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Clinical Investigation

CLINICAL INVESTIGATION

Carotid ultrasound measurements for assessing fluid responsiveness in spontaneously breathing patients: corrected flow time and respirophasic variation in blood flow peak velocity

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Abstract

Background: This study evaluated the ability of two Doppler ultrasound-derived parameters, the carotid corrected flow time (FTc) and respirophasic variation in carotid artery blood flow peak velocity (ΔVpeak), to predict fluid responsiveness in spontaneously breathing patients.

Methods: A total of 53 spontaneously breathing patients were studied before anaesthetic induction for neurosurgery. Carotid FTc, ΔVpeak, and haemodynamic data were measured before and after administration of 6 ml kg^{-1} colloid. Fluid responsiveness was defined as a 15% or more increase in stroke volume index as assessed by transthoracic echocardiography after the fluid challenge.

Results: Twenty-two (42%) patients were fluid responders. The areas under the receiver operating characteristic curves for FTc and ΔVpeak were 0.842 [95% confidence interval (CI) 0.735–0.948, $P<0.001$] and 0.818 (95% CI: 0.701–0.935, $P<0.001$), respectively. The optimal cut-off values of FTc and ΔVpeak for fluid responsiveness were 349.4 ms (sensitivity of 72.7%; specificity of 83.9%) and 9.1% (sensitivity of 72.7%; specificity of 87.1%), respectively. The grey zone for FTc was 346.9–361.0 ms and included 28% of the patients, and the grey zone for ΔVpeak was 6.5–10.2% and included 50% of the patients.

Conclusions: Using Doppler ultrasound-derived parameters measured at the carotid artery, FTc predicted fluid responsiveness in spontaneously breathing patients better than ΔVpeak. However, further studies are warranted before these parameters are recommended for clinical use.

Clinical trial registration: NCT 02843477.

Keywords: blood flow velocity; carotid artery; Doppler ultrasound; fluid therapy; respiration

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Editor's key points

- Dynamic haemodynamic indices to assess fluid responsiveness in awake patients are influenced by spontaneous breathing patterns.
- The flow time in the carotid artery as predictor for fluid responsiveness can easily be measured by ultrasonography, and is not affected by spontaneous breathing.
- Carotid artery corrected flow time had good predictive value for fluid responsiveness in awake patients, however the clinical applicability of this indicator should be further elaborated.

Determining fluid responsiveness is a critical task in perioperative care, as inappropriate fluid administration can lead to poor outcomes.[1,2] However, accurate assessment of a patient's intravascular volume status during the perioperative period remains challenging.

Traditional static indices, including central venous pressure and pulmonary capillary wedge pressure, have been criticised for a lack of accuracy in predicting fluid responsiveness despite their invasive nature.[3,4] In contrast, dynamic indices based on heart–lung interactions, such as pulse pressure variation (PPV), have been used as robust guides to predict fluid responsiveness in mechanically ventilated patients.[5,6] The ability of dynamic indices to assess fluid responsiveness during spontaneous breathing has been extensively studied, but the results have been generally disappointing.[7–10] Moreover, the invasive arterial catheterisation required for measuring these indices can be unpleasant in awake patients.

Recently, ultrasonography for estimating volume status has been widely recommended because of its non-invasive nature, ease of acquisition, and reproducibility of measurements.[11] Among these ultrasound modalities, corrected flow time (FTc) measured in the carotid artery is a new approach for predicting fluid responsiveness that has shown promising results.[12,13] Previous studies have demonstrated that changes in carotid FTc were correlated with changes in volume state.[12,13] Additionally, carotid FTc is unaffected by respiration,[14] so it could be a reliable static parameter for predicting fluid responsiveness in spontaneously breathing patients. However, no studies using the reference standards have assessed this issue. Another parameter obtained by carotid artery ultrasound is blood flow velocity. In a previous study, the predictive power for fluid responsiveness of respirophasic variation of carotid artery blood flow peak velocity (ΔVpeak) was greater than that of PPV.[15] Therefore, although it is a dynamic index, it may be able to adequately evaluate volume status in spontaneously breathing patients.

The aim of this study was to evaluate whether carotid FTc as determined by Doppler ultrasound could be a predictor of fluid responsiveness in spontaneously breathing patients before anaesthetic induction for brain tumour surgery. We also evaluated the predictive ability of ΔVpeak for fluid responsiveness in spontaneously breathing patients as a secondary outcome.

Methods

Study population

The study protocol was approved by the Institutional Review Board of the Yonsei University Health System, Seoul, South Korea (#4-2016-0426), and registered at ClinicalTrials.gov (NCT02843477). After receiving written informed consent from all patients, we enrolled 54 patients (19–80 yr old) with an ASA physical status class of I–III, who were scheduled to undergo elective neurosurgery for brain tumour from August 2016 to February 2017. Exclusion criteria were as follows: BMI >35 or <15 kg m^{-2}, the presence of carotid artery stenosis >50% (by conventional angiography, computed tomographic angiography, magnetic resonance angiography, or duplex ultrasonography), newly detected common carotid stenosis >50% during the study period (Doppler-derived peak systolic velocity >182 cm s^{-1}, end-diastolic velocity >30 cm s^{-1}, or both),[16] systolic blood pressure >160 mm Hg, cardiac rhythm other than sinus, valvular heart disease, left ventricular ejection fraction <50%, right ventricular failure, chronic obstructive pulmonary disease, pulmonary hypertension, chronic kidney disease (estimated glomerular filtration rate <60 ml min^{-1} 1.73 m^{-2}), and pregnancy.

Study procedures

No premedication was administered. Upon arrival in the operating room, three-lead electrocardiography, non-invasive blood pressure, and pulse oximetry monitoring were commenced. Patients were placed in the supine position with nothing placed under their head. They breathed spontaneously while resting quietly for 5 min before each measurement. First, baseline carotid FTc, ΔVpeak, stroke volume index (SVI), and haemodynamic data were measured. After recording these data, the patients were administered a fluid challenge of 6 ml kg^{-1} ideal body weight of 6% hydroxyethyl starch 130/0.4 over 10 min. Five minutes after completion of the fluid challenge, the same haemodynamic parameters were measured again. No vasoactive medications were administered during the measurement period, and all measurements were obtained while the patients were haemodynamically stable.

Carotid ultrasonography

FTc and ΔVpeak were measured using carotid ultrasonography as previously described by Blehar and colleagues[12] and Song and colleagues[15] (Supplementary Fig. S1). Both parameters were measured by two independent examiners using an ultrasound device (Vivid E9; GE Vingmed Ultrasound AS, Horten, Norway). The examiners were blinded to each other's Doppler results, and the patient's haemodynamic parameters. First, a 4.5–12.0 MHz linear array transducer (11L-D transducer; GE Healthcare, Tokyo, Japan) was placed longitudinally on the neck with the probe marker pointing to the patient's head. The long axis B-mode image of the right common carotid artery was obtained at the level of the lower border of thyroid cartilage. Then, the sample volume was placed on the centre of the lumen, approximately 2 cm proximal to the carotid bifurcation. Next, a pulsed wave Doppler tracing of flow through the artery was obtained with angle correction. Using the calliper function on the machine, cycle time was obtained by measuring the interval between heartbeats at the beginning of the Doppler flow upstroke, and flow time was measured from the beginning of the systolic upstroke to the dicrotic notch. FTc was calculated by dividing the flow time by the square root of the cycle time as assessing a single cycle after several consecutive cycles became stable and reached the level of acceptable quality. Two examiners each performed the