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Original Article

Anatomical variation of the internal jugular vein and its impact on temporary haemodialysis vascular access: an ultrasonographic survey in uraemic patients

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Abstract

Background. Creation of a reliable haemoaccess is a critical problem for practicing nephrologists once haemodialysis has been considered. A double-lumen internal jugular-vein catheter is favoured in most cases requiring temporary haemoaccess. However, numerous complications, even lethal ones, may occur with the cannulating procedure. Using ultrasound, we attempted to describe the occult anatomical variations of vessels which may be responsible for complications.

Methods. A 'SiteRite' ultrasonographic device was used to inspect the anatomical structure of the internal jugular veins (IJV) in 104 consecutive uraemic patients undergoing creation of internal jugular vein temporary angioaccess. Images of the vessels and demographic data of patients were recorded and analysed.

Results. Anatomical variations of the right and left IJVs were found in 19 (18.3%) and 17 (16.4%) uraemic patients respectively. Unilateral IJV variations were found in 18 patients (17.3%) and bilateral variations were discovered in nine patients (8.7%). A total of 27 patients (26.0%) had IJV anatomical variations that might contribute to difficulty in external landmark-guided IJV cannulation.

Conclusions. The external anatomical landmarks for cannulating the IJV are not reliable in about one-quarter of uraemic patients. An ultrasound survey on the IJV anatomy is recommended for selecting proper puncture site and reducing risks of insertion complications for IJV dialysis catheters.

Key words: jugular vein; anatomy; uraemia; haemodialysis catheter; vascular access; ultrasonography

Introduction

Haemodialysis is indicated in clinical situations such as advanced renal failure, refractory fluid overload, marked electrolyte imbalance, and severe metabolic acidaemia. An angioaccess is always essential for the performance of haemodialysis. Double-lumen catheters are now widely used to cannulate the central veins for this purpose [1]. Most nephrologists prefer the internal jugular veins (IJV) because they provide reliable blood flow and extend functional life [2,3]. The subclavian route is accompanied by not only acute complications such as haemothorax, pneumothorax or pericardial temponade frequently, but also vascular stricture in about half of the patients [4,5]. The femoral route usually immobilizes the patient and is associated with a high prevalence of phlebothrombosis and infective complications [6]. However, successful IJV cannulation is not always the rule. Acute complications such as accidental carotid arterial puncture, irritation to the brachial plexus, pericardial temponade, haemothorax, pneumothorax and formation of a local haematoma compromising the upper airway are not uncommon even when the procedure is performed by experienced operators [7–9]. If anatomical variations of vessels are responsible, it would be expected that an image study prior to cannulation would reduce the number of complications [10]. The purpose of present study is to utilize ultrasound imagery to inspect the anatomical structure of IJV in uraemic patients. We intend to reveal the probability of occult anatomical variations in IJV and the reliability of external landmark-guided approach on creating a temporary IJV haemodialysis angioaccess in uraemic patients.

Subjects and methods

One hundred and four consecutive patients (68 males, 36 females; aged 60.0 ± 16.2 years, blood urea nitrogen 100.7 ± 43.5 mg/dl and serum creatinine 9.4 ± 3.9 mg/dl, expressed as mean $\pm$ SD) undergoing IJV cannulation for

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Table 1. Demographic data of patients

Diagnosis	Age* (years)	Gender (M/F)
ARF ($n=20$; 19.2%)	67.4±11.6	15/
CRF ($n=44$; 42.3%)	62.4±15.3	29/15
DMN ($n=24$; 23.1%)	56.4±14.7	16/8
SLE ($n=9$; 8.7%)	34.2±10.7	2/7
Miscellaneous ($n=7$; 6.7%)	69.9±4.9	6/1
All patients ($n=104$)	60.0±16.2	68/36

ARF, acute renal failure; CRF, chronic renal failure; DMN, diabetic nephropathy; SLE, lupus nephritis; Miscellaneous, including contrast-associated nephropathy, post-bilateral nephrectomy, obstructive uropathy, and other glomerulonephritides. *Mean±SD.

haemodialysis vascular access from November 1995 to April 1996 were recruited in this study. The demographic data are depicted in Table 1.

Before ultrasonographic study, patients were positioned as if for cannulation of the internal jugular veins; supine position with a rolled towel or small pillow placed under their shoulders and the head turned 15–30° to the opposite side [11]. Because of respiratory distress, most of the uraemic patients could not tolerate the Valsalva manoeuvre or head-down tilt to increase the size of the IJV, and their heads were held slightly up. The anatomical landmark for puncture was the triangle formed by the clavicle, the sternal head, and the clavicular head of the sternocleidomastoid muscle at the level of the cricoid cartilage (C6). This level was marked on both sides of the neck.

