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● *Original Contribution*

EVALUATION OF INTERVENTIONAL THERAPY FOR PATIENTS WITH INTRACRANIAL VERTEBRAL ARTERY STENOSIS BY TRANSCRANIAL COLOR-CODED SONOGRAPHY

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Abstract—The aim of this study was to evaluate the efficacy of stenting for patients with intra-cranial vertebral artery stenosis by trans-cranial color-coded sonography and to analyze the risk factors of in-stent restenosis (ISR). In total, 121 patients with intra-cranial vertebral artery stenosis stents were included. The follow-up time was 3–12 mo (mean: 9.9 mo). The success rate was 92.6%. Peak systolic velocity and end-diastolic velocity decreased from 261 ± 63 to 109 ± 41 cm/s and from 133 ± 44 to 47 ± 18 cm/s, respectively (both $p < 0.001$). Peak systolic velocity (245 ± 47 cm/s) and end-diastolic velocity (121 ± 31 cm/s) of patients with ISR (18.9%, 20/106) were higher than those of patients without ISR (101 ± 38 and 44 ± 17 cm/s, respectively) at 12 mo post-procedure ($p < 0.05$). The length of the stent and residual stenosis were related to ISR. In conclusion, stenting is a feasible treatment method for intra-cranial vertebral artery stenosis. Trans-cranial color-coded sonography can be used for monitoring patients to identify ISR. (E-mail: dryanghua99@163.com) © **2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Intra-cranial vertebral artery, Stenosis, Stenting, In-stent restenosis, Trans-cranial color-coded sonography.**

INTRODUCTION

Approximately 25% of ischemic strokes occur within the territory of the vertebral basilar artery. Severe intra-cranial vertebral artery stenosis (IVAS) or occlusion is the most common arterial lesion causing posterior circulation ischemia (Caplan 2012). The rate of recurrent stroke in patients with symptomatic intra-cranial atherosclerotic stenosis has been higher than 10% per year, despite aggressive medical treatment (Chimowitz et al. 2005; Derdeyn et al. 2014). With the development of interventional therapy, stenting has increasingly become an important treatment strategy for intra-cranial stenosis (Jiang et al. 2011; Siddiq et al. 2009). However, the peri-procedural morbidity and high restenosis rate of stenting affect its long-term outcome (Chimowitz et al. 2011; Derdeyn et al. 2014). The benefits of stent implantation for IVAS and the optimum imaging methods for in-stent restenosis (ISR) also remain unclear (Ding et al. 2013; Psychogios et al. 2013). Although digital subtraction angiography (DSA) is the gold standard for the diagnosis of IVAS, it is nonetheless an expensive and invasive examination. Repeated DSA tests within a short span for follow-up after stenting are still limited. Recently, trans-cranial color-coded sonography (TCCS) was reported to be an effective tool for intra-cranial stenting evaluation (Moreira et al. 2012; Wang et al. 2013). However, evaluations of the clinical application of TCCS in the management of stenting for IVAS have been lacking. In this study, we used TCCS as a follow-up method to assess hemodynamic changes before and after stenting in patients with IVAS and to identify the risk factors associated with in-stent restenosis (ISR).

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The authors have no conflicts of interest to disclose.

METHODS

Patients

The study protocol was approved by our institutional review board. All patients were fully informed of the procedure and signed a consent form. The study was conducted in compliance with Health Insurance Portability and Accountability Act (HIPAA) regulations. The privacy of personal health information was protected appropriately according to the HIPAA Privacy Rule. We retrospectively selected 121 patients (105 males and 16 females) with a mean age of 63.7 ± 8.4 y (range: 45–85 y) from 167 consecutive patients with severe (≥70%) symptomatic IVAS undergoing stenting at our institution from November 2011 to December 2013. The exclusion criteria for this study were severe stenosis of the extra-cranial vertebral artery (which could cause under-evaluation of the degree of stenosis of IVAS) or basilar artery (increased resistance of the vertebral artery), non-atherosclerotic stenosis (such as arterial dissection) and other conditions, such as chronic pulmonary disease and coronary arterial disease with low cerebral blood flow. All of the patients' demographic characteristics were collected and are summarized in Table 1.

