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Case Report

Method of Recording Reverse and Delayed Turbulent Blood Flow in an Obese Pediatric Patient with Congenital Aortic Stenosis

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Abstract

Introduction: The combination of pediatric obesity and congenital aortic stenosis (AS) may be clinically challenging. Many obese patients have technically difficult echocardiograms with poor acoustic windows. However, the suprasternal notch (SSN) may provide adequate images in these patients. By combining echocardiography with duplex sonography, the flow characteristics of turbulent blood flow (TBF) are shown in this patient.

Case: An asymptomatic 12-year-old female presented in our outpatient clinic for routine surveillance of moderate congenital AS. As a neonate the patient required balloon aortic valvotomy for critical aortic stenosis. The body surface area was 2.1 m^2 with a body mass index of 34.6 kg/m^2. Reverse TBF was recorded along the medial wall of the ascending aorta (AO). Delayed TBF was recorded in the distal ascending AO, proximal left common carotid artery (LCC), and the proximal thoracic AO. The peak velocity of TBF in the proximal LCC was 3.9 m/sec and a 560% drop in peak velocity was shown between the proximal and distal LCC.

Discussion: Pediatric obesity is an important consideration in congenital AS. Up to 27% of patients with congenital heart disease may be affected. The study of TBF may show changes that can lead to low velocity carotid blood flow.

Conclusion: Recordings of TBF are feasible, even in some obese and technically difficult patients. The onset of reverse TBF, delayed TBF, and low velocity carotid blood flow could be indicators of TBF severity. Severe turbulence could be an indicator of long-term mortality.

Keywords: *Turbulent Blood Flow; Congenital Aortic Stenosis; Obese Pediatric Patient.*

Introduction

The severity of TBF may be expressed as a Reynolds number. The normal Reynolds number in the ascending aorta is 1000 TBF begins between 2000-2500, and the velocity of the forward flow component of TBF is a good indicator of the velocity in the ascending AO[1]. By combining duplex sonography with echocardiography, we present a method of recording reverse and delayed TBF. The progression and flow characteristics of TBF from the ascending aorta to the left common carotid superiorly and abdominal aorta inferiorly are shown in an obese pediatric patient with moderate congenital AS.

Case Presentation

A 12-year-old asymptomatic female presented in our outpatient clinic for routine surveillance of congenital AS. As a neonate the patient required balloon aortic valvotomy for critical aortic stenosis. The patient denied any history of tobacco or intravenous drug use.

Vital signs showed a heart rate of 73 beats per minute, a respiratory rate of 16 breaths per minute, and a body temperature of 37 degrees Celsius. Physical examination revealed, 2/6 systolic murmur that radiated to the neck, and 2+ arterial pulses. The body surface area was 2.1 m^2 with a body mass index of 34.6 kg/m^2. The height was at the 50^{th} percentile and the weight was above the 95^{th} percentile for age. Results of complete blood count, renal function and liver function analysis were normal. Electrocardiography revealed sinus rhythm.

Vascular and echocardiographic Images were recorded with a Siemens Sequoia C512 (Siemens Medical Solutions USA, Mountain view, CA). M-mode echocardiography showed a normal left ventricular end diastolic dimension (LVEDD) of 5.48 cm and an estimated left ventricular mass of 78 grams / m^2. Left ventricular bi-plane ejection fraction was 68%. The peak aortic flow velocity was 3.9 m/sec with a peak gradient of 54 mm Hg and a mean gradient of 34 mm Hg. The estimated aortic valve orifice was 1.21 cm^2. Trace aortic regurgitation was present. The tricuspid regurgitation jet showed a peak velocity of 1.9 M / sec. A high frequency (8 MHz) phased array probe was employed from the suprasternal notch to perform a vascular ultrasound assessment of the brachiocephalic arteries and veins. The pulsed wave Doppler (PWD) sample volume was placed in the proximal left common carotid artery (LCC) from a modified aortic arch view and the distal LCC was recorded from the left lateral neck. Spectral Doppler tracings were recorded at a sweep speed of 100mm/sec and a PWD sample volume size of 5mm. Echocardiography was performed with a 4 MHz phased array probe placed in the suprasternal notch (SSN) or abdomen without angle correction.

