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Internal Jugular Vein Stenosis: Diagnostic Criteria, Impact on Intracranial Pressure and Cerebral Venous Outflow Redistribution

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Abstract

Background: This study was aimed to establish a standard for internal jugular vein-J3 segment stenosis by jugular ultrasound and to investigate the impact of IJV-J3 segment stenosis on intracranial pressure and cerebral venous outflow.

Methods: 126 subjects who underwent jugular ultrasound from January 2015 to December 2020 were retrospectively recruited.

Results: The flow velocity of internal jugular vein -J3 segment was significantly lower in subjects with the trans-stenotic pressure ≥ 4 mmHg compared with those with trans-stenotic pressure <4 mmHg (p=0.0402). Flow velocity ≤ 27.5 cm/s suggested a trans-stenotic pressure ≥ 4 mmHg and was defined as internal jugular vein stenosis (p=0.0254). No difference was found between the intracranial pressure of internal jugular vein stenosis subjects and that of non-internal jugular vein stenosis subjects (p=0.7329). Results from linear regression also implied no correlation between internal jugular vein stenosis and intracranial pressure. However, the flow velocity in both left and right vertebral vein were significantly higher in internal jugular vein stenosis subjects as compared to normal controls (p=0.0056, p=0.0454).

Conclusion: Flow velocity ≤ 27.5 cm/s in internal jugular vein-J3 segment was defined as internal jugular vein stenosis. Internal jugular vein stenosis did not lead to intracranial hypertension, but resulted in cerebral venous outflow redistribution which presented as increased venous outflow in vertebral veins.

Keywords: Internal jugular vein stenosis • Diagnostic criteria • Intracranial hypertension • Cerebral venous outflow • Vertebral vein

Introduction

Internal Jugular Vein Stenosis (IJVS), a major type of cerebrospinal venous insufficiency, has received considerable attention in recent year [1]. Intraluminal anomalies, extraluminal oppression and systemic factor-related anomalies were considered as etiologies of IJVS [2-4]. Symptoms such as long-term unbearable head noise, tinnitus, headache, dizziness and sleeping disorder were observed in IJVS [5].

However, there is no valid and reliable diagnostic standard for IJVS. The only reported diagnostic standard for IJVS was put up by Utriainen D et al, [6]. IJVS was defined as Cross-sectional Area (CSA) less than 25 mm^2 below the C3 level which is one-third of a normal jugular CSA an expected diameter of 1 cm and a circular circumference. However, this diagnostic standard was groundless. First, there is no evidence supporting why one-third was chosen. Second, the diameter and CSA in right internal jugular vein (IJV) was reported to be 17 ± 5 mm and 181 ± 111 mm^2 whereas those in left IJV was 14 ± 5 mm and 120 ± 81 mm^2 [7]. IJV did not exhibit an expected diameter of 1 cm. Third, IJV exhibits an elliptical shape instead of a circular shape [8]. Furthermore, IJV above the C3 neck level was defined as CSA less than 12.5 mm^2 which is half of the lower neck level [6]. No evidence was found with regard to why IJVS in upper segment was defined as half of CSA in lower segment.

Our previous study demonstrated a remarkable alleviation of the clinical manifestations after stenting in IJVS patients with trans-stenotic pressure ≥ 4 mmHg [9]. It is suggested that trans-stenotic pressure ≥ 4 mmHg is pathological and can be defined as IJVS. However, the use of trans-stenotic pressure, which was measured by intravascular pressure wire, was limited due to inconvenience and invasiveness. Therefore, a new diagnostic method for IJVS is in urgent need.

Despite the extensive use of carotid ultrasound, jugular ultrasound was not widely used. Several recent studies have used jugular ultrasound to assist the diagnose of cerebrospinal venous insufficiency [1,10,11]. However, no diagnostic standard was established of jugular ultrasound in diagnosing IJVS. Although stenosis may appear in any segment of IJV, most of the stenosis occurred in J3 segment [12-15]. This study was aimed to establish a standard for IJV-J3 stenosis by jugular ultrasound and to investigate the impact of IJV-J3 segment stenosis on intracranial pressure and cerebral venous outflow.

Materials and Methods

Subject recruitment

Subjects who were suspected to suffer from IJVS were retrospectively

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recruited from neurology and neurosurgery department of Xuanwu Hospital from January 2015 to December 2020. Inclusion criteria were as follows: 1) No past medical history of central nervous system diseases; 2) No intracranial lesions on cranial magnetic resonance imaging; 3) No dysplasia or focal stenosis in intracranial sinuses, J2 and J3 segment of IJV. 4) No acute or chronic heart failure. This study was approved by the ethnic committee. All subjects enrolled in this study gave their informed consent.

