Original Article

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대한영상의학회지

Clinical Efficacy of the Transradial Approach in Percutaneous Intervention for a Malfunctioning Arteriovenous Fistula

혈액 투석 동정맥루의 기능 부전에 대한 인터벤션 치료 시 경요골 동맥 접근법의 유용성

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Purpose To evaluate the effectiveness of the transradial artery approach (TRA) for treating malfunctioning arteriovenous fistulas (AVFs) in patients on hemodialysis.

Materials and Methods A retrospective analysis was conducted in this single-center study of TRA endovascular procedures in 73 patients (43 male and 30 female; mean age of 67.4 years (range, 42–92 years) with malfunctioning AVFs, between January 2008 and April 2019. Patients' baseline and lesion characteristics, technical and clinical success, and complications were evaluated, and functional patency was analyzed using the Kaplan-Meier method.

Results Radial artery approaches were successful in all patients. Angioplasty performed using the TRA achieved technical and clinical success rates of 98.6%(72/73) and 91.7%(67/73), respectively. The median primary patency time was 18.8 ± 15.9 months. The primary functional patency rates at 3, 6, and 12 months were 82.1%, 68.6%, and 63.9%, respectively. There were no major complications or adverse events, such as hand ischemia, related to the radial artery approach.

Conclusion In selected cases, the TRA can be used complementary to the transvenous approach to treat malfunctioning AVFs.

Index terms Radial Artery; Arteriovenous Fistula; Renal Dialysis

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INTRODUCTION

Mortality rates among patients with chronic kidney disease are on a steady decline, and the long-term dialysis patient population has increased. With this prolonged life span, maintaining dialysis access patency has become increasingly important (1-3). Stenotic or occlusive lesions often threaten the patency of an arteriovenous fistula (AVF) access leading to maturation or maintenance failure. These lesions can occur at various locations including the juxta-anastomotic area, draining vein, feeding artery or central vein. Conducting balloon angioplasty is a reasonable primary treatment of dysfunctional AVF lesions that are both clinically and angiographically significant (4). In general, transvenous access is easily accessible for puncture and well-suited for larger sheath sizes. However, in a traditional transvenous antegrade access, additional angiography with compression of the venous limb is required to visualize the juxta-anastomotic area and arterial limb. This can add more time and radiation exposure to the procedure (5). When a juxta-anastomotic stenosis is identified on fistulogram with the traditional antegrade venous approach, a second access site may be necessary to treat the lesion (6, 7). Recently, the transradial approach (TRA) has been reported as an option for treat malfunctioning dialysis access in AVFs (5, 6). The TRA is effective in visualizing and treating both arterial and venous limbs through a retrograde brachial angiogram via a single puncture (8). In addition, the operator's fluoroscopic exposure is substantially reduced with TRA compared to the transvenous approach because the operator is positioned farther away from the image intensifier (9, 10).

The purpose of this retrospective study was to evaluate the feasibility and effectiveness of TRA intervention for the treatment of dysfunctional and immature AVFs in hemodialysis patients.

MATERIALS AND METHODS

PATIENT POPULATION

The ethics committee of the participating hospital approved this study (IRB No. KUGH 2020-07-037).

From January 2008 to April 2019, a total of 309 endovascular procedures for malfunctioning hemodialysis fistula were performed in 214 patients. The TRA was used on 86 of these patients. Of these 86 patients, 13 patients were excluded: 12 were excluded because only a diagnostic fistulogram was performed, and the other was excluded because an arteriovenous graft was performed. Seventy-three patients presenting with dialysis access failure (occlusion, feeding artery or vein stenosis) or stenosis-induced maturation failure of an AVF underwent an endovascular procedure using the TRA. Fifty-seven patients had dysfunctional AVFs and 16 had immature AVFs. The mean age of the patients was 67.4 years (range: 42–92 years), and there were 43 males and 30 females. The types of fistula were radio-cephalic in 53 patients and brachial-cephalic in 20. The patients presented clinical manifestations such as ipsilateral arm or neck swelling, reduced or pulsatile thrill, low flow volumes or difficulty in accessing the fistula. Fifty-one patients had diabetes mellitus and 52 had hypertension.

