Incidence and Risk Factors of Cerebrovascular Events Following Cardiac Catheterization

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Background—One of the most daunting complications of cardiac catheterization is a cerebrovascular event (CVE). We aimed to assess the real-life incidence, etiology, and risk factors of cardiac catheterization-related acute CVEs in a large cohort of patients treated in a single center.

Methods and Results—We undertook a retrospective analysis of 43 350 coronary procedures performed on 30 907 procedure days over the period 1992-2011 and compared patient and procedural characteristics of procedures complicated by CVEs with the remaining cohort. CVEs occurred in 47 cases: 43 were ischemic, 3 intracerebral hemorrhages, and 1 undetermined. The overall CVE rate was 0.15%, with percutaneous coronary intervention (PCI) and diagnostic coronary angiography rates 0.23% and 0.09%, respectively. Using a forward stepwise multivariate logistic regression model including patient demographic and procedural characteristics, a total of 5 significant predictors were defined: prior stroke (OR=15.09, 95% CI [8.11 to 28.08], $P<0.0001$), presence of coronary arterial thrombus (OR=2.79, 95% CI [1.25 to 6.22], $P=0.012$), age >75 years (OR=3.33, 95% CI [1.79 to 6.19], $P<0.0001$), triple vessel disease (OR=2.24, 95% CI [1.20 to 4.18], $P=0.011$), and performance of intervention (OR=2.21, 95% CI [1.12 to 4.33], $P=0.021$). An additional analysis excluded any temporal change of CVE rates but demonstrated a significant increase of all high-risk patient features.

Conclusion—In a single-center, retrospective assessment over nearly 20 years, cardiac catheterization-related CVEs were very rare and nearly exclusively ischemic. The independent predictors for these events were found to be the performance of an intervention and those associated with increased atherosclerotic burden, specifically older age, triple vessel disease, and prior stroke. The presence of intracoronary thrombus appears also to raise the risk of procedure-related CVE. (*J Am Heart Assoc.* 2013;2:e000413 doi: 10.1161/JAHA.113.000413)

Key Words: catheterization • risk factors • stroke

One of the most daunting complications of cardiac catheterization is a cerebrovascular event (CVE). CVEs can include ischemic and hemorrhagic stroke and transient ischemic attacks.[1]

Stroke after cardiac catheterization procedures occurs mostly in older patients with vascular comorbidities, undergoing complicated invasive procedures.[2,3] The incidence of stroke following percutaneous coronary intervention (PCI) has been variably reported between 0.3% and 0.4%.[4–6]

The aim of our study was to assess the real-life incidence, etiology, risk factors, and temporal trends of cardiac catheterization-related acute CVEs (ischemic stroke; transient ischemic attack; intracerebral hemorrhage) in a large cohort of patients treated in a single center.

Materials and Methods

All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Study Population

The study population consists of all patients undergoing coronary angiography and/or a coronary intervention over the period 1992–2011 at the Shaare Zedek Medical Center, Jerusalem, Israel. All noncoronary procedures were excluded,

particularly peripheral interventions (including carotid), structural heart procedures, and right heart catheterizations. The data were derived from the electronic medical record of the cardiology department, based on Clicks software (Roshtov Software Industries Ltd). This record contains data including demographics, diagnoses, risk factors, angiographic and procedural details, medications, hospitalization course, ancillary tests, and outpatient follow-up for all patients undergoing cardiac catheterization.

