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Procedural Factors Associated With Percutaneous Coronary Intervention-Related Ischemic Stroke

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Objectives This study sought to determine whether procedural factors during percutaneous coronary intervention (PCI) are associated with the occurrence of ischemic stroke or transient ischemic attack (PCI-stroke).

Background Stroke is a devastating complication of PCI. Demographic predictors are nonmodifiable. Whether PCI-stroke is associated with procedural factors, which may be modifiable, is unknown.

Methods We performed a single-center retrospective study of 21,497 PCI hospitalizations between 1994 and 2008. We compared procedural factors from patients who suffered an ischemic stroke or transient ischemic attack related to PCI ($n = 79$) and a control group ($n = 158$), and matched them 2:1 based on a predicted probability of stroke developed from a logistic regression model.

Results PCI-stroke procedures involved the use of more catheters (median: 3 [quarter (Q) 1, Q3: 3, 4] vs. 3 [Q1, Q3: 2, 3], $p < 0.001$), greater contrast volumes (250 ml vs. 218 ml, $p = 0.006$), and larger guide caliber (median: 7-F [Q1, Q3: 6, 8] vs. 6-F [Q1, Q3: 6, 8], $p < 0.001$). The number of lesions attempted (1.7 ± 0.8 vs. 1.5 ± 0.8, $p = 0.14$) and stents placed (1.4 ± 1.2 vs. 1.2 ± 1.1, $p = 0.35$) were similar between groups, but PCI-stroke patients were more likely to have undergone rotational atherectomy (10% vs. 3%, $p = 0.029$). Overall procedural success was lower in the PCI-stroke group compared with controls (71% vs. 85%, $p = 0.017$). Evaluation of the entire PCI population revealed no difference in the rate of PCI-stroke between radial and femoral approaches (0.4% vs. 0.4%, $p = 0.78$).

Conclusions Ischemic stroke related to PCI is associated with potentially modifiable technical parameters. Careful procedural planning is warranted, particularly in patients at increased risk. (J Am Coll Cardiol Intv 2012;5:200–6) © 2012 by the American College of Cardiology Foundation

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Stroke is an infrequent but potentially devastating complication of percutaneous coronary intervention (PCI). It is associated with an in-hospital mortality rate of 20% (1–4), and in survivors of the initial event, with markedly increased long-term mortality (1). Moreover, for the patient, the possible occurrence of a major stroke may be perceived as being an outcome worse than death (2).

PCI-related mortality and adverse events other than stroke have progressively declined over the last 2 decades (3–5). However, the incidence of PCI stroke has remained unchanged at approximately 0.3% to 0.4% (1,6–8). Independent predictors include age, female sex, renal failure, and prior history of stroke or transient ischemic attack (TIA) (1,6–8). With the worsening demographic risk profile of patients being referred for PCI, and increasing procedural complexity (1), it seems unlikely that the incidence of stroke related to PCI will decline in the near future.

Approximately 90% of symptomatic strokes or TIAs related to PCI are ischemic (PCI-stroke [1,4]). The potential mechanisms underlying these events include embolization of atheroma from the aortic wall due to catheter-related trauma, embolization of thrombus or air, dissection from catheter or guidewire manipulation, and periprocedural hypotension (9–11). In support of the hypothesis of debris dislodgement during catheterization, transcranial Doppler signals have been shown to increase during passage of catheters around the aortic arch, suggestive of microembolization (12). Studies assessing the risk of catheter-related emboli report a significantly higher embolic event rate in patients with atherosclerosis compared to those without atherosclerosis (13). Furthermore, analysis of 1,000 consecutive guiding catheters removed after PCI revealed the presence of macroscopic aortic debris within the guide lumen in more than 50% of cases (14).

Whether there is a relationship between procedural factors that might influence the extent of embolization and the occurrence of PCI-stroke remains unknown. Given the devastating nature of the complication, and the inability to affect demographic risk factors, it is critically important to identify those variables that could potentially be modifiable in an attempt to reduce the risk of procedural stroke. In this retrospective, single-center study, our objective was to identify procedural factors in patients undergoing PCI who experienced an ischemic neurologic complication compared with a matched control population of those who did not.

