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Comparison Between Carotid Ultrasound and Digital Subtraction Angiography in the Diagnosis of Carotid Artery Stenosis in Patients with Cerebral Infarction

Comparación entre la Ecografía Carotídea y la Angiografía por Sustracción Digital en el Diagnostic de Estenosis de la Arteria Carótida en Pacientes con Infarto Cerebral

Si-Yu Chen[1]; Chen Chen[2]; Ling Ding[1]; Hong Liu[2]; Ting Yang[2] & Jiang Wu[2]

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SUMMARY: This study aimed to compare the clinical value of carotid ultrasound and digital subtraction angiography (DSA) for carotid artery stenosis in patients with cerebral infarction. Sixty patients with cerebral infarction underwent carotid ultrasound and DSA. Carotid artery stenosis, degree of stenosis (mild, moderate, severe, and occlusion), and carotid artery plaques were recorded and compared. Carotid stenosis rate was 96.67 % (58/60) and 91.67 % (55/60) on DSA and carotid ultrasound, respectively, and the difference was not statistically significant. Mild, moderate, and severe carotid artery stenosis and occlusion were diagnosed in 35, 28, 20, and 17 arteries, respectively, with DSA, and in 39, 25, 10, and 9 arteries, respectively, with carotid ultrasound. There was a statistically significant difference in the degree of carotid stenosis between the two methods ($p<0.05$). The kappa value of carotid plaques detected by carotid ultrasound and DSA was 0.776, indicating good consistency. Both carotid ultrasound and DSA are effective for screening carotid artery stenosis and carotid atherosclerotic plaques. While carotid ultrasound is faster and more convenient, DSA can more accurately detect the degree of stenosis and presence of occlusion. Thus, our recommendation is a combination of carotid ultrasound and DSA in clinical settings to improve the convenience and accuracy of diagnosis.

KEYWORDS: Carotid ultrasound; Digital subtraction angiography; Carotid artery stenosis; Diagnostic value.

INTRODUCTION

Cerebral infarction is the third most disabling disease in the world, the second leading cause of death after cardiac ischaemic disease, and one of the most common causes of death among Chinese adults (Hankey, 2017). Carotid atherosclerotic stenosis is considered the most important risk factor of cerebral infarction. There are currently two main hypotheses on the pathogenesis of carotid atherosclerosis leading to cerebral infarction: (1) luminal stenosis caused by carotid atherosclerotic plaques causes hypoperfusion haemodynamic changes in brain tissue, leading to cerebral infarction; (2) Unstable carotid atherosclerotic plaque results in local thrombosis or detaches to produce microembolus that blocks blood vessels and causes cerebral infarction (Parmar *et al*., 2010). Studies on the correlation between the degree of carotid artery stenosis and cerebral infarction have found that the prognosis after cerebral infarction is worse in patients with stenosis ranging from 85 % to 99 %, while patients with a mild degree of stenosis are more likely to have better prognosis of lacunar infarction (Paciaroni *et al*., 2000). The degree of carotid artery stenosis in patients with cerebral infarction affects the condition and treatment plan; therefore, early and accurate evaluation of the degree of stenosis and understanding of the haemodynamic characteristics of patients are conducive to guiding clinical diagnosis and treatment and are of great significance to improving prognosis.

At present, the commonly used carotid artery stenosis diagnostic methods include digital subtraction angiography (DSA) and carotid ultrasound. DSA has always been considered to be the "gold standard" for carotid artery stenosis diagnosis and has high application value in determining the degree of carotid artery stenosis. Yet, this method has a certain degree of associated trauma, complex

[1] Shanxi Medical University, Taiyuan, China.
[2] Shanxi Cardiovascular Hospital Affiliated to Shanxi Medical University, Taiyuan, China.

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operation steps, use of professional digital subtraction machines in the examination process, higher requirements for technology and equipment, and many primary hospitals do not meet these criteria. Further, the cost of diagnosis is high, making it more restricted in clinical application (Rodriguez *et al*., 2011). With the continuous development of medical technology, carotid artery ultrasound can help laboratory and clinical physicians analyse the degree of carotid artery stenosis in patients with ischaemic cerebrovascular disease and understand the morphology of the vascular wall as an important non-invasive examination method of cervical movement stenosis; this method is widely used because it is safe, convenient, economical, and efficient (Arous *et al*., 2014).