Study design

The demographic data, jugular ultrasound parameters, Cerebrospinal Fluid (CSF) opening pressure and trans-stenotic pressure gradient in IJV-J3 segment was recorded. Jugular ultrasound was conducted with echo-color doppler in a supine position. The CSF opening pressure was detected by lumbar puncture. The trans-stenotic pressure gradient was detected by intravascular pressure wire. Based on our previous report, the trans-stenotic pressure ≥ 4 mmHg in IJV-J3 segment was defined as IJVS [9]. Subjects were subsequently divided into IJVS and non-IJVS.

Statistical analysis

All statistical analyses were conducted using SPSS Version 16.0 (SPSS, Inc., Chicago, Illinois, United States). Continuous data were expressed as mean ± standard deviation and processed by using student's t-test. Correlations were performed with Pearson correlation coefficients. Binary logistic regression analysis was conducted with the enter method to identify odds ratio and the corresponding 95% confidence interval. The cutoff point was calculated by using receiver operating characteristic (ROC) curves. A p value of <0.05 was considered statistically significant.

Results

The diagnostic criteria of IJVS in IJV-J3 segment

A total of 82 non-IJVS and 44 IJVS subjects were enrolled in this study. Detailed demographic features were summarized in Table 1. Diameter, flow volume and flow velocity in IJV-J3 segment were analyzed. No statistical differences were found in diameter and flow volume between subjects with trans-stenotic pressure <4 mmHg and those with trans-stenotic pressure ≥ 4 mmHg (p=0.1418, p=0.1536 (Figure 1A and 1B). The flow velocity of IJV-J3 segment was significantly lower in subjects with trans-stenotic pressure ≥ 4 mmHg compared with those with trans-stenotic pressure <4 mmHg (p=0.0402, Figure 1C). It is suggested that low flow velocity of IJV-J3 segment may be correlated with IJVS. Further analysis by ROC curve indicated that diameter and flow volume were not appropriate indicators for IJVS (p=0.1851, p=0.1099, Figure 1D and 1E). Flow velocity ≤ 27.5 cm/s suggested a trans-stenotic pressure ≥ 4 mmHg (p=0.0254, Figure 1F). Therefore, subjects with flow velocity ≤ 27.5 cm/s in IJV-J3 segment can be diagnosed as IJVS.

The impact of IJVS on ICP

There was no difference in ICP between IJVS subjects and non-IJVS subjects (p=0.7329) (Figure 2). Results from linear regression also implied no correlation between IJVS and ICP (Table 2).

Cerebral venous outflow redistribution in IJVS subjects

The internal jugular veins and the vertebral veins are the two major pathways for cerebral venous outflow [16,17]. We subsequently investigated whether the blood flow was altered in vertebral veins in the presence of IJVS. The flow velocity in both left and right vertebral vein were significantly higher in IJVS subjects as compared to non-IJVS subjects (p=0.0056, p=0.0454) (Figure 3A and 3B).

Discussion

In current clinical using of jugular ultrasound, IJVS was diagnosed by comparing the abnormal side with contralateral side subjectively [18-20]. However, it is difficult to diagnose IJVS when stenosis was present in both sides or when dysplasia was present in contralateral side. The diagnostic criteria of jugular ultrasound in diagnosing IJV-J3 segment stenosis remained unknown. Remarkably, results from this study identified that flow velocity ≤ 27.5 cm/s may serve as the diagnostic criteria for IJV-J3 segment stenosis. Although previous report suggested that trans-stenotic pressure ≥ 4mmg was the indication of stenting in IJV [2], the measurement of trans-stenotic pressure has to be done intraoperatively and invasively. A non-invasive method before operation would help to decide whether stenting evaluation was required. Our results indicated that subjects with flow velocity ≤ 27.5 cm/s in IJV-J3 segment requires further evaluation for stenting if no external compression is present. It is report that a proportion of IJV-J3 segment stenosis was caused by elongated styloid process with the transverse process of C1 [21]. Symptoms were alleviated after Styloidectomy [22]. Whether flow velocity ≤ 27.5 cm/s serve as the indication of styloidectomy requires further evaluation.

It is reported that transverse sinus stenosis (TSS) is associated with intracranial hypertension (IH) [23,24]. However, the present study demonstrated that IJVS did not necessarily lead to IH. IJV is a continuation of transverse sinus [25]. It seems confusing why subjects with TSS suffered from IH whereas subjects with IJVS had normal ICP. Doepp F et al, reported that condylar vein drains venous blood from jugular bulb to vertebral veins [26]. Furthermore, the flow volume in collateral veins was increased in presence of IJVS [8]. It is suggested that venous blood was drained into vertebral veins and collateral veins in presence of IJV-J3 segment stenosis. Studies have shown that extra-jugular venous system is sufficient to take over the entire cerebral venous outflow [26]. The relatively stable ICP in the presence of IJV-J3 segment stenosis is probably due to the existence of extra-jugular venous system including condylar vein and collateral veins.

