intravenous tissue plasminogen activator was attempted, but without success. The patient continued to have chest pain and developed ventricular tachycardia requiring electrical cardioversion and infusion of antiarrhythmic drugs. He was transferred to our hospital for emergency/rescue PCI.

In the catheterization laboratory, he was found to have a long 90% stenosis of the proximal left anterior descending artery (LAD) and 95% stenosis of the mid-segment of the LAD. PCI was successfully performed with deployment of drug-eluting stents (2.75 × 23 mm and 2.75 × 12 mm, respectively) and restoration of normal TIMI (Thrombolysis In Myocardial Infarction) grade 3 (normal) flow through the LAD. Because of persistent systemic hypotension during PCI, a 50-cc intra-aortic balloon catheter (Mega) was inserted for hemodynamic support. The patient had a good post-procedural clinical course, remaining asymptomatic. After 24 hours, he was weaned from intra-aortic counterpulsation and the balloon was removed without complication.

Doppler echocardiography was performed during counterpulsation, with measurements of the aortic annulus and TVI in different assist modes. The aortic annulus diameter was 2.34 cm. The measurements for TVI were performed both in continuous-wave and pulsed-wave modes for consistency and to demonstrate the absence of additional supra- or subaortic pressure gradients. Pulse-wave-measured TVI values were used for these calculations.

Table 1. Measurements and Calculations for Different Assist Modes

Assist mode	Time-velocity integral (cm)	Stroke volume (mL)	Cardiac output (L/min)
1:1	19.92	85.66	5.14
1:2	18.92	81.36	4.88
1:3	18.08	77.74	4.66

Table 2. Calculated Relative Augmentation of Cardiac Output for Various Assist Modes

Assist mode	Time-velocity integral (cm)	Cardiac output (L/min)	Relative augmentation (%)
1:1	19.92	5.14	15.25
1:2	18.92	4.88	9.42
1:3	18.08	4.66	4.48
“Baseline”	17.30	4.46	Reference

Pulsed- and continuous-wave Doppler tracings were recorded after ≥ 5 minutes had elapsed in each assist mode. Standby mode was not considered for determinations because of the specific clinical circumstances. Measurements of TVI were performed for 5 consecutive cardiac cycles and averaged according to the current American Society of Echocardiography (ASE) recommendations.⁵

For the 1:1 assist mode, the average TVI (pulsed-wave mode) was determined to be 19.92 cm (Figure 2). For the 1:2 and 1:3 assist modes, the average measured TVIs (pulsed-wave mode) were 18.92 cm and 18.08 cm, respectively (Figures 3 and 4). The calculated aortic annulus area ($0.785 \times D^2$, where D = diameter) was 4.3 cm².

We performed the calculations described above for stroke volume and cardiac output (in L/min) considering an average heart rate of 60 beats/minute (61, 61, and 58, respectively, for the 3 measurements). The results are depicted in Table 1. For clinical reasons, no measurements were performed in standby mode (no counterpulsation).

Use of IABP in the 1:1 assist mode conferred an additional 10.2% increase in stroke volume and cardiac output relative to the 1:3 mode, whereas the 1:2 mode yielded a 4.6% increase compared with the 1:3 mode.

To estimate the absolute increase in cardiac output using IABP in various assist modes, we inferred a “baseline” stroke volume, using the TVI for the cycle preceding the assisted one in

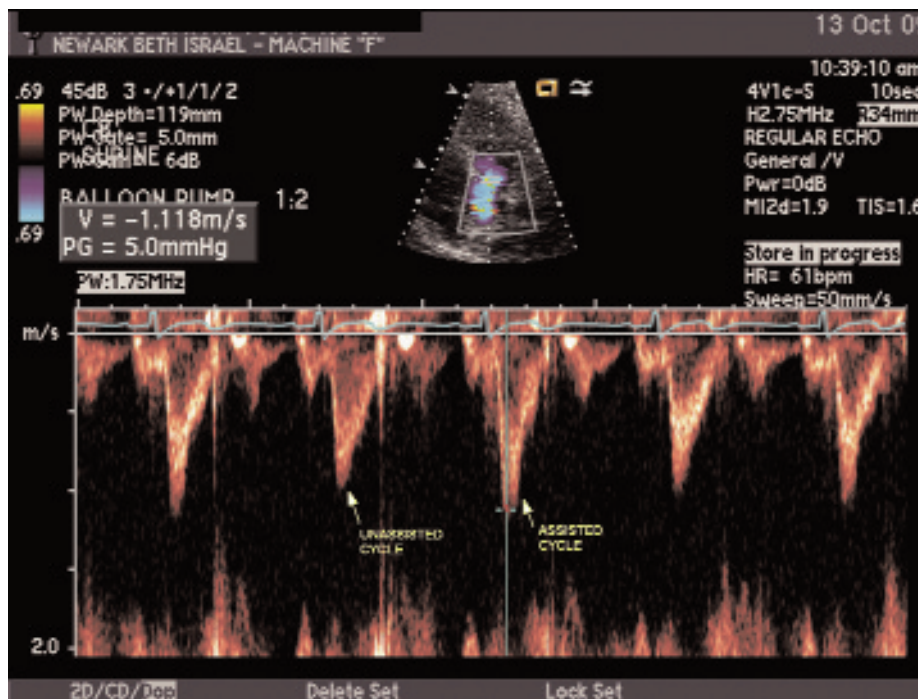


Figure 3. Pulsed-wave-mode Doppler showing time-velocity integral of the flow across the aortic valve in 1:2 assist mode.