Different diagnostic methods have varied diagnostic accuracy and different effects on patient prognosis. Therefore, the present study provides a comparative analysis between carotid artery ultrasound and DSA to determine the more accurate and convenient diagnostic method in clinical settings and evaluate their diagnostic values for carotid artery stenosis in patients with cerebral infarction.

MATERIAL AND METHOD

Participants

This single-centre, retrospective study consisted of a cohort of patients from the neurology department of Shanxi Cardiovascular Hospital who were admitted to our institution between August 2021 and February 2022 with a diagnosis of cerebral infarction. The study included 33 men and 27 women, with a mean age of 61.97 (±10.14) years; 23 cases of hypertension, 19 cases of diabetes mellitus, and 8 cases of hyperlipidaemia were enrolled. The study design was approved by the local ethics committee, and all patients provided signed informed consent.

The participants must meet the diagnostic criteria in the China Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2018, and their diagnosis must be confirmed by clinical symptoms, signs, and imaging tests. The participants were the confirmed diagnoses, with complete clinical and imaging data.

Patients with other known diseases (cerebral haemorrhage, intracranial infection, cardiovascular disease, vasculitis, dissection aneurysm, liver and kidney dysfunction, or organ damage) were excluded from the study. Some patients had missing clinical data and were thus excluded from the study population.

Carotid ultrasound

All patients were examined in a recumbent position, with the head on the lateral side and the neck fully exposed, using Philips IU-22 colour Doppler ultrasonic diagnostic instrument. The probe was placed on the neck and scanned upward along the anterior/posterior edge of the sternocleidomastoid muscle. Two-dimensional images of the transverse and longitudinal axes were selected to observe the external carotid artery and internal carotid artery. The transverse and longitudinal axes of the extracranial segment from the internal carotid artery to the common carotid artery was scanned, and the blood vessel along the neck, blood flow, degree of vascular stenosis, presence of plaque in the carotid artery tube, and location and size of the plaque were determined.

Digital subtraction angiography

DSA was performed with the patient in the supine position. Conventional bilateral inguinal and perineal skin disinfection and 1 % lidocaine local infiltrative anaesthesia were achieved after successful puncture of the right femoral artery using the Seldinger technique. A 5F artery sheath was used as the indwelling catheter; 3000 units of heparin was used for systemic heparination; under the bilateral internal and external carotid arteries, bilateral subclavian, bilateral vertebral artery compression injection, with 5F pigtail and single curved catheter for aortic arch + whole cerebral angiography; the aortic arch and common carotid angiography images were collected. The diameter of the common carotid artery, inner diameter of the internal carotid artery, and lumen of the vessel were measured, and the inner diameter of the narrowest carotid blood vessel was measured.

Observation index.

(1) DSA and carotid artery ultrasound were used to detect carotid artery stenosis; (2) degree of carotid artery stenosis was determined according to the North American symptomatic carotid artery intimal artery decortication test (Grant *et al*., 2003), and the degree of carotid artery stenosis was divided into mild stenosis (<50 %), moderate stenosis (50 %–69 %), severe stenosis (70 %–99 %), and occlusion (100 %); (3) carotid artery ultrasound and DSA detected carotid artery plaque consistency.

Statistical analysis

Statistical analyses were performed using SPSS version 22.0 software. Statistical significance was assessed at a p-value of <0.05. Descriptive statistics were calculated for all variables of interest and included means and standard deviations.

RESULTS

Analysis of carotid artery ultrasound and DSA findings in the diagnosis of carotid artery stenosis. Among the 60 patients with cerebral infarction, carotid artery stenosis rate was 96.67 % (58/60) on DSA and 91.67 % (55/60) on carotid artery ultrasound (Table I), and there was no significant difference between the results ($\chi^2 = 1.365$, $p = 0.243$).

Table I. Analysis of carotid artery ultrasound and digital subtraction angiography (DSA) in the diagnosis of carotid artery stenosis.

Diagnostic methods	Carotid artery stenosis (%)
DSA (n=60)	96.67 %
Carotid artery ultrasound (n=60)	91.67 %

Carotid artery ultrasound and DSA in the diagnosis of the degree of carotid artery stenosis. Mild, moderate, and severe carotid artery stenosis and occlusion were diagnosed in 35, 28, 20, and 17 arteries, respectively, by DSA, and in 39, 25, 10, and 19 arteries, respectively, by carotid ultrasound (Table II). There was a significant difference in the degree of carotid stenosis between the two methods ($\chi^2 = 4.462$, $p = 0.024$).