INTERVENTIONAL PROCEDURE

All procedures were performed by two board certified interventional radiologists at our hospital. Both interventionists have more than 4 years of experience in vascular intervention.

Allen's test was used to assess the integrity of the radial artery to perfuse the palmar arch. A negative Allen's test was documented before all transradial punctures. Pre-interventional radial artery sonography was performed in all patients for evaluation of radial artery patency (Fig. 1). The TRA procedure could be considered when the size of radial artery measured over 2–2.5 mm. Pre-interventional ultrasonographic evaluation of the dialysis circuit was also performed to determine the location and number of lesions.

After administration of local anesthesia (lidocaine HCL injection 2%), the radial artery was punctured under ultrasonography guidance using an echogenic 21-gauge needle. A 4-Fr 10-cm micropuncture sheath (MERIT Medical, South Jordan, UT, USA) was inserted into the radial artery over a 0.018-inch in diameter, 40 cm long, extra-support, hydrophilic-coated, nitinol wire. To prevent thrombus formation, 1000 units of heparin solution was routinely injected via the intravenous route. A diagnostic fistulogram was performed by injecting contrast medium (diluted 1:1 with saline) into the micropuncture sheath to define the complete anatomy of the dialysis access and stenosis site. After administration of 0.1% isosorbide dinitrate (Isoket 0.1%) to prevent vasospasm, the 4-Fr micropuncture sheath was exchanged with a 5-, 6- or 7-Fr transradial sheath depending on the size of the angioplasty balloon being used. The location of the stenosis or occlusion of AVF circuit was identified on the diagnostic fistulogram. The 0.035-inch in diameter, 150-cm long, hydrophilic guidewire (Terumo Medical corporation, Tokyo, Japan) was used to cross the stenotic or occluded area. Balloon angioplasty was performed after the balloon catheter crossed the lesion. The size of the balloon catheter was selected depending on the diameter of the nonstenotic portions of the vessel below the stenosis site. The diameter of the selected balloon was usually 4 or 5 mm for a juxta-anastomotic lesion and up to 8 mm for a draining vein lesion; a 14 mm balloon was used for central vein stenosis (Figs. 2, 3). In four cases, there was no improvement after repeated inflation of the conventional balloon catheter, and additional angioplasty using a cutting bal-

Fig. 1. Ultrasonography-guided radial artery puncture. The patent radial artery (arrow) is delineated using an intraluminal echogenic 21-gauge micropuncture needle.
R = radius

