Complications of Brachial Artery Catheterization: Prospective Evaluation with the Doppler Ultrasonic Velocity Detector*

Robert W. Barnes, M.D., F.C.C.P.,** John L. Petersen, M.D.,† R. B. Krugmire, Jr.;‡ and D. Eugene Strandness, Jr., M.D.||

A prospective evaluation of catheter-induced arterial injury was carried out in 100 consecutive patients who underwent 104 cardiac catheterizations via the brachial artery. The Doppler ultrasonic velocity detector was utilized to noninvasively assess brachial, radial and ulnar arterial signals and pressures. Brachial artery obstructions occurred in 18 patients (17 percent), two-thirds of whom had no, or only transient, symptoms of ischemia. Six patients developed palpable pulses during the immediate period after catheterization. Complications correlated with duration of indwelling arterial catheter. The mean arm–forearm pressure gradient was 47 mm Hg (range 20–105), the magnitude of which correlated with symptoms and pulse deficits. Five patients underwent successful thrombectomy, with ablation of the pressure gradient. Five had unsuccessful thrombectomies, but only two had persistent ischemic symptoms, which abated as collateral circulation developed. Eight asymptomatic patients with low pressure gradients were observed. The Doppler ultrasonic velocity detector is a simple noninvasive technique to guide the physiologic assessment and management of complications of arterial catheterization.

Despite the pivotal role of cardiac catheterization in the assessment of cardiovascular disease, this procedure continues to be associated with a small risk of potentially serious complications. The most common significant accident following retrograde catheterization of the femoral or brachial artery is acute arterial occlusion secondary to thrombosis or thromboembolus.1,2 The fallability of pulse detection by different observers and the fact that arterial complications may frequently be asymptomatic have led to more sensitive and objective techniques,3,4 which have detected a greater number of these complications. An accurate, objective knowledge of the true frequency of such accidents is especially important when assessing the efficacy of prophylactic measures to reduce the incidence of arterial thromboemboli after catheterization.

A recent increase in brachial artery catheterization has accompanied the evolution of coronary arteriography and coronary artery surgery. Although the procedure involves catheterization of an exposed artery and often is accompanied by systemic heparinization, brachial artery occlusion has been reported in from 0.3 percent7 to 65 percent8 of these studies. Many reported rates of brachial artery occlusion may be underestimated when one realizes that the excellent collateral circulation about the elbow may result in an asymptomatic extremity or even detectable distal pulses coexistent with brachial artery occlusion.9

The Doppler ultrasonic velocity detector is a valuable noninvasive technique to accurately and objectively assess the peripheral circulation of patients undergoing arterial catheterization.10 This study was undertaken to utilize this instrument for prospective assessment of the arterial circulation in a consecutive group of patients undergoing cardiac catheterization by the retrograde brachial artery route.

MATERIALS AND METHODS

From March through October, 1972, 100 patients were studied consecutively before and after retrograde brachial artery catheterization in the cardiac catheterization laboratory at the University Hospital of the University of Washington. A total of 104 procedures were performed, with four patients undergoing catheterization on two separate occasions. All procedures were carried out with the Sones technique. The proximal and distal arteries were flushed with heparinized saline solution prior to catheterization. The catheters were wiped and frequently flushed with heparinized saline solution. The arteriotomy was closed with a horizontal mattress suture of fine nonabsorbable suture. A Fogarty catheter thrombectomy was performed in situations of decreased blood flow from the arteriotomy or when brachial artery obstruction was recognized at the conclusion of the procedure.
The patient assessment included records of upper extremity symptoms, color, temperature and pulses before and after catheterization. Arm and forearm systolic blood pressures were determined with the Doppler ultrasonic velocity detector, which was also used to assess the quality of the brachial, radial and ulnar arterial velocity signals.

To measure the blood pressure, an appropriately sized pneumatic cuff, initially placed on the arm, was inflated until the Doppler arterial signal at the wrist was obliterated (Fig 1). The cuff was then slowly deflated until the Doppler arterial signal returned at the systolic blood pressure of the brachial artery. The procedure was repeated with the cuff on the forearm for determination of radial and ulnar arterial pressures. The pressures obtained by this method agree with the intra-arterial pressures to within 26 mm Hg, with a correlation coefficient of 0.991.11

The forearm systolic pressure is normally equal to or slightly higher than that of the arm. An obstructive or thromboembolic complication of catheterization was defined as an arm-forearm systolic pressure gradient of 20 mm Hg or greater following catheterization, or a pressure reduction of 20 mm Hg or greater in the catheterized arm compared to the opposite arm. Although a pulse deficit usually coexisted with an arterial obstruction, for the purpose of this study diagnosis of such a complication was made only in the presence of a systolic pressure gradient in the catheterized arm.

