Acta Cardiol Sin 2001; 17:193-200

Interventional Cardiology

Color Doppler Ultrasound Evaluation of Radial Artery Occlusion in Transradial Catheterization

Jan-Yow Chen, Ping-Han Lo, Jui-Sung Hung, Jen-Jyh Lin, Han Lee, Kuan-Cheng Chang, Hsiang-Tai Chou

Division of Cardiology, Department of Medicine, China Medical College Hospital, Taichung, Taiwan

Background: The transradial route is widely accepted as a safe and useful alternative to the traditional transfemoral approach in coronary angiography and intervention. However, it carries a relatively high risk of radial artery occlusion. Studies on radial artery occlusion after transradial catheterization using the color Doppler ultrasound method are limited. The present study was undertaken to examine the incidence and mechanism of radial artery occlusion after transradial procedures using the technique.

Methods: Two-dimensional color Doppler ultrasound examinations of both radial arteries were performed in 81 patients who underwent transradial coronary angiography or coronary intervention. The examination was carried out in each patient immediately before and one month after the procedure.

Results: Post-procedural occlusion of the radial artery with absence of antegrade flow occurred in 10 patients (12.3%) without clinical ischemia. Five of the 10 patients had absent radial pulse and abnormal reverse Allen test. The other 5 patients with palpable but reduced radial pulse had reversed radial Doppler flow via ulnar collaterals. However, they also had abnormal reverse Allen test. Univariate analysis showed borderline significance of radial artery inner diameter to sheath outer diameter (RAID/SOD) ratio to be a predictor of radial artery occlusion (24% with RAID/SOD ratio < 1.0 vs. 7.1% with the ratio being ≥ 1.0, $p = 0.06$). Multivariate analysis revealed RAID to be the only significant predictor of post-procedural radial artery occlusion.

Conclusions: Absolute and relative radial artery size (to sheath size) are important predictors of post-procedural radial artery occlusion. Routine ultrasound examination is not indicated in evaluation of radial artery occlusion after transradial catheterization, but pre-procedural ultrasound evaluation is helpful. Radial pulse may be palpable in the presence of radial artery occlusion due to reversed flow via ulnar collateral supply. Abnormal reverse Allen test is sensitive and specific for radial artery occlusion.

Key Words: Color Doppler ultrasound; Coronary intervention; Radial artery occlusion.

Introduction

Transradial coronary angiography was introduced by Campeau in 1989.[1] Kiemeneij and associates in 1992 first reported percutaneous transluminal coronary angioplasty (PTCA) using the transradial

Received March 6, 2001; **Accepted** May 2, 2001
Correspondence: Dr. Jui-Sung Hung
Division of Cardiology, China Medical College Hospital, No. 2, Yuh Der Road, Taichung 404, Taiwan, R.O.C.
Tel: 886-4-2205-2121 ext. 2011; Fax: 886-4-2203-4608

approach.[2,3] With minimization of guiding and balloon catheters in recent years, transradial catheterization has gained world-wide acceptance in Western as well as Oriental countries.[3-9] In some institutions, the radial artery has become the route of choice for performing diagnostic as well as interventional procedures.[5,10,11,12]

Radial artery occlusion is the major complication of transradial catheterization. The reported occlusion rates of the radial artery ranged from 1-24% and varied with study methods.[1,3,6,10,13-17] With its ability to delineate the vascular lumen clearly and detect the direction of blood flow, color Doppler ultrasound has become the examination of choice in evaluating vascular disease. However, studies on radial artery occlusion after transradial catheterization using the color Doppler ultrasound method are limited.[10,16] Accordingly, the present study was undertaken to examine the incidence and mechanism of radial artery occlusion after transradial procedures using the color Doppler flow imaging technique.

Patients and Methods

Patients

From August 1998 to June 1999, 97 patients with normal Allen test underwent transradial catheterization. Of the 97 patients, 16 patients who failed to receive follow up ultrasound examination were excluded from the study. The other 81 patients who had ultrasonic examination both immediately before and one month after transradial catheterization procedure constituted the study group. They were 60 males and 21 females, aged between 20 and 87 years (mean 61 ± 3.1). Of the 81 patients, 58 patients received diagnostic procedures and the other 23 patients underwent PTCA (including 10 stenting procedures). Hypertension was present in 47 (58%), diabetes mellitus in 10 (12%) and hyperlipidemia in 28 (35%) patients. Thirty-six (44%) patients were smokers.