DSA and stenting procedure

The DSA and stenting procedures were performed by experienced neuroradiologists in an operating room. A total of 98 balloon-expandable stents and 23 self-expandable stents were applied in this study. The stents were classified as either bare metal stents (n = 86) or drug-eluting stents (n = 35). All intra-cranial vertebral artery (IVA) stenting procedures were performed using a Neurostar Plus/T.O.P double C-arm angiography system (Siemens, Munich, Germany) according to a protocol described previously (Jiang et al. 2011). Briefly, during the procedure, all patients received intra-venous heparin to maintain an activated clotting time of between 250 and 300 s. A 6-Fr guiding catheter was used to deliver the stent system *via* the femoral artery. Under roadmap guidance, an assembly of a microcatheter and a microwire was carefully steered through the target lesion to its distal segment. The stent delivery system was advanced over the microwire across the target lesion, the stent was deployed and the delivery catheter was removed. The success of stent placement was defined as a reduction in lumen diameter to <30% at the lesion site after the procedure (SSYLVIA Study Investigators 2004). The length of the stent was recorded from the DSA images. Pre-procedure and post-procedure medical therapy for all patients was managed in accordance with the SAMMPRIS (Stenting and Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis) trial (Chimowitz et al. 2011) and Chinese guidelines for endovascular management of ischemic cerebrovascular diseases (Liu et al. 2013). Patients were pre-treated with 300 mg aspirin for at least 2 h (24 h is recommended) before the operation. After the procedure, 75 mg/d clopidogrel was continued for at least 1 mo, and 300 mg/d aspirin was continued for the entire follow-up period. Underlying stroke risk factors were strictly controlled, so that the target systolic blood pressure was lower than 140 mm Hg (<130 mm Hg if diabetic) and the low-density lipoprotein cholesterol was lower than 1.81 mmol/L.

Table 1. Demographic characteristics of the patients

Number of patients	121
Number of males	105 (86.7%)
Co-morbidities (%)	
Hypertension	93 (76.9%)
Coronary heart disease	28 (23.1%)
Diabetes mellitus	43 (35.5%)
Dyslipidemia	60 (49.6%)
Smoking	69 (57.0%)

Trans-cranial color-coded sonography

According to the trans-cranial color-coded sonography (TCCS) protocol previously described by Nedelmann et al. (2009), all ultrasonography examinations were performed by physicians who had at least 5 y of vascular ultrasound experience. A Philips ultrasound systems (IU-22, Philips, Bothell, WA, USA) with a 1.0- to 5.0-MHz phased array probe was used to examine the IVA. Patients were in the prone position with their heads bowed toward the chest. The probe was placed below the tuberosity of the occipital bone. Optimal images were obtained by turning the transducer slightly off midline and the ultrasound beam directly toward the bridge of the patient's nose. A Y-shaped color flow image of the vertebro-basilar junction was visualized at a depth of 60–80 mm. The direction, brightness and tortuosity of the blood flow were observed by color Doppler flow imaging. Peak systolic velocity (PSV) and end-diastolic velocity (EDV) of the IVA were measured before the stenting procedure and 1 wk and 3, 6 and 12 mo after the procedure. An IVAS was diagnosed when the spectral waveforms exhibited a focal increase in PSV and EDV and color Doppler flow imaging revealed a bright and mosaic-like color change of the blood flow at the stenotic lesions. According to the criteria for evaluating the degree of IVAS by TCCS published by Baumgartner et al. (1999), if PSV is ≥120 cm/s, the degree of stenosis is ≥50%, and if PSV is ≥90 cm/s, the degree of stenosis is ≤50%. ISR was defined as a luminal narrowing of ≥50% in the stented segment (SSYLVIA Study Investigators 2004) assessed by TCCS and DSA.