Both color Doppler and PWD show the onset of reverse TBF to be nearly immediate after valve opening. Reverse TBF persisted into early diastole (Figure 1, Video 1, Figure 2).

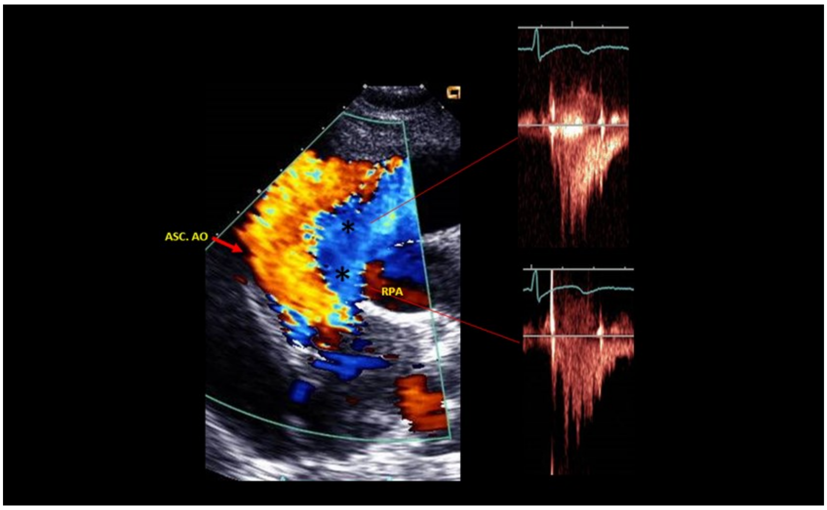
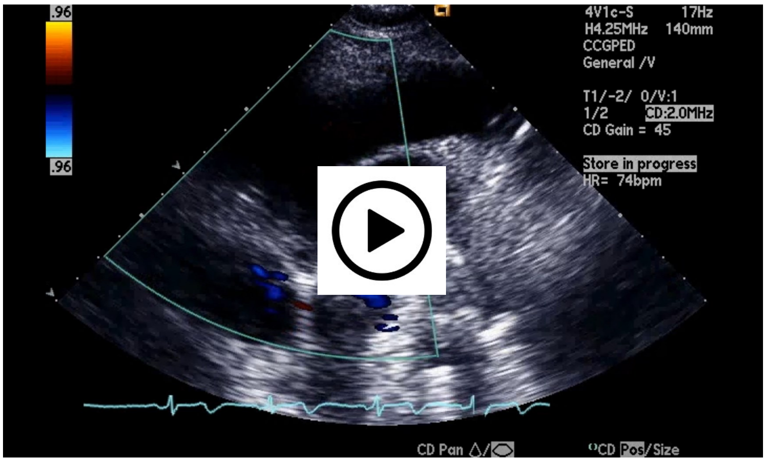


Figure 1. *Transthoracic spectral and color Doppler echocardiography recorded from the SSN along the medial wall of the proximal ascending AO (lower trace) and distal ascending Ao (upper trace) showing the nearly immediate onset of reverse TBF. ASC. AO: ascending aorta, RPA: right pulmonary artery.*



Video 1*. Transthoracic slow motion color Doppler echocardiography of the ascending aorta arch recorded from the SSN showing the immediate onset of reverse TBF and reverse flow persisting into diastole.*

