Ultrasound in Med. & Biol., Vol. 40, No. 6, pp. 1072–1082, 2014

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2013.12.004

● *Original Contribution*

COMPLETELY REVERSED FLOW IN THE VERTEBRAL ARTERY DOES NOT ALWAYS INDICATE SUBCLAVIAN STEAL PHENOMENON

SHUN-PING CHEN,* YUAN-PING HU,* LIANG-HAO FAN,† and LI-JIE GUAN*

*Department of Ultrasonography, First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang Province, China; and †Department of Interventional Radiology, First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang Province, China

(*Received* 5 *June* 2013; *revised* 7 *November* 2013; *in final form* 5 *December* 2013)

Abstract—We evaluated the causes, differential diagnosis and clinical significance of completely reversed flow (CRF) in the vertebral artery (VA). Twenty-three patients diagnosed with CRF in the VA by Doppler ultrasound were studied retrospectively. CRF was divided into intermittent CRF and continuous CRF. The peak reversed velocity (PRV) and ratio of time in intermittent CRF to one cardiac cycle (t_{ICRF}/CC) were calculated. Causes of CRF were determined on the basis of previous angiography results. The results indicated that subclavian steal phenomenon (SSP) caused all cases of continuous CRF (n = 8). Intermittent CRF was caused by SSP (n = 6) or proximal VA occlusion (n = 9). PRV and t_{ICRF}/CC were increased in SSP as compared with VA occlusion ($p < 0.05$). Using a cutoff of t_{ICRF}/CC = 0.30, we achieved excellent accuracy in predicting the cause of intermittent CRF (100%) and posterior circulatory infarction (91%). Thus, analysis of CRF patterns and measurements of VA parameters can be used in differential diagnosis of the causes of CRF and in prediction of posterior circulatory infarction. (E-mail: csping123@163.com) **© 2014 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Occlusion of vertebral artery, Doppler ultrasonography, Subclavian artery, Vertebrobasilar circulation, Blood flow velocity.**

INTRODUCTION

Subclavian steal phenomenon (SSP) is defined as reversal of blood flow in the vertebral artery (VA) ipsilateral to a proximal high-grade stenosis or occlusion of the subclavian or innominate artery before the VA origin (Buckenham and Wright 2004; Kaneko et al. 1998). Patients with SSP may experience symptoms, including presyncope, syncope, neurologic deficits and impaired circulation of the extremities. However, most patients with SSP are asymptomatic and have benign outcomes (Labropoulos et al. 2010; Nicholls et al. 1991).

The gold standard for diagnosing stenosis or occlusion of the subclavian or vertebral arteries is digital subtraction angiography (DSA). However, because of its applicability, accuracy, cost-effectiveness and short examination time, Doppler ultrasonography of an intertransverse segment of the VA is the most commonly used method for detecting disease at any level of the vertebrobasilar circulation and, especially, for evaluating whether blood flow in the VA is reversed (Buckenham and Wright 2004; Nicolau et al. 2000; Savitz and Caplan 2005). Doppler ultrasound-detected reversed flow, especially completely reversed flow (CRF), in the VA has been found to indicate the presence of SSP (Buckenham and Wright 2004; Kaneko et al. 1998). However, there are other causes of CRF, such as occlusion of the VA origin (Päivänsalo et al. 1998; Von Reutern and Pourcelot 1978), which could lead to serious outcomes, including posterior circulation infarction (PoCI) (Savitz and Kaplan 2005). Therefore, the causes of CRF of the VA require further evaluation to identify individuals who require treatment.

Little information is available in the literature concerning the differential diagnosis of CRF in the VA. Thus, the purpose of this study was to evaluate the causes and differential diagnosis of CRF in the VA, using DSA as the standard reference. In addition, ultrasound parameters of the VA in patients with CRF and their correlations with cerebral infarction or with the degree of subclavian artery (SCA) stenosis were determined.

Address correspondence to: Shun-Ping Chen, Department of Ultrasonography, First Affiliated Hospital of Wenzhou Medical University, No. 2 Fu Xue Lane, Wenzhou 325000, Zhejiang Province, China. E-mail: csping123@163.com

METHODS

Patients

This retrospective study was approved by our institutional review board. The requirement for informed consent was waived. A list of all patients who underwent VA examinations was generated from the picture archiving and communication system of the Department of Sonography. Patients diagnosed with reversed flow in the VA by Doppler ultrasonography from January 2005 to April 2012 were retrospectively studied. A total of 135 consecutive cases were reviewed. Patients were included if: (i) they had had CRF in a unilateral VA; and (ii) they had undergone conventional aortic arch, selective SCA and/or VA DSA examination to determine the cause of CRF. Fifty-four patients with bidirectional flow in the VA were excluded. Of the 81 remaining patients, 58 patients were excluded because they had not undergone DSA examination.