the 1:3 mode (green arrow in Figure 4). This value is the lowest in all observed modes and most closely estimates a “baseline,” unassisted cycle. Using this surrogate value (TVI = 17.3 cm) and repeating the calculations, we obtained a “baseline” stroke volume and cardiac output of 74.4 mL and 4.46 L/min, respectively (heart rate, 60 beats/minute). We used these reference values to evaluate the relative augmentation with balloon counterpulsation in all three assist modes (Table 2).

Discussion

Using a surrogate baseline estimate, we calculated augmentations of

at least 15%, 9%, and 4% in the 1:1, 1:2, and 1:3 modes, respectively. These findings, which exceed the average augmentations reported in the literature using smaller-volume balloons in patients with the same characteristics as in our case (unpublished data),⁶ may be representative for the 50-cc balloon.

The explanation for these findings may be more complex than it first appears. Along with the simple increase in the volume of blood displaced during inflation, an additional benefit can be provided by the larger diameter of the inflated balloon (17.4 mm), which reduces the cross-sectional aorta-to-balloon ratio (average normal

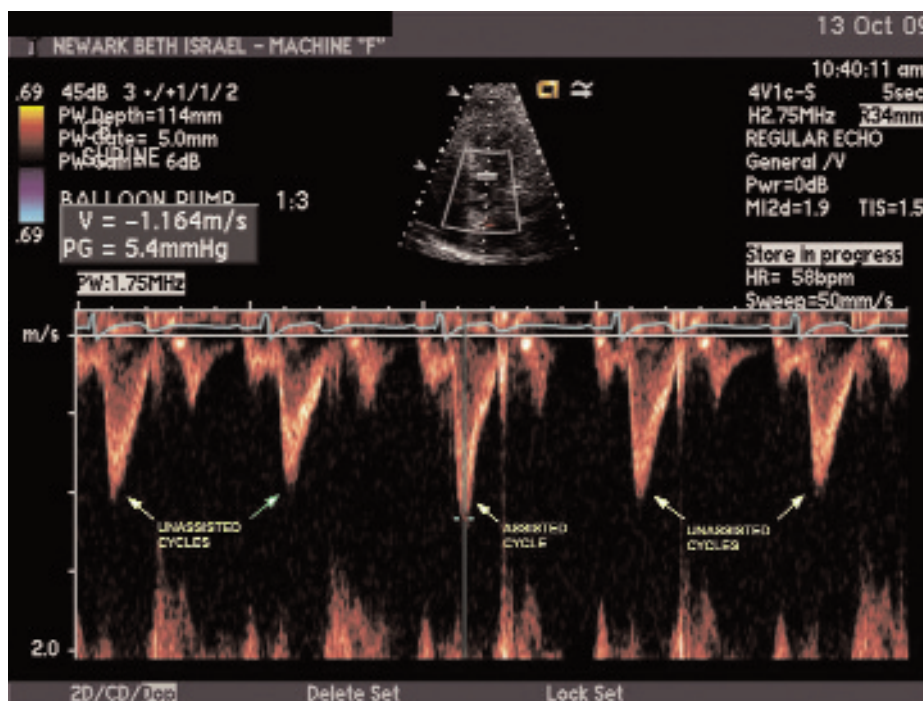


Figure 4. Pulsed-wave-mode Doppler showing time-velocity integral of the flow across the aortic valve in 1:3 assist mode. Green arrow represents the TVI for the cycle immediately preceding the assisted one.

descending aorta diameter at diaphragm level, 24.3 ± 3.5 mm, slightly larger in men) compared with smaller-volume balloon catheters (15-mm inflated diameter for the 40-cc balloon, for example), thus improving augmentation. A “tighter” balloon-to-aorta fit can presumably also modify the propagation of the pulse wave generated through the aortic wall and possibly improve distal perfusion. Further research is needed to clarify these hemodynamic aspects.

An additional benefit of this counterpulsation balloon is the use of a lower-caliber shaft (8-Fr), which can translate into a true reduction in the incidence of vascular complications commonly related to IABP use.⁷

In conclusion, the use of a larger-volume, improved, potentially safer counterpulsation balloon appears to provide enhanced cardiac augmentation. The mechanisms and implications of this effect warrant further research. ■

The authors can be contacted at cboiang@yahoo.com

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