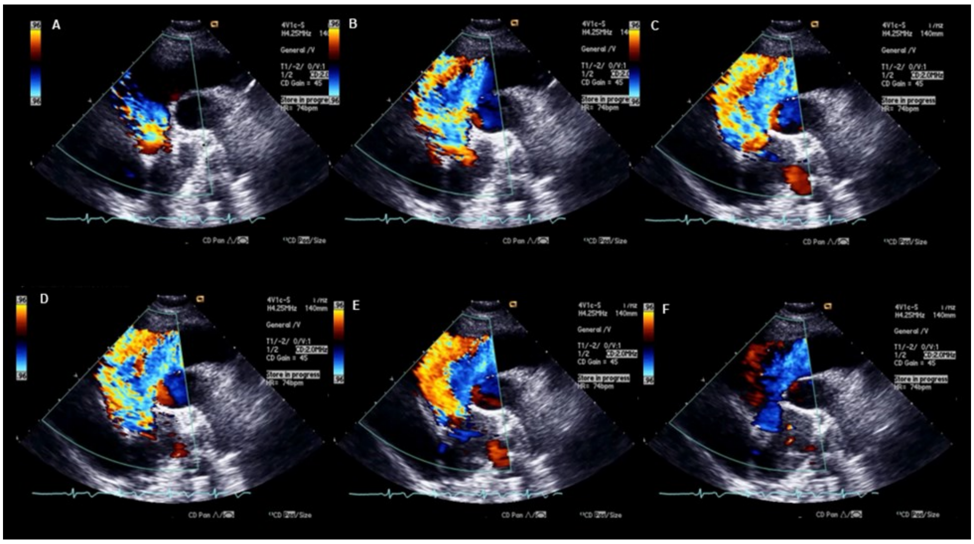


Figure 2. *Transthoracic color Doppler echocardiography of the ascending AO recorded from the SSN. (A) first systolic frame shows simultaneous forward and reverse flow. (B) second systolic frame shows nearly circular flow. (C) third systolic frame shows peak forward and reverse flow. (D) fourth systolic frame showing some convergence of forward and reverse flow. (E) fifth systolic frame showing reduction in forward and reverse flow velocity near end systole. (F) first diastolic frame shows reverse flow persists into diastole.*

The progression of TBF from the ascending aorta to the proximal and distal LCC is demonstrated. Continuous wave Doppler (CWD) recorded from the apical window shows a clear envelope with a peak velocity of 3.9 m/sec. The onset of systolic flow was immediately after the valve opening line and terminated at the valve closing line. The wave form was inverted to better show the velocity relative to the proximal and distal LCC. The proximal LCC flow was recorded from the SSN using duplex sonography and shows a peak velocity of 3.9 m/sec. This was preceded by a delay in TBF. The ratio of high to low velocity flow was 3.2 to1. The duration of this transient low velocity flow was 124 msec. After this delay period, high frequency velocity fluctuations that persisted into diastole were recorded. The distal LCC was recorded from the lateral neck using duplex sonography and shows a 560% drop in peak velocity between the proximal and distal LCC with rounding (blunting) of the wave form (Figure 3).

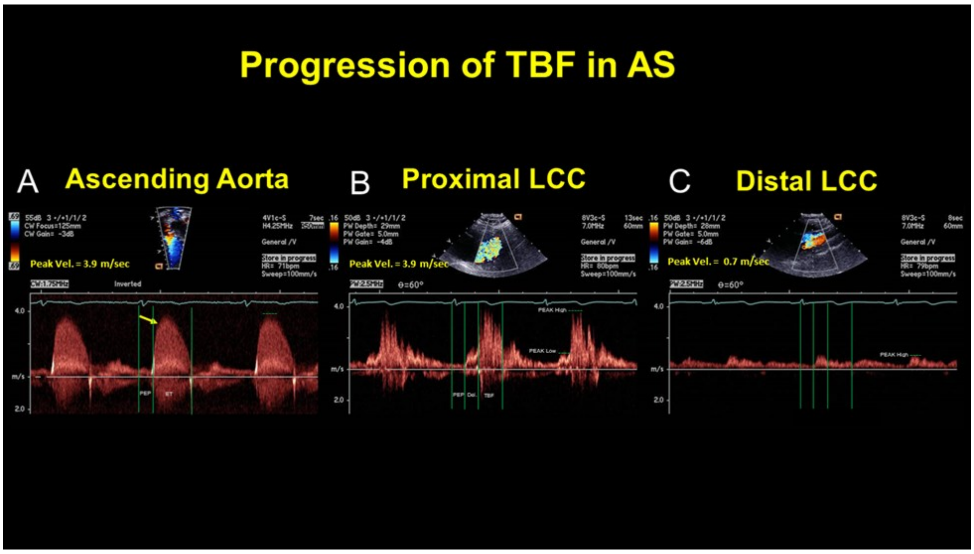


Figure 3. *Spectral Doppler of AS showing the progression of TBF. (A) continuous wave Doppler recorded from the apical window (inverted to show relative velocity) shows a clear envelope (yellow arrow), the pre-ejection period and ejection time are shown (green lines). (B) Duplex sonography of the proximal left common carotid artery recorded from SSN, the ejection time has two components, the peak low velocity flow (doted green lines) and the Peak high velocity flow (doted green lines) show a ratio of 3.2 to1, the peak velocity of the TBF is 3.9 M/sec. (C) Duplex sonography the distal LCC artery recorded from the left lateral neck showing a 560% drop in peak velocity (dotted green line) and blunting of the carotid wave form. The isovolumic and delay periods are similar between the proximal and distal LCC (green lines). PEAK Low: Peak low velocity flow, PEAK High: Peak High velocity flow, PEP: pre-ejection period, Del.: delay period, LCC: left common carotid.*