The 'SiteRite' (Dymax Corporation, Pittsburgh, PA), a real-time, two-dimensional, portable, lightweight, and battery-powered device with high resolution was used to visualize the vascular structure. A 7.5-MHz probe with a sector angle of 25°, a standoff distance of 4.0 cm from the crystal to cap, and a focal length positioned 1.5 cm from the cap and scanner provided images at 40 f.p.s. with a density of 108 lines/frame.

The 1-cm markers on the screen and calipers were used to estimate distance. The probe was placed perpendicular to the skin over the clavicle–sternocleidomastoid triangle at the level of the cricoid cartilage. Vascular diameters, distance between IJV and carotid artery (CA), and distance between IJV and skin were measured. Changes in intrathoracic pressure during respiration may alter both central venous pressure and IJV vascular size. All measurements were made at the end-expiratory phase to avoid this effect.

The internal jugular veins were classified according to their diameters and anatomical locations. The IJVs were divided into adequate sized (5 mm diameter or more) and small sized (less than 5 mm) groups. An IJV was defined to be of normal location if it lay superficially and laterally to the CA with a distance less than 10 mm between them. An IJV located ⩾10 mm lateral to the carotid artery was defined to be far away from the carotid artery. The reverse of CA and IJV indicated that the IJV was located medially to the CA. The term 'overriding' was used for an IJV located directly above the CA. For each continuous variable, normality was checked and data are expressed as mean±SD

Results

The sizes and locations of the internal jugular veins are summarized (Tables 2, 3). The venous diameters

Table 2. Vascular diameters and distances (mm)

Parameters	Right neck	Left neck
Diameter of IJV	10.2±3.8	9.1±3.0
Diameter of CA	8.1±1.5	8.0±1.5
Distance between IJV and skin	10.1±3.1	9.5±2.7
Distance between IJV and CA	2.3±1.5	2.0±1.0

Mean±SD.

Table 3. Grouping of patients according to IJV anatomy

		Right neck	Left neck
Group I	Adequate size and location	63 (60.6%)	60 (57.7%)
Group II	Adequate size, overriding	22 (21.2%)	27 (26.0%)*
Group III	Small size, normal location	9 (8.7%)	9 (8.7%)
Group IV	Miscellaneous findings	10 (9.6%)	8 (7.7%)
1.	Adequate size, distant location	5 (4.8%)	2 (1.9%)
2.	Small size, overriding,	5 (4.8%)	1 (1.0%)
3.	Reversal of CA and IJV	0	4 (3.9%)
4.	Invisible IJV	0	1 (1.0%)

Case numbers and percentage. *Group II included completely overriding and partially overriding IJV.

measured 9.1–10.2 mm (in comparison with arterial diameter, 8.0–8.1 mm). The veins were 9.5–10.0 mm beneath the skin with a distance of 2.0–2.3 mm between the IJV and CA. The variable vascular structural patterns are shown (Figures 1, 2). According to the anatomy of the IJVs, the patients were divided into four groups.

Adequate size, normal location

In this group (Table 3, group I), the IJVs lay superficially, laterally, and close to the carotid pulse and were of adequate size (>5 mm). This accounts for 60.6% of the right and 57.7% of the left IJVs.

Adequate size, overriding location

The IJVs were more medial and overrode the carotid arteries, and were of adequate size. This group was regarded as 'near normal' or 'acceptable' (Table 3, group II), comprising 21.2 and 26.0% of the right and left IJVs respectively.

Small size, normal location

Small IJV (<5 mm in diameter) located in the normal position were found in 8.7% of both the right and left veins (Table 3, group III), representing a small target for cannulation.

Miscellaneous findings of IJV

Prediction of the location of the IJV using the external landmarks was difficult for 9.6 and 7.7% of the right and left IJV in uraemic patients respectively (Table 3, group IV). The IJV was located far away from the