Data collection was performed using computerized queries, retrieving all angiographic and procedural details and discharge summaries. These were then transferred to an electronic spreadsheet. CVE patients were identified by searching for any of the terms "Cerebrovascular Accident" or "C.V.A." or "T.I.A." or "Stroke" or "Intracranial Hemorrhage" in the diagnoses of discharge summaries and in the complications recorded in the angiographic summaries. In addition hospitalization courses after the procedure were searched for keywords such as "neurologic consultation," "CT referral," "weakness or paralysis of one side of the body," "speech problems," etc. All files with one of these diagnoses or keywords were reviewed by an experienced neurologist (IL-K), including computed tomography (CT) scans. Final clinical neurological diagnosis was evaluated blinded to patients' clinical and procedural characteristics. Events with an onset time within 24 hours from procedure completion were included and defined as CVE group. Due to the specific local health fund system, readmissions of patients discharged in less than 24 hours from the index procedure would be detected by interrogation of the database.

The study was approved by the Ethics Committee of the Shaare Zedek Medical Center, Jerusalem, Israel.

Definitions

Diagnostic and interventional catheterization procedures were included. As the considered risk period was 24 hours, the assessment unit used was procedural days. If a patient underwent both a diagnostic and an interventional procedure within the same 24-hour period, this was considered an interventional procedural day.

Stroke was diagnosed according to World Health Organization criteria, which defines a stroke as a focal deficit that lasts for more than 24 hours.[7]

Transient ischemic attack (TIA) was defined as focal neurological signs lasting fewer than 24 hours. Ischemic strokes (IS) and intracerebral hemorrhages (ICH) were differentiated by the findings on brain CT, performed between day 1 and day 2 after the onset of the stroke. Contrast reactions were determined by brain imaging and were not considered as CVEs.

Anatomical localization of stroke was performed based upon clinical subtypes of ischemic stroke using the Oxfordshire Community Stroke Project classification.[8] Stroke was classified as undetermined when a brain CT was not performed.

Onset time was defined as the first appearance of abnormal signs that were noticed by the treating team during the cardiac catheterization or after, while hospitalized in the cardiology department.

Study Variables

The principal outcome of this study was periprocedural CVE (CVE that occurred within 24 hours of the procedure). The following explanatory variables were assessed: (1) patient demographics: gender, ethnicity, and age; (2) clinical characteristics and risk factors: hypertension, diabetes mellitus, smoker, hyperlipidemia, prior myocardial infarction (MI), prior coronary arteries bypass surgery (CABG), prior stroke, renal disease, peripheral vascular disease (PVD), previously diagnosed carotid artery disease, atrial fibrillation (AF), and acute coronary syndrome (ACS); (3) procedural characteristics and findings: puncture site, performance of ventriculography, percutaneous coronary intervention (PCI), stent implantation, drug eluting stent (DES), number of catheters, use of eptifibatide or bivalirudin, vessel treated, triple vessel disease, bifurcation lesion, chronic lesion, and coronary artery thrombus.

Statistical Analysis

Patient characteristics were described by percentages, means±SD, and medians with interquartile ranges. Categorical variables were compared using chi-square test or Fisher exact test and continuous variables using unpaired Student t test. A multivariate forward, stepwise logistic regression analysis was performed to determine independent predictors for periprocedural stroke. The criterion for entrance into the model was a univariate probability value of $P<0.05$ and $P>0.10$ for removal from the model. The discriminatory power of the model was examined using c statistics, whereas c value ranges from 0.5 (the model's predictions are not better than chance) to 1.0 (the model always assigns higher probabilities to correct cases than to incorrect cases). C values of 0.7 to 0.8 are considered to show acceptable discrimination, values of 0.8 to 0.9 to indicate excellent discrimination, and values of $\geq$0.9 to show outstanding discrimination.[8] Odds ratios (OR) with 95% confidence intervals (CIs) were reported. The statistical tests were 2 sided. A P value <0.05 was considered as statistically significant. Analyses were carried out using SPSS version 15.0 statistical package (SPSS, Inc).

Results

Over the study period 43 350 procedures were performed on 30 907 procedure days. On these days, 17 150 diagnostic

and 13 757 interventional procedures (comprising 1314 interventional only and 12 443 combined procedures) were performed.