Although CWD typically has a clear envelope, some miscellaneous flow can be included in the signal. To show the progression of TBF from the proximal to the distal ascending aorta, we confirmed this with PWD (avoiding high pulse repetition frequency mode). The probe was placed in the SSN and the sample volume depth was 64 mm and 42 mm respectively. Proximal PWD tracings confirm the immediate onset of systolic flow without delay. However, distal PWD show a delay followed by high frequency velocity fluctuations with a frequency of 21 fluctuations / sec. Since these recordings had no angle correction an accurate velocity could not be determined (Figure 4&5).

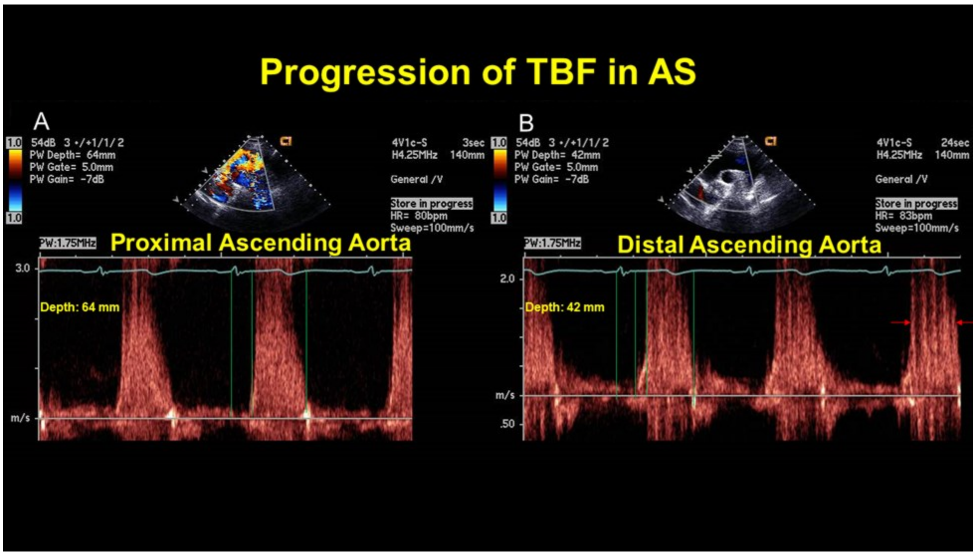


Figure 4. *Transthoracic PWD echocardiography recorded from the SSN (A) proximal ascending aorta at a depth of 64 mm from the SSN, spectral broadening without a delay is shown (green lines). (B) distal ascending AO at a depth of 42 mm from the SSN showing a delay in TBF (green lines) and high frequency velocity fluctuations at 21 fluctuations/sec (red arrows).*