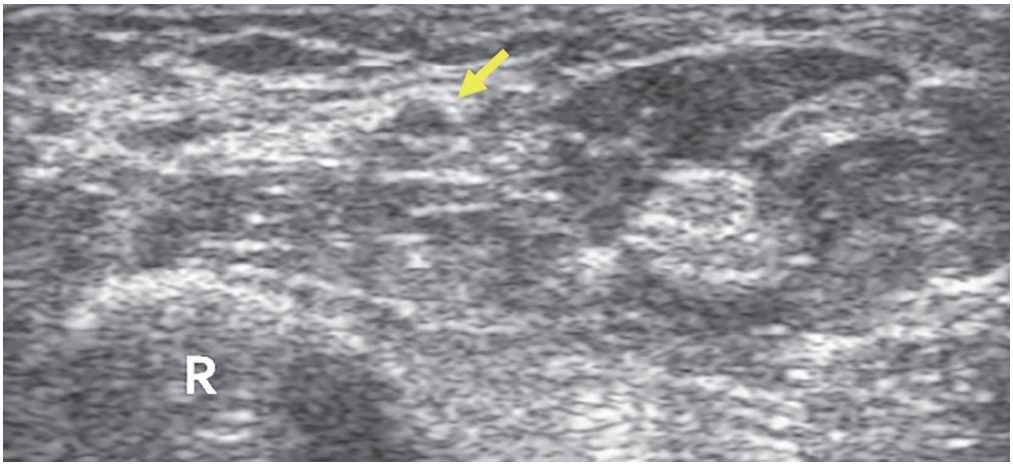
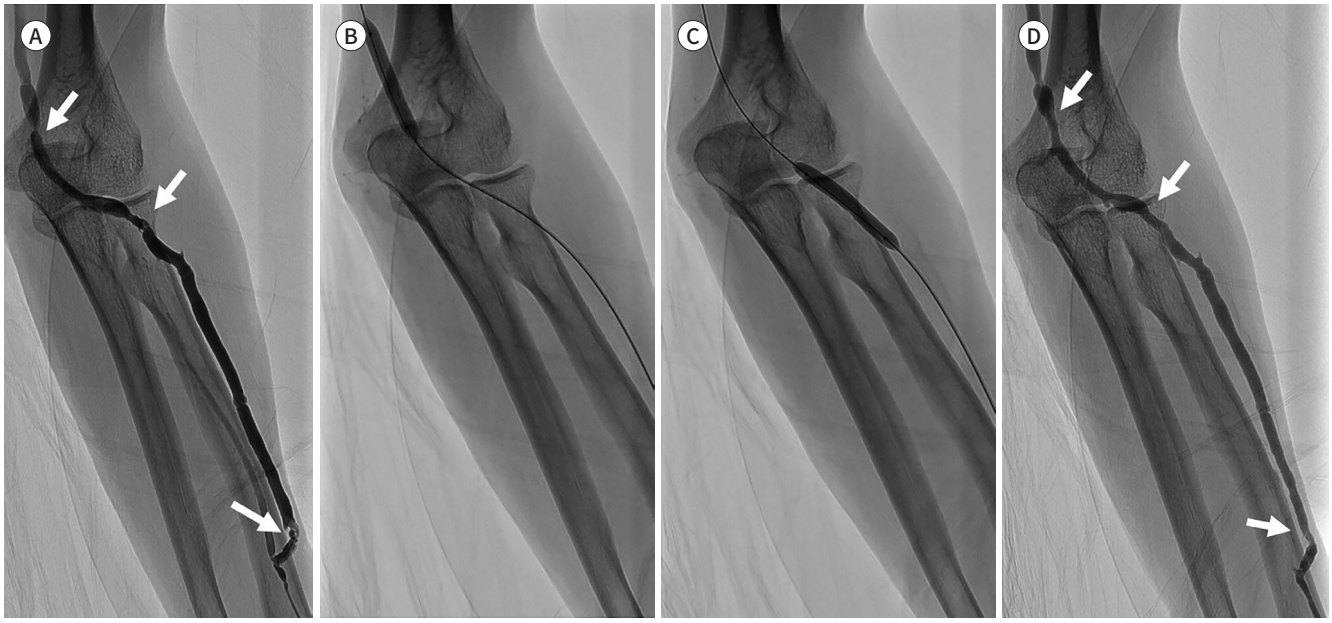


Fig. 2. A 90-year-old male with chronic kidney disease demonstrating draining vein and juxta-anastomotic stenoses.
A. The transradial approach is successfully performed in the malfunctioning radio-cephalic arteriovenous fistula, and the fistulogram shows multiple stenoses (arrows): the draining vein and the juxta-anastomotic vein.
B-D. Balloon angioplasty is performed in each lesion using a 6-mm balloon catheter (B, C), and the final angiogram shows an improvement in the stenoses (arrows) (D).



loon (Boston Scientific Corporation, Galway, Ireland) was performed. In the 4 cases that were combined with thrombosis, aspiration thrombectomy was performed after 100000 unit of urokinase and 1000 unit of heparin injection through the arterial sheath.