From this total cohort, 110 patient admission files were individually assessed based upon the predetermined key-words in the search. Fifty in-hospital CVEs were identified. Of these, 1 occurred prior to the index catheterization and 2 others appeared to not be related to the index procedure and were beyond the predetermined 24-hour window. Forty-seven (0.15%) procedure-related CVEs were identified with 37 ischemic strokes (IS), 6 TIAs, 3 ICH intracerebral hemor-rhages, and 1 undetermined stroke (CT not performed) (Figure 1).

Twenty-seven ischemic strokes were located in the ante-rior circulation (right hemisphere 15; left hemisphere 12) while 10 strokes were within the posterior circulation.

Of the 47 CVEs occurring in the entire cohort, 31 occurred related to a PCI and 16 related to a diagnostic coronary angiogram. The CVE rate for the entire cohort was 0.15%, while the rates for PCI and diagnostic coronary angiography were 0.23% and 0.09%, respectively.

Baseline patient and procedural characteristics of the patients undergoing CVE and those of the remaining population are presented in Table 1. When compared with patients not suffering a CVE, those experiencing CVEs were older (71.3±11.3 years versus 63.3±11.8 years, $P<0.0001$), more likely to suffer from hypertension (74% versus 51%, $P=0.008$), had prediagnosed carotid artery disease (6% versus 1%, $P=0.002$), had suffered a previous stroke (51% versus 5%, $P<0.0001$), had prior or current AF (15% versus 6%, $P=0.021$), were admitted with ACS (55% versus 35%, $P=0.014$), were non-smokers (81% versus 62%, $P=0.003$), and were undergoing an intervention (66% versus 44% $P=0.003$). There was a trend to increased risk for a CVE in patients with known PVD (0.34% with PVD versus 0.15%

without PVD, $P=0.08$). No increased risk for CVEs was associated with female gender, ethnicity, presence of diabetes mellitus, hyperlipidemia, obesity, previous MI, prior CABG, congestive heart failure, left ventricular dysfunction, or use of intraortic balloon pump.

Multiple procedural characteristics were assessed for relationships with CVEs (Table 1). These included, but were not limited to, access site, performance of ventriculography, the number of catheters used, extent of coronary disease (single, double, or triple vessel), presence of a coronary artery thrombus, intervened vessel, chronic or bifurcation lesions, and treatment with eptifibatide or bivalirudin. At univariate analysis, the presence of coronary artery thrombus and triple vessel disease were the only procedural variables found to be significant and a trend to increased risk was found in patients treated with eptifibatide or bivalirudin.

Forward, stepwise logistic regression analysis was used to assess associations of all background demographics, risk factors, and procedural characteristics with catheterization-related CVE adjusted for other significant risk factors. A total of 5 significant predictors were thus defined: prior stroke (OR=15.09, 95% CI [8.11 to 28.08], $P<0.0001$), the presence of coronary arterial thrombus (OR=2.79, 95% CI [1.25 to 6.22], $P=0.012$), age greater than 75 years (OR=3.33, 95% CI [1.79 to 6.19], $P<0.0001$), triple vessel disease (OR=2.24, 95% CI [1.20 to 4.18], $P=0.011$), and the performance of an intervention (OR=2.21, 95% CI [1.12 to 4.33], $P=0.021$). The C statistic was 0.865, suggesting an excellent discriminatory power of the model. This logistic regression is presented in Table 2 model A.

