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● *Original Contribution*

FEASIBILITY OF COMBINED DOPPLER–ECG ASSESSMENT OF INTERNAL JUGULAR VEINS

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Abstract—A standardized combined Doppler–electrocardiography technique was developed for measurement of the triphasic waveform characteristics in the internal jugular vein. Flow velocities at the A, X, V and Y peaks, the RR interval and the PA and RX times were measured. From these the venous impedance index ([X−A]/X) and the ratios PA/RR and RX/RR were calculated. Six measurements were performed at three different locations by two ultrasonographers in 21 randomly selected pregnant and non-pregnant women. Statistical models proved the feasibility and reproducibility of this technique, with the highest concordance correlation coefficients in the right distal internal vein. Bootstrapping revealed that repeating the measurements more than four times would not significantly enhance the precision of the estimated mean. Concordance correlation coefficients for the venous impedance index, PA time and PA/RR ratio were >0.63 for all three locations, proving their possible use in ongoing and future studies, analogous to previous studies in kidney and liver. (E-mail: inge.dierickx@azstlucas.be) © 2017 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Internal jugular vein, Jugular venous pulse, Heart–brain axis, Cerebral venous return, Venous hemodynamics, Electrocardiography, Doppler ultrasound.**

INTRODUCTION

Hypertensive disorders are leading causes of morbidity and mortality during both pregnancy and the postnatal period. In fact, it was estimated that 10%–15% of deaths during pregnancy are associated with pre-eclampsia and eclampsia, and most of these deaths are due to acute cerebral complications (*e.g.,* eclampsia, stroke, edema, and hemorrhage) (Duley 2009).

Evidence obtained in the last few decades indicates that the venous compartment is actively involved in cardiovascular and cerebral hemodynamics and that dysfunction of the venous compartment may play important roles in gestational and non-gestational (patho)physiology (Beggs 2013; Gyselaers et al. 2011, 2014, 2015; Haacke et al. 2012; Kampman et al. 2015; Khalil et al. 2014; Melchiorre et al. 2014, 2016; Tiralongo et al. 2015; Tomsin 2013; Verlohren et al. 2014; Zivadinov 2013).

Venous pulse waves indirectly reflect right cardiac atrial function and can be detected in the caval, jugular, hepatic and renal veins (Ommen et al. 2000). With increasing distance from the heart, the triphasic shape of these pulse waves gradually changes into biphasic, monophasic and, subsequently, flat patterns, analogous to the fetal venous circulation (Hecher and Campbell 1996). Each component of this venous pulse reflects a specific stage of the right atrial cycle, as illustrated in Figure 1 and listed in Table 1 (Ommen et al. 2000). Although physicians first associated conspicuous neck veins with heart disease three centuries ago, only recently have researchers used imaging modalities (*e.g.,* magnetic resonance imaging, angiography, catheter venography and ultrasound) to evaluate cerebral venous return (Dolic et al. 2013; Gadda et al. 2016; Kim et al. 2015; Marcotti et al. 2015; Menegatti et al. 2014;

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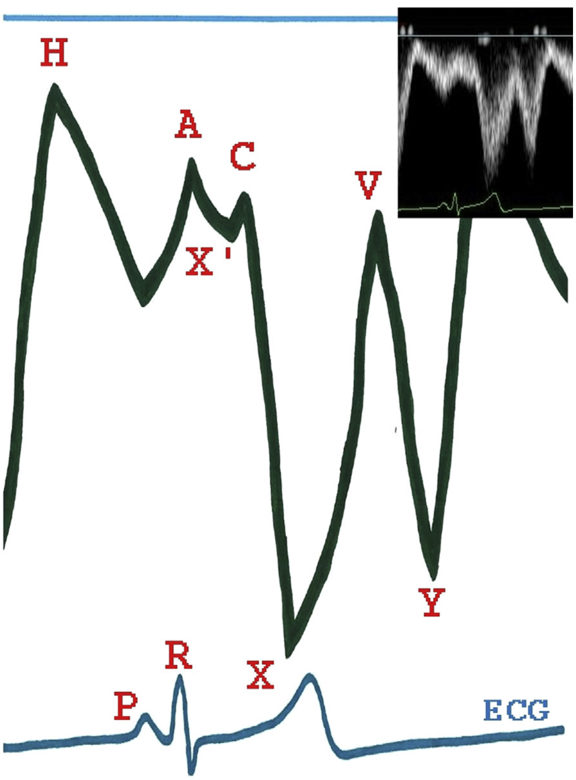

Fig. 1. Components of the jugular venous waveform. The jugular venous waveform consists of four positive waves (H-, A-, C- and V-waves) and two negative waves (X′-, X- and Y-descent).

Sisini et al. 2016; Zamboni 2016). Most of the available knowledge on the heart–brain axis was obtained from studies of the arterial compartment (Thomas et al. 2015). The cerebrovenous system is more complex than the arterial heart–brain axis owing to the existence of anatomic variants; the presence of valves and collateral veins; vessel capacity, collapsibility and compressibility; and the effects of respiration/postural changes on the venous system (Kim et al. 2015; Marcotti et al. 2015; Menegatti et al. 2014; Schaller 2004; Toro et al. 2015; Valdueza et al. 2000; Zamboni 2016; Zamboni et al. 2012, 2013; Zivadinov et al. 2014).

Doppler ultrasound is a simple, tolerable, non-invasive bedside technique that is easily performed in pregnant women. Several recent Doppler ultrasound studies of the hepatic and renal interlobar veins have improved our understanding of gestational hemodynamics in normal pregnancies and in pregnancies complicated by hypertensive disease (Gyselaers et al. 2014, 2015; Tomsin 2013).

From this context, we believe that assessing the venous pulse in the heart–brain axis might provide insight into the hemodynamics of the cerebral venous return in normal pregnancies and in pregnancies complicated by hypertensive disorders. Therefore, in this study, we focused on combined Doppler–electrocardiography (ECG) to assess the venous pulse in the internal jugular vein.

METHODS

Ethics

This study was approved by the local ethics committee (Medical Ethical Committee Sint Lucas Hospital, Project No. 2011-12). Written informed consent was signed by every participant before onset of the study.

Table 1. Components of the normal waveform of the internal jugular vein

Wave	Deflection	Timing in cardiac cycle	Hemodynamics
H	Positive		Artifactual bulging of the fully filled right ventricle in the right atrium at the end of diastole (only visible when diastole is long [slow heart rate])
A	Positive (or negative)	End of diastole; just before the first heart sound (S1) and just after the P-wave of the ECG	Right atrial contraction with active filling of the right ventricle causing retrograde (or slowing of forward) blood flow to the internal jugular vein
X′	Negative	Begins during systole	Early fast filling of the right atrium during atrial relaxation
C	Positive	Early systole	Artifactual bulging in the jugular vein caused by carotid expansion due to ventricular contraction with pushing up the tricuspid valve
X	Negative	Ends just before the second heart sound (S2)	Atrial relaxation, the downward displacement of the tricuspid valve during right ventricular systole (R-top of the ECG), and the ejection of blood from both the ventricles
V	Positive (or negative)	Peaks just after S2	Passive filling in late systole and early diastole of the right atrium while the tricuspid valve is closed, causing a passive increase in pressure and volume of the right atrium
Y	Negative	Begins and ends during diastole	Fall in right atrium pressure caused by opening of the tricuspid valve in early diastole and resulting in rapid blood flow from the right atrium to the right ventricle