Dukkipati et al. (1) accomplished the important task of characterizing the locations of strokes in their patients. More than one-half of the cerebrovascular events involved the posterior (vertebrobasilar) circulation. This is of interest because only about one-fifth of blood flow to the brain traverses the vertebrobasilar arteries whereas two-fifths goes to each carotid artery. By chance, only 20% of ischemic events should have involved the brainstem, cerebellum, and occipitotemporal lobes fed by the vertebrobasilar arterial system, but in this study, 54% of infarcts were vertebrobasilar in location. Similar to the pattern of stroke after PCI, emboli that originated in patients with patent foramen ovale or atrial septal defects also reached locations within the posterior circulation more often than expected (3,4). In one large series, 42.7% of strokes in patients with a patent foramen ovale, atrial septal aneurysm, or both were located within the posterior circulation compared with 35.4% of strokes in posterior circulation locations in patients without atrial septal abnormalities (3). Posterior circulation symptoms and infarcts were also found more often than expected after cardiac catheterization. In one series (5), 6 of 10 ischemic events that followed cardiac catheterization could be localized to the posterior circulation.

The anatomy of the branchings from the aortic arch probably favors small emboli entering the vertebral arteries.

The importance of this for cardiologists is that the symptoms and signs are mostly visual field defects and gait abnormalities caused by occipital lobe and cerebellar infarctions. Unfortunately, vision and gait are not often tested by non-neurologists. Cardiologists should become aware of this point and ensure that their patients can walk normally and have normal visual fields and visual function after interventional procedures. Asking patients to describe a picture and read will have relatively high yield. The other lesson is that the incidence of stroke of 0.30% reported in this study (1) is probably an underestimate that overlooked patients with mild cognitive deficits, subtle neurologic syndromes that could have been identified only by neurologists (6), or neurologic events that became apparent after hospital discharge.

Strokes also were noted more often when interventional procedures were urgent or emergent and when intra-aortic balloons were used. Heparin and thrombolytic agents were used more often in those that had events than those who did not. How can we make sense of this data to help understand why cerebrovascular events occur?

It is self-evident and well known that heparin and thrombolytic agents increase the risk of brain hemorrhage, so we will comment here on the mechanism of brain ischemia. Dukkipati et al. (1) identified brain embolism as the most common cause of stroke after PCI, which is also the most common cause of brain ischemia in the general population (7).

Thrombolytic agents and anticoagulant drugs may contribute directly or indirectly to the risk of embolization. Thrombolytic agents on occasion may break up intracavitary cardiac thrombi, but their use has been associated with the cholesterol embolization syndrome (8). The use of anticoagulants has been also been associated with an increased risk of the cholesterol embolization syndrome (9), providing one hypothetical connection between heparin use and adverse outcomes among patients with cerebrovascular events. Anticoagulants are not recommended for the treatment of the cholesterol embolization syndrome (10).

Patients undergoing PCI often have severe atherosclerotic disease of the aorta. Large-bore catheters or intra-aortic balloons may dislodge atheromatous material that embolizes to the cerebral circulation. Cholesterol embolization to the kidneys is probably responsible for the occurrence of renal failure and the new need for hemodialysis (9).

The immediate lesson for stroke avoidance is a technical one. Back bleeding should be allowed whenever guide catheters are advanced around the aortic arch over a guide wire. If the catheter is connected to a Tuohy–Borst Y-adapter during advancement, the valve should be left open. This should always be followed by strict double flushing, to discard any atherosclerotic debris that may be entrained by the guide catheter (11).

Dukkipati et al. (1) found that cerebrovascular events were more common in patients with pre-existing hyperten-
sion, diabetes, and renal insufficiency. Hypertension and diabetes predispose to occlusive disease of intracranial and extracranial arteries. Arterioles and small arteries are often heavily involved. The pre-existing neurovascular and systemic vascular compromise greatly reduces cerebrovascular reserve and hampers the ability of the brain (and the kidneys) to tolerate embolization, especially of cholesterol emboli to many different vessels. It has been established that spontaneously hypertensive rats are more severely injured by experimental emboli than normotensive animals, thus identifying a useful model for experimental studies (12,13).

Patients with prior stroke are intuitively at increased risk for recurrent stroke during invasive procedures, and a stroke actually occurred in 1.0% of these patients (as calculated from data in Table 1 of reference 1). It is clear, however, that the more commonly occurring baseline characteristics of diabetes and hypertension do not carry the highest risk of stroke and that the strongest risk factors of thrombolytic therapy and previous stroke are not the commonest baseline characteristics. Thus, there is no single baseline characteristic identified in this study that should exclude patients from undergoing PCI because of an excessive risk of stroke.

More refined identification of risk factors for embolization may come from the preprocedural assessment of cardiac and aortic anatomy. A satisfactory assessment of the aorta can often be made using ultrasound probes. The ascending aorta can be visualized using a Duplex ultrasound probe placed in the right supraclavicular fossa and the arch and proximal descending thoracic aorta can be visualized using a left supraclavicular probe (14). Most plaques are located in the curvature of the arch from the distal ascending aorta to the proximal descending aorta, regions that can be shown by B-mode ultrasound (14). Although it may seem intuitive that a right brachial or radial approach may reduce cholesterol embolism by decreasing the linear contact between catheter and aorta, the role of access is controversial in actual practice. A recent prospective study suggested an equal incidence of the cholesterol embolization syndrome for both the brachial and femoral approaches (15). Patients with protruding atherosomas confined to the arch or descending aorta, however, may have a lower risk of catheter-induced embolization if a right radial or brachial approach is used.

What is to be learned from this knowledge of the pathogenesis of stroke after PCI? Avoiding stroke continues to be a good reason to choose direct PCI over thrombolytic therapy for acute myocardial infarction (16–19). Coronary interventional procedures must be performed with meticulous attention to technical detail, but cardiologists must have the presence of mind to flush catheters thoroughly, minimize catheter manipulation, and use minimal contrast even when they are distracted by such findings as shock, arrhythmia, and complex anatomy in emergency cases. Future efforts should be made to move beyond such traditional broad clinical categories as diabetes and hypertension to define the individual characteristics such as shaggy aortas that put patients at high risk of stroke from embolization.

REFERENCES