Physical Examination of Radial Artery

Palpation of both radial arteries, Allen test and reverse Allen test were performed before and 1 month after transradial catheterization. The Allen test was defined as normal when color of the hand returned within 10 seconds after pressure release over the ulnar artery. It was defined to be abnormal if the color recovery was delayed. Reverse Allen test was normal when color of the hand returned within 10 seconds after release of compression over the radial artery. An abnormal reversed Allen test was when the color return was delayed.

Color Doppler Ultrasound Examination

Ultrasound evaluation of both radial arteries was performed using a 7.5 MHz probe (SONOS 2500 system, Hewlett-Packard, US). Inner diameter of the radial artery and Doppler signals of blood flow were measured approximately 1 cm proximal to the styloid process. The inner lumen of the artery was investigated carefully with the aid of color Doppler mapping of blood flow (Fig. 1).

Vascular Access

A puncture site was chosen over the radial pulse, about 1.0 cm proximal to the styloid process. After sterilization, local anesthesia was achieved by injection of 2% lidocaine with a 25 gauge needle. Transradial kits (Terumo Corp., Tokyo, Japan) were used exclusively in this study. Puncture of the radial

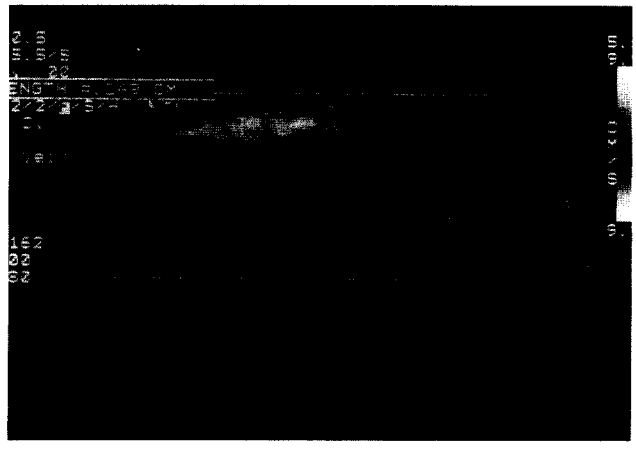

Fig. 1. Color Doppler ultrasound of radial artery. Radial artery inner diameter is measured as the width of color flow (between two cross marks) at site 1 cm proximal to the styloid process.

artery was performed with a 20 gauge sheathed needle. When good back-bleeding from the needle was observed, the needle was removed and a 0.025″ guide wire was introduced into the artery through the sheath. After removal of the sheath, a 5 Fr or 6 Fr introducer (16 cm in length) was advanced into the radial artery over the guide wire. Ten milliliters of normal saline containing 40 mg of lidocaine, 200 ug of nitroglycerin and 2,500 U of heparin was injected via the side port of the introducer.

Hemostasis

Immediately after the diagnostic procedure, the introducer was removed in the laboratory and double pressure bandages were applied over the puncture site for hemostasis. In cases of interventional procedure, in which a total of 10,000 U of heparin was given, the introducer was removed one hour after the procedure. The pressure bandage was removed one hour later in cases of diagnostic procedure and 4 hours later in interventional cases. If bleeding was still observed, the radial artery was compressed again for another 2 to 3 hours.

Definition of Radial Artery Occlusion

Radial artery occlusion was defined as absence of antegrade Doppler blood flow signal, and was divided into two types: type I, with absence of palpable radial pulse and type II, with palpable radial pulse due to retrograde flow from the ulnar artery (Fig. 2).