The remaining 23 patients with CRF in the VA were included in this study. Figure 1 is the patient flowchart for this study. The mean interval between DSA and Doppler ultrasonography examinations in the 23 included patients was 6.1 ± 5.6 d (range: 1–18 d). DSA data were used as a reference standard for the cause of CRF in the VA. Demographic data, clinical history and outcomes were obtained from the hospital's electronic medical information database.

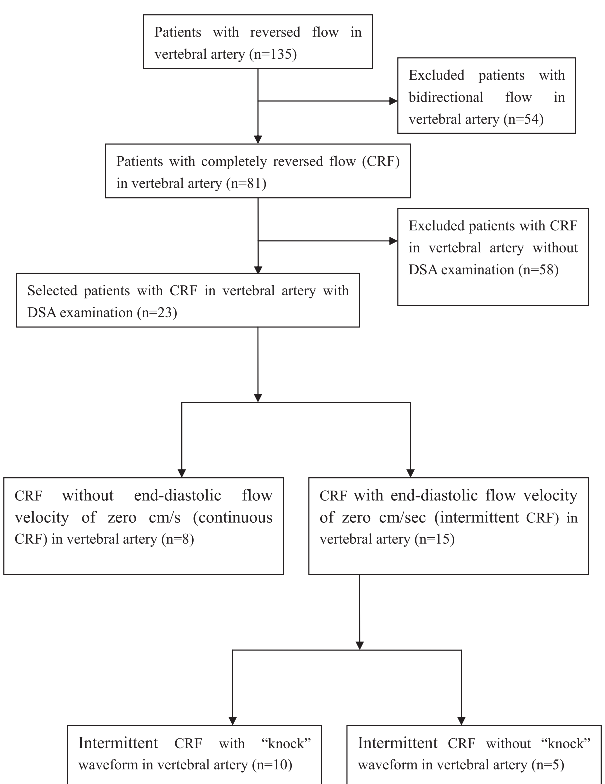

Fig. 1. Flowchart of the process for selecting patients.

Doppler ultrasonography

Experienced vascular radiologists performed all of the Doppler ultrasonograms. Patients were imaged in the supine position using standard sonographic equipment (HDI 5000, Philips ATL, Bothell, WA, USA, and Sequoia 512, Acuson/Siemens, CA, USA) with a 4.0- to 8.0-MHz standard vascular linear probe. VA waveform sampling was performed in the mid-portion of the VA extracranial segment. According to Kliewer et al. (2000), the measured angle of insonation was ≤60°. Specifically, insonation angles of 51° to 60° were used, with an average insonation angle of 56.5 ± 3.0° in 46 VAs from 23 selected patients.

Standard Doppler parameters were adjusted to the lowest pulse repetition frequency (PRF). The gain was set to the maximal value without background noise. A 1- to 3-mm Doppler sample gate was used for optimal signal detection from the VA. When Doppler signals with aliasing artifacts were detected (which could result in inaccurate waveform data), the PRF was increased or the baseline was adjusted to alter the velocity range and eliminate the aliasing artifacts (Kruskal et al. 2004).

Doppler ultrasonography analysis

Reversed flow, including bidirectional flow and CRF, was defined as a retrograde flow waveform in the VA in each cardiac cycle (Buckenham and Wright 2004; Labropoulos et al. 2010; Päivänsalo et al. 1998). Bidirectional flow was defined as initial antegrade flow and subsequent continuous retrograde flow in each cardiac cycle (Buckenham and Wright 2004). CRF was defined as a completely retrograde flow waveform in each cardiac cycle (Labropoulos et al. 2010). CRF cases were divided into two types, according to whether the end-diastolic flow velocity of the CRF was 0 cm/s (intermittent CRF [ICRF], n = 15) or >0 cm/s (continuous CRF [CCRF], n = 8). ICRF cases were subdivided into two types: ICRF with (n = 10) or without (n = 5) knock-type Doppler signals. "Knock-type" Doppler signals were characterized previously by several authors (Syme 2005, 2009; Tsivgoulis et al. 2009) as bright signals of a transient nature and short duration that occur periodically and at low frequency during the Doppler ultrasonography analysis.

Peak reversed velocity (PRV), cardiac cycle time (CC), ICRF time in the target VA (t_{ICRF}) and bilateral VA diameter were measured. t_{ICRF} was defined as the duration of the entire reversed flow period. Peak systolic velocity (PSV) and end-diastolic velocity (EDV) of the contralateral VA were recorded. The resistance index (RI) in the contralateral VA and the t_{ICRF}/CC ratio in