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● *Original Contribution*

# DIASTOLIC RETROGRADE ARTERIAL FLOW AND BIPHASIC ABDOMINAL AORTIC DOPPLER WAVE PATTERN: AN EARLY SIGN OF ARTERIAL WALL DETERIORATION?

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**Abstract—Many authors have found that diastolic retrograde arterial flow is associated with increased stiffness of the arterial wall. Most of the studies were based in femoral or brachial artery examination. As the abdominal aorta is a large vessel routinely explored in abdominal ultrasound scans, we decided to study whether it could be useful for early identification of abnormalities of the arterial wall. Sixteen young and 16 old, healthy patients matched for sex, weight and height were studied using pulsed Doppler at the level of the abdominal aortic bifurcation. Different hemodynamic factors were measured and compared to establish the systolic and diastolic function of this artery. Triphasic wave pattern was present in 14 of 16 patients in the younger group and only in 4 of 16 in the older group. In addition, diastolic retrograde arterial flow duration and retrograde components of diastolic phase were more prominent in the advanced age group. Increased retrograde flow and incapacity to impulse arterial flow forward during diastolic time are early markers of vascular wall deterioration that can be observed easily in the abdominal aorta during routine abdominal ultrasound scans. (E-mail: mario.mcloughlin@gmail.com) © 2013 World Federation for Ultrasound in Medicine & Biology.**

*Key Words:* **Doppler, Abdominal aorta, Pulsed Doppler, Hemodynamics, Vascular pathology.**

## INTRODUCTION

The basic assumptions underlying Poisueille’s flow law are that there is steady, laminar, parallel flow of a Newtonian liquid in a straight, smooth-walled tube. The arterial blood circulation is pulsatile, the fluid is non-Newtonian and the vessels are of complex geometry and elasticity, with forward and reverse movement that is influenced by blood pressure, vascular resistance, vascular compliance, blood viscosity, flow shear stress and endothelial function (Peterson 1954; Zamir et al. 2007). Because Doppler examination directly addresses hemodynamics, it has been extensively used for the non-invasive study of human vascular flow (Callaghan et al. 1964; Franklin et al. 1961; Legarth and Thorup 1989; Mc Loughlin and Garcilazo 1995; Rushmer et al. 1966; Strandness et al. 1966, 1967). Doppler beam insonation angle modifies the calculation of velocities, and different indexes have been developed to compare systolic and diastolic velocities in the same pulse wave, in which all measurements are made with the same angle (Bude and Rubin 1999; Gosling and King 1974; Legarth and Thorup 1989; Mc Loughlin and Mc Loughlin 2011; Pourcelot 1974).

Pulsatile peripheral arterial flow has forward and backward movement. The former depends on left ventricle stroke volume, and the latter depends on diastolic arterial wall function. We have previously reported the presence of diastolic retrograde arterial flow (DRAF) in the brachial artery during arm elevation, muscle contraction and increased peripheral impedance (*e.g.*, compartment syndrome; Mc Loughlin et al. 2011, 2012). Moreover, Credeur et al. (2009) demonstrated that retrograde flow in the brachial artery is increased with aging, and we have observed a similar DRAF increase in hypertensive patients compared with normal subjects (Mc Loughlin et al. 2011). In a study in the common femoral artery, Young et al. (2010) also found an oscillatory flow pattern, reduced mean flow velocity and decreasing arterial shear stress with aging. Likewise, Hashimoto and Ito (2010) suggested that aortic stiffening could predispose to peripheral artery disease as a consequence of reduced blood flow into the lower extremities.

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Nevertheless, to our knowledge, the presence of DRAF in the abdominal aorta and its possible relation to aging and increased arterial stiffening have not been studied using the Doppler technique. Because the abdominal aorta is easily accessible during the routinely performed abdominal ultrasound study, and because Hashimoto and Ito (2010) have recently suggested that aging may be related to reduced retrograde flow from peripheral arteries into the aorta reducing diastolic splenic perfusion, we decided to analyze the aortic Doppler velocities and wave forms at the level of abdominal aortic bifurcation. Moreover, considering that arterial stiffness is increased with aging, we studied the aortic Doppler parameters in young and old subjects to investigate whether aortic stiffness might result in reduced Doppler velocities, decreased diastolic forward flow to the extremities and increased retrograde diastolic abdominal aortic flow.

