

Venogram of the Upper Extremity Using the Tourniquet Technique for the Evaluation of Central Vein Patency: A Comparison to Conventional and CO₂ Venogram

중심 정맥 개통성 평가에 있어 토니켓 기법을 이용한 상지 정맥조영술:
고식적 정맥조영술 및 이산화탄소 정맥조영술과의 비교

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Purpose: To compare the tourniquet technique (TT) with the conventional venogram (CV) and the carbon dioxide venogram (CO₂V) for the evaluation of central vein patency of the upper extremity.

Materials and Methods: CO₂V, TT, and CV were performed on 100 upper extremities prior to an arteriovenous fistula operation. The central vein was divided into four segments. The best image of the venograms for each segment was chosen as a reference, and the venogram techniques for each segment were graded from 1 (invisible) to 5 (excellent) compared with those of the reference image. The grades of the various venogram techniques at each segment of the vein were compared statistically.

Results: For the SVC segment, the mean grades of CO₂V, TT, and CV were 4.32, 3.60, and 2.45, respectively. TT is statistically superior to CV but inferior to CO₂V. On the brachiocephalic vein, the mean grades of CO₂V, TT, and CV were 4.41, 4.37, and 2.77 and were 4.81, 4.85, and 3.78 for the subclavian vein and 4.75, 4.93, and 4.57, respectively, on the axillary vein. On these segments, TT was statistically superior to CV, but no difference was noted with CO₂V.

Conclusion: TT is superior to CV in every segment of the central vein and presents similar values to those of the CO₂V, except for the SVC.

Index terms

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INTRODUCTION

Asymptomatic central vein stenosis has been shown to compromise the sufficiency of blood flow during hemodialysis, causing swelling of the extremities and venous hypertension (1, 2). Therefore, the diagnosis of central vein stenosis before the arteriovenous fistula (AVF) operation greatly influences the success of AVF creation (1). For central vein evaluation, the conventional venography has been used as the investigation modality of choice (3, 4). However, sometimes central vein venography is not assessable or visible with iodinated contrast material because of insufficient flow due to

the high viscosity of the contrast material, resulting in the dilution with non-contrast-enhanced blood (5). In this case, CO₂ can be valuable for the evaluation of central vein patency because it is about 400 times less viscous than iodine (5). In spite of this basic advantage, CO₂ has not been widely used because of its drawbacks (6), which include: 1) CO₂ is less available than iodine contrast material in clinical practice and an additional CO₂ stacking software program is needed; 2) CO₂ may cause pain and discomfort at the delivery site in the venous system (7-9), 3) the contrast material must be changed when using CO₂ for the central vein after evaluation of peripheral veins with iodinated contrast, because iodine con-

trast is better than CO₂ when it comes to the evaluation of peripheral veins (5); 4) CO₂ can produce a pseudostenosis artifact because of its buoyant nature (6, 10). Therefore, in this study, the tourniquet technique was designed as a new venogram method for central vein evaluation to solve the problems associated with conventional and CO₂ venogram techniques. The purpose of this prospective study was to compare the tourniquet technique with conventional and CO₂ venograms for the evaluation of central vein patency.

MATERIALS AND METHODS

Patient Population

The study was approved by the institutional review board and was prospectively performed until 100 good quality venograms were obtained. Between April 2008 and June 2009, upper extremity venograms were performed on 128 limbs of 66 patients for the evaluation of peripheral and central veins prior to an arteriovenous fistula operation. A peripheral vein was evaluated by a conventional venogram, and then the conventional, tourniquet, and CO₂ techniques were performed for central vein evaluation. Of the patients, 62 underwent a bilateral venography, while the others received a unilateral venography (65 on the right, 63 on the left). Three of the patients who underwent a bilateral venography had received previous access in one arm. Three of the venograms performed in the arm having previous fistula and 25 poor quality venographies due to respiratory motion artifact or patient movement were excluded from the study. In total 100 cases in 56 patients were included. Forty-four patients underwent bilateral venography, and 12 patients received unilateral venography (51 on the right, 49 on the left). Thirty-two patients were male and 24 patients were female; patient age ranged from 23 to 81 years, with a mean age of 59.8 years.