Temporal Analysis

Although in the first half of the study period the rate of CVE was 0.08% and rose to 0.22% over the next 10 years, this did
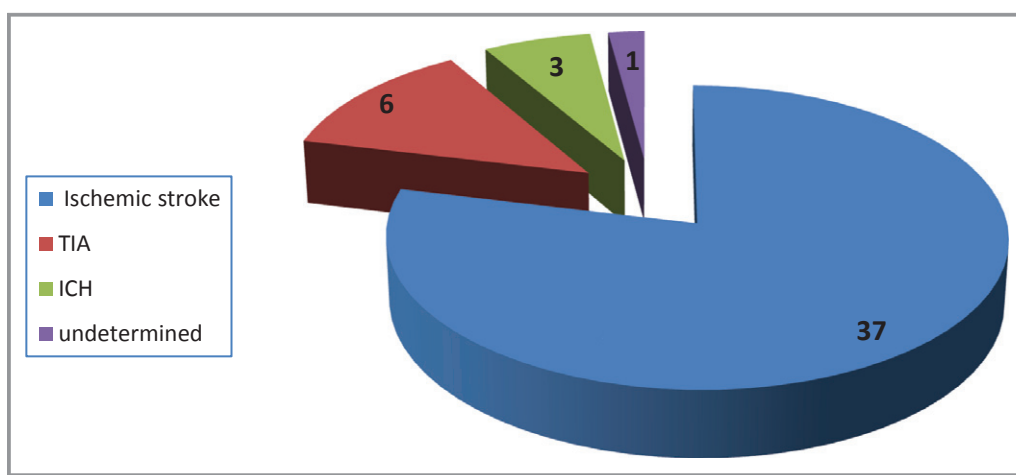
Figure 1. Incidence of procedure-related CVEs and their subtypes expressed in absolute numbers. CVE indicates cerebrovascular event; ICH, intracerebral hemorrhage; TIA, transient ischemic attack.

Table 1. Patients' Baseline and Procedural Characteristics

	All	CVE	No CVE	*P* Value
	30 907	47 (0.15%)	30 860 (99.85%)	
Demographic characteristics				
Age, y	63.3±11	71.3±11	63.3±11	<0.0001
Age ≥75 y	5397 (17%)	23 (49%)	5374 (17%)	<0.0001
Male gender	22 634 (73%)	31 (66%)	22 603 (73%)	0.26
Arab ethnicity	4538 (14.7%)	6 (13%)	4532 (15%)	0.71
Clinical characteristics and risk factors				
Hypertension	15 898 (51%)	35 (74%)	15 863 (51%)	0.008
Diabetes mellitus	9074 (29%)	16 (34%)	9058 (29%)	0.72
Hyperlipidemia	15 224 (49%)	25 (53%)	15 199 (49%)	0.98
Smoker	11 598 (38%)	9 (19%)	11 589 (38%)	0.003
Obesity	3760 (12%)	6 (13%)	3754 (12%)	0.95
Renal disease	2107 (7%)	4 (9%)	2103 (7%)	0.76
Prior stroke	1417 (5%)	24 (51%)	1393 (5%)	<0.0001
PVD	1453 (5%)	5 (11%)	1448 (5%)	0.08
Carotid artery disease	377 (1%)	3 (6%)	374 (1%)	0.002
Prior CABG	3499 (11%)	7 (15%)	3492 (11%)	0.58
Prior MI	5749 (19%)	8 (17%)	5741 (19%)	0.59
ACS	10 927 (35%)	26 (55%)	10 901 (35%)	0.014
AF	1871 (6%)	7 (15%)	1864 (6%)	0.021
Procedural characteristics				
Radial approach	2508 (8%)	5 (11%)	2503 (8%)	0.62
Interventional procedure	13 757 (45%)	31 (66%)	13 726 (44%)	0.003
Stent implantation	9984/13 757 (73%)	24 (51%)	9960 (32%)	0.54
Drug eluting stent	2409/9984 (24%)	8 (17%)	2401 (8%)	0.29
Eptifibatide/Bivalirudin	1090 (4%)	4 (9%)	1086 (4%)	0.09
Number of catheters	2 [2 to 3]	2 [2 to 3]	2 [2 to 3]	0.995
Vessel treated				
LAD	6099/13 757 (44%)	15/31 (48%)	6084/13 726 (44%)	0.65
CX	2257/13 757 (16%)	5/31 (16%)	2252/13 726 (16%)	0.97
RCA	3776/13 757 (27%)	10/31 (32%)	3766/13 726 (27%)	0.55
LM	307/13 757 (2%)	0/31 (0%)	307/13 726 (2%)	0.4
SVG/LIMA	643/13 757 (5%)	3/31 (10%)	640/13 726 (5%)	0.18
Procedure findings				
Triple vessel disease	8240 (27%)	23 (49%)	8217 (27%)	<0.0001
Thrombus	2021 (7%)	8 (17%)	2013 (7%)	0.009
Bifurcation lesion	1060 (3%)	3 (6%)	1057 (3%)	0.35
Chronic lesion	563 (2%)	1 (2%)	562 (2%)	0.91