The existence and location of the arterial obstruction was also determined by the abnormality of the quality of the arterial velocity signals (Fig 2). The normal arterial velocity signal is multiphasic, with a prominent systolic component and one or more diastolic sounds which may include a reversed flow component. Distal to an arterial obstruction the arterial velocity signal is attenuated, with a consequent reduction of the systolic amplitude and loss of the diastolic components. The character of the Doppler arterial signal also permits definition of the type of arterial obstruction. Arterial stenosis may be identified by the typical high-pitched velocity at the site of the lesion. An arterial occlusion is accompanied by an absent signal at the expected location of the vessels, with high-pitched collateral arterial signals around the site of the obstruction.

Results

There were 68 men and 32 women ranging in age from 26 to 74, with a mean of 54 years. Sixty patients had coronary artery disease, 37 had cardiac disease not involving the coronary arteries, and 3 had no abnormalities on catheterization.

Of the 104 procedures, there were 22 complications (21 percent), the majority of which were brachial artery obstructions (Fig 3). There were two deaths, both the result of myocardial infarction which developed during the period of catheterization.

Of the 18 patients with brachial artery obstruction, 7 were asymptomatic and 5 had only mild transient symptoms of ischemia. Four of these patients had palpable pulses, and in two others pulses returned during the period of hospitalization following catheterization. The Doppler arterial signals from these patients were of better amplitude than those from patients without palpable pulses. Six patients had more sustained symptoms of ischemia but only two had complaints of mild discomfort at the time of discharge from the hospital. The arm-forearm systolic pressure gradient ranged from 20 to 105 mm Hg, with a mean of 47 mm Hg. The mean pressure gradient in those without symptoms was 35 mm Hg (range 20-65), and in those with ischemic

![Figure 2](image-url) Brachial artery velocity in normal and obstructive circulation.

![Figure 3](image-url) Complications of 104 brachial artery catheterizations.
symptoms it was 63 mm Hg (range 40-105). The mean gradient in those with palpable pulses was 26 mm Hg (range 20-35) and in those without pulses it was 56 mm Hg (range 25-105).

The number of separate catheters utilized for each procedure ranged from one to five, with a mean of two. There was no difference in the number of catheters used in patients with complications as compared to those who did not suffer complications. The total period of indwelling brachial arterial catheters varied from 15 to 110 minutes. The mean time of indwelling catheter was 61 ± 23 minutes for patients suffering brachial artery obstruction as opposed to 43 ± 19 minutes for those without complications, which is a significant difference (p 0.01).

Of the 18 patients with brachial artery obstruction, 8 asymptomatic patients were observed without specific therapy (Fig 4). Ten patients had a Fogarty catheter thrombectomy in the catheterization laboratory because of absence of the radial artery pulse and symptoms of ischemia in the arm at the conclusion of the procedure. Five patients subsequently maintained normal circulation, while five developed recurrent thrombosis of the brachial artery. Three of the latter underwent a second thrombectomy in the catheterization laboratory, but occlusion developed again in all.

Figure 5 depicts the arm pressure gradients in the patients with brachial artery obstruction at the time of discharge from the hospital. There was no significant pressure gradient in the five patients who underwent a successful thrombectomy. In those with an unsuccessful thrombectomy the mean arm-forearm gradient was 70 mm Hg, while in those who were only observed the gradient averaged 34 mm Hg. The pressure differential between the two groups correlates with the fact that the former patients were symptomatic, while the latter had no symptoms of ischemia.

Of the 13 patients with persistent brachial arterial obstruction, only 2 had persistent symptoms of ischemia of the arm by the time of discharge. One had undergone a thrombectomy which failed, followed by a sympathetic block without benefit, with a residual pressure gradient of 70 mm Hg. The other patient had undergone two unsuccessful thrombec-

![Figure 5](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/20957/)

**Figure 5.** Pressure gradients according to therapeutic status of patients with brachial artery obstruction.

The variable incidence of reported complications of arterial catheterization may reflect differences of technique, investigator experience, patient selection or diagnostic criteria. Whereas most investigators report the incidence of vascular complications of arterial catheterization to be less than 5 percent, such studies are usually retrospective, based on recorded pulse deficits or significant symptoms. Several factors suggest that the existing literature may reflect an underestimation of the true incidence of thromboembolic complications of arterial catheterization. There is a recognized discrepancy in pulse detection by different observers. Pulses may exist distal to an arterial obstruction in the presence of prominent collaterals. Such collateral circulation, if sufficiently adequate, may permit some patients to be asymptomatic with arterial complications after catheterization. Finally, some studies have reported an increased incidence of thromboembolic complications that have been detected by such sensitive techniques as withdrawal angiography, routine Fogarty catheter thrombectomy or oscillometry.

The findings of the present investigation are similar to our previous prospective study utilizing the
Doppler ultrasonic velocity detector in a group of patients undergoing cardiac catheterization by the percutaneous femoral artery route. In that study thromboembolic complications in the legs were detected in 14 percent of patients, two-thirds of whom were asymptomatic. That experience likewise confirmed our impression that pulse detection is an unreliable guide to these complications. The hemodynamic information provided by the Doppler detector permitted selection of subjects for thrombectomy among those who had femoral as opposed to below-knee thrombemboli.