Statistics

Statistical analyses were performed using the SAS system (WIN SAS Ver 6.12). Continuous data were expressed as mean ± SD and compared by Student's *t* test. Categorical data were compared with Chi-square test and Fisher's exact test. The changes in 10 clinical variables (Table 1) before and after transradial catheterization were analyzed by univariate and multivariate analyses, respectively. The relative influ-

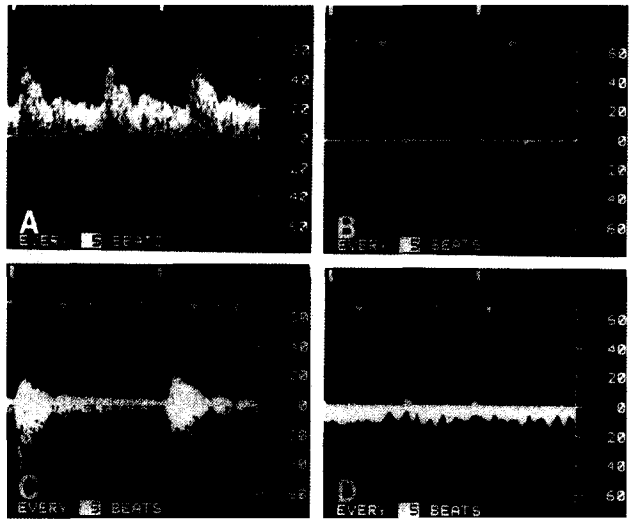

Fig. 2. Doppler flow signals in post-procedural radial artery. A. Normal Doppler flow signals in non-occlusive radial artery. B. Type I occlusion: absence of antegrade Doppler flow signals. C. Type IIA: pulsed reverse Doppler flow during systolic phase. D. Type IIB: Continuous flow signals of reverse Doppler flow. See texts for discussions.

Table 1. Variables Analyzed in Univariate and Multivariate Analysis

	Occlusion (N = 10)	No occlusion (N = 71)	Univariate *p* value	Multivariate *p* value
Age (yr)	56 ± 11	61 ± 13	0.24	NS
Sex (male)	7 (70%)	53 (75%)	0.71	NS
BMI (Kg/M^2)	24.5 ± 2.2	25.3 ± 3.3	0.44	NS
Hypertension	4 (40%)	43 (61%)	0.31	NS
DM	1 (10%)	9 (13%)	1.0	NS
Smoking	4 (40%)	32 (45%)	1.0	NS
RAID (mm)	2.5 ± 0.4	2.8 ± 0.4	0.01	0.015
RAID/SOD < 1	6 (60%)	19 (27%)	0.06	NS
PTCA	1 (10%)	22 (31%)	0.27	NS
Duration of sheath indwelling (min)	57 ± 75	70 ± 82	0.62	NS

BMI = body mass index; DM = diabetes mellitus; PTCA = percutaneous transluminal coronary angioplasty; RAID = radial artery inner diameter; SOD = sheath outer diameter; NS = not significant.

ence of clinical variables was tested by logical stepwise analysis. A p value < 0.05 was considered statistically significant.

Results

Raidal Artery Inner Diameter (RAID)

The mean RAID at baseline was 2.77 ± 0.47 mm on the right arm and 2.70 ± 0.40 mm on the left arm. The difference was not statistically significant (p = 0.12). The RAID in the male patients was larger than in the females (2.87 ± 0.47 mm vs 2.46 ± 0.32 mm on right, 2.81 ± 0.39 mm vs 2.40 ± 0.27 mm on left side, p < 0.001). The RAID in the catheterizied arm decreased significantly from 2.79 ± 0.44 mm to 2.28 ± 1.02 mm after the transradial catheterization. (p < 0.001) (Fig. 3). Even excluding the 10 patients with the radial artery lumen obliterated after the procedure (marked by open triangles in Fig. 3), the difference in the RAID before and after the procedure was still significant (2.83 + 0.44 mm vs 2.60 + 0.58 mm, p = 0.0001). In the contralateral (uncatheterized) arms, the RAID did not change significantly between the two examinations (2.68 ± 0.43 mm vs. 2.69 ± 1.02 mm, p = 0.71) (Fig. 4). There was only weak correlation between the patient height and RAID (r = 0.28 on right side, r = 0.23, on left side).

Color Doppler flow

After transradial catheterization, 10 patients (12.3%) developed radial artery occlusion with absence of antegrade radial flow and obliterated inner lumen, as stated above. None of the patients had clinical ischemic symptoms. Five of the 10 patients had type I occlusion with absence of the radial pulse and also absence of retrograde flow. The other 5 patients had type II occlusion with reduced but palpable radial pulses along with the presence of retrograde flow from the ulnar artery. The retrograde flow patterns were pulsed (type IIA) in 4 and continuous in the remaining 1 patient (type IIB) (Fig. 2).