Table 1. Baseline demographic features of enrolled subjects. BMI: Body Mass Index.

Characteristics	Enrolled Subjects (N = 126)	Non-IJVS Subjects (N = 82)	IJVS Subjects (N = 44)
Age (years)	55.07 ± 2.36	54.48 ± 2.54	56.17 ± 2.19
Female	49 (38.9%)	33 (40.2%)	16 (36.4%)
BMI	24.97 ± 3.75	24.28 ± 3.36	26.25 ± 3.89
Smoking	29 (23.0%)	20 (24.4%)	9 (20.5%)
Alcohol	23 (18.3%)	14 (17.1%)	9 (20.5%)
Co-morbid disease			
Hypertension	49 (38.9%)	32 (39.0%)	17 (38.6%)
Diabetes mellitus	6 (4.8%)	4 (4.9%)	2 (4.5%)
Coronary artery disease	6 (4.8%)	4 (4.9%)	2 (4.5%)
Hyperlipidemia	26 (20.6%)	18 (22.0%)	8 (4.5%)
Vital signs at admission			
Systolic pressure (mmHg)	125.50 ± 2.17	124.24 ± 2.05	127.84 ± 3.02
Diastolic pressure (mmHg)	76.27 ± 1.50	76.65 ± 1.42	75.57 ± 1.78
Heart rate (bpm)	78.45 ± 1.31	78.72 ± 1.28	77.95 ± 1.52
Respiratory rate (/min)	19.25 ± 0.18	18.99 ± 0.16	19.86 ± 0.21
Body temperature (°C)	36.42 ± 0.03	21.09 ± 0.03	36.35 ± 0.04

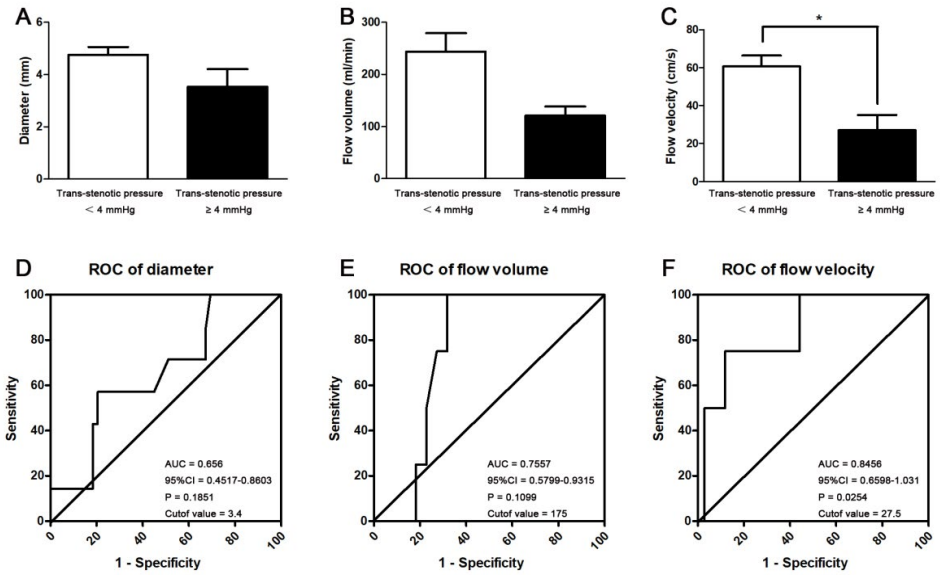

Figure 1. No statistical difference in diameter (A) and flow volume (B) were found between subjects with trans-stenotic pressure ≥ 4mmHg and those with trans-stenotic pressure <4 mmHg in IJV-J3 segment. The flow velocity in IJV-J3 segment was lower in subjects with trans-stenotic pressure ≥ 4 mmHg compared with those with trans-stenotic pressure <4 mmHg (C). The receiver operating characteristics curve of diameter (D), flow volume (E) and flow velocity (F) in IJV-J3 segment were performed. Flow velocity ≤ 27.5 cm/s indicated a trans-stenotic pressure ≥ 4 mmHg in IJV-J3 segment *p<0.05.