ACS indicates acute coronary syndrome; AF, atrial fibrillation; CABG, coronary artery bypass graft surgery; CVE, cerebrovascular event; CX, circumflex; LAD, left anterior descending; LIMA, left internal mammary artery; LM, left main; MI, myocardial infarction; PVD, peripheral vascular disease; RCA, right coronary artery; SVG, saphenous vein graft.

not achieve statistical significance. This is despite the numerical increase of strokes noted since 2005 (chi-square analysis *P*=0.264) (Figure 2).

Temporal analyses of patients' and procedural character-istics revealed significant increase rates of almost all variables found to be independent risk factors. Rates of prior stroke

Table 2. Predictors for CVE After Cardiac Catheterization: Multiple Logistic Regression

	Model A			Model B		
	OR	95% CI	*P* Value	OR	95% CI	*P* Value
Prior stroke	15.09	8.11 to 28.06	<0.0001	14.89	7.99 to 27.73	<0.0001
Age >75 years	3.33	1.79 to 6.19	<0.0001	3.23	1.73 to 6.02	<0.0001
Thrombus	2.79	1.25 to 6.22	0.012	2.79	1.25 to 6.24	0.012
TVD	2.24	1.20 to 4.18	0.011	2.29	1.23 to 4.28	0.009
PCI	2.21	1.12 to 4.33	0.021	2.08	1.05 to 4.13	0.035
Year	—	—	—	1.03	0.96 to 1.10	0.373

CI indicates confidence interval; CVE, cerebrovascular event; OR, odds ratio; PCI, percutaneous coronary intervention; TVD, triple vessel disease.

increased from 2% to 7%, presence of thrombus rose from 4% to 10%, percent of elderly population (age over 75 years) undergoing procedure increased from 10% to 24% and finally percent of interventional procedures performed over the study period changed from 14% in 1992 to over 50% since 2005 (*P*<0.0001 for all) (Figure 3).

In order to assess its impact as a possible cofounder, the year of procedure was forced into the model developed from the previous stepwise method as an additional step and referred to as model B. This further step did not reduce the strength nor the statistical significance of the independent stroke predictors that were identified in model A (Table 2,

model B). The c statistic was 0.866, still indicating an excellent discriminatory power of the model.

Intra Cerebral Hemorrhages

There were a total of 3 ICHs. All 3 cases occurred related to PCI and additional, anticoagulation/antiplatelet therapy. All were treated with aspirin, clopidogrel, and heparin, with 2 patients treated with additional eptifibatide and 1 with bivalirudin.