Venography Protocol

Iso-osmolar nonionic contrast agent (Visipaque®; GE healthcare, Carrigtohill, Ireland) was used for conventional venograms and the tourniquet technique, while carbon dioxide was used for the CO₂ venogram. A dorsal vein in the hand was punctured with a 20-gauge Angiocath needle (Sminthos Medical International Ltd., Rossendale, UK) and the upper

extremity was positioned in supination and abduction at 45°. After performing the venogram for the forearm and upper arm with iodinated contrast material, a central vein venogram was performed using three different techniques (conventional, tourniquet, and CO₂ in sequence). High-quality digital subtraction equipment (Integris Allura Biplane; Philips Medical System, Best, the Netherlands) was used under the following conditions: 65 kv, 300 ms, large focus, a sequence of two images per second for five seconds, and then one image per second for 20 seconds. Thirty to fifty milliliters of iodinate contrast material was injected through a superficial dorsal vein of the hand for the conventional venogram technique. Pure normal saline was injected for removing the remnant contrast material in the vein. After placement of a tourniquet at the upper arm near the axilla, the iodinated contrast material was injected until it fully filled the upper extremity of the venous system. Then, 30 mL of pure normal saline was injected to push the contrast material within the upper extremity vein into the central vein, while quickly untying the tourniquet. Pure normal saline was injected again for removal of the remnant contrast material in the vein. Finally, CO₂ venograms were obtained by injecting 50 mL of CO₂ through the dorsal vein with a sequence of three images for five seconds, and then an image per second until complete injection of CO₂ was achieved. Composite images were constructed by superimposing multiple frames using stacking software and the contrast agent and CO₂ were injected manually.

Image Analysis

The central venograms were evaluated by three radiologists in consensus with more than five years of experience in vascular imaging. The central vein was divided into four segments: the superior vena cava (SVC), brachiocephalic vein (BC), subclavian vein (SC), and axillary vein (A), each of which was evaluated independently. At first, the best image for each segment of the central vein among the three venogram types was chosen as the reference. Then, each venogram method was graded at each segment according to the relative density and diameter compared to those of the reference image. The grades were assigned as follows: excellent (Grade 5) - reference or comparable to the reference, good (Grade 4) - both the density and diameter are more than 50% of that of

the reference, fair (Grade 3) - either the density or the diameter is less than 50% of that of the reference, poor (Grade 2) - both the density and diameter are less than 50% of that of the reference, and invisible (Grade 1) - no visible contrast material in the segment. If stenosis was detected during evaluation, it was recorded.

Statistical Analysis

The grades of the conventional, tourniquet technique, and CO₂ venograms were compared statistically using Friedman's test to determine the probability that the null hypothesis was true. Subsequently, three paired sample *t*-tests were performed at each central vein segment to compare the grades of two venogram types: conventional vs. tourniquet, tourniquet vs. CO₂, and CO₂ vs. conventional technique. Then, the Bonferroni correction was applied to the three *p*-values which were previously obtained by paired samples *t*-tests. All statistical analyses were performed using MedCalc version 11.0.0 (MedCalc Software, Mariakerke, Belgium).

RESULTS

The grades of the venogram techniques at each segment of the central vein are shown in Tables 1, 2, 3, and 4.

The SVC segment was not visible in 50 cases (50%) with a conventional venogram in 23 cases (23%) using the tourniquet technique, as well as in eight cases (8%) using the CO₂ venogram. In the SVC segment, the distribution of the reference image modalities for CO₂ venogram, tourniquet technique, and conventional venogram were 47.9%, 36.4%, and 15.7%, respectively. The mean grades of the CO₂, tourniquet