Table II. Carotid artery ultrasound and digital subtraction angiography (DSA) in the diagnosis of the degree of carotid artery stenosis.

Diagnostic methods	mild stenosis	moderate stenosis	severe stenosis	occlusion
DSA	35	28	20	17
carotid	39	25	10	9

Values are expressed as numerals.

Carotid artery ultrasound and DSA detected carotid artery plaque consistency. The findings on carotid artery ultrasound and DSA (Table III) differed in the 12 arteries, and the two methods showed good consistency in the carotid plaque evaluation (κ= 0.813).

Imaging analysis of typical cases. Figures 1 and 2 show the preoperative image data of a 59-year-old male patient. Figure 1 shows the carotid artery ultrasound image; plaque formation at the beginning of the right side can be observed with the ultrasound and was approximately 4.7 × 2.1 mm (length × thickness); the plaque caused local lumen stenosis, and the estimated diameter stenosis rate was approximately 59 %. Figure 2 shows a DSA image showing mild stenosis at the beginning of the right internal carotid artery. Carotid artery ultrasound can observe the location, size, and shape of carotid atherosclerotic plaque in multiple sections and angles, while DSA cannot determine the plaque composition. The patient had mild carotid artery stenosis; however, moderate stenosis was diagnosed with carotid artery ultrasound. The accuracy of carotid artery ultrasound in diagnosing the degree of stenosis was lower than that of DSA.

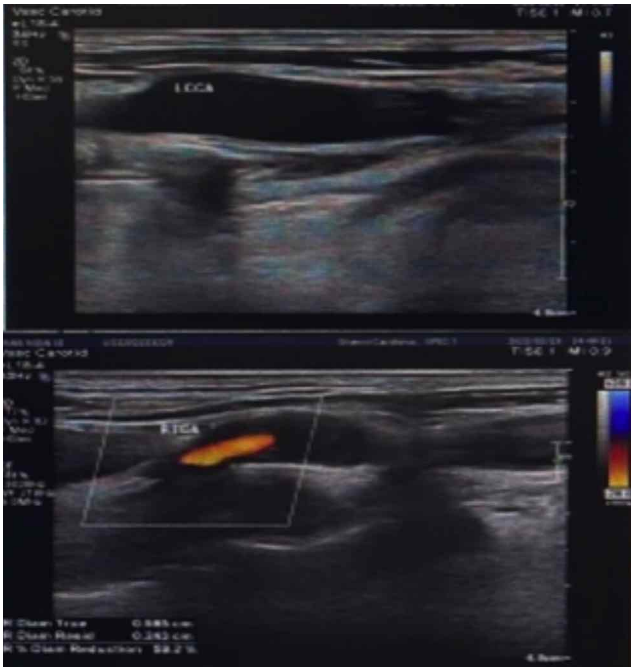

Fig. 1. Carotid artery ultrasound image.

Table III. Carotid artery ultrasound and digital subtraction angiography (DSA) detected carotid artery plaque consistency analysis (n)

Carotid artery ultrasound	DSA		
	Common carotid artery	Internal carotid artery	Bifurcation of common carotid artery
Common carotid artery	29	2	2
Internal carotid artery	2	31	2
Bifurcation of common carotid artery	1	3	25

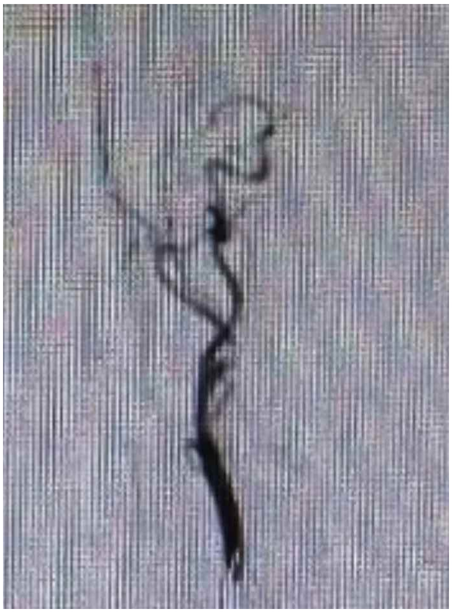

Fig. 2. Digital subtraction angiography image.