Methods

Patient population. Patients undergoing PCI at the Mayo Clinic in Rochester, Minnesota, are prospectively followed in a registry that includes demographic, clinical, angiographic, and procedural data. Immediate and in-hospital events are recorded, and each patient is surveyed by telephone using a standardized questionnaire at 6 months, 1 year, and then annually after the procedure. Ten percent of all records are randomly audited by the supervisor for data integrity. All adverse events are confirmed by reviewing the medical records of the patients followed at our institution and by contacting the patients' physicians and reviewing the hospital records of patients followed elsewhere.

All PCIs from January 1, 1994, to March 31, 2008, were eligible for analysis. For patients with multiple PCIs during a single hospitalization, only the first PCI was included. Patients who did not consent to use of their records for research were excluded as per Minnesota state statute. There were 22,038 PCI hospitalizations of 17,689 unique patients during this period. Of those, 440 patients refused authorization of their records for research and were excluded, leaving 21,497 hospitalizations for analysis. Seventy-nine patients experiencing an in-hospital ischemic stroke or TIA relating to PCI were identified, and their demographic and angiographic variables were compared with the entire remaining nonstroke population as controls. Next, detailed medical record and angiographic review was performed to identify procedural variables from the PCI-stroke patients, which were compared with procedural variables from 158 matched control patients.

Abbreviations and Acronyms

LV = left ventricular

PCI = percutaneous coronary intervention

PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention

TIA = transient ischemic attack

Definitions. Ischemic stroke was defined as nonhemorrhagic stroke or TIA related to PCI in the absence of other causes. All patients suffering ischemic stroke after PCI were evaluated by a consultant neurologist. Brain imaging (computed tomography, magnetic resonance imaging, or both) excluded hemorrhage in all patients. Where there was uncertainty as to the relationship between the PCI procedure and neurologic event, adjudication was performed by an independent consultant neurologist.

The number of diseased coronary arteries was defined by the number of major arteries with at least 50% stenosis, provided at least 1 of the major arteries had at least 70% stenosis. Patients with ≥50% stenosis in the left main coronary artery were considered to have 2-vessel disease if there was right dominance and 3-vessel disease if there was left dominance. Myocardial infarction was diagnosed in the presence of at least 2 of 3 criteria: 1) typical chest pain for at least 20 min; 2) elevation of serum creatine kinase levels (or the myocardial band fraction) >2 times normal; and 3) a new Q-wave on the electrocardiogram. Severe renal dysfunction was defined as a creatinine level of >3.0 mg/dl or a history of dialysis or renal transplant. Cardiogenic shock was defined as a prolonged systolic arterial pressure <95 mm Hg, or systolic arterial pressure <110 mm Hg while on ino-

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tropes or with intra-aortic balloon pump support. Procedural success was defined as a reduction of residual luminal diameter stenosis to ≤20% without in-hospital death, Q-wave myocardial infarction, or need for emergency coronary artery bypass graft. Prior history of stroke or TIA was defined as a documented history of stroke or TIA that resulted in abnormalities in vision, speech, sensation, or motor function or a history of cerebrovascular (carotid) surgery. Congestive heart failure was defined as any documentation of congestive cardiac failure in the medical record.

Matching and statistical analysis. Continuous variables are summarized as mean ± SD (unless otherwise noted) and categorical variables as frequency (percentage). In the overall PCI population, differences between patients with and without stroke were calculated via logistic models with generalized estimating equations to account for the correlation between multiple PCIs on the same patient. Patients without stroke were matched to ischemic stroke patients at a 2:1 matching ratio. Matching was based on the logit of the predicted probability of stroke from a logistic regression model, including age, sex, body mass index, unstable angina, pre-PCI myocardial infarction, pre-PCI shock, congestive heart failure at presentation, hypertension, history of peripheral vascular disease, history of stroke or TIA, diabetes, chronic renal disease, ejection fraction ≤40%, number of diseased vessels, presence of thrombus, multivessel intervention. Control subjects must have had their PCI within 2 years of their matched stroke patient, and the propensity score had to be within one-quarter of the sample standard deviation. Conditional logistic regression was used to compare clinical, angiographic, and procedural variables between stroke patients and the matched controls.