technique, and conventional venograms were 4.32, 3.60, and 2.45, respectively. The tourniquet technique was superior to the conventional technique ($p < 0.0001$), but inferior to the CO₂ venogram ($p = 0.0007$) (Table 1). In 32 of 100 cases (32%), the brachiocephalic vein segment was not seen with a conventional venogram, but the tourniquet technique and CO₂ venogram did not demonstrate the brachiocephalic vein in only four (4%) and three (3%) cases, respectively. For the brachiocephalic vein, the proportion of the reference image modalities was 44.7% for the tourniquet technique, 41.5% for the CO₂ venogram, and 13.8% for the conventional venogram. However, the mean grades of the CO₂, tourniquet technique, and conventional venograms were 4.41, 4.37, and 2.77, respectively. The tourniquet technique is superior to the conventional technique ($p < 0.0001$). However, there is no statistically significant difference between the tourniquet technique and the CO₂ venogram ($p = 0.8091$) (Table 2) (Figs. 1-3). Nine cases (9%) were not seen using the conventional venogram, but the tourniquet technique and CO₂ venograms were all visible in the subclavian vein. The modalities of the reference image were distributed as follows; tourniquet technique (41.4%), CO₂ (38.6%), and conventional venogram (20.0%). The mean grades for the CO₂, tourniquet technique, and conventional venograms were 4.81, 4.85, and 3.78, respectively. The tourniquet technique was superior to the conventional venogram ($p < 0.0001$), but no statistically significant difference was found between the tourniquet technique and the CO₂ venogram technique ($p = 0.5663$) (Table 3) (Figs. 1, 2). While using the conventional venogram and CO₂ venogram, the axillary vein was not seen in one case, although all of the axillary veins were visible using the tourniquet technique. The mean grades ob-

Table 1. Numbers of Limbs for Each Grade of the Three Venogram Techniques for SVC Evaluation

	G5 (Excellent)	G4 (Good)	G3 (Fair)	G2 (Poor)	G1 (Invisible)	Mean Grade
Conventional V	22	10	9	9	50	2.45
Tourniquet T	51	12	6	8	23	3.60
CO ₂ V	67	15	9	1	8	4.32

Note.—Conventional vs. Tourniquet; $p < 0.0001$, Tourniquet vs. CO₂; $p = 0.0007$, CO₂ vs. Conventional; $p < 0.0001$. T = technique, V = venogram, G = grade

Table 2. Numbers of Limbs for Each Grade of the Three Venogram Techniques for Evaluation of the Brachiocephalic Vein

	G5 (Excellent)	G4 (Good)	G3 (Fair)	G2 (Poor)	G1 (Invisible)	Mean Grade
Conventional V	21	13	20	14	32	2.77
Tourniquet T	68	13	11	4	4	4.37
CO ₂ V	63	23	9	2	3	4.41

Note.—Conventional vs. Tourniquet; $p < 0.0001$, Tourniquet vs. CO₂; $p = 0.8091$, CO₂ vs. Conventional; $p < 0.0001$. T = technique, V = venogram, G = grade

served for the axillary vein using the CO₂ venogram, tourniquet technique, and conventional venogram technique were 4.75, 4.93, and 4.57, respectively and the distribution of the reference image modalities was tourniquet technique (37.6%), CO₂ (33.6%), and conventional venogram (28.8%). The tourniquet technique was superior to the conventional venogram technique ($p = 0.0001$), but presented no difference when compared to the CO₂ venogram ($p = 0.0215$) (Table 4) (Fig. 1).

In seven of 100 cases (7%), central vein stenosis was suspected (four in the left brachiocephalic vein, two in the right subclavian vein, and one in the left subclavian vein). Although two stenosis cases were suspected for all three venogram types, five cases of stenosis were not diagnosed on a conventional venogram, but were detected using the tourniquet technique or CO₂ venogram technique. These five cases showed invisible

or decreased opacification of the brachiocephalic or subclavian veins with conventional venograms; therefore, stenosis could not be confirmed. Additional findings suggesting that stenosis, such as direct visualization of focal narrowing or collateral vessels, was noted using the tourniquet technique and CO₂ venograms (Fig. 3).