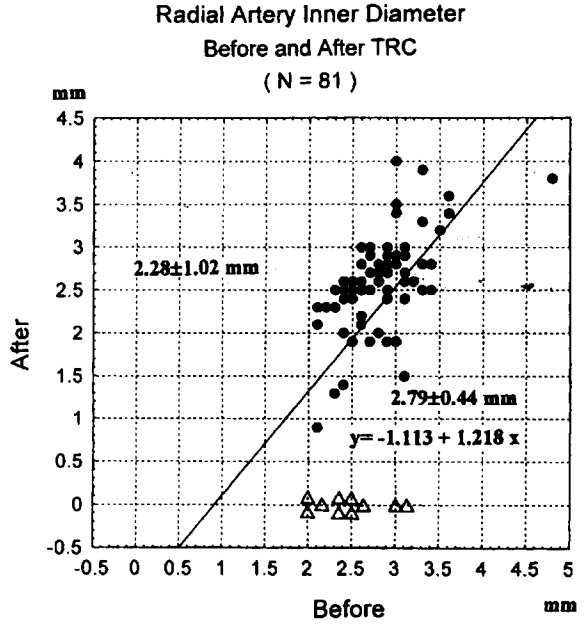

Fig. 3. Scattergram of radial artery inner diameters before and after transradial catheterization (TRC) showing overall reduction in arterial diameters after catheterization. Those patients with total occlusion of their radial arteries (diameter of 0 mm) are indicated with open triangle marks.

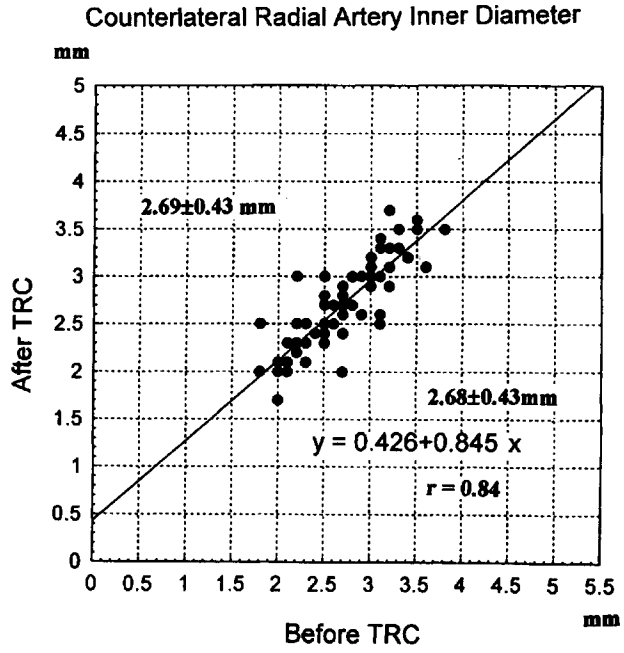

Fig. 4. Scattergram of non-catheterized radial artery inner diameters before and after contralateral transradial catheterization (TRC). There were no significant peri-procedural changes in non-catheterized radial artery diameters.

In univariate analysis, only RAID and RAID/SOD (sheath outer diameter) ratio were identified as significant predictors of radial artery occlusion after transradial catheterization. Radial artery occlusion developed in 6 of 25 patients (24%) whose RAID/SOD ratio was < 1.0. In contrast, occlusion occurred in 4 of 56 patients (7.1%) with RAID/SOD ratio > 1.0 ($p = 0.06$). However, RAID was the only independent predictor for radial artery occlusion by multivariate stepwise analysis ($p = 0.015$) (Table 1). In 7 patients with RAID < 2.3 mm (43%) had radial artery occlusion after the procedure.

There was a trend of less radial artery occlusion after interventional procedures than after diagnostic procedures. One (4.0%) of the 23 patients who underwent interventional procedures had occluded radial artery, while 9 (15.6%) of 58 patients with diagnostic procedures had arterial occlusion ($p = 0.27$).