The first case was a 78-year-old male that presented with an acute anterior wall myocardial infarction. He was
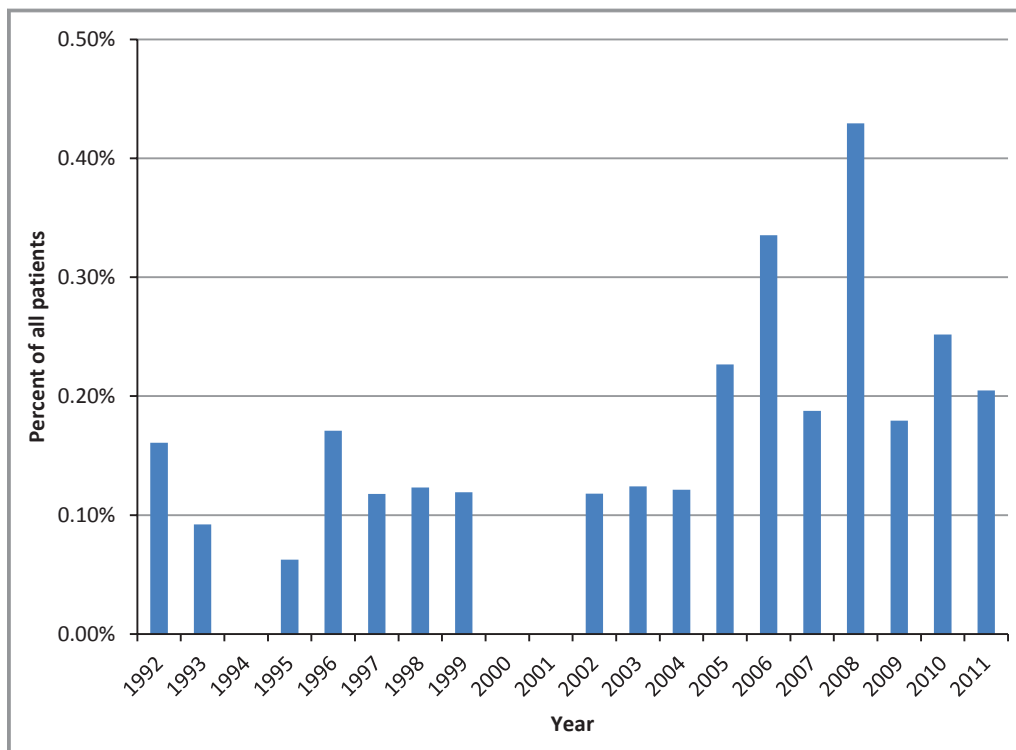
Figure 2. Procedure-related CVE rates over the study period expressed as percentages of cases. CVE indicates cerebrovascular event; PCI, percutaneous coronary intervention.
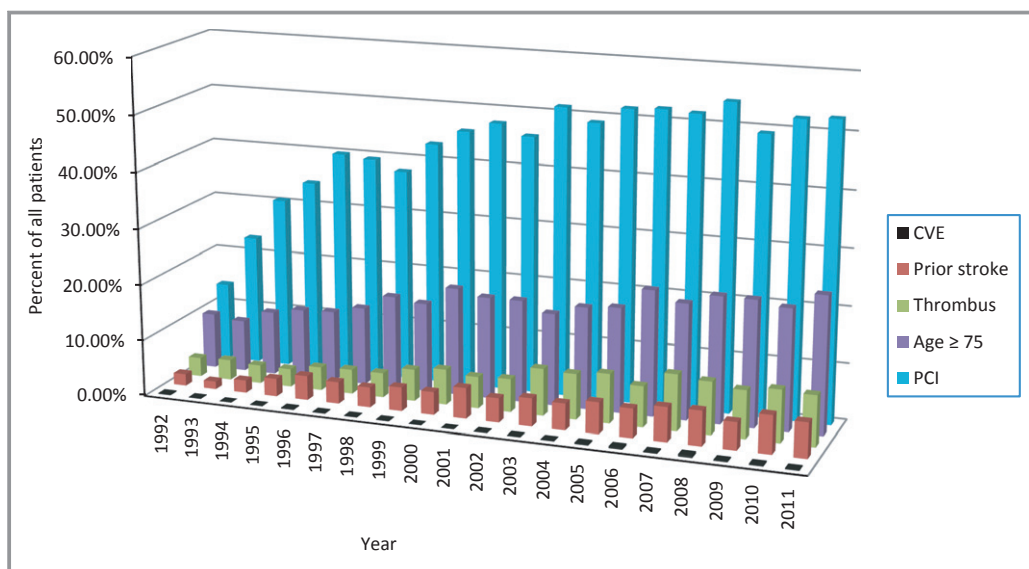
Figure 3. Temporal variation of procedure-related CVE risk factors over the study period.