DISCUSSION

Arteriovenous fistula (AVF) is the preferred approach for hemodialysis in patients with end-stage renal disease (3, 5, 10-12), and preoperative evaluations of the peripheral and central veins are essential prior to AVF operation. In addition to the preoperative detection of peripheral vein stenosis, diagnosing central vein stenosis prior to AVF operation greatly

Table 3. Numbers of Limbs for Each Grade of the Three Venogram Techniques for Evaluation of the Subclavian Vein

	G5 (Excellent)	G4 (Good)	G3 (Fair)	G2 (Poor)	G1 (Invisible)	Mean Grade
Conventional V	43	23	12	13	9	3.78
Tourniquet T	89	8	2	1	0	4.85
CO ₂ V	83	15	2	0	0	4.81

Note.—Conventional vs. Tourniquet; $p < 0.0001$, Tourniquet vs. CO₂; $p = 0.5663$, CO₂ vs. Conventional; $p < 0.0001$. T = technique, V = venogram, G = grade

Table 4. Numbers of Limbs for Each Grade of the Three Venogram Techniques for Evaluation of the Axillary Vein

	G5 (Excellent)	G4 (Good)	G3 (Fair)	G2 (Poor)	G1 (Invisible)	Mean Grade
Conventional V	72	18	6	3	1	4.57
Tourniquet T	94	5	1	0	0	4.93
CO ₂ V	84	11	2	2	1	4.75

Note.—Conventional vs. Tourniquet; $p = 0.0001$, Tourniquet vs. CO₂; $p = 0.0215$, CO₂ vs. Conventional; $p = 0.0746$. T = technique, V = venogram, G = grade

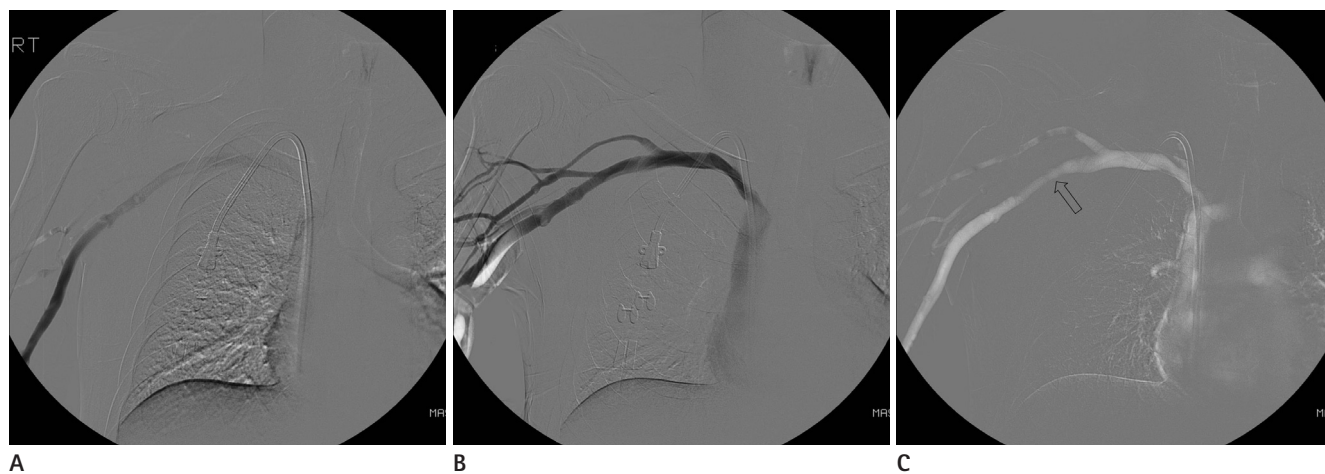


Fig. 1. Venogram of the right central vein in a 48-year-old man.