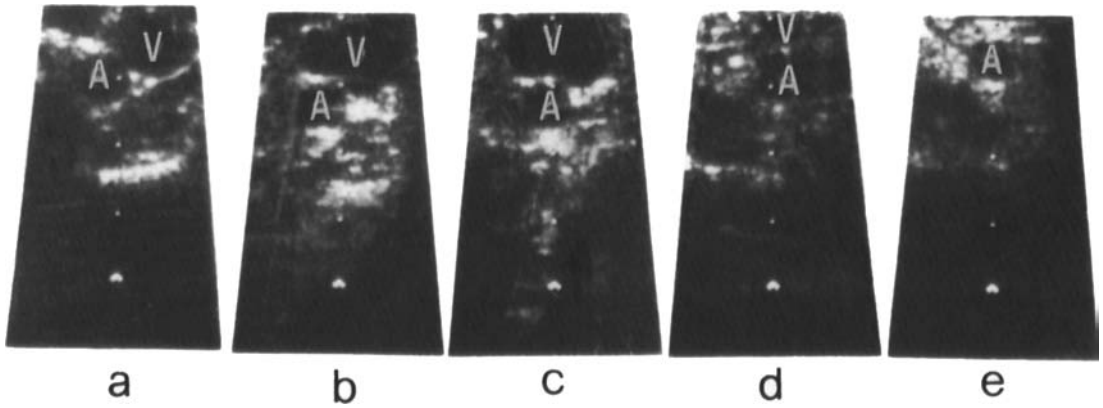

Fig. 1. Ultrasound images of various IJV anatomy (A, carotid artery; V, internal jugular vein). **a**, Normal vascular structure; **b**, IJV overrides the carotid artery partially; **c**, IJV completely overrides the carotid artery; **d**, IJV overrides the carotid artery with unusually small vascular size; **e**, The carotid artery is visualized without an IJV surrounding it.

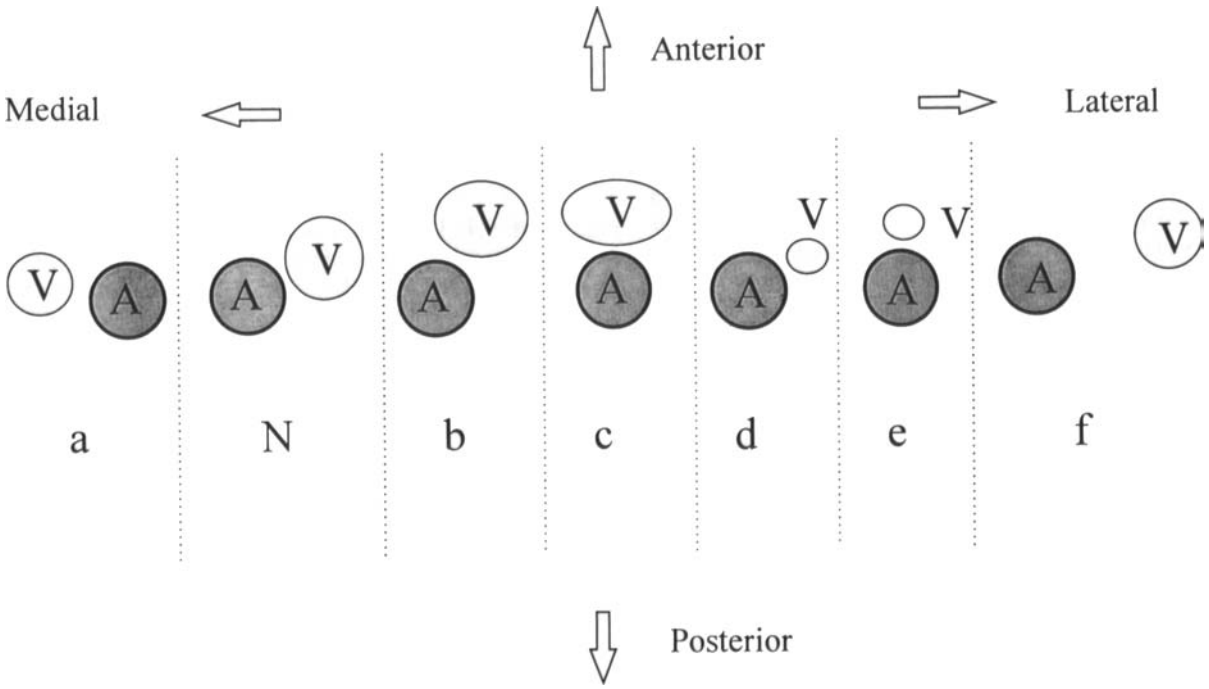

Fig. 2. Various sizes and locations of IJV (A, carotid artery; V, internal jugular vein). N, IJV of adequate size and normal location. **a**, Reversal of CA and IJV; **b**, partially overriding IJV; **c**, completely overriding IJV; **d**, small IJV at normal location; **e**, small, overriding IJV; f, distant IJV.

carotid artery ($\geqslant$10 mm; 4.8% for the right and 1.9% for the left IJV), overrode the carotid artery with an unusually small size (4.8% for the right and 1.0% for the left IJV), or was located medial to the carotid artery (3.9% for the left IJV). Strikingly, in one patient (1.0% for the left IJV) the carotid artery was visualized without any venous structures surrounding the artery! In this group, exact location of the IJV was absolutely unpredictable using external landmarks.

