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● *Original Contribution*

CARDIAC, RESPIRATORY AND POSTURAL INFLUENCES ON VENOUS RETURN OF INTERNAL JUGULAR AND VERTEBRAL VEINS

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Abstract—It is known from physiology that heartbeat and respiration influence venous return, but little is known regarding the extent to which these two factors affect flow. In this study, we estimated the prevalence of cardiac- and breathing-induced venous flow modulations in the internal jugular vein (IJV) and vertebral vein (VV) and the effects of posture. In 19 healthy patients, neck vein flow was examined with pulsed wave Doppler. Electrocardiogram and respiratory signals were simultaneously acquired. In supine position, heart contraction always influenced venous flow, whereas breathing influenced 68% of IJV and 34% of VV flow. In sitting position, heart contraction influenced 74% of IJV and 42% of VV flow; breathing influenced 68% of IJV and 61% of VV measures. Thus, cardiac influence is greatly present in supine position, whereas breathing influence prevails in the VV while sitting. This setup allowed us to observe that in some patients, expiration may cause an unexpected increase in venous flow. (E-mail: mlagana@dongnocchi.it) © 2017 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Ultrasound imaging, Jugular vein, Pulsed Doppler ultrasonography, Blood flow velocity.**

INTRODUCTION

It is known from physiology that heart beating, respiration, muscular contraction, valves and posture influence venous return (Brecher and Hubay 1955; Gisolf et al. 2004; Hall 2010; Nordenström and Norhagen 1965; Schaller 2004; Wexler et al. 1968). Nevertheless, there is no systematic characterization of these influences, and their prevalence remains unknown.

Neck and head venous flow has recently gained particular attention because of the hypothesized link between its impairment and cerebral nervous system disorders (Zivadinov and Chung 2013), such as transient global amnesia (Han et al. 2015), cough headache (Knappertz 1996), idiopathic intracranial hypertension (Nedelmann et al. 2009), transient monocular blindness (Hsu et al. 2008), multiple sclerosis (Zamboni et al. 2009) and Alzheimer's disease (Chung et al. 2014) and for the diagnosis of chronic cerebrospinal venous insufficiency (Zamboni et al. 2009). For the clinical investigation of these pathologies, ultrasound (US) is the most frequently used non-invasive technique for imaging neck and head veins. The cervical veins usually examined with US are the internal jugular vein (IJV) and the vertebral vein (VV) (Cejas et al. 2010; Chung et al. 2007; Doepp et al. 2008; Hsu et al. 2008; Knappertz 1996; Lane and Davies 2013; Nedelmann et al. 2009; Zamboni et al. 2009) because they are the main drainage pathways for venous flow from the brain. Neck venous US examination consists of the real-time investigation of various morphologic, functional and hemodynamic characteristics. In particular, vessel patency and blood flow velocity are measured in distinct vessel segments, with the subject in different positions (supine and sitting), according to recent guidelines (Zivadinov et al. 2014).

Because, in addition to the kind and amount of flow, respiration usually influences venous dimensions, it is necessary to monitor how the examined subject is breathing. It is reported that IJV flow typically increases during inspiration and decreases during expiration (Pucheu et al.

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1994; Schrauben et al. 2015; Zamboni et al. 2012). In addition to examination during normal breathing, the sonographer may ask a subject to engage in various respiratory activities (*e.g.,* relaxed or deep respiration, breath holding, Valsalva or Muller maneuver), to check vessel behavior under different conditions (Attubato et al. 1994). Currently, correspondence between a specific respiratory phase and the current vascular echographic image (morphologic or hemodynamic) is possible because the sonographer visually observes the subject's respiration. Nonetheless, the matching is not exact, and when an examination is subsequently reviewed it is difficult, if not impossible, to know the kind of breathing pattern corresponding to a specific image and, consequently, to evaluate if a particular morphology or blood flow is due to a maneuver, a subject movement or abnormal breathing. For this reason, we recently proposed use of a respiratory sensor connected to the US system (Lagana et al. 2014) to measure and record the respiratory pattern synchronously with the US images.