Tourniquet technique (**B**) and CO₂ venogram (**C**) demonstrate the patency of the central vein very well, as opposed to the right brachiocephalic vein and superior vena cava (SVC), which are invisible on conventional venogram, and the subclavian and axillary veins are similarly poorly visible (**A**). Image qualities of the tourniquet technique and CO₂ venogram are quite similar, but a mild degree of pseudostenosis is shown in the right axillary vein using the CO₂ venogram (arrow) (**C**).

influences the success of AVF creation (1, 2). Conventional venograms with iodinated contrast material have been the most widely used for central vein evaluation (3, 4), but it is sometimes not possible to assess or observe central vein venography with iodinated contrast material because of insufficient flow resulting in high viscosity (5). In this case, CO₂ can be a valuable alternative for the of central vein patency (5). Sullivan et al. (13) reported that CO₂ produced significantly better quality upper extremity central vein images, which our study results support. In all segments of the central veins except the axillary vein, CO₂ venograms are statistically superior to conventional venograms. Moreover, superior-quality imag-

es of the central veins in CO₂ venograms are attributed to the less viscous nature of CO₂ (about 400 times less viscous than iodine), which allows it to travel more rapidly than iodine contrast material (6, 13).

However, in spite of the advantage of CO₂, it has not been widely used because of its own drawbacks. 1) Contrary to requiring only one contrast agent (iodinated contrast) for evaluation of both peripheral and central veins in conventional venograms, the contrast agent must be changed for the measurement of CO₂ in the central vein after evaluation of peripheral veins with iodinated contrast, because iodine contrast is better than CO₂ for the evaluation of the peripheral

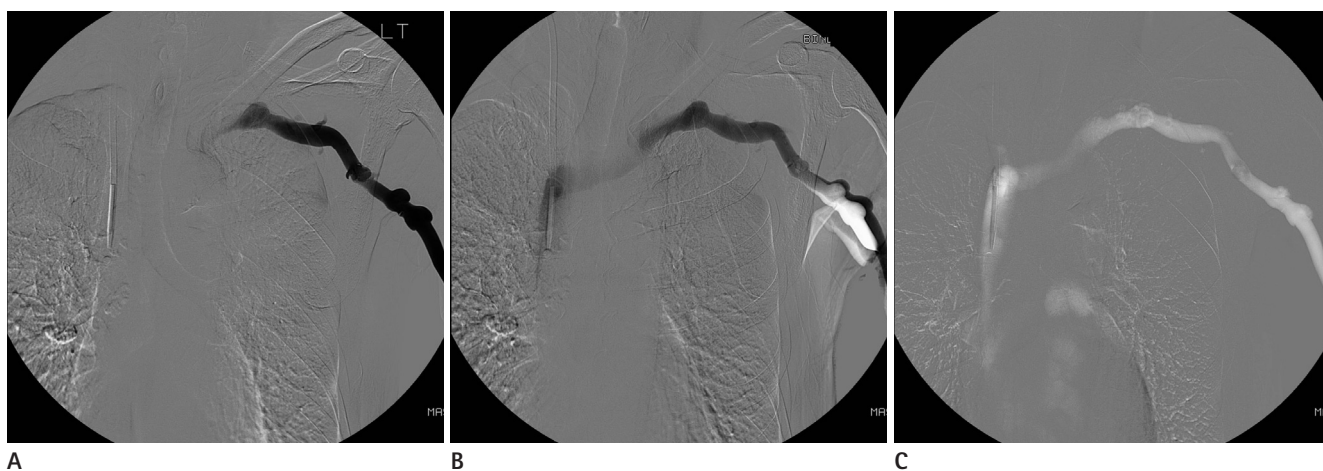


Fig. 2. Venogram of the left central vein in a 65-year-old man.

Because the left brachiocephalic vein was poorly visible by conventional venogram (A), it was uncertain whether true stenosis was present or whether it was the result of slow flow of the iodine contrast material due to its high viscosity. However, the tourniquet technique (B) and CO₂ venogram (C) demonstrate patency of the left brachiocephalic vein.

