Transcranial Doppler Detection of Microemboli During Percutaneous Transluminal Coronary Angioplasty

Christopher F. Bladin, FRACP; Linda Bingham, B Med Sci; Leeanne Grigg, FRACP; Anthony G. Yapanis, FRACP; Richard Gerraty, MD, FRACP; Stephen M. Davis, MD, FRACP

Background and Purpose—The use of percutaneous transluminal coronary angioplasty (PTCA) to treat coronary artery disease is now commonplace. The occurrence of microemboli during invasive procedures such as cardiac angiography and bypass surgery is well documented, although neurological complications are relatively uncommon. To date, no investigation has been undertaken of the frequency or nature of microemboli occurring during PTCA or of the correlation with aortic atheroma.

Methods—Twenty patients having elective PTCA underwent examination by transcranial Doppler ultrasonography (TCD) to detect left middle cerebral artery microemboli occurring during the procedure. Blinded off-line analysis correlated microembolic signal counts on TCD with the components of each stage of the PTCA. Patients later underwent transesophageal (TEE) echocardiography, with measurements made of the thickness of the intima and atheroma in the ascending and descending thoracic aortic arch by cardiologists blinded to the TCD results.

Results—A total of 973 microembolic signals were detected (mean ± SD, 48.7 ± 36.7 per patient); 196 (20%) occurred on movement of the PTCA catheter and wire around the aortic arch, 84 (9%) with other PTCA catheter–associated movements, and 679 (70%) in association with injection of solutions (eg, saline and contrast). Mean signal counts during contrast injection were significantly greater than during the other 3 phases (P < 0.001). No neurological events occurred in the study. Although not statistically significant, there was a trend toward greater microembolic signal counts with the number of times the catheter was passed around the aortic arch and the amount of arch atheroma detected by transesophageal echocardiography.

Conclusions—Microemboli detected on TCD are a common occurrence during PTCA but are largely asymptomatic. The majority of microembolic signals are most probably gaseous in origin and do not appear to be related to the extent of aortic atheroma or to clinical events. (Stroke. 1998;29:2367-2370.)

Key Words: ultrasonography, Doppler, transcranial ■ embolism ■ angioplasty

Percutaneous transluminal coronary angioplasty (PTCA) is a well-established nonoperative method of myocardial revascularization for atheromatous coronary artery disease. The most frequent major complication is the development of arterial restenosis, which is reported to occur in up to 30% of cases, between 1 and 6 months after the procedure.1 Acute complications occur in approximately 5.6% of cases and include coronary artery closure due to dissection, thrombosis, or vasospasm. Neurological complications have been reported to occur in <1% of cases, with the most frequent being stroke.2,3

Both hemodynamic and embolic mechanisms have been postulated for the development of neurological complications during catheter-based interventions such as PTCA.3,4 Gaseous bubbles may be introduced with the injection of radiological contrast agent5–7; particulate embolic material may be generated by the dislodging of atheromatous plaque or thrombus by movement of the angioplasty catheter. However, the relationship between aortic atheroma and transcranial Doppler microemboli remains unclear. Postmortem studies reveal that aortic atheroma is more commonly seen in patients with stroke of unknown cause.5 TEE allows ultrasound visualization of the thoracic aorta, and case-control studies using this technique reveal that aortic atheroma is an independent risk factor for stroke.8 Hence, we postulated that the frequency of microembolism should increase with increased degrees of aortic arch atheroma.

TEE has been used to detect cerebral microemboli in patients with carotid stenosis,9,11,12 prosthetic cardiac valves, and atrial fibrillation,13 and during surgical procedures such as cardiac bypass surgery14 and carotid endarterectomy.15 However, to date there has been little information on the prevalence, timing, or source of microembolic signals detected during PTCA. The aim of this study was to further explore these issues and to examine the relationship between microembolism and aortic arch atheroma detected by TEE.

Subjects and Methods
This study was performed in the Departments of Neuroscience and Cardiology, Royal Melbourne Hospital, in Melbourne, Australia.
The study was approved by the Institutional Ethics Committee, and all patients gave written consent. Patients recruited into the study were undergoing elective PTCA for symptomatic ischemic heart disease. The PTCA was performed by experienced cardiologists trained in this technique. Vascular entry was via the femoral artery using the Seldinger technique, with fluoroscopic guidance of guide wire and catheter to the heart. The catheter was connected to a closed injection system or manifold to allow pressure monitoring or injection. The radiographic contrast agent, iopromide (Ultravist 370, Schering AG), was drawn into the manifold as required from a suspended bottle. The timing of the different stages of the PTCA was recorded for off-line correlation with microembolic signals detected on TCD.

