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Original Studies

Percutaneous Radial Artery Approach for Coronary Angiography

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Percutaneous entry into the distal radial artery and selective coronarography using a French 5 sheath and preshaded catheters were attempted in 100 patients with a normal Allen test. Cannulation of the radial artery was not possible in ten patients, and selective catheterization of the coronary arteries was unsuccessful in two. Manipulation of catheters presented no problem, and arterial spasm was rarely observed, only before the use of a 23-cm-long sheath. Only two complications without symptoms were observed: arterial dissection of the brachial artery in one patient and occlusion of the radial artery in another. With experience, this approach may become as effective and possibly safer than the transbrachial entry.

Key words: percutaneous radial catheterization, brachial artery catheterization, "inverse" Allen test, complications of arterial catheterization, coronarography

INTRODUCTION

The percutaneous transbrachial artery approach for left heart catheterization and coronary angiography has recently been described as a safe alternative to the standard cut-down arteriotomy brachial artery and the percutaneous axillary and femoral artery techniques [1–7]. All these procedures are associated with rare vascular complications, frequently requiring surgery, such as arterial occlusion, false aneurysm, arteriovenous fistula, or nerve injury [5–14]. We postulate that the radial artery approach can be free of significant complications because blood supply to the hand is provided, in the majority of patients, by two large-size arteries, and there are no nerves or veins of significant size near the cannulation site. This belief is further strengthened by the almost total absence of ischemic damage to the hand or disability, in spite of a high incidence of occlusion following prolonged cannulation of the radial artery for monitoring procedures in critically ill patients [15–17]. The radial artery approach became feasible with the availability of small French 5 introducer sheaths and preshaped catheters. This report concerns our first 100 patients in whom it was attempted.

PATIENTS

The first 30 patients were men selected on the basis of an apparently large radial artery, an easily palpable ulnar artery, and a normal Allen test. A test was considered normal only when the following two conditions were observed: following manual compression of both arteries, a return of normal color of the hand within 10 sec after opening the closed hand and release of the pressure over the ulnar artery; and absence of significant reactive hyperemia upon release of the pressure over the radial artery [17]. The remaining 70 were consecutive patients of both genders referred to the author for coronarography who had a normal Allen test and a palpable ulnar artery. Seventeen patients (20%) were omitted because of an unsatisfactory Allen test response; half of these had no palpable ulnar artery pulse. Subjects who required studies other than coronary angiography and left ventriculography were also excluded from study. There were no patients with vascular disease of the upper extremities, such as Raynaud's or Burger's disease. In only five patients (5%) was the arm approach absolutely indicated because of severe arteriopathy of the lower limbs or aneurysm of the abdominal aorta. There were 90 men and 10 women. Their age varied between 35 and 71 years, with a median of 58 years. Twenty percent had no significant coronary artery disease, 49% had one-to-two vessel disease, 27% had three-artery involvement, and only five patients had a left main trunk stenosis.

MATERIALS AND METHODS

The left arm is abducted at a 70° angle, and the wrist is hyperextended over a gauze roll. After skin anesthesia with lidocaine and a small scalpel skin incision just prox-

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imal to the styloid process of the radius where the course of the artery is straight, a tunnel is made with a forceps to facilitate the entry of the introducer sheath. For large-size arteries, an 18-gauge multipurpose needle is introduced at a 45° angle, avoiding the posterior wall (Becton Dickinson, Rutherford, NJ). When the artery appears small, or when the previous needle has failed (25% of cases), an 18-gauge Potts-Cournand needle is used to transfix the artery (also from Becton Dickinson). A short, 0.038-inch straight-end or J-tip guide wire is then introduced, followed by a French 5 USCI hemaquet introducer sheath. The standard 10-cm-long sheath used initially was replaced by a custom-made 23-cm-long sheath to prevent spasm of the radial artery. Attempts at puncture and cannulation are limited to 15 min before going to the percutaneous brachial approach. Heparin, 5,000 U, is injected through the side arm of the sheath. French 5 catheters are advanced slowly over a J-tip 0.035- or 0.038-inch guide wire to the ascending aorta. The tip of the guide wire is maintained inside the catheter when necessary to facilitate progression to the subclavian artery. In ten patients, French 6 and French 7 introducer sheaths and catheters were used because suitable smaller size catheters were not available or selective coronary artery catheterization was unsuccessful using the smaller catheters. The left coronary artery is selectively catheterized by one of the following catheters in order of preference: 1) brachial coronary Castillo type II; 2) left femoral coronary B Amplatz; 3) coronary A 4-cm-tip Judkins. The right coronary artery is easily catheterized by any of these three catheters: 3-cm-tip multipurpose, right Judkins, and #1 Amplatz. All catheters, except the 3-cm-tip multipurpose, have no side hole, and all are 100 cm to 125 cm long, thin wall, high flow (Cordis Corporation, Miami, FL; USCI Division, C.R. Bard Inc., Billerica, MA; Mallinckrodt, Angleton, TX). Left ventriculography is obtained with a femoral-aortic flush pigtail tip catheter or with a multipurpose 3-cm-tip catheter having side holes. The pigtail tip catheter is removed over a guide wire to prevent spasm of the artery and to reduce the possibility of intimal damage. In seven patients who complained of pain in the arm during catheter manipulations, a hot towel was placed over the forearm to decrease vasospasm.