## MATERIALS AND METHODS

*Subjects*

Sixteen young (10 female) and sixteen old, healthy patients (10 female; 35 vs. 73 years old) matched for sex, weight and height participated in the study (Table 1). All subjects were active, free of known cardiovascular, pulmonary, metabolic or neurologic disease and none were using prescribed or over-the-counter medications. Fasting blood chemistry screening indicated that triglycerides, cholesterol, lipoproteins and glucose concentrations were within the normal range for healthy adults. There were no significant age-group differences in resting systolic, diastolic or mean arterial blood pressures. This prospective study was approved by the ethics committee and adhered to the Declaration of Helsinki. All subjects gave previous written consent.

*Experimental design*

This study was performed in a quiet and temperature-controlled environment. Before each test, subjects were requested to fast for 6 hours, abstain from alcohol and caffeine for 18 hours and avoid exercise for 24 hours. Abdominal aorta was scanned in longitudinal and transverse planes with the patient in supine position to exclude aortic pathology.

*Doppler assessment*

Doppler measurements were obtained in a longitudinal plane of abdominal aorta, using a commercially available Doppler scanner (ATL HDI 3000, 3.5 MHz convex transducer; Seattle, WA, USA). Sample volume was 1 mm and was positioned under ultrasound control in the middle of the aortic lumen at the most caudal point that allowed us to obtain a constant insonation angle of 60 degrees. The wall filter was set at the lowest possible level.

Table 1. Patient demographics

| | Group 1 | Group 2 |
|---|---|---|
| Patient demographics | Mean (standard deviation) | Mean (standard deviation) |
| Age (y) | 35 (11) | 73 (11) |
| Women | 10/16 | 10/16 NS |
| Weight (kg) | 68 (13) | 70 (13) NS |
| Height (cm) | 166 (8) | 163 (9) NS |
| SBP (mm Hg) | 126.4 (21) | 130.5 (12) NS |
| DBP (mm Hg) | 74.5 (15) | 79.4 (9) NS |
| MAP (DBP + [PP/3]) (mm Hg) | 91.8 (16) | 98.9 (13) NS |

SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; NS = not significant; PP = pulse pressure.

Results (except women) are expressed as mean (standard deviation).

Doppler measurements were taken from at least three cycles and averaged.

*Doppler measurements*

Measurement of end-diastolic velocity (EDV; 0), developed velocity (DV; 0–2), minimum diastolic velocity (MDV; 4), peak systolic forward velocity (2), systolic forward acceleration time (1–2), systolic forward deceleration time (2–3), peak negative velocity (4), negative acceleration time (3–4), negative deceleration time (4–5), peak diastolic forward velocity (PDFV) (6), diastolic forward acceleration time (5–6), diastolic forward deceleration time (6–7) were made using calipers (peak diastolic forward velocity, diastolic forward acceleration time and diastolic forward deceleration time only if diastolic forward flow was present). Calculations of pulsatility index (PI) and modified resistivity index (MRI) for triphasic flow (considers minimum diastolic velocity instead of end-diastolic velocity; *MRI = peak systolic velocity (PSV) – MDV/PSV*) were made with the ultrasound equipment built-in software. Mean flow velocity was calculated as *PSV – MDV/PI*; resistivity index was calculated as *PSV – EDV/PSV*; acceleration was calculated as *peak velocity/acceleration time (AT)*; and deceleration was calculated as *peak velocity/deceleration time (DT)*. Retrograde flow duration was measured as the total time in which the flow was reversed. Intervals measured are shown in Figure 1.

Because end-diastolic velocity in triphasic flow frequently is 0 cm/s, it was necessary to use MRI measuring minimum diastolic velocity to find differences between patients. In patients with DRAF and negative end diastolic velocity, Resistivity index could be $>1$.

*Statistics*

Statistical analysis was performed using SPSS for Windows (version 17.0) software. Continuous variables were expressed as mean $\pm$ 1 standard deviation. Both