The TCD (Medasonics CDS) was performed with transtemporal insonation of the left middle cerebral artery using a 2-Mz pulse wave probe fixed with a headband. Patients underwent insonation of the left middle cerebral artery for 10 minutes before PTCA and during the PTCA procedure (average time, 54 minutes). The signal was recorded onto audiotape (Tascam 134 Syncaset) for blinded off-line data analysis by the examiners. Microemboli were counted manually and assigned to 1 of the 5 stages of PTCA: (1) wire/catheter crossing of aortic arch, (2) other catheter manipulation, (3) injection of contrast agent, (4) injection of other materials (e.g., heparin, saline flush), and (5) miscellaneous (e.g., none of the above categories).

Microemboli were identified according to standard published criteria. In addition, an attempt was made to characterize the microemboli as either gaseous or particulate in nature, according to previous studies. TEE (Hewlett-Packard Sonos 2500 omniplane probe) was performed by trained cardiologists. A comprehensive cardiac investigation was performed, during which the ascending aorta was visualized in transverse and longitudinal planes. Posterior rotation of the TEE probe with advancement into the distal esophagus enabled careful analysis of the descending thoracic aorta. Videotapes of the procedure were later analyzed by cardiologists blinded to other results. Measurements were made of the intimal thickness (in millimeters) of the worst areas of atheroma from each ascending aortic arch and descending thoracic aorta. The thickness of the atheromatous disease was measured by freezing the on-screen image and using the digital calipers of the Hewlett-Packard TEE calculation software. Atheroma was considered mild at <1 mm, moderate at 1.0 to 3.9 mm, and severe at >4.0 mm.

Statistics
Mean emboli counts for each stage of the PTCA were compared with Poisson regression and values with the F statistic. The relationship between the count of microembolic signals and the number of times the PTCA catheter was passed around the aortic arch, and the amount of aortic atheroma, was assessed using Kruskal-Wallis analysis for nonparametric data. Values of \( P < 0.05 \) were considered significant.

Interobserver variability was assessed with the methods of Bland and Altman for each of the procedural stages.

Results
Twenty patients were recruited into the study. All patients were men (average age, 61 ± 9.5 years) undergoing PTCA for ischemic heart disease. No microembolic signals were detected with TCD during recording prior to PTCA. During PTCA a total of 973 signals were detected across all 20 cases (mean ± SD, 48.7 ± 36.7) (Table 1). Of these signals, 196 (20%) occurred on movement of the PTCA catheter and wire around the aortic arch and 84 (9%) with other PTCA

<table>
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<th>Patient No.</th>
<th>Arch Manipulations</th>
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<th>Other Injections</th>
<th>Miscellaneous</th>
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<td>Mean</td>
<td>9.8</td>
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<td>23.9</td>
<td>10.1</td>
<td>0.7</td>
<td>48.7</td>
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<tr>
<td>SD</td>
<td>17.3</td>
<td>5.2</td>
<td>17.7</td>
<td>9.4</td>
<td>1.3</td>
<td>36.7</td>
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</table>

The count presented is the average of the two observers.
Graph of the percentage of the total number of microembolic signals associated with each stage of the PTCA procedure. Significantly more microembolic signals occurred during contrast injection than any other stage ($P<0.001$).

catheter–associated movements; 679 (70%) occurred in association with injection of solutions (eg, saline and contrast). Miscellaneous signals accounted for 14 events (1%). The interobserver variability of detection of microembolic signals was 0.99.6 No neurological events occurred during the study.

Pairwise comparison of the mean signal counts during the 4 procedural stages revealed that counts during contrast injection were significantly greater than during the other 3 phases (Figure 1; $P<0.001$). There was also a significant relationship between the mean number of signals detected during contrast injection and the volume of contrast given ($P<0.006$).

We were able to perform TEE of the aortic arch in 17 of 20 patients. The mean±SD aortic arch atheroma thickness was 2.1±1.4 mm (range, 0.6 to 8.46 mm).

The number of microembolic signals counted when the PTCA catheter crossed the aortic arch was not significantly related to the number of times the catheter was moved across the aortic arch or the amount of arch atheroma detected by TEE, although trends were evident for a higher embolic signal count with increasing arch atheroma and the increasing number of aortic arch crossings by the PTCA catheter (Table 2).

**TABLE 2. Emboli Counts for PTCA Catheter Crossing Aortic Arch**

<table>
<thead>
<tr>
<th>No. of Aortic Arch Crossings by PTCA Catheter</th>
<th>1</th>
<th>2</th>
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<tr>
<td>Mean emboli counts*</td>
<td>4.3</td>
<td>16</td>
<td>29.6</td>
</tr>
<tr>
<td>Arch Atheroma Thickness</td>
<td>&lt;1 mm</td>
<td>1 to &lt;2 mm</td>
<td>&gt;2 mm</td>
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<tr>
<td>Mean emboli counts/aortic arch crossing†</td>
<td>0.5</td>
<td>2.8</td>
<td>9.5</td>
</tr>
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</table>

A trend is apparent for greater emboli counts with more arch crossings and increasing arch atheroma.

* $P=0.39$ between groups.
† $P=0.14$ between groups.