After the procedure, the sheath is left in place while the patient is transferred to the postcatheterization room, where it is removed. Allowing bleeding for a few beats, digital pressure is applied proximal to the puncture site for 6 to 10 min. Sufficient pressure is maintained to prevent bleeding but without obliterating the pulse in the anatomical fossa. Heparin was not reversed except in one patient with severe hypertension. When the pulse failed to return in 16 patients, an additional 2,000 U of heparin was given intravenously, as well as a continuous drip at a rate of 1,000 U per hr for 6–24 hr, or until the pulse recovered satisfactorily. A small pressure dressing is applied for 3 hr, and the patient is asked to remain in bed without flexing the wrist during that period. The next day, the pulses distal to the puncture site and in the anatomical fossa are graded 0 to 3/3, 0 being definitely absent, 1 being equivocal, 2 being decreased, and 3 normal. A reversed Allen test is performed by releasing pressure first over the radial artery and then over the ulnar artery. Claudication of the hand is tested by repeat opening and closing at a rate of 60 times per min for 3 min. When the radial pulse is absent or equivocal, blood flow is evaluated using a portable Sonar Doppler (Parks Electronics Laboratory, model 802-A, Beaverton, OR). The systolic blood pressure is measured at three levels, over the brachial artery, at or distal to the puncture site, and at the anatomical fossa. The systolic blood pressure is indicated by the reappearance of the pulse or the Doppler sound during deflation of the arm cuff. All patients were re-examined or questioned by telephone concerning potential local complications 1 to 3 months after the procedure, and most had quantitative Doppler analysis of the upper extremities during that interval (bidirectional Doppler Vasculab Spectrum analyser, Medasonics, Mountain View, CA).

RESULTS

The artery could not be punctured in four patients, and it could not be effectively cannulated in six. In one patient, the procedure was abandoned after selective opacification of the left coronary artery because an arterial dissection was produced at the elbow during the introduction of the right coronary artery catheter. In another patient, selective opacification of the coronary arteries was not obtained, presumably because of severe ostial disease of both coronary arteries, which was subsequently demonstrated using the femoral artery approach. Progression of the catheter from the subclavian artery to the ascending aorta was difficult in only three patients. Manipulation of catheters caused pain in the forearm and elbow area in only six patients (before using custom-made 23-cm-long introducer sheaths). Most of these problems were eliminated by changing catheters over a 250-cm guide wire.

The average time for successful cannulation was 4.7 ± 3.9 min, and that of the catheterization procedure 30.5 ± 10 min. Good-quality opacification of both coronary arteries was obtained in all 88 patients in whom selective catheterization was carried out.

The pulse at or distal to the puncture site as well as in the anatomical fossa was absent after removal of the introducer sheath and compression in 22 of the 90 patients in whom catheterization was carried out (24%).