Results

Baseline clinical characteristics. ISCHEMIC STROKE VERSUS ALL NONSTROKE PATIENTS. Between 1994 and 2008, the incidence of PCI-related ischemic neurologic events was 0.37%. Patients who experienced PCI-stroke (n = 79; comprising 60 strokes and 19 TIAs) compared with nonstroke control subjects (n = 21,418) were more likely to be older (age 75 ± 10 years vs. 66 ± 12 years, $p < 0.001$); women (51% vs. 29%, $p < 0.001$); have a prior history of stroke or TIA (35% vs. 11%, $p < 0.001$); have a history of peripheral vascular disease (19% vs. 11%, $p = 0.034$), congestive heart failure (24% vs. 15%, $p = 0.046$), or cardiogenic shock before the procedure (11% vs. 4%, $p < 0.001$); or have suffered myocardial infarction within 7 days of PCI (59% vs. 32%, $p < 0.001$) (Table 1). Further analysis revealed older patients with a prior neurologic history to be a high-risk subgroup for developing ischemic stroke related to PCI. Specifically, in patients aged 70 to 79 years with a prior history of stroke or TIA, the risk of PCI-stroke was 1.4% in men and 1.6% in women. In those over 80 years, the risk rose further to 1.6% in men and 3% in women.

Table 1. Patient Characteristics: Ischemic Stroke Versus Nonstroke Control Subjects

	PCI-Stroke (n = 79)	Control Subjects (n = 21,418)	p Value
Age, yrs	74.9 ± 10.0	66.3 ± 12.0	<0.001
Male	39 (49)	15,141 (71)	<0.001
Body mass index, kg/m^2	28.5 ± 5.1	29.5 ± 5.6	0.13
Unstable angina	40 (51)	12,867 (60)	0.089
MI within 7 days prior	46 (59)	6,824 (32)	<0.001
History of MI, >7 days	19 (24)	6,813 (32)	0.14
Pre-procedural shock	9 (11)	816 (4)	<0.001
CHF status			0.046
Never	55 (76)	17,318 (85)	
Previous	4 (6)	917 (4)	
Current	13 (18)	2,235 (11)	
History of cholesterol ≥240, mg/dl	56 (80)	14,714 (75)	0.38
Peripheral vascular disease	15 (19)	2,393 (11)	0.034
History of CVA or TIA	26 (35)	2,415 (11)	<0.001
Diabetes	24 (31)	5,339 (25)	0.25
Moderate-to-severe renal disease	6 (8)	800 (4)	0.081
Tumor/lymphoma/leukemia	10 (13)	2,514 (12)	0.82
Metastatic cancer	1 (1)	188 (1)	0.72
EF ≤40%	13 (16)	2,126 (10)	0.056

Values are mean ± SD or n (%).
CHF = congestive heart failure; CVA = cerebrovascular accident; EF = ejection fraction; MI = myocardial infarction; PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention; TIA = transient ischemic attack.

ISCHEMIC STROKE VERSUS MATCHED CONTROLS. Based on the preceding predictors, a logistic regression model was constructed, allowing the calculation of a logit of probability of PCI-stroke for patients undergoing PCI from 1994 to 2008. Matching was performed using this logit and identified 2 control patients, with similar baseline probability of ischemic PCI-stroke but who did not suffer an event, for each PCI-stroke patient studied. After matching, there were no major differences in demographic characteristics between patients who experienced ischemic PCI-stroke and their control subjects (Table 2). The presence of hypercholesterolemia was found to be statistically greater in the ischemic stroke group than in the control group, but this variable was not found to be a significant predictor in logistic regression analysis. Additionally, there was no significant difference in pre-procedural cardiac medication profile, including antiplatelet and heparin usage between groups, although there were trends toward less angiotensin-converting enzyme inhibitor and more thrombolysis usage in the PCI-stroke population (Table 3).