**Discussion**

The results of this study indicate that there is a high prevalence of microemboli during PTCA. The generation of microembolic signals typically occurred in conjunction with either movement of the PTCA guide wire or catheter or the injection of solutions. Overall, only 1% of signals were unable to be assigned to either of these categories.

Of the various stages of PTCA, significantly more signals were associated with contrast injection than with any other phase. Moreover, the number of microembolic signals associated with contrast injection correlated with the total volume of contrast injected. The majority of these microembolic signals were bidirectional in nature and of a very high amplitude (exceeding the TCD velocity envelope), indicating very strong reflection of the ultrasound beam. To achieve these high-amplitude signals requires ultrasound reflection from an interface with a high acoustic impedance, such as air bubbles. Even large particulate emboli do not produce these high amplitude signals. Although some investigators8 have attempted to determine the nature (particulate or gaseous) of the microembolic signals by their intensity, in practice this is often difficult.

The results of this study are consistent with those of other studies using TCD detection of microemboli during arterial interventions. In a study of 15 patients undergoing cerebral angiography, Dagirmanjian et al5 reported that 86% of detected microemboli occurred in association with injection of contrast or flushing solutions. Work by our group and others using TCD during cerebral angiography have confirmed that the majority of microembolic signals detected during carotid angiography are in relation to intravascular injections and are gaseous in origin and of no clinical relevance.6,8 Similarly, in a study of TCD during carotid angioplasty, Markus et al7 reported that microembolic signals were particularly common during injection of radiographic contrast media.

In this study it was not possible to give an accurate count of gaseous versus particulate emboli. However, a qualitative statement can be made that although most of the high-intensity signals observed during the injection of solutions during PTCA conformed in part with published criteria16 in respect to their characteristic noise, signal duration, and signal intensity, their signal profile was either unidirectional or bidirectional, often large, and extended outside the velocity envelope. As previous studies6,8 have noted, it is most likely that such signals are gaseous in origin. In contrast, high-intensity signals detected during other phases of the PTCA more closely conformed to the conventional criteria16 and were most probably particulate in nature.

Another characteristic feature of microembolic signals detected during solution injection was that of “clustering,” with microembolic signals of differing sizes often tightly packed together in groups. This is consistent with the concept of small clusters of air bubbles, often of differing sizes, or possibly even micelles of blood/contrast medium, causing these signals. However, it is also possible that during the injection solid particles may be dislodged from arterial wall atheroma by small movements of the catheter. Again, it is difficult to determine whether smaller microembolic signals detected as part of these signal clusters may have resulted from particulate emboli or possibly from very small air bubbles.
This study indicated that significantly more signals were associated with movement of the catheter/guide wire around the aortic arch than with other catheter manipulations (such as engaging the ostia of the coronary arteries). Moreover, the majority of these signals were smaller than those seen during injections, suggesting a particulate origin. Again, atheromatous debris that is dislodged as the instrumentation is being passed around the aortic arch may account for this observation.

We initially proposed there would be a correlation between the numbers of microembolic signals detected during movement of the catheter/guide wire around the aortic arch and the extent of aortic atheroma detected on TEE. However, no significant correlation was found. The explanation for this is probably threefold: first, the small number of cases studied (type II error); second, the limitations in the sensitivity of TEE for the detection and quantification of ascending aorta and arch atheroma (in contrast to the descending aorta); and third, the lack of severe (>4 mm²) aortic disease in the patients studied.

Furthermore, because of the interposition of the trachea and bronchi between the esophagus and the aorta, it has been reported that TEE may not visualize as much as 42% of the ascending aorta. 20 Konstad et al 21 compared biplanar TEE with the “gold standard” of intraoperative epiaortic ultrasound scanning. For the detection of ascending aortic atheroma, TEE had a sensitivity of only 29%, specificity of 99%, and positive predictive value of 80%. In a similar study, Sylvis et al 22 examined the ascending aorta of patients undergoing cardiac surgery. They found that TEE significantly underestimated the severity of atheroma, particularly in the mid and distal sections of ascending aortic arch.

Others have used TEE as a means of assessing embolism from the aortic arch. Barbut and colleagues 23 combined TCD and TEE monitoring in 20 patients undergoing coronary bypass surgery. By both methods they found that a majority of signals occurred in relation to clamp placement and release. They also established a relationship between both the TCD- and TEE-detected microembolic signals and the severity of arch atheroma as graded by TEE. Karalis et al 24 similarly found that in patients undergoing cardiac angiography with detectable thoracic aortic atheroma on TEE, there was greater risk of clinically determined embolic events. Moreover, this risk increased with the severity of the disease.

In conclusion, asymptomatic microemboli are a common occurrence during PTCA. The majority of microembolic signals detected on TCD are most probably gaseous in origin and do not relate to clinical events. The relationship between ascending aortic atheroma, aortic catheter manipulation, and TCD-detected microemboli warrants further investigation, preferably with more precise methods of evaluating aortic atheroma, such as epiaortic ultrasound.

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References


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