TABLE I. Procedural Difficulties and Complications

	Male (n = 90)	Female (n = 10)	Total (n = 100)
Puncture or cannulation failure	10	0	10
Coronary catheterization failure	2	0	2
Painful catheter manipulation	5	2	7
Early pulse deficit	19	3	22
Late pulse deficit	5	1	6
Radial artery occlusion	1	0	1

Nifedipine, 10 mg sublingually and 10 mg q 4 hr × 2 was administered orally, a hot towel was applied over the forearm, and heparin therapy was instituted as previously described. A normal pulse returned in 16 patients within 2–8 hr. It remained diminished in five and absent in one. None, however, showed signs of ischemia or claudication of the hand. In three of these patients, including the patient with an absent pulse, an "inverse" Allen test was positive (compression of the ulnar artery produced blanching of the palm of the hand and its release was followed by reactive hyperhemia). In the five patients with decreased pulse, the Doppler curve obtained 2–12 weeks later was compatible with a decreased flow at the level of the radial and anatomical fossa, but the systolic pressure measured at both sites was not significantly different, compared with the other arm. All patients with a good radial pulse had a normal Doppler flow pattern.

Bleeding occurred 1 hr after the procedure in one patient, and a hematoma without sequella in another, both complications in patients receiving postprocedural heparin. Nerve injury and arteriovenous fistula were not observed. Procedural difficulties and complications were not more frequent in women (Table I), taking into consideration that only ten were included. Ventricular fibrillation occurred in one patient and mental confusion persisted for several days in another. No myocardial infarction occurred, and there were no deaths.

DISCUSSION

It is too early to compare the efficacy and safety of this new approach to the standard cut-down arteriotomy and the percutaneous transbrachial artery techniques. Arterial puncture and cannulation of the radial artery appear more difficult, but the failure rate should decrease with experience and improved puncture-cannulation material. The introduction and manipulation of preshaped catheters presented no problem. However, the 23-cm-long introducer sheath and the change of catheters over a 250-cm-long guide wire appeared to facilitate the procedure. The Amplatz- and Castillo-type curves seemed best suited for the left coronary artery. The right coronary was catheterized equally well with all three types of curves, 3-cm-tip multipurpose, Judkins, or Amplatz.

The only significant complications were arterial dissection in one patient and radial artery occlusion in another, both without symptoms of ischemia of the hand. On theoretical grounds, most local complications observed with the brachial approach should occur more rarely, if at all, except for pseudoaneurysm. The absence of nerves and veins of significant size near the cannulation site is a safeguard against nerve injury and arteriovenous fistula. Postprocedural bleeding and hematoma are indeed rare, because of the ease and efficacy of arterial compression at that site. Although radial artery occlusion may occur more frequently because of the smaller size of the vessel, the dual supply to the hand by the radial and ulnar arteries and the palmar arches should prevent hand ischemia and disability when it happens. Slogoff et al. [15] observed neither ischemia damage to the hand nor disability in 1,700 cardiovascular surgical patients who had radial cannulation for monitoring, in spite of an abnormal radial artery flow pattern by quantitative Doppler analysis in 25% of the patients. Bedford et al. [16] concluded that the percutaneous cannulation of the radial artery for 1 to 10 days has generally been free of serious sequellae, although arterial occlusion may occur in 10–30% of cases, depending on the duration of the cannulation period. Nonetheless, isolated reports of thromboembolic phenomena resulting in distal vascular insufficiency have been reported, always following cannulation for several days [17]. There should be no problem for procedures of short duration in patients who have a palpable ulnar pulse and a normal Allen test, two recommended selection criteria for this procedure. The aforementioned theoretical considerations and these preliminary results do suggest that the radial artery approach may be safer than other techniques, although a larger number of cases is required before a definite statement can be made.

Hessel et al. [13] reported a puncture-site complication rate of 1.7% in 4,590 cases of transaxillary entry for angiographic examinations. Arterial obstruction was observed in 0.8%, and pseudoaneurysm and arteriovenous fistula needed surgical repair in 0.24%. Amputation of the arm was necessary in one patient. Median and ulnar nerve injury caused by needle puncture or compression from an hematoma were observed in 0.3% to 0.8%. However, Valeix et al. [18] had no complications in 105 cases using an introducer sheath, a method unknown in previous series.

The more standard cut-down arteriotomy technique for brachial artery entry is complicated by clinically evident arterial thrombosis in 1% to 2% [5,9]. Thrombectomy can be achieved in the catheterization room at the end of the procedure when antegrade flow appears inadequate. Surgery is necessary in about 1% of patients [11]. However, Barnes and associates [12] considered that pulse detection of arterial obstruction is unreliable because well-developed collaterals may maintain a pulse of good amplitude and prevent symptoms and signs of ischemia. In a prospective study of 100 consecutive patients who had brachial catheterization with the Sones technique, the Doppler ultrasonic velocity detector identified brachial artery obstruction in 18 patients (17%), two-thirds of whom had no or only transient symptoms of ischemia; six had a palpable pulse. Of these 18 patients with brachial artery obstruction, 10 had Fogarty catheter thrombectomy in the catheterization laboratory because of absence of the radial artery pulse. Nonetheless, only two patients were discharged with modest persistent symptoms of ischemia in spite of thrombectomies.