After the procedure, the arterial sheath was removed and puncture site was compressed manually for approximately 10–30 minutes.

DEFINITION AND STATISTICAL ANALYSIS

A significant stenosis was defined as 50% or more luminal narrowing compared to the normal vascular segment located adjacent to the stenosis. Technical success was defined as less than a 30% residual stenosis on completion fistulography and restoration of blood flow. Clinical success was defined as the ability to perform at least one session of successful hemodialysis. The primary patency rate was defined as the interval between the initial successful procedure and the first subsequent radiological or surgical re-intervention for recurrent lesions. The duration of primary patency included death or renal transplantation with a patent fistula.

Major complication was defined as resulting in admission to a hospital for therapy, an unplanned increase in the level of care, prolonged hospitalization, or death. Minor complication was defined as resulting in no sequelae, possibly requiring nominal therapy or a short (generally overnight) hospital stay for observation.

Statistical analysis was performed using SPSS version 19 statistical software (IBM Corp., Armonk, NY, USA). Primary patency rate was analyzed using the Kaplan-Meier method.

Fig. 3. A 72-year-old male with chronic kidney disease demonstrating non-mature draining vein stenosis.
A. The transradial approach is successfully performed for a non-mature radio-cephalic arteriovenous fistula.
B. The fistulogram shows stenosis (arrow): juxta-anastomotic lesion of non-mature draining vein.
C. Juxta-anastomotic lesion crossed and treated with angioplasty using a 5-mm balloon catheter.
D. The final angiogram shows successful treatment of the juxta-anastomotic lesion with resolution of the stenosis (arrow).

RESULTS

Success rate of radial artery puncture was 100%. The location of lesions and causes of AVF dysfunction are summarized in Table 1. The locations of lesions were categorized into juxta-anastomotic vein (*n* = 27), draining vein (*n* = 21), central vein (*n* = 1), artery (*n* = 1), and multiple lesions (*n* = 23). The main causes were stenosis (*n* = 67, 92%), four cases caused by occlusions, and two cases had both stenosis and occlusion. Thrombosis was combined in three cases.

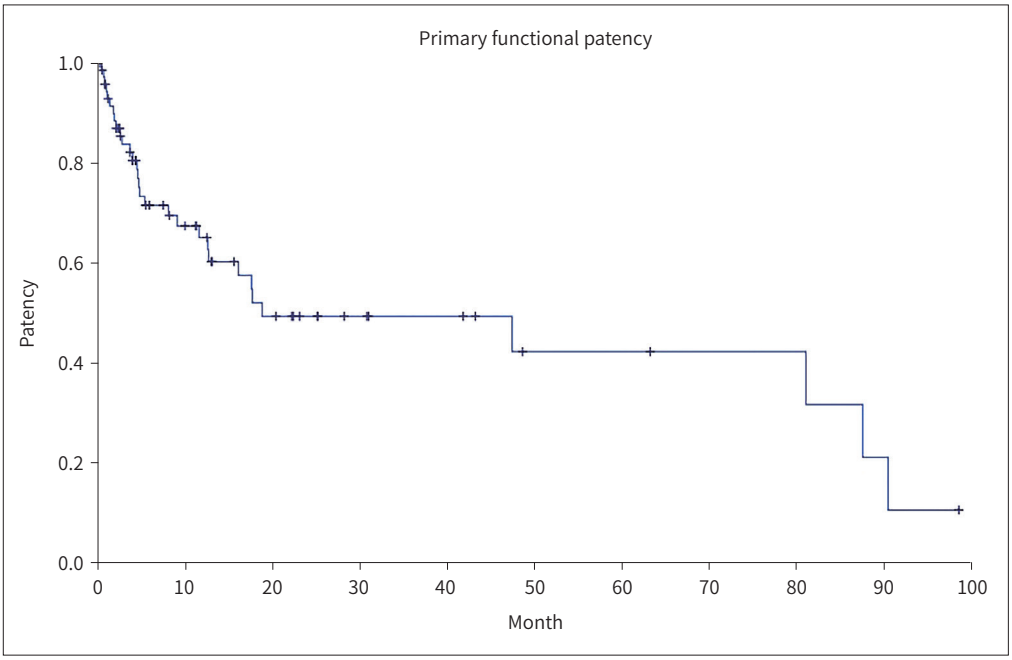
The technical success rate was 98.6% (72/73). One case failed to cross the occluded lesion. The clinical success rate was 91.7% (67/73). One of the six clinical failures was technical failure. Three of the six clinical failures were due to maturation failure (two could not maintain flow rate and one could not feel a thrill after intervention), one of the six cases failed due to arm swelling, and the other case did not use the AVF due to needling pain.