DISCUSSION

Cerebral infarction refers to a disorder or even interruption of blood circulation in the brain due to various aetiologies resulting in ischemia and hypoxia of brain tissue, which in turn causes ischaemic necrosis or softening of localised brain tissue, ultimately damaging the nerve function of brain tissue (Worthmann *et al*., 2015). The fatality, disability, and recurrence rates of cerebral infarction are usually high, and the duration and recovery period are long, which seriously threaten the safety of patients and reduce the quality of life of patients and their families. With the accelerated pace of modern lifestyle and changes in diet and lifestyle, the age of onset of cerebral infarction is becoming lower; this has become a global public health problem (Nazari *et al*., 2018). The degree of carotid atherosclerotic stenosis and susceptibility to plaques are important factors in predicting cerebral infarction (Howard *et al*., 2015). Early detection of carotid atherosclerotic lesions, accurate assessment of whether it causes stenosis, degree of stenosis, and presence of atherosclerotic plaques influence clinicians' decision in choosing an individualised treatment plan, which effectively reduces the risk of stroke and recurrence.

Studies have shown that 15 % of cerebral infarctions are caused by carotid artery stenosis (Momjian-Mayor *et al*., 2012). In patients with >70 % of carotid artery stenosis, the incidence of cerebral infarction can be as high as 13 % per year (Jander *et al*., 2001). Among people aged >65 years, 5 %–10 % have >50 % proximal carotid artery stenosis, and 0.3 %–2.0 % of patients with asymptomatic carotid artery stenosis develop cerebral infarction each year (Park *et al*., 2019). The related mechanism is as follows: carotid atherosclerotic lesions lead to arterial lumen stenosis, blood flow rate at the arterial stenosis site is significantly accelerated, and distal blood flow rate is significantly reduced, resulting in a corresponding decrease in cerebral blood flow and oxygen exchange. The brain tissue cells are thus in a state of hypoperfusion and cerebral infarction occurs. At the same time, arterial stenosis or occlusion forms a hypoperfusion state, leading to impaired clearance of microemboli due to exacerbated cerebral infarction (Caplan *et al*., 2006). The study showed that the carotid artery stenosis rate was 96.67 % on DSA and 91.67 % on carotid ultrasound. Eight arteries, which were diagnosed as occluded by digital subtraction angiography, were diagnosed as other degrees of stenosis by carotid ultrasound. According to previous studies, the analysis may be to detect the influence of receptor sites, poor detection effect, carotid artery ultrasound is affected by the depth of blood vessels, tube diameter, probes from different angles to detect blood flow in blood vessels, the results will be different. Carotid artery ultrasound has the following limitations in the examination of carotid artery stenosis: (1) carotid artery ultrasound position of the patient may lead to a weak local blood flow signal, affecting examination results; (2) the spatial resolution of the ultrasound image is limited compared with that of DSA; (3) the quality of the ultrasound image and the judgment regarding carotid artery disease are influenced by the examiner's expertise.

Some studies have shown that the occurrence and development of cerebral infarction are related not only to the degree of carotid artery stenosis but also to carotid artery plaque (Palmieri *et al*., 2017). Carotid atherosclerosis is a complex dynamic progression process. Under the stimulation of various factors, the balance of the vascular endothelium is disrupted; gradually, the carotid artery intima thickens, and carotid artery plaques form. The disease progressively worsens and eventually causes carotid artery stenosis and plaque shedding to form a thrombus, resulting in cerebral infarction (Altaf *et al*., 2014). Relevant studies have found that 52 % of patients with cerebral infarction have carotid artery plaques (Liu & Chen, 2014), and some studies have confirmed that the detection rate of carotid plaques and proportion of unstable plaques in patients with cerebral infarction are significantly higher than those in normal control populations (Singh *et al*., 2013). Carotid plaques aggravate cerebral infarction, especially in patients with vulnerable plaques and promote the deterioration and recurrence of cerebral infarction (Xu *et al*., 2016). Carotid plaque is involved in the occurrence of the first cerebral infarction as well as in recurrence, thus increasing the risk of death from cerebral infarction (Di Tullio *et al*., 2009). This study showed that carotid artery ultrasound and DSA detected a highly consistent carotid plaque (k= 0.813), indicating that carotid artery ultrasound can accurately identify the location of carotid atherosclerotic plaques. Carotid ultrasound integrates the functions of colour blood flow imaging, two-dimensional images, and Doppler spectrum, which are very important in the diagnosis of carotid artery disease (Cires-Drouet *et al*., 2017). This method can thus be used to observe the patient's carotid artery condition, type of carotid artery plaque for identification, which can be used to identify plaque as early as possible, and nature of the plaque. resulting in timely and effective intervention for reducing the incidence of cerebral infarction.