Cohen et al. [5] found no significant difference in local complication rates between the standard cut-down arteriotomy technique and the percutaneous entry of the brachial artery. In the combined series of 2,818 cases of percutaneous brachial catheterization in the literature [2,4–7], arterial obstruction was observed in 37 patients (1.3%), arteriovenous fistula in 4, false aneurysm in 2, and median nerve injury in 2. Surgery was required in 12, and a percutaneous balloon angioplasty in 1 (0.5%). In our personal experience with over 875 cases of percutaneous transbrachial procedures, 4 have permanent disability: ischemia of the hand in spite of surgery in 2, and median nerve injury in 2 (0.5%).

There is no doubt that the percutaneous femoral artery remains the most appealing approach for left heart catheterization and coronarography, because arterial cannulation and catheter manipulation are easier and safer. Davis et al. [9] compared the complications in 6,328 consecutive patients studied by the femoral approach to that of 1,187 patients in whom the standard cut-down arteriotomy brachial artery technique was performed. Arterial thrombosis was almost ten times less frequent with the femoral entry, 0.2% versus 1.9% ($P < 0.001$). Similarly, Morton and Beanlands [10] reported an incidence of arterial injury in transfemoral procedures of 0.4% compared with 2.7% in transbrachial procedures. Hessel et al. [13] compared the transfemoral and transaxillary approaches in a multicenter survey involving 83,068 cases of the former, and 4,590 of the latter procedure. Puncture-site complications, including hemorrhage, thrombosis, and pseudoaneurysm, were observed in only 0.5% with the femoral entry in contrast to 1.7% for the transaxillary technique. There were no significant differences in the incidence of arteriovenous fistula with both approaches, 0.01% and 0.02%, respectively. About half of these puncture-site complications required surgery, but few left permanent disabling incapacity. There were, nonetheless, seven leg amputations following the transfemoral approach (0.01%), and one arm resection with the transaxillary (0.02%). Although rare, this unfortunate complication is indeed sad for a diagnostic procedure. It is also likely that complications of the femoral approach are underestimated. Barnes et al. [12], using the Doppler technique, detected thromboembolic complications in the legs following this procedure in 14% of patients, two-thirds of whom were asymptomatic. Bleeding from the puncture site into the retroperitoneal space is probably frequently unrecognized. However, the use of French 5 and 6 introducer sheaths and catheters may diminish the puncture site complications further. It may also foster early ambulation and outpatient practice, advantages usually considered exclusive attributes of the brachial approach, although the safety of outpatient cardiac catheterization using larger size catheters for the transfemoral entry has already been documented [19].

Nonetheless, the transfemoral entry is not possible in at least 2–8% of the patients because of severe aortoileofemoral obstructive disease or aneurysm of the abdominal aorta. Maoud et al. considered that it was not feasible in only 25 patients during an 18-month experience with 1,500 patients (2%). Valeix et al. [18] estimated that 6% required an arm approach. In the present series, it was not amenable in only five patients (5%). In our recent experience with over 875 consecutive cases of percutaneous brachial entry for coronarography, 8.1% could not be studied by the femoral approach. We suspect that its use is unwarranted and hazardous in another 10% of patients who have good femoral pulses, in spite of significant peripheral vascular disease, as evidenced by systolic bruit over the femoroiliac area or abdomen. Transarterial prostheses should not be attempted, although feasible. Peripheral vascular disease is frequent in patients with coronary artery disease, reported in 55 of 100 patients after acute myocardial infarction, of whom 18 manifested intermittent claudication [20]. Thus entry in one of the arteries of the arm is necessary or preferable in 10–20% of cases. Of the arm approaches, the brachial appears better than the axillary for patient comfort and safety. The radial artery entry may be the best alternative in order to prevent the rare but troublesome complications related to arterial occlusion and median nerve injury following the transbrachial entry, if the cannulation failure rate can be substantially decreased with further experience.

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