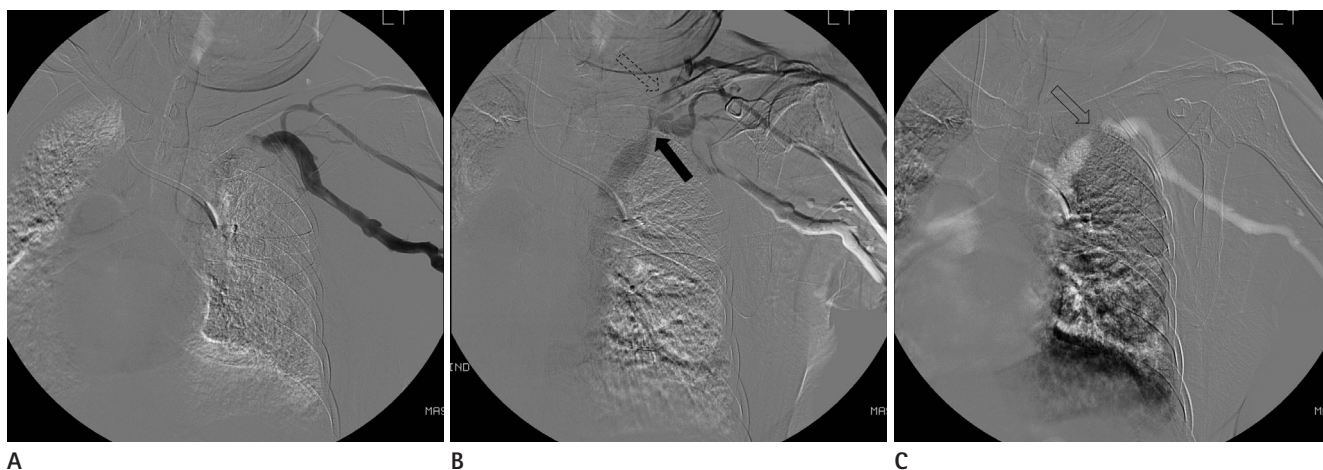


Fig. 3. A venogram of the left central vein in a 72-year-old woman having situs inversus.

Conventional venogram (A) shows a poorly visible left brachiocephalic vein, which is not clear whether or not true stenosis is present. Nevertheless, the tourniquet technique (B) demonstrated not only an actual narrowing of the brachiocephalic vein (black solid arrow), but also combined collateral veins (dotted arrow). The CO₂ venogram (C) also showed an actual narrowing of the left brachiocephalic vein (empty arrow), but the collateral veins were not visible.

vein (5). 2) When CO₂ passes through bifurcations, the bolus tends to break up into discrete bubbles. Moreover, because of the buoyant nature of the gas, even large injection volumes were not capable of displacing the slow-moving fluid; and as a result, the gas will float on the surface. Pseudostenosis is an artifact of these gas fragmentation and buoyancy characteristics (6, 14, 15). 3) CO₂ may cause pain and discomfort at the delivery site in the venous system. CO₂ delivery by a stand power injector or manual injection would initially compress the gas and result in the delivery of the majority of CO₂ in an explosive manner. This may result in an unsatisfactory filling of the arterial system and may cause pain and discomfort at the delivery site. The explosive injection of CO₂ not only causes pain and discomfort, but also leads to patient motion, often resulting in degraded images (7-9). Furthermore, 4) CO₂ is less available than iodine contrast material in clinical practice and, as a result, additional CO₂ stacking software is required. For these reasons, a CO₂ venography has not been widely used despite its better image quality in the upper extremity central vein.

Based on this information, the tourniquet technique was designed as a new venogram method for central vein evaluation to overcome the slow flow of the iodinated contrast material and the pseudostenosis or inconvenience of using CO₂. After tying the tourniquet at the upper arm near the axilla, contrast material was injected to fill the upper extremity vein. Next, the contrast material in the upper extremity vein was rapidly pushed into the central vein by injecting additional normal saline, while quickly untying the tourniquet, yielding a high-speed flow of contrast material sufficient for evaluation of the central vein. Our study, which evaluated the techniques based on the densities and diameters, showed that the tourniquet technique is superior to a conventional venogram in every segment of the central vein, and has a similar value for central vein evaluation as that of the CO₂ venogram, except in the SVC segment. These results suggest that the tourniquet technique can overcome the limitations of the conventional venogram technique, which is sometimes not able to assess the central vein because of insufficient flow and can be used more conveniently than the CO₂ venogram.