Angiographic characteristics. Baseline angiographic characteristics were compared between the stroke patients and their matched control subjects. Most angiographic parameters were similar in both groups (Table 4). Consequent to

Table 2. Patient Characteristics: Ischemic Stroke Versus Matched Controls

	PCI-Stroke (n = 79)	Matched Control Subjects (n = 158)	p Value
Age, yrs	74.9 ± 10.0	74.6 ± 9.3	0.78
Male	39 (49)	85 (54)	0.48
Body mass index, kg/m^2	28.5 ± 5.1	28.0 ± 5.3	0.53
Unstable angina	40 (51)	70 (44)	0.36
MI within 7 days prior	46 (59)	92 (59)	1.00
History of MI, >7 days	19 (24)	32 (21)	0.51
Pre-procedural shock	9 (11)	19 (12)	0.89
CHF status			0.90
Never	55 (76)	115 (78)	
Previous	4 (6)	8 (5)	
Current	13 (18)	25 (17)	
History of cholesterol ≥240, mg/dl	56 (80)	99 (68)	0.035
Peripheral vascular disease	15 (19)	36 (24)	0.38
History of CVA or TIA	26 (35)	56 (36)	0.95
Diabetes	24 (31)	57 (36)	0.49
Hypertension	65 (84)	123 (81)	0.47
Moderate-to-severe renal disease	6 (8)	19 (12)	0.28
Current/former smoker			0.90
Never	55 (76)	115 (78)	
Former	4 (6)	8 (5)	
Current	13 (18)	25 (17)	
Prior PTCA	16 (20)	38 (24)	0.51
Prior CABG	14 (18)	34 (22)	0.63
Tumor/lymphoma/leukemia	10 (13)	18 (12)	0.83
Metastatic cancer	1 (1)	3 (2)	0.72
EF ≤40%	13 (16)	25 (16)	0.90
History of atrial fibrillation	8 (10)	14 (10)	0.82

Values are mean ± SD or n (%).
CABG = coronary artery bypass graft; PTCA = percutaneous transluminal coronary angioplasty; other abbreviations as in Table 1.

matching, procedural urgency, the number of diseased vessels, and the presence of intracoronary thrombus were equally represented in the 2 groups. Unmatched parameters, including number of lesions treated and frequency of vein graft interventions, were not statistically different between the groups. Overall procedural success was lower in the PCI-stroke group than with control subjects, driven by higher rates of in-hospital death (18% vs. 8%, $p = 0.043$), requirement for coronary artery bypass graft (5% vs. 0%, $p = 0.003$), and residual stenosis after PCI (18% vs. 10%, $p = 0.09$).

Procedural characteristics. Features of the procedure itself were compared between patients who suffered a PCI-related ischemic stroke and matched control subjects, and these are outlined in Table 5. Ischemic stroke was associated with rotational atherectomy, urgent intra-aortic balloon pump usage, higher contrast volumes, total number of diagnostic and guiding catheters passed, and with caliber of guiding catheter used. Moreover, larger caliber guide catheters (≥7-F) were used in 66% of PCI-stroke patients but only

Table 3. Pre-PCI Medications

	PCI-Stroke (n = 79)	Matched Control Subjects (n = 158)	p Value
Heparin	64 (81)	118 (75)	0.25
Thrombolytic	8 (10)	6 (4)	0.06
Antiarrhythmic	11 (14)	19 (12)	0.69
ACE inhibitor	24 (30)	67 (42)	0.07
Aspirin	71 (90)	137 (87)	0.47
Thienopyridine	16 (20)	23 (15)	0.26
Beta-blocker	56 (73)	107 (68)	0.50
Calcium-channel blocker	18 (23)	36 (23)	1.00
Cardiac glycoside	6 (8)	15 (9)	0.64
Diuretic	35 (45)	58 (37)	0.26
Lipid-lowering	21 (28)	49 (31)	0.60

Values are n (%).
ACE = angiotensin-converting enzyme; PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention.