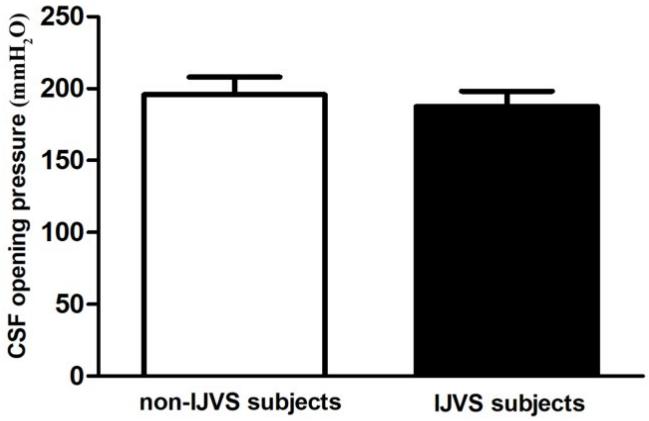

Figure 2. There was no difference in ICP between IJVS subjects and normal controls. (ICP: Intracranial Pressure; IJVS: Internal Jugular Vein Stenosis).

Table 2. IJVS exerted no impact on ICP. IJVS: Internal Jugular Vein Stenosis; ICP: Intracranial Pressure; CI: Confidence Interval; OR: Odds Ratio; N = 39.

Independent Variable	Dependent Variable	OR	*P*	95% CI for OR	
				Lower	**Upper**
IJVS	ICP (mmH_2O)	0.998	0.725	0.985	1.010

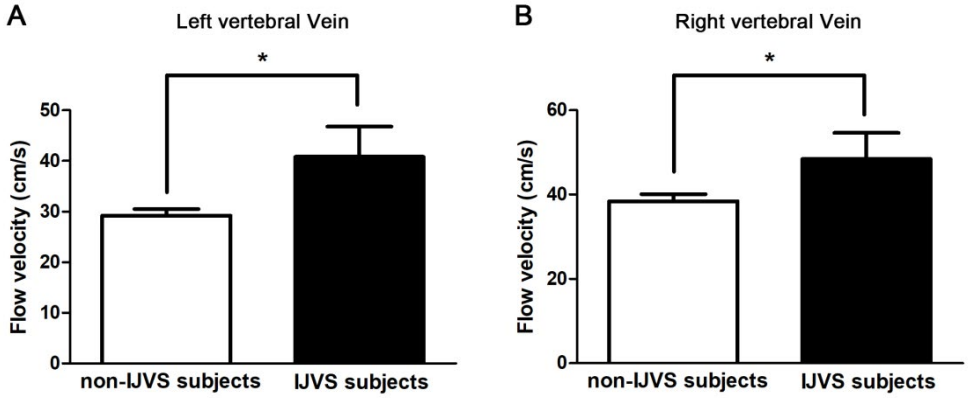

Figure 3. The flow velocity in left (A) and right (B) vertebral venous of IJVS subjects were higher than those of normal controls. *p<0.05; IJVS: Internal Jugular Vein Stenosis.

It is well-known that theflow velocity increases at the stenotic site in the presence of arteriostenosis [27]. Results from the present study revealed a reduced flow velocity in IJV and an increased flow velocity in vertebral veins in the presence of IJV-J3 segment stenosis. Interestingly, we found that the flow velocity reduces in the presence of phlebostenosis. The venous blood might bypass the stenotic vein and drains into adjacent veins. It is suggested that cerebral venous outflow diverted from IJV to vertebral veins. IJVS resulted in cerebral venous outflow redistribution.

The limitations of this study were: 1) a relatively small sample size; 2) Lack of ultrasonographic diagnostic criteria in IJV-J1 and IJV-J2 segment. As collaterals entered IJV, the flow volume increased from J3 to J1 segment in normal subjects [8,28]. Ultrasound parameters in each segment should be analyzed independently instead of considering IJV as a whole. Unfortunately, there was inadequate sample size of IJVS in J1 and J2 segment.

Conclusion

Flow velocity ≤ 27.5 cm/s in IJV-J3 segment can be defined as IJVS. IJVS did not lead to IH, but resulted in cerebral venous outflow redistribution which presented as increased venous outflow in vertebral veins.

Statement of Ethics

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The trial was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Xuanwu Hospital ethnics committee. The ethnic number is 2019 [006] and individual consent for this retrospective analysis was waived.

Conflict of Interest Statement

All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

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Author Contributions

Min Li: Contributed to analyzing clinical data and drafting the manuscript, Manuscript writing and final approval of manuscript.

Xiaogang Gao: Contributed to drafting the manuscript, Manuscript writing and final approval of manuscript. Fengwei Liu: contributed to collecting clinical data, Manuscript writing and final approval of manuscript.

Yaqiong Jia: Contributed to collecting clinical data, Manuscript writing and final approval of manuscript.

Ran Meng: Contributed to acquisition of study funding and critical revision of the manuscript, Manuscript writing and final approval of manuscript.

Xunming Ji: Contributed to analyzing clinical data and critical revision of the manuscript, Manuscript writing and final approval of manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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