In the case of an invisible central vein on a conventional venogram, the determination of stenosis is uncertain. In spite

of that uncertainty, this finding tends to be regarded as an indication of a lack of stenosis in many practical centers because the incidence of central vein stenosis is not common, and the evaluation of the venogram is more focused on peripheral veins where the operation will be performed. Because of its invasiveness, it is very rare to perform a catheter-directed venogram for those invisible central vein segments in non-symptomatic patients. However, if there was undetected stenosis, it would result in failed surgery, dysfunctional fistula, or severe arm swelling. In this study, venograms using the tourniquet technique and CO₂ technique demonstrated lower rates of invisible central veins than did conventional venograms, along with better image qualities. Seven of 100 cases (7%) showed central vein stenosis and five cases of stenosis were not diagnosed using the only conventional venogram; however, these stenoses were detected by the tourniquet or CO₂ venogram techniques. Moreover, these five cases showed non-visible or decreased opacification of the brachiocephalic or subclavian veins on conventional venograms; therefore, it is not certain whether stenosis was actually present. Additional findings suggesting stenosis, such as direct visualization of focal narrowing or collateral vessels, were noted with the tourniquet technique and CO₂ venograms. Even though the incidence of central vein stenosis is not common, the correct diagnosis of central vein stenosis is very important for the successful creation of an arteriovenous fistula, considering the result of undetected central vein stenosis.

Furthermore, although a correct diagnosis of stenosis in the central vein is important, it also seems to be meaningful that 'no stenosis' could be diagnosed correctly with the tourniquet technique, allowing surgeons to perform AVF operations with more confidence.

Our study had several limitations. First, the best image technique among the three types of venograms was used as the reference, instead of using the gold standard technique of the catheter-directed central venogram for comparison because of its invasiveness. Second, we did not consider the diameter or degree of patency in the upper arm or forearm veins. It is believed that wider and more patent peripheral veins show more potential for fast flow, so some conventional venograms could demonstrate good image quality. Third, we did not statistically analyze the detection rate of central vein

stenosis itself, because the sample size of each group should be very large for such a study, considering the low incidence of central vein stenosis in the patients.

The tourniquet technique, a new method of upper extremity central vein evaluation, which is performed prior to the creation of AVF, is superior to a conventional venogram in every segment of the central vein and provides a value similar to that of the CO₂ venogram, except in the SVC segment. This new technique can be used effectively for central vein evaluation in clinical practice.