Table 1. Location of Lesions and Causes of AVF Dysfunction

Variables	Number (%)
Location of lesions	
Juxta-anastomotic vein	27 (37)
Draining vein	21 (29)
Central vein	1 (1)
Artery	1 (1)
Multiple	23 (32)
Juxta-anastomotic vein and draining vein	14
Juxta-anastomotic artery and draining vein	1
Draining vein and central vein	1
Multiple lesions at draining vein	7
Causes of AVF dysfunction	
Stenosis	67 (92)
Occlusion	4 (5)
Both	2 (3)
Thrombosis*	3

*Combined thrombosis.
AVF = arteriovenous fistula

Fig. 4. Kaplan-Meier curve of the estimated primary functional patency after endovascular intervention via the transradial approach.



The follow-up period is median 10 (range: 0–130) months. In clinically success group of 67 patients, the primary functional patency rates at 3, 6, and 12 months were 82.1%, 68.6%, and 63.9%, respectively. Fig. 4 shows the Kaplan-Meier curve of the primary patency rate.

Nineteen repeated procedures were required during the median follow-up of 10.27 (range: 0–130) months. Restenosis occurred within a mean period of 10.2 months after the first pro-

cedure. Repeated intervention using TRA was conducted in 9 cases. All repeated punctures and angiography via TRA were successfully conducted without significant stenosis even for third use (n = 1). The other ten cases were conducted via conventional venous approaches.

In all patients, complete hemostasis was achieved. And hemodialysis could be immediately performed after the procedure except those with non-maturing AVFs. Hemodialysis was performed in non-maturing AVF patients via hemodialysis catheter.

There were no major complications and no adverse events, especially related to the radial artery approach. One minor complication, ecchymosis around the puncture site, was reported.

DISCUSSION

To manage dysfunctional forearm AVFs, there are a number of access sites; transvenous, transarterial, and combined transvenous and transarterial approaches are all available (6, 8, 11). The transvenous approach is generally considered the standard method because of the ease of puncture and rare spasm in matured dilated AVFs. The transvenous approach is also suited for larger-sized sheaths in treating various lesions. There may be difficulty in clearly evaluating the juxta-anastomosis and arterial limb region because of venous reflux; and, in some cases, contrast may leak through the venous side branches, diluting the contrast. After the additional angiography, an additional access site may be required to complete the intervention (7).

The TRA has been commonly used for percutaneous coronary intervention. Kawarada et al. (5) initially documented the TRA intervention in 11 patients for treating the predominantly non-thrombosed Brescia-Cimino fistulas. Recently, TRA has been reported as an option for treatment of malfunctioning AVFs (5, 6, 12, 13).

There are several advantages of TRA. First, TRA allows visualization and treatment of juxta-anastomotic lesions as well as multiple lesions in both limbs via a single puncture. Second, occlusions occurring at the puncture site are usually tolerable because the ulnar artery also supplies blood to the hand. Third, hemostasis can be applied directly to the radial artery without interrupting the flow of the dialysis circuit. Because the distal radial artery is usually not included in the dialysis circuit, puncture-induced trauma or complications involving the dialysis circuit can be prevented. Fourth, similar to the transfemoral approach, the operator can perform the procedure in a comfortable position when using the TRA. And the operator is positioned farther away from the image intensifier, fluoroscopic exposure is substantially reduced with TRA compared to the transvenous approach (8-10). Theoretically, most of the transvenous or transbrachial artery approach drawbacks can be overcome by the TRA.