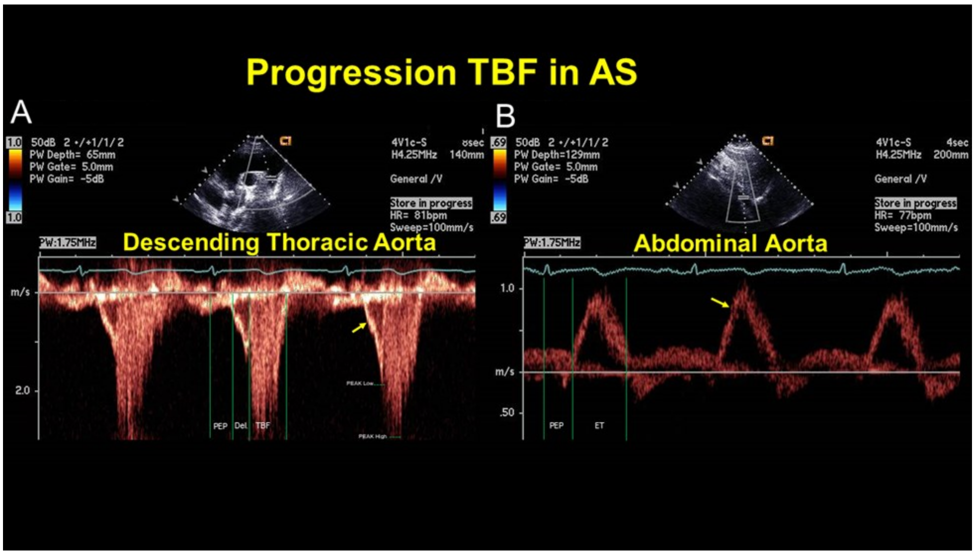


Figure 5. *Progression of TBF from the thoracic to the abdominal aorta (A) Transthoracic PWD echocardiography recorded from the SSN at a zero-degree angle showing a delay in TBF (yellow arrow). (B) Transthoracic PWD recorded from the upper abdomen showing pulse wave reconstitution with some spectral dispersion (yellow arrow). ET: ejection time, PEP: pre-ejection period, TBF: turbulent blood flow, PEAK High: peak high velocity blood flow, PEAK Low: peak low velocity blood flow.*

Discussion

We present an obese pediatric patient with congenital AS and describe a simple method of recording TBF from the SSN. By combing duplex sonography with echocardiography, the spectral Doppler characteristics of TBF are shown. The onset of reverse TBF was immediate, while delayed TBF could be seen in the distal ascending aorta, proximal LCC, and proximal thoracic aorta. We measured the peak velocity of TBF in the proximal LCC and calculated the ratio of high to low velocity. A large drop in peak velocity was shown between the proximal and distal LCC with low velocity carotid blood flow and a rounded wave form. High frequency velocity fluctuations were seen in the distal ascending aorta but not in the proximal ascending aorta. The physical properties of TBF and their clinical relevance are discussed.

In 1883 Osborne Reynolds showed that the severity of turbulent flow could be calculated as a simple ratio of inertia to viscosity and that flow turbulence resulted in eddy currents (reverse flow) and the formation of vortices[2]. Using microphone tipped indwelling catheters Sabbah et al. measured the severity of TBF and showed that TBF resulted in a transient delay in systemic blood pressure[3]. In simulated carotid stenosis using laser Doppler anemometry, Khalil et al found that turbulent flow had a distinct break frequency for each severity level and that high-energy, high-frequency velocity fluctuations were only seen in severe stenosis[4]. These reports are consistent with our observation of reverse TBF, delayed TBF, and high frequency velocity fluctuations.

The incidence of pediatric obesity is estimated at 9.5 to 26 % and has been shown to be progressive[5,6]. As obesity progresses, echocardiography becomes more difficult while the cardiac burden of combined AS and obesity increases and may have significant clinical ramifications. Some patients with obesity have good SSN windows making our method ideal for the serial study of TBF.

A clinically important aspect of severe AS is a drop in carotid flow velocity. In adults, O'Boyle et al used duplex sonography the common carotid arteries to evaluate patients with severe AS and found a reduction in velocity, long acceleration times, and rounding of the Doppler wave form while patients with mild or moderate AS had normal carotid wave forms[7,8,9]. A drop in carotid flow velocity and blunting of the carotid wave form could result in symptomatic AS.

Reverse and delayed TBF could be due to obesity, a history of balloon aortic valvotomy or other factors. However, the physical properties of flow turbulence suggest that reverse and delayed blood flow may be expected in patients with AS. Age-related sclerotic AS and prosthetic valve replacement may have unique TBF characteristics. Supine exercise testing and serial study could show the spectrum of TBF in patients with AS.

In keeping with the Helsinki convention all patient data has been anonymized and parental informed consent was obtained.

Conclusion

Recordings of TBF are feasible, even in some obese and technically difficult patients. The onset of reverse TBF, delayed TBF, and low velocity carotid blood flow may be indicators of TBF severity. Severe turbulence could be an indicator of long-term mortality.

Conflict of Interest

The authors declare they have no potential conflicts of interest to disclose.

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