41% of control subjects (Fig. 1). Among PCI procedures using smaller caliber guides, 6-F was used significantly more often than 5-F in PCI-stroke procedures than in procedures for matched controls ($p < 0.001$). Notably there were no ischemic strokes at all in patients who underwent PCI with 5-F guides.

Retrospective angiographic and procedural review was performed for all PCI-stroke procedures to determine which could have been performed with smaller caliber guide catheters without compromising procedural strategy or difficulty. Conservatively, it was found that 18 of 30 (60%) of

Table 4. Angiographic Characteristics

	PCI-Stroke (n = 79)	Matched Control Subjects (n = 158)	p Value
No. of diseased vessels (70/50)			1.00
1	17 (21)	35 (23)	
2	31 (37)	56 (37)	
3	32 (40)	58 (39)	
Thrombus in any lesion	38 (54)	68 (47)	0.50
No. of lesions			0.30
1	42 (53)	97 (62)	
2	27 (34)	39 (25)	
3	8 (10)	15 (10)	
4	1 (1)	2 (1)	
Urgency of PCI			0.32
Elective	19 (24)	41 (26)	
Urgent	30 (38)	70 (44)	
Emergency	30 (38)	47 (30)	
Vein graft intervention	8 (10)	15 (9)	0.88
Procedural success	56 (71)	132 (85)	0.017

Values are n (%).
PCI = percutaneous coronary intervention; PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention.

Table 5. Procedural Characteristics

	PCI-Stroke (n = 79)	Matched Control Subjects (n = 158)	p Value
LV angiogram	16 (20)	29 (19)	0.76
Aortic angiogram	1 (1)	3 (2)	0.72
Thrombectomy	6 (8)	6 (4)	0.19
Rotational atherectomy	8 (10)	5 (3)	0.029
Fluoroscopy time, min	23 (18, 39)	20 (13, 30)	0.14
Contrast volume, cc	250 (160, 350)	218 (150, 275)	0.006
Sheath size, F	7 (6, 8)	6 (6, 8)	<0.001
No. of catheters	3 (3, 4)	3 (2, 3)	<0.001
Guide caliber			<0.001
5-F	0 (0)	19 (12)	
6-F	27 (34)	72 (46)	
7-F	14 (18)	16 (10)	
8+-F	38 (48)	49 (31)	
No. of catheters			<0.001
1	4 (5)	20 (13)	
2	4 (5)	37 (24)	
3	47 (59)	63 (40)	
4	8 (10)	24 (15)	
5+	16 (20)	12 (8)	
Total no. stents placed	1.4 ± 1.2	1.2 ± 1.1	0.35
No. of segments treated	1.7 ± 0.8	1.5 ± 0.8	0.14
Total no. vessels treated			0.68
1	66 (77)	126 (80)	
2	17 (22)	30 (19)	
3	1 (1)	2 (1)	
Prophylactic IABP	4 (5)	8 (5)	1.00
Urgent IABP	9 (11)	4 (3)	0.005
LV assist device	1 (1)	1 (1)	0.63
GP IIb/IIIa inhibitor use	41 (52)	70 (44)	0.22
Peak ACT, s	313 (286, 341)	298 (267, 349)	0.80

Values are n (%), median (Q1, Q3), or mean ± SD.
ACT = activated clotting time; IABP = intra-aortic balloon pump; GP = glycoprotein; LV = left ventricular; PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention.

8-F procedures could have been performed as a 6-F procedure without affecting upstream stent strategy, procedural difficulty, or anticipated strategy in case of failure. Those procedures that were nonmodifiable (n = 12) required 8-F guides for support due to aortic and coronary anatomy (n = 6), large burr rotational atherectomy (n = 4), simultaneous kissing stents or crush stenting approaches (n = 3), and because of an elevated risk of conversion to a 2-stent strategy (n = 4). Of the 6-F procedures, 16 of 30 (53%) could be performed with 5-F catheters in the current era. The remaining, nonmodifiable procedures required 6-F guides for support (n = 10), rotational atherectomy (n = 2), upfront simultaneous balloon approaches (n = 4), and anticipated risk of requiring a simultaneous balloon approach (n = 5).