Discussion

Radial artery occlusion is an important complication of transradial catheterization. The mechanism of occlusion has been suspected to be due to denuded vascular lining, thrombus formation, subsequent proliferated endothelium, arterial constriction, vessel remodeling and other factors yet to be determined. [16,18] The occlusion rates varied with different methods of radial artery occlusion detection. Based on simple palpation of the radial pulses, Wu et al. found in Chinese patients a 12% incidence of reduced pulses, including 2.4% with absent pulses after diagnostic and interventional procedures.[6] Kiemeneij et al. utilized Doppler ultrasound method to detect radial artery occlusion and found a 3% occlusion rate at one-month follow-up after transradial catheterization.[3,14] Hall et al. utilizing a similar Doppler method, observed radial artery occlusion of 5% at 2-weeks follow-up.[15] Recently, Saito et al. used Doppler ultrasound with color display, and identified a radial artery occlusion rate of 6.8% at 1 to 2 weeks follow-up.[10] Also using color Doppler ultrasound, Nagai et al. detected a early radial artery occlusion rate of 9% of 2 days and late occlusion rate of 5% 95 days after transradial procedures.[16] In the present study, we observed a 12.3% incidence of radial artery occlusion with absence of antegrade color Doppler flow and obliterated inner lumen 1 month after transradial catheterization.

The RAID in the catheterizied arm decreased significantly in the present study. However, the reduction of diameter was predominantly demonstrated in patients with small RAID. Occlusion also mainly developed in patients with low RAID. Those patients with total occlusion of their radial arteries (RAID = 0 mm) were accumulated within the region of lower baseline RAID (Fig 3). Saito et al. have observed that the radial artery occlusion rate increased from 4.0% to 13.0% when the RAID/SOD ratio was less than 1.0, and stressed the important impact of the radial artery inner diameter relative to the sheath size on radial artery occlusion after transradial catheterization.[10] In the present study, RAID and RAID/SOD ratio were identified as significant predictors of radial artery occlusion after transradial catheterization by univariate analysis. However, RAID was found to be the only independent predictor for radial artery occlusion by multivariate stepwise analysis. This finding was similar to that of Nagai et al.[16] Therefore, absolute RAID appears to be more important in predicting radial artery occlusion after transradial catheterization than RAID/SOD ratio. In our study, a high occlusion rate of 42.9% was observed in 3 of the 7 patients with RAID < 2.3 mm. Patients with small radial artery should probably be avoided for transradial catheterization if an alternative route is available.

A previous study by Spaulding et al. reported that radial artery occlusion rate could be reduced from 24% to 4.3% when dosage of heparin was increased from 2,000-3,000 to 5000 U.[13] Our study also showed a trend ($p = 0.27$) of less radial artery occlusion after interventional procedures than after diagnostic procedures. This may be attributed to a much higher dosage of heparin (10,000 U) given before the interventional procedures, compared to a small dosage (2,500 U) of heparin administered during diagnostic procedures. At present, we have increased the heparin dosage from 2,500 to 4,000 U in diagnostic procedures. Whether or not this increase in heparin dosage will reduce the radial artery occlusion rate remains to be de-

termined.

As in previous studies,[14,15,18] this study also demonstrated that a palpable radial pulse does not guarantee patency of the artery because falsely palpable pulse may be due to the presence of retrograde flow from the ulnar artery via the palmar arch. In our study, 5 of the 10 patients with occluded radial arteries after the transradial procedures had palpable although weak pulses. By color Doppler ultrasound study, all 5 patients had retrograde blood flow signals in the distal portion of their radial arteries. The retrograde flow patterns were pulsed in 4 and continuous in the other patient. In the latter patient, presence of smaller collateral channels causing continuous pressure gradient throughout the cardiac cycle probably attributed to the continuous flow pattern.

Besides the finding that simple palpation of the radial pulse is inadequate to assess the arterial patency after transradial procedures, our study has shown that addition of reversed Allen test is quite sensitive and specific in predicting radial artery status. In the 71 patients in whom radial arteries were palpable and the color Doppler ultrasound examination confirmed patent arteries, the radial arteries were palpable and reversed Allen tests were normal. On the other hand, all of the 10 patients who were shown to have occluded radial arteries by the ultrasound test had abnormal reversed Allen tests regardless of absence of the radial pulses or presence of palpable radial arteries due to retrograde flow (in 5 patients, as discussed above).