However, there are some limitations of the TRA. First, the radial artery is a small artery, limiting sheath size. This is a disadvantage especially when treating central venous or thrombosis lesions needing larger-sized sheaths. In this study, three cases of combined thrombosis were treated with aspiration thrombectomy using 6-Fr sheaths. In thrombosed cases, thrombectomy can be used limitedly, and good results were obtained in this study. One intervention due to right subclavian vein stenosis was performed using a 7-Fr sheath and 14 mm balloon catheter with no immediate or major complications. Saito et al. (14) reported that the incidence of severe radial arterial flow reduction after transradial coronary intervention was negatively correlated with the ratio of the radial arterial inner diameter to the outer sheath

diameter, and the incidence of flow decrease was 4.7% when using a 7-Fr sheath. Second, when conducting TRA interventions, adequate ulnar artery circulation has to be ensured to protect from hand ischemia in case of radial artery occlusion (15). The authors performed Allen's test before TRA intervention in all patients. Third, TRA cannot be performed in certain anastomotic conditions, especially in side-to-end cephalic vein-to-radial anastomosis, close anastomosis site to the wrist and loop graft implantation state. Fourth, radial artery puncture is more difficult than traditional draining vein puncture because of the artery's small diameter. The failure rate of radial artery puncture is reported as 0.25%–10% (7-18). We performed radial artery puncture under ultrasonography guidance and all procedures were successful.

There were no reported indication for selecting TRA patients. In this study, TRA patients were selected based on own indication. First, patients with immature AVFs were selected. It is possible to implement an intervention that can help progress maturation through TRA even in immature veins of a size that is difficult for retrograde venous approach. Second, the TRA approach was chosen when multiple lesions, a juxta-anastomotic lesion or an arterial lesion were suspected in pre-interventional ultrasonographic evaluation. In this study, there were 19 multiple lesions, 21 juxta-anastomotic lesions, and one arterial lesion in mature AVFs. Sixteen immature AVFs with variable stenosis sites were also included. In all, 78% of patients (57/73) fulfilled the indication after conducting the endovascular intervention.

In this study, the technical success rate, clinical success rate and 1-year primary patency rate were 98.6%, 91.7%, and 63.9% respectively. Manninen et al. (18) reported their clinical success rate as 91% and 1-year primary functional patency as 44% in 53 patients via the transbrachial artery approach. Lay et al. (19) reviewed 31 interventions on dysfunctional forearm AVFs via the transvenous approach. Their technical success rate was reported as 90%, and their 1-year primary patency rate was 64%. The clinical success rate and primary patency rate were comparable to studies in which percutaneous transluminal angioplasty by traditional approaches was performed. Overall 1-year primary patency rates after intervention of dysfunctional AVFs via the TRA have been previously reported and ranged from 32.8% to 83% (5, 8, 12, 20, 21). Previous studies with higher primary patency rates did not include occluded or thrombosed lesions which can affect the patency rate (8, 20). Four occlusions, two combined occlusions and stenosis, and three thrombosis lesions were included in this study; this may have influenced the primary patency rate.