Procedural variables that did not differ between stroke and control patients included total fluoroscopy time, the use of left ventricle and aortic angiography, use of thrombectomy, glycoprotein IIb/IIIa inhibitors, performance of multivessel intervention (which was included in the matching), prophylactic intra-aortic balloon pump use (likely because of matching for cardiogenic shock), and peak activated clotting time during the procedure. Evaluation of the entire PCI population revealed no statistically significant difference in the rate of ischemic stroke occurring in procedures that employed a radial versus femoral approach over this period (0.4% vs. 0.4%, p = 0.78).

Discussion

In this study, by matching affected and unaffected individuals at similar risk of an event, we have identified several procedural factors associated with PCI-related ischemic stroke. Ischemic stroke occurred after PCI procedures during which large diameter guide calibers, increasing numbers of catheter exchanges, and rotational atherectomy devices were used, in addition to those cases necessitating greater volumes of contrast.

Despite an increase in applicability and procedural complexity, the risks of most major PCI complications, including death, continue to decline (3,4). The rate of PCI-related stroke, however, has remained static over the last 20 years with ongoing catastrophic short- and long-term outcomes (1,6–8). Whereas previous studies have indicated that the risk of PCI-stroke increases with age and demographic parameters, these are not modifiable. Accordingly, it is important to establish whether there are modifiable, non-patient-dependent predictors of stroke. Recognition of such associations might allow for the adjustment of procedural techniques

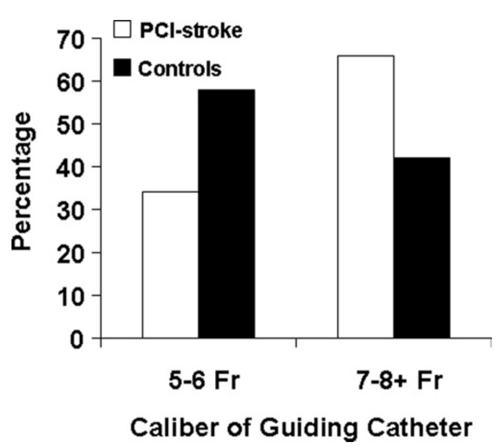

Figure 1. Guide Catheter Caliber in Procedures Resulting in PCI-Stroke Versus Matched Control Subjects

PCI-stroke = ischemic stroke or transient ischemic attack related to percutaneous coronary intervention.

when performing PCI, particularly in those patients at greatest risk of a periprocedural cerebrovascular event.

Consistent with previous studies (1,6–8), the patient-dependent (thus nonmodifiable) predictors of ischemic stroke identified in the present study included age, sex, multivessel coronary disease, coexisting peripheral arterial disease, and history of prior stroke or TIA. All of these could be considered as surrogate markers of atherosclerotic plaque burden and complex aortic anatomy. The current study does highlight a subset of patients at particularly high risk. Women over 80 years of age with a prior history of stroke or TIA were found to have a 3% risk of PCI-ischemic stroke. This is similar in magnitude to the stroke risk associated with transcutaneous aortic valve implantation (15). A number of prophylactic emboli deflection and filter devices designed to reduce transcutaneous aortic valve implantation embolic stroke risk are under investigation. Whether high-risk PCI subsets could be similarly targeted with such devices is worthy of strong consideration.

It remains speculative that the relationship between procedural factors and the occurrence of ischemic stroke is causative. As the presence of atheromatous plaque in the aortic arch poses a risk of spontaneous embolism and is an independent risk factor for recurrent stroke (16–19), it is thus certainly possible that procedural associations identified, including number of catheter exchanges and use of larger caliber guides, are surrogate markers of aortic disease and plaque burden. That said, these procedural factors also directly increase the chance of dislodging atherosclerotic debris from the aorta by physical abrasion, thereby inducing embolization. Earlier studies have suggested that large (8-F and 9-F) lumen guiding catheters displace debris from the aorta more than one-half of the time during PCI, and that the likelihood of displacing debris is greater in larger versus smaller caliber catheters (14,20). Consistent with this notion, in the present study, multiple catheter exchanges and greater guide caliber were both independently associated with increased risk of ischemic stroke.