As far as the current clinical situation is concerned, the main treatment method for carotid artery stenosis is to stabilise the plaque and avoid thrombosis, but it is necessary to formulate a reasonable treatment plan according to the degree of carotid artery stenosis. Therefore, determining the degree of carotid artery stenosis as soon as possible is critical. Carotid ultrasound is the use of ultrasound to clearly display the anatomy of blood vessels, cavity diameter, and other vascular conditions, which can be the carotid artery lesion range, size, plaque condition (with or without plaque, plaque nature), and stenosis (with or without stenosis, degree of stenosis). It is non-invasive, and convenient to operate, repeated multiple times, and can provide early diagnosis. Primary hospital do not always have access to large and expensive equipment; however, ultrasound instruments have been popularised owing to their price advantages. Active carotid artery screening for high-risk groups will greatly promote stroke prevention and control projects in China. DSA has been clinically recognised as the gold standard for diagnosing carotid artery stenosis (Brinjikji *et al*., 2016). It has a high application value in the identification of high-risk groups of carotid artery stenosis; it mainly uses X-ray technology to inject contrast medium into the common carotid artery, internal and external carotid artery for diagnosis, which can clearly show the distribution, specific location, and morphology of the cerebral arteries, sinuses, and reflux veins in different periods; this provides information to fully understand the patient's arterial stenosis at this stage and physicians can perform stenting while discovering the stenosis. The limitation of DSA is that it is an invasive examination, has high-dose radiation, and has complications such as puncture site haematoma and pseudoaneurysm during contrast injection; when the guidewire and catheter pass through the plaque site, it may also lead to plaque shedding that induces cerebrovascular accidents, and occasionally, allergic reactions to contrast agents may occur.

In summary, for the diagnosis of carotid artery stenosis in patients with cerebral infarction, carotid ultrasound is more convenient and cheaper; however, DSA is more accurate, and if necessary, a clinical combination can be applied. This study explored the consistency of carotid artery stenosis diagnosis in patients with cerebral infarction between cervical ultrasound and DSA. A limitation of the study is the small sample size.

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RESUMEN: Este estudio tuvo como objetivo comparar el valor clínico de la ecografía carotídea y la angiografía por sustracción digital (DSA) para la estenosis de la arteria carótida en pacientes con infarto cerebral. Sesenta pacientes con infarto cerebral fueron sometidos a ecografía carotídea y DSA. Se registraron y compararon la estenosis de la arteria carótida, el grado de estenosis (leve, moderada, grave y oclusión) y las placas de la arteria carótida. La tasa de estenosis carotídea fue del 96,67 % (58/60) y del 91,67 % (55/60) en DSA y ecografía carotídea, respectivamente, y la diferencia no fue estadísticamente significativa. Se diagnosticaron estenosis y oclusión de la arteria carótida leve, moderada y grave en 35, 28, 20 y 17 arterias, respectivamente, con DSA, y en 39, 25, 10 y 9 arterias, respectivamente, con ecografía carotídea. Hubo una diferencia estadísticamente significativa en el grado de estenosis carotídea entre los dos métodos (p<0,05). El valor kappa de las placas carotídeas detectadas por ecografía carotídea y DSA fue de 0,776, lo que indica una buena consistencia. Tanto la ecografía carotídea como la DSA son eficaces para detectar la estenosis de la arteria carótida y las placas ateroscleróticas carotídeas. Si bien la ecografía carotídea es más rápida y conveniente, la DSA puede detectar con mayor precisión el grado de estenosis y la presencia de oclusión. Por lo tanto, nuestra recomendación es una combinación de ecografía carotídea y DSA en entornos clínicos para mejorar la conveniencia y precisión del diagnóstico.

PALABRAS CLAVE: Ultrasonido carotídeo; Angiografía por sustracción digital; estenosis de la arteria carótida; Valor de diagnostic.

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Corresponding author:
Chen Chen
Shanxi Cardiovascular Hospital Affiliated to
Shanxi Medical University
18 Yifen Street
Taiyuan 030024
CHINA

E-mail: 13934161870@163.com