Carotid Flow Time Changes With Volume Status in Acute Blood Loss

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Study objective: Noninvasive predictors of volume responsiveness may improve patient care in the emergency department. Doppler measurements of arterial blood flow have been proposed as a predictor of volume responsiveness. We seek to determine the effect of acute blood loss and a passive leg raise maneuver on corrected carotid artery flow time.

Methods: In a prospective cohort of blood donors, we obtained a Doppler tracing of blood flow through the carotid artery before and after blood loss. Measurements of carotid flow time, cardiac cycle time, and peak blood velocity were obtained in supine position and after a passive leg raise. Measurements of flow time were corrected for pulse rate.

Results: Seventy-nine donors were screened for participation; 70 completed the study. Donors had a mean blood loss of 452 mL. Mean corrected carotid artery flow time before blood loss was 320 ms (95% confidence interval [CI] 315 to 325 ms); this decreased after blood loss to 299 ms (95% CI 294 to 304 ms). A passive leg raise had little effect on mean corrected carotid artery flow time before blood loss (mean increase 4 ms; 95% CI –1 to 9 ms), but increased mean corrected carotid artery flow time after blood loss (mean increase 23 ms; 95% CI 18 to 28 ms) to predonation levels.

Conclusion: Corrected carotid artery flow time decreased after acute blood loss. In the setting of acute hypovolemia, a passive leg raise restored corrected carotid artery flow time to predonation levels. Further investigation of corrected carotid artery flow time as a predictor of volume responsiveness is warranted. [Ann Emerg Med. 2015;66:277-282.]

Please see page 278 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Effective use of intravenous fluid therapy is an essential element of caring for the critically ill.[1] Aggressive fluid resuscitation is encouraged by evidence-based guidelines for the treatment of some shock states, and failure to optimize preload may lead to inappropriate initiation of vasopressor therapy.[2] However, recent evidence has highlighted that overresuscitation with fluid may worsen patient outcomes.[3]

Importance

Approximately 50% of unstable patients in the critical care setting fail to improve their cardiac output in response to an intravenous fluid bolus.[4] Clinical examination and static physiologic measurements, such as mean arterial pressure and central venous pressure, have not proven reliable in identifying patients who will respond to volume expansion.[5] Dynamic predictors of volume responsiveness have demonstrated encouraging results but are not routinely available in many settings in which critical care is provided, including the emergency department. Improved tools to predict which patients will respond to fluid are needed to help balance the goals of optimizing preload, administering intravenous fluids judiciously, and avoiding resource-intensive and potentially harmful invasive procedures.

Goals of This Investigation

Studies of esophageal Doppler monitoring have suggested the value of using changes in aortic flow time to guide fluid therapy.[6] Flow time is the systolic fraction of the cardiac cycle, corrected for pulse rate. Although esophageal Doppler monitoring typically requires intubation, it may be feasible to use flow time through the carotid artery as a substitute, given that the carotid artery is only slightly distal to the aortic outflow tract and has similar flow characteristics.

Editor's Capsule Summary

What is already known on this topic
Invasive hemodynamic monitoring can predict volume responsiveness in some ICU patients.

What question this study addressed
Can noninvasive Doppler measurements of carotid flow time, in conjunction with passive leg raise, identify volume responsiveness in 70 healthy volunteers after a mean 452-mL blood donation?

What this study adds to our knowledge
There was no cut point that successfully differentiated pre– versus post–blood loss states even though there was a significant difference in mean carotid flow time response to passive leg raise between groups.

How this is relevant to clinical practice
This study does not support the clinical utility of this test to detect a 1-unit blood loss in healthy young unstressed volunteers; better noninvasive measures may one day be developed.

To investigate the potential value of corrected carotid artery flow time as a marker of volume responsiveness, we sought to determine whether it changed in response to acute blood loss and to evaluate a passive leg raise maneuver's effect on it. We hypothesized corrected carotid artery flow time would decrease after blood loss and that a passive leg raise maneuver would have no effect on it before phlebotomy but would increase it after blood loss.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted in adult volunteer whole blood donors. We enrolled a convenience sample of donors presenting to the hospital blood donor center. Subjects were recruited from March to September 2013. The institutional review board approved this study.

Selection of Participants

Prospective donors found to be fit for whole blood donation by the blood donor center staff were screened to participate in the study. Subjects were recruited when a study investigator was available. Donors aged 18 to 55 years and with no history of atrial fibrillation or aortic disease were eligible to participate. There were no other exclusion criteria.

Methods of Measurement

Study investigators were 2 emergency physicians with fellowship training in emergency ultrasonography. Investigators completed a series of measurements to standardize approach and technique before enrolling subjects. Study participants' age, height, weight, sex, blood pressure, and pulse rate were recorded from the blood donor center's intake form.

Subjects were seated in a reclining chair for whole blood donation, with their legs parallel to the ground and their back angled at 45 degrees. Before phlebotomy, an investigator acquired an ultrasonographic image of the right common carotid artery in long axis proximal to the carotid bulb and obtained a pulse wave Doppler tracing of flow through the artery. Ultrasonographic images were obtained with a 10-5 MHz linear transducer on a SonoSite M-Turbo (SonoSite, Bothell, WA). The peak velocity, cardiac cycle time, and carotid flow time were recorded. The cardiac cycle time was obtained with electronic calipers in the ultrasonographic machine's software by measuring the distance between heartbeats at the beginning of the Doppler flow upstroke. Carotid flow time was measured between the upstroke of the flow tracing and the dicrotic notch, and it was corrected for pulse rate by dividing flow time by the square root of the cardiac cycle time to calculate corrected carotid artery flow time. Typical times to obtain an image of the artery and a Doppler tracing were 20 to 30 seconds. Figure E1 (available online at http://www.annemergmed.com) illustrates a representative pulse wave Doppler tracing.

After this measurement, a passive leg raise maneuver was performed. In the reclining chair, subjects' feet were elevated 45 degrees above the level of the heart. After 30 seconds in this position, another tracing of Doppler flow through the carotid artery was obtained, and the parameters were measured again. Subjects were returned to a neutral position with their legs at the level of their heart. Blood donor center staff performed phlebotomy according to their protocol. Immediately after the donation, repeated Doppler tracings and measurements were obtained before and after a passive leg raise maneuver.

All images were saved as still pictures, with and without measurements. A third investigator with fellowship training in emergency ultrasonography independently analyzed the image of the Doppler waveform that did not have measurements, blinded to the subject time. This blinded reviewer measured corrected carotid artery flow time measured from the still pictures with an electronic ruler (OndeRulers, version 1.13.1; Ondesoft, http://www.ondesoft.com), calibrated to the measurements on the ultrasonographic image. This was performed to assess that placement of calipers was not subject to bedside sonographer bias.