REFERENCES

1. Karakayali F, Ekici Y, Görür SK, Arat Z, Boyvat F, Karakayali H, et al. The value of preoperative vascular imaging in the selection and success of hemodialysis access. *Ann Vasc Surg* 2007;21:481-489
2. Chalmers N. The role of vascular radiology in hemodialysis access. *Semin Dial* 2002;15:259-268
3. Robbin ML, Gallichio MH, Deierhoi MH, Young CJ, Weber TM, Allon M. US vascular mapping before hemodialysis access placement. *Radiology* 2000;217:83-88
4. Turmel-Rodrigues L, Bourquelot P, Raynaud A, Beyssen B, Sapoval M. Hemodialysis fistula: preoperative MR venography--a promising but partial view. *Radiology* 2000;214:302-303
5. Heye S, Maleux G, Marchal GJ. Upper-extremity venography: CO₂ versus iodinated contrast material. *Radiology* 2006;241:291-297
6. Shaw DR, Kessel DO. The current status of the use of carbon dioxide in diagnostic and interventional angiographic procedures. *Cardiovasc Intervent Radiol* 2006;29:323-331
7. Hahn ST, Pfammatter T, Cho KJ. Carbon dioxide gas as a venous contrast agent to guide upper-arm insertion of central venous catheters. *Cardiovasc Intervent Radiol* 1995;18:146-149
8. Caridi JG, Hawkins IF Jr. CO₂ digital subtraction angiography: potential complications and their prevention. *J Vasc Interv Radiol* 1997;8:383-391
9. Kerns SR, Hawkins IF Jr. Carbon dioxide digital subtraction angiography: expanding applications and technical evolution. *AJR Am J Roentgenol* 1995;164:735-741
10. Geoffroy O, Tassart M, Le Blanche AF, Khalil A, Duédal V, Rossert J, et al. Upper extremity digital subtraction venography with gadoterate meglumine before fistula creation for hemodialysis. *Kidney Int* 2001;59:1491-1497
11. Windus DW. Permanent vascular access: a nephrologist's view. *Am J Kidney Dis* 1993;21:457-471
12. Menegazzo D, Laissy JP, Dürrbach A, Debray MP, Messin B, Delmas V, et al. Hemodialysis access fistula creation: preoperative assessment with MR venography and comparison with conventional venography. *Radiology* 1998;209:723-728
13. Sullivan KL, Bonn J, Shapiro MJ, Gardiner GA. Venography with carbon dioxide as a contrast agent. *Cardiovasc Intervent Radiol* 1995;18:141-145
14. Hyland K, Cohen RM, Kwak A, Shlansky-Goldberg RD, Soulen MC, Patel AA, et al. Preoperative mapping venography in patients who require hemodialysis access: imaging findings and contribution to management. *J Vasc Interv Radiol* 2008;19:1027-1033
15. Moresco KP, Patel N, Johnson MS, Trobridge D, Bergan KA, Lalka SG. Accuracy of CO₂ angiography in vessel diameter assessment: a comparative study of CO₂ versus iodinated contrast material in an aortoiliac flow model. *J Vasc Interv Radiol* 2000;11:437-444

중심 정맥 개통성 평가에서 토니켓 기법을 이용한 상지 정맥조영술: 고식적 정맥조영술 및 이산화탄소 정맥조영술과의 비교

이선아 · 정환훈 · 이승화 · 차상훈 · 제보경 · 서보경 · 김백현 · 서형석

목적: 중심 정맥 개통성 평가에 있어 토니켓 기법을 이용한 상지정맥조영술을 고식적 및 이산화탄소를 이용한 정맥조영술과 비교하였다.

대상과 방법: 혈액투석용 인공동정맥루 수술 전 상지정맥 평가를 시행한 100개의 상지 정맥조영술을 대상으로 하였다. 각 각의 환자에서 이산화탄소, 토니켓 및 고식적 정맥조영술을 모두 시행하였고 상지 중심정맥은 네 개의 분절로 나누었다. 각 분절마다 세 종류의 정맥조영술 중에서 가장 좋은 영상을 기준으로 삼고 이와 비교하여 1(보이지않음)부터 5(아주 좋음)까지 등급을 정하여 각 분절에 대한 세 종류 정맥조영술의 등급을 통계학적으로 비교하였다.

결과: 상대정맥은 이산화탄소, 토니켓 및 고식적인 정맥조영술의 평균등급이 각 4.32, 3.60, 2.45였고, 팔머리정맥과 쇄골 아래정맥은 각각 4.41, 4.37, 2.77과 4.81, 4.85, 3.78, 그리고 겨드랑정맥은 4.75, 4.93, 4.57이었다. 상대정맥은 토니켓 정맥조영술이 고식적 정맥조영술보다 통계학적으로 등급이 높고 이산화탄소 정맥조영술보다 낮았다. 나머지 세 개의 분절에서 토니켓 정맥조영술은 고식적 정맥조영술보다 통계학적으로 의미 있게 등급이 높았으나, 이산화탄소 정맥조영술과는 통계학적 차이가 없었다.

결론: 토니켓 정맥조영술은 중심정맥의 모든 분절에서 고식적 정맥조영술보다 우수한 영상을, 이산화탄소 정맥조영술과는 상대정맥을 제외한 분절들에서 대등한 영상을 보였다.

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