Although the influence of cardiac pulsatility and breathing on venous flow modulation has been known since the 1950s (Brecher and Hubay 1955), it is still unclear to what extent these two factors affect IJV and VV flow and if their effects may change with posture.

In this study, we focused on the above unresolved issues. We investigated the influence of heartbeat, breathing and posture on IJV and VV venous velocity in a group of healthy patients. This was achieved by simultaneously recording breathing, electrocardiogram (ECG) and blood flow pulsed wave Doppler (PW) images of the neck veins in the sitting and supine positions. In this article, methodologic details on the practical implementation of the innovative experimental setup are also provided.

METHODS

Patients

Nineteen healthy volunteers of both sexes were consecutively recruited. The inclusion/exclusion criteria were age between 18 and 60 y; a normal weight for height (body mass index between 18.5 and 25); and no history or sign of neurologic, respiratory or cardiovascular diseases. Patients with an anomalous breathing influence on venous flow (flow decrement instead of increment during inspiration) were re-evaluated during another session 1 y later to assess the repeatability of the heartbeat and breathing influence on the venous flow waveform and the persistence of the anomalous pattern.

This study complied with the Declaration of Helsinki recommendations for investigations on human patients; it was approved by the local ethics committee, and a written informed consent was provided by all patients before study entry.

Acquisitions

All patients IJVs and VVs were examined by a radiologist with the MyLabVinco US system (Esaote, Florence, Italy) equipped with a linear array transducer probe (LA332, Esaote). The operating bandwidth was 3–11 MHz; the imaging frequencies were 3.5, 5.0, 6.6 and 10.0 MHz; and the Doppler frequency range was: 3.3–5.0 MHz. A thick US gel layer (Aquasonic 100, Parker Laboratories, Fairfield, NJ, USA) was used to ensure complete coupling between the transducer and the subject's skin to avoid black cones and dark areas on the US image.

The radiologist has been working in vascular sonography for 25 y, and in the last 7 y he specialized in neck venous examinations. Specific training for performing these measurements is needed to avoid placing pressure on the subject's neck with the probe, which distorts vein shape and dimensions and thus may alter hemodynamic measures (Nicolaides et al. 2011).

Each subject was positioned on an electromechanical tilting chair (AP4295, Givas, Padua, Italy), avoiding hypo- or hyperextension of the neck. The three ECG electrodes embedded in the US device were positioned in the standard three-lead configuration, and ECG trace quality was verified on the system screen. A respiratory sensor was then fixed with a plaster strip on the subject's abdomen or thorax, depending on which position was associated with greater movement caused by respiration, allowing us to obtain the best signal indicative of the subject's inspiration/expiration/apnea phases. The output was connected to the auxiliary input of the US device, so that respiratory signal could be displayed on the US screen synchronously with ECG and US images. The sensor, based on an accelerometer, was specifically developed for this application; the technical characteristics have been previously described (Lagana et al. 2014). The respiratory sensor was positioned in such a way that inspiration could be displayed as signal increment and expiration as decrement in all acquisitions.

For each subject, the examination consisted of eight different acquisitions performed as follows. The left and right IJVs and VVs were first insonated with the subject in supine position, after a preliminary 5-min quiet rest. The chair was then tilted 90°, the quality of the two physiologic signals was checked with the patient in the new position and sensors were adjusted if needed. After an additional 5-min quiet rest, the IJV and VV examinations were repeated as for the supine schedule. In the end, $19 \times 8 = 152$ total acquisitions were performed. During each acquisition, the subject was asked to breathe regularly, and the pulsed wave of the vessel of interest was obtained as detailed hereafter. The B-mode plus color Doppler (B-ref) in the longitudinal view was used to examine the vein of interest to select the position and