The color Doppler ultrasound method used in the present study for detection of radial artery flow and occlusion is considered to be superior to the simple Doppler flow mapping because the color Doppler ultrasound provides clearer images and better mapping guidance for detection of radial artery occlusion. However, from our study observations, it appears that in practice, palpation of the radial pulse coupled with the reversed Allen test is sufficient for assessing the patency of the radial artery. Absent radial pulse with abnormal reversed Allen test indicates occlusion of the radial artery. Palpable radial pulse along with abnormal reversed Allen test reflects occluded artery with retrograde flow from the ulnar artery, while palpable radial pulse and normal reverse Allen test ensures patency of the artery.

The female patients failed to show a significantly higher radial artery occlusion rate than the male group (14% (3/21) vs 12% (7/60), female vs male, $p = 0.71$), despite their lower RAID. A similarly conflicting result has been described by Stella et al.[14] The sex factor may play a role in radial artery occlusion. Further investigation and large series study are warranted to clarify its influence on radial artery occlusion after transradial catheterization.

In conclusion, radial artery size, either absolute size measured as RAID or relative size expressed in RAID/SOD ratio, is a predictor of radial artery occlusion after transradial catheterization. Simple palpation of the radial pulse is not adequate for assessing patency of the radial artery because there may be retrograde flow supplied from the ulnar artery. Abnormal reverse Allen test indicates radial artery occlusion regardless of the presence or absence of palpable radial pulses. Therefore, routine ultrasound examination is not indicated in evaluation of the radial artery occlusion after transradial catheterization, but pre-procedural ultrasond evaluation is helpful in identifying those patients who have small radial arteries and thus are at high risk of post-procedural radial artery occlusion.

References

1. Campeau L. Percutaneous radial artery approach for coronary angiography. *Cathet Cardiovasc Diagn* 1989; 16:3-7.
2. Kiemeneij F, Laarman GJ, de Melker E. Transradial artery coronary angioplasty. *Am Heart J* 1995; 129:1-7.
3. Kiemeneij F, Laarman GJ, Odekerken D, Slagboom T, van der Wieken R. A randomized comparison of percutaneous transluminal coronary angioplasty by the radial, brachial and femoral approaches: the access study. *J Am Coll Cardiol* 1997; 29:1269-1275.
4. Lotan C, Hasin Y, Mosseri M, Rozenman Y, Admon D, Nassar H, Gotsman MS. Transradial apporach for coronary angiography and angioplasty. *Am J Cardiol* 1995; 76:164-167.
5. Saito S, Miyake S, Hosokawa G, Tanaka S, Kawamitsu

K, Kaneda H, Ikei H, Shiono T. Transradial coronary intervention in Japanese patients. *Cathet Cardiovasc Intervent* 1999; 46:37-41.