Repeated procedures were performed in 19 patients within a mean period of 10.2 months after the first procedure. Ten interventions were successfully performed via the same approach, TRA. Among these ten interventions, eight were secondary and one was tertiary; all were successfully conducted. There was no stenosis or occlusion of the radial artery associated with repeated puncture. The other ten cases were conducted via conventional venous approaches. In these ten cases, a previous fistulogram and pre-procedural ultrasonography were performed to evaluate the malfunctioning lesion and optimal puncture site, and transvenous approach was judged to be better way. Sakai et al. (22) reviewed the success rate and dropout rate of repeated TRA in 812 patients. Documented success rates were 90% in male and 80% in female in which a third TRA was attempted. The dropout rate increased with repeated punctures and increased rapidly at the fifth repeated puncture. These researchers rec-

ommended repeated puncture of radial artery only up to 3 to 5 times in the same arm. According to the report, TRA may be limited if TRA interventions were performed over 3–5 times previously.

There were no major complications and no immediate event related to the radial artery approach. One ecchymosis, considered as a minor complication, was reported. The complication rate was documented as 12% for the transbrachial artery approach (18). The reported TRA complication rate was much lower, 4%–6% (12, 21) and included venous rupture, stenosis, and subsequent hematoma.

This study has several limitations. First, this study was retrospectively conducted with nonrandomized patients from a single center. Second, while the authors believe that operator fluoroscopic radiation exposure was reduced in the TRA compared to the transvenous or transbrachial artery approach, the authors did not evaluate the fluoroscopic and procedure time. Third, the authors could not suggest the available size criteria of the radial artery for the TRA. In addition, the authors did not evaluate the patency of the radial artery in repeated interventions via the transvenous approach.

In conclusion, the TRA can be used in a way that is complementary to the transvenous approach to treat the malfunctioning AVFs in selected cases such as patients with immature AVFs or multiple lesions.

Author Contributions

Conceptualization, Y.J.H, J.G.; data curation, C.H.Y., Y.J.H.; formal analysis, C.H.Y., Y.J.H.; investigation, C.H.Y.; methodology, Y.H.Y, J.G.; project administration, Y.J.H.; supervision, Y.J.H., J.G.; validation, Y.J.H., K.H., K.Y.N., M.H.H.; visualization, C.H.Y.; writing—original draft, C.H.Y.; and writing—review & editing, Y.J.H., K.H., K.Y.N., M.H.H.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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혈액 투석 동정맥루의 기능 부전에 대한 인터벤션 치료 시 경요골 동맥 접근법의 유용성

최현영[1] · 정규식[2] · 강 희[1] · 김예나[3] · 문형환[4] · 윤종혁[1*]

목적 혈액투석경로의 기능부전에 대한 인터벤션 치료 시 경요골 동맥 접근법의 유용성을 연구하고자 한다.

대상과 방법 2008년 1월부터 2019년 4월까지 73명의 환자에서(남성 43명, 여성 30명, 평균 연령 67.4세; 범위 42–92세) 경요골 동맥 접근법을 이용한 시술을 시행한 환자들에 대해 후향적 연구를 시행하였다. 환자들의 기본적인 특성과 병변의 특성, 경요골 동맥 접근을 통한 인터벤션 시술의 기술적 및 임상적 성공률, 시술과 연관된 합병증에 대해 조사하였고 장기 개통성에 대해서는 카플란-마이어 방법을 이용하여 분석하였다.

결과 모든 환자에서 요골 동맥을 통한 혈관조영술을 성공적으로 시행하였고, 기술적 성공률은 98.6%(72/73), 임상적 성공률은 91.7%(67/73)였다. 일차적 개통률의 중앙값은 18.8 ± 15.9개월이었고, 3, 6, 12개월 누적 개통률은 각각 82.1%, 68.6%, 그리고 63.9%였다. 모든 환자에서 손의 허혈과 같은 주요한 합병증은 발생하지 않았으며 경요골 동맥 천자와 연관한 즉각적인 합병증 또한 발생하지 않았다.

결론 혈액투석경로 기능 부전 환자에서 경요골 동맥 접근법을 통한 인터벤션 시술은 안전하고 임상적으로 유용한 방법으로 생각된다. 또한 선별된 환자에서 전통적인 경정맥 접근법에 대해 대안으로 기능할 수 있을 것으로 생각된다.

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