A key issue is to what extent such procedural factors may be modifiable. Regarding guide catheter caliber, the current study determined that more than one-half of 8-F procedures could have been performed as 6-F procedures without affecting strategy or difficulty, suggesting a significant degree of modifiability. Noting that there were no strokes at all with 5-F procedures, it was also found that more than one-half of the 6-F procedures were straightforward enough for a 5-F approach.

Acknowledging modifiable procedural factors, altering current practice necessitates meticulous procedural planning when performing complex PCI in high-risk patients. Starting with the correct guide for PCI and considering using a single diagnostic or guiding catheter designed to intubate both coronaries may serve to reduce the number of catheter exchanges. Planning of bifurcation techniques, use of "mother–child" techniques for support and acknowledging 5-F PCI feasibility can all help to further limit guide size. Consideration could be given to imaging aortic arch plaque distribution in high-risk subsets, which might influence choice of access site. Finally, modifying the technique of catheter exchange warrants thought and investigation as a potential target in reducing trauma to the atheromatous aorta.

The procedural variables that did not differ between stroke patients and nonstroke control subjects were also of interest in this analysis. Crossing the aortic valve particularly in elderly patients has long been assumed to be associated with an increased risk for stroke. However, we found that left ventricular (LV) angiography was undertaken no more frequently in the stroke group than in the control group. In prior transcranial Doppler studies, most microembolic signals were detected during contrast injection and LV angiography (21). The correlation between Doppler signals and clinical events, however, is poor, leading to the conclusion that most emboli are gaseous and harmless. The present study suggests that avoiding LV angiography does not affect ischemic stroke risk. We found no difference in periprocedural usage of aspirin, thienopyridines, glycoprotein IIb/IIIa agents, heparin, and mean procedural activated clotting time in PCI-stroke patients compared with control subjects. In contrast, a recent National Cardiovascular Data Registry (NCDR) study identified significant differences in antiplatelet usage between groups (8). These seemingly discrepant findings may be due to the inclusion of hemorrhagic strokes as part of the latter study.

We have previously shown that the incidence of PCI-stroke has not changed over a 16-year period (1). It seems likely that refinement in technique or devices that might be expected to reduce the incidence has been offset by a corresponding increase in the risk profile of patients undergoing PCI. Risk factors for PCI-stroke that have been previously identified have been mostly patient-related and unavoidable. The present study identifies technical factors that are associated with the occurrence of ischemic/embolic stroke. A number of these technical factors are associated with an increased propensity to displace atheroma from the aortic wall. Whereas it remains to be determined whether modification of procedural techniques affects ischemic stroke risk in future, it seems reasonable to employ techniques, such as the use of small caliber guides and minimal catheter exchanges, particularly when undertaking PCI in patients at highest risk for an event, such as elderly females with a prior history of stroke.

Study limitations. The present study is a retrospective analysis from a single institution, which might limit its broad application. Our small sample size precluded the ability to investigate associations between stroke and procedural variables in a multivariable model. Due to the small number of stroke patients, a propensity score matching approach was used, rather than adjusting or matching for variables separately. National Institutes of Health Stroke Scale assessment was not available for a significant number of patients, such that stratification of outcome by degree of impairment was not possible. Even though records were scrutinized to ensure that all events included were appropriate, it is possible that a number of strokes went unrecognized (nonspecific symptoms, brief duration, occurrence of sudden death without post-mortem evaluation), thereby underestimating the true incidence.

Conclusions

Ischemic stroke related to PCI is associated with potentially modifiable technical parameters. Careful procedural planning should thus be undertaken in an attempt to reduce the risk of PCI-stroke, particularly in patients at increased risk.

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