In the present study, two-thirds of the patients with brachial artery obstruction were asymptomatic or had only mild transient symptoms of ischemia. One-third had definitely palpable radial pulses, present from the time of catheterization in four and returning during the course of hospitalization in two: a testimony to the excellence of collateral circulation of the arm. The absence of symptoms or pulse deficit correlated with significantly lower pressure gradients across the obstruction than that present in patients with symptoms or absent pulses.

There was no correlation of the incidence of brachial artery obstruction with patient age, sex, or diagnosis of heart disease. Although there was no correlation of complications with the number of catheters used, the total period of indwelling catheters was significantly longer in patients suffering complications than in those who did not develop brachial artery obstruction.

The Doppler ultrasonic velocity detector provides an objective quantitative assessment of the degree of circulatory impairment in the presence of arterial obstruction. Such hemodynamic information may aid in the selection of therapy based on the magnitude of circulatory obstruction, providing objective indices of the course and efficacy of such treatment. In this study, eight patients with brachial artery obstruction were treated without operation. All were asymptomatic and all but one had an arm-forearm pressure gradient of less than 40 mm Hg. Of the ten patients who underwent thrombectomy, five maintained normal circulation, with abolition of the pressure gradient. The remaining five developed repeated occlusion of the brachial artery, including repeated thrombosis in three patients despite a second thrombectomy. The mean arm-forearm pressure gradient of these patients was 70 mm Hg, but only two had ischemic symptoms by the time of discharge from the hospital. Restudy of the latter two patients in the followup period demonstrated a reduction of the pressure gradient which correlated with improvement of symptoms as collateral circulation increased with time. Although hemodynamic improvement in these patients can be objectively documented, there was no evidence of significant lysis of thrombus or release of "vasospasm" to explain such improvement. The Doppler arterial velocity signals continued to reveal areas of brachial artery obstruction, with the characteristic signals of collateral vessels about the occlusion. Distal arterial velocity signals would often improve in amplitude with time, but the loss of diastolic sounds would continue to be evidence of proximal arterial obstruction. Although arteriography was not obtained for followup evaluation, the Doppler arterial signals usually implied arterial occlusion with collateral circulation, as opposed to brachial artery stenosis, as the cause of the hemodynamic impairment.

Although objection might be raised to an approach to brachial artery obstruction without operation, the present study demonstrates that many patients will tolerate such complications without symptoms or functional disability. While a patient with brachial artery occlusion may be asymptomatic in the hospital, the possibility of future arm claudication frequently prompts a thrombectomy in such patients. In this study no patient with an arm-forearm pressure gradient of 50 mm Hg or less developed subsequent arm claudication. Only two of the four patients with gradients over 50 mm Hg had residual symptoms, and these abated as collateral circulation and pressure gradients improved with time. Contrariwise, some patients will not be restored to a normal circulatory status despite balloon catheter thrombectomy. Indeed, it is our impression that in some instances the Fogarty catheter may be the cause of subsequent arterial thrombosis due to endothelial injury by injudicious use of balloon pressure or by repeated passages of the catheter. The propensity of this catheter to denude arterial endothelium is the basis of its application in experimental animals to create arterial thrombosis.

The Doppler ultrasonic velocity detector might be considered an unduly sensitive instrument for detecting catheter-induced arterial injury, inasmuch as many such patients may be asymptomatic, with minimal circulatory impairment and without need for specific therapy. However, an accurate knowledge of the true incidence of these complications is necessary for their proper management and prevention. We feel that the Doppler detector has several attributes which make it of value in screening patients who undergo arterial catheterization. Being simple, portable and noninvasive, the Doppler detector can be readily used by a technician in the laboratory or at the bedside without discomfort to the patient. Qualitative (velocity) and quantitative (pressure) physiologic information is provided which permits accurate detection of complications, even in asymptomatic patients. These hemodynamic data permit objective assessment of the degree of circulatory impairment, which in turn may aid in the
selection and evaluation of therapy. Finally, the Doppler ultrasonic velocity detector may provide a more reliable assessment of the efficacy of various prophylactic measures, such as anticoagulation, platelet antiaggregants or modification of catheters, which are used to minimize the complications of arterial catheterization.

References


One of the Lesser-Known Greats

As a scientist, Francois Vincent Raspail (1794-1878) left his mark on three areas of investigation: histochemistry, cell theory, and parasitology. He founded histochemistry by studying animal and plant tissues under the microscope at a time when this instrument was disdained by French biologists. In 1830 he wrote an original treatise on microscopic technique. In the mid-1820s already twelve years before Schleiden and Schwann, he described the growing cell and accurately analyzed its contents. He studied the cell's pathology long before Virchow. He contributed to the knowledge of scabies, and pointed out the role of "infinitely small parasites" as agents of communicable disease almost quarter of a century before Pasteur. His capacity for work was great: witness more than fifty scientific articles, nine pamphlets, eight books, and four annual publications. The famous Health Annual continued for over thirty years. In medicine Raspail tended to confine himself to therapy. For forty years he propagated his dietary, antiseptic and anticontagionist views.