Discussion

This is the first study focusing on the anatomical variation of IJV in uraemic patients. We discovered anatomical variations in 18.3% (19/104) of the right and 16.4% (17/104) of the left IJVs. Unilateral IJV variations were found in 18 patients (17.3%) and bilateral variations were discovered in nine patients (8.7%).

Both variations in size and location of the IJV may result in complications following external landmark-guided cannulation. An overriding IJV of group II always should be cannulated with caution; otherwise accidental arterial puncture might occur once the cannulating needles have been introduced through the IJV. IJV of group III represent a small target which might be difficult to be cannulated with external landmark-guided technique. The exact location of the IJV in group IV was absolutely unpredictable using

external landmarks, and patients of group III and group IV should be considered at high risk for complications using external landmark-guided cannulation of the IJV.

The failure rate of the IJV cannulation in general medical and surgical patients has been estimated to be from 4.7 to 17.6% and the complication rate has been reported to be from 3.9 to 14.3% [12,13]. Vanholder *et al.* [14] estimated an incidence of 3.7% for traumatic complications in uraemic patients, including bleeding, arterial puncture, local haematoma, haemothorax, and pneumothorax in a follow-up study of 157 patients receiving IJV cannulation for haemodialysis. Campistol *et al.* [15] reported an arterial puncture rate of 4.0% in 25 IJV cannulations for haemodialysis. In the last two series, cannulations were performed by experienced nephrologists, indicating that even skillful operators cannot avoid traumatic complications in creation of temporary haemoaccess.

The anatomical variations of IJV in healthy volunteers and non-uraemic patients has been well studied. Metz *et al.* [16] examined the anatomical structures of IJV in 16 healthy individuals and claimed that only techniques using the CA pulse as a landmark reduced CA puncture rate. Alderson *et al.* [17] examined the anatomy of IJV in 50 children younger than 6 years and found that 18% (9/50) of them had anatomical factors that may complicate external landmark-guided cannulation of the IJV. Denys and Uretsky [18] examined 183 patients, of whom 164 (89.6%) were cardiac-transplant recipients, and found that 11 patients (5.5%) had the right IJV outside the path that would be predicted by the external landmarks. Troianos *et al.* [19] viewed the anatomy of IJV using ultrasound in 1136 patients and found that the IJV overlies the carotid artery in 54% of patients, predisposing them to carotid arterial puncture if the cannulating needle traverses the IJV.

In our study, 81.7–83.6% of patients had normal or near normal (Table 3, group I and II) IJV location and size, in contrast to the 92% reported by Denys and Uretsky. The difference may arise from lack of manoeuvres to increase IJV size in ours. If we take into account group III (small size, normal location), the total percentage is 92%, similar to that found by Denys and Uretsky.

We performed ultrasonography of the IJV anatomy from the high position (cricoid cartilage) rather than the low position (Sedillot triangle). This was due to the fact that most of our dual-lumen catheters are inserted from the high position to avoid pulmonary complications. Meanwhile, the distance from the clavicle within the triangle did not markedly alter the position of the IJV in relation to the CA, although the size of the IJV is slightly larger closer to the clavicle [18].

Are uraemic patients prone to complications during establishment of temporary angioaccess? Valsalva manoeuvre, abdominal banding, or the Trendelenberg position with the head down may increase IJV size [20]. However, most uraemic patients cannot tolerate these manoeuvres because of respiratory distress, and most of them had had repeated jugular venepunctures. In our study, 28 patients (26.9%) had been cannulated once, 14 patients (13.5%) had been cannulated twice, and 11 patients (10.6%) had been cannulated more than twice before the ultrasound survey. Repeated cannulation with a large-bore (11.5-French) dialysis catheters may result in scarring of surrounding tissue, distortion of anatomical structures, and occlusion of vessels because of thrombosis, which in turn make cannulation more difficult. Comorbid thrombocytopenia and bleeding diatheses may further increase risk of complications. In comparison to the general population, uraemic patients carry more risks for complications resulting from cannulation of the IJV for temporary haemoaccess. Thus, an ultrasound survey of the IJV anatomy may disclose occult anatomical variance of the IJV and result in avoidance of both morbidity and mortality of cannulation.

In addition, the 'SiteRite' ultrasound device provides real-time, continuous guidance of the cannulating procedure, and marking the position of the IJV on the skin followed by blind puncture might be an alternative method. It is hoped that these ultrasound techniques will promote successful cannulation and decrease the incidence of insertion complications in uraemic patients. However, further studies are needed to evaluate the various ultrasound techniques available for insertion of IJV catheters.

In conclusion, our findings support the hypothesis that the external-landmark technique for IJV is not reliable in about one-quarter of uraemic patients. Sonographic inspection should be routinely applied to increase the chance of successful cannulation of the IJV to create temporary angioaccess for haemodialysis.

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