6. Wu CJ, Lo PH, Chang KC, Fu M, Lau KW, Hung JS. Transradial coronary angiography and angioplasty in Chinese patients. *Cathet Cardiovasc Diagn* 1997; 40: 159-163.
7. Ochiai M, Isshiki T, Toyoizumi H, Eto K, Yokoyama N, Koyama Y, Takeshita S, Sato T. Efficacy of transradial primary stenting in patients with acute myocardial infarction. *Am J Cardiol* 1999; 83:966-968.
8. Mann T, Cubeddu G, Bowen J, Schneider JE, Arrowood M, Newman WN, Zellinger MJ, Rose GC. Stenting in acute coronary syndromes: a comparison of radial versus femoral access sites. *J Am Coll Cardiol* 1998; 32:572-576.
9. El-Shiekh RA, Burket MW, Mouhaffel A, Moore JA, Cooper CJ. U.S. experience of transradial coronary stenting utilizing Palmaz-Schatz stents. *Cathet Cardiovasc Diagn* 1997; 40:166-169.
10. Saito S, Ikei H, Hosokawa G, Tanaka S. Influence of the ratio between radial artery inner diameter and sheath outer diameter on radial artery flow after transradial coronary intervention. *Cathet Cardiovasc Intervent* 1999; 46:173-178.
11. Kiemeneij F, Laarman GJ, Slagboom T, van der Wieken R. Outpatient coronary stent implantation. *J Am Coll Cardiol* 1997; 29:323-327.
12. Kiemeneij F, Laarman GJ. Transradial artery Palmaz-Schartz coronary stent implantation: results of a single-center feasibility study. *Am Heart J* 1995; 130: 14-21.
13. Spaulding C, Lefevre T, Funck F, Thebault B, Chauveau M, Ben Hamda K, Chalet Y, Monsegu H, Tsocanakis O, Py A, Guillard N, Weber S. Left radial approach for coronary angiography: results of a prospective study. *Cathet Cardiovasc Diagn* 1996; 39:365-370.
14. Stella PR, Kiemeneij F, Laarman GJ, Odekerken D, Slagboom T, van der Wieken R. Incidence and outcome of radial artery occlusion following transradial artery coronary angioplasty. *Cathet Cardiovasc Diagn* 1997; 40:156-158.
15. Hall JJ, Arnold AM, Valentine RP, McCready RA, Matthew JM. Ultrasound imaging of the radial artery following its use for cardiac catheterization. *Am J Cardiol* 1996; 77:108-109.
16. Nagai S, Abe S, Sato T, Hozawa K, Yuki K, Hanashima K, Tomoike H. Ultrasonic assessment of vascular complications in coronary angiography and angioplasty after transradial approach. *Am J Cardiol* 1999; 83:180-186.
17. Benit E, Missault L, Eeman T, Carlier M, Muyldermans L, Materne P, Lafontaine P, Keyser JD, Decoster O, Pourbaix S, Castadot M, Boland J. Brachial, radial, or femoral approach for elective Palmaz-Schatz stent implantation: a randomized comparison. *Cathet Cardiovasc Diagn* 1997; 41:124-130.
18. Bedford RF, Wollman H. Complications of percutaneous radial artery cannulation: an objective prospective study in man. *Anesthesiology* 1973; 38: 228-236.

彩色杜卜勒超音波對經橈動脈心導管術後橈動脈阻塞之評估

陳建佑 羅秉漢 洪瑞松 林楨智 李 翰 張坤正 周湘台

台中市 中國醫藥學院附設醫院心臟內科

背景：經橈動脈途徑，在冠狀動脈血管造影術及介入性治療上，已經廣被接受為經股動脈途徑外的另一種安全且有效的選擇，然而它卻有相當高的橈動脈阻塞風險，過去使用彩色杜卜勒超音波評估經橈動脈心導管術後橈動脈阻塞的研究很有限，本研究嘗試利用此技術以探求經橈動脈導管術後橈動脈阻塞的發生率及機轉。

方法：81 個進行經橈動脈冠狀動脈血管造影術或介入性治療的病人接受二維彩色杜卜勒超音波檢查，這項檢查是在心導管術前當時及術後一個月進行。

結果：術後橈動脈阻塞且無前行血流發生在 10 位 (12.3%) 病人身上，無病患有臨床上的缺血症候，這 10 位病人有 5 位脈搏消失且反式亞藍氏試驗異常，另外 5 位脈搏減弱但仍可觸，且經由尺動脈的側枝循環而有著反向的杜卜勒血流訊號，且他們的反式亞藍氏試驗也異常，單變數分析顯示橈動脈內徑對血管鞘外徑比 (RAID/SOD) 在預測橈動脈阻塞上有著統計學上的邊界值意義 (24% 當 RAID/SOD 值 <1.0 比上 7.1% 當此值 ≥1.0，$p = 0.06$)，多變數分析顯示橈動脈內徑為經橈動脈心導管術後橈動脈阻塞之唯一有意義的預測因子。

結論：絕對和相對的橈動脈內徑大小 (對血管鞘尺寸) 為術後橈動脈阻塞重要的預測因子。常規性超音波檢查在經橈動脈心導管術後橈動脈阻塞的評估上並非絕對必需，但術前超音波檢查則有幫助。橈動脈脈搏因為尺動脈側枝循環反向血流的原因可以在阻塞時仍可觸及。異常的反式亞藍氏試驗對橈動脈阻塞敏感且精確。

關鍵詞：彩色杜卜勒超音波；冠狀動脈介入性治療；橈動脈阻塞。

聯絡人：洪瑞松醫師，404 台中市育德路 2 號，中國醫藥學院附設醫院心臟內科

投稿日期：90 年 3 月 6 日；同意刊登：90 年 5 月 2 日