transferred for primary PCI. He had no known coronary disease but had a history of paroxysmal AF treated with amiodarone and had suffered an ischemic stroke 4 months prior. At catheterization he was found to have triple vessel disease. He was treated with IV heparin and eptifibatide and underwent stent implantation to the mid-left anterior descending (LAD) artery. At the completion of the procedure, he became nonresponsive and urgent CT revealed severe left occipital intraparenchymal and subarachnoid bleeding with mass effect on the left lateral ventricle. He died 5 days later.

The second patient was a 48-year-old male that presented with an acute anterior wall MI. He had a past history of ischemic heart disease, hypertension, smoking, and hyperlipidemia. Diagnostic angiography revealed single vessel disease in the proximal LAD. He was pretreated with aspirin, clopidogrel, and heparin and received intravenous (IV) eptifibatide following the diagnostic study. He underwent successful primary PCI to the proximal LAD. Six hours following the procedure, he became noncommunicative and was found to have a right hemiplegia with facial palsy. The IV eptifibatide was then ceased. Urgent CT scan demonstrated a left parieto temporo hemorrhage with mass effect on the left lateral ventricle intraparenchymal and subarachnoid. Twelve hours later he became bradycardic and repeat CT revealed intraventricular extension of the bleed. He was transferred to neurosurgery. After rehabilitation there was some improvement but he remained hemiplegic and dysphatic.

The third patient was a 55-year-old woman with no significant past history that presented with an acute anterior wall MI. She underwent successful primary PCI to LAD while being treated periprocedurally with aspirin, clopidogrel, and bivalirudin. Intraprocedurally she complained of vision disturbance. The next day she further complained of headaches and

a right hemianopia was diagnosed. CT scan revealed a left occipital ICH. Supportive therapy only was instituted and at 6-month follow-up her vision had returned to normal.

Discussion

Over the past 2 decades interventional cardiology has made enormous strides in progressing from balloon angioplasty to relatively simple lesions through early stenting with anticoagulants and subsequently antiplatelets through to drug eluting stents and multiple ancillary devices with powerful intravenous antiplatelet agents. With the progression of interventional hardware and escalation of the interventionalist's capabilities leading to a reduction in intraprocedural and improved long-term outcomes, a concomitant change has occurred in the patient profile being treated. Whereas in the initial period, relatively simple patients were treated, the lesion and patient complexity has developed such that primary PCI in many centers can reach 30% of their patient load, multivessel disease and intervention is a matter of course as well as the routine treatment of octogenarians with diffuse atherosclerosis.

Our findings of low CVE rate (0.15%) have been relatively stable over the entire study period with the benefits of improved hardware and techniques being offset by a far more challenging population as demonstrated by our temporal analysis. Our principal findings demonstrate, similar to previously reported analyses, that age greater than 75 years, prior stroke and triple vessel disease all are strongly associated with a procedure-related CVE. Most of these features appear to be related to the burden of atherosclerotic disease. The increased risk in this population has been attributed in part to the increased incidence of aortic plaques,

particularly if mobile, that are present in this population. This has been further substantiated by the finding of atherosclerotic debris derived from the aorta in catheter aspirates. Interestingly in our study we failed to find a correlation with the number of catheters used or previous CABG, both of which would have increased the amount of aortic passages and intra-aortic manipulations, likely increasing stroke risk if this was the predominant mechanism. The additional 2 independent predictors that we found (undergoing an intervention and the presence of coronary artery thrombus) suggest that an alternative source for embolic material is present. In distinction to previously published analyses we have shown that the presence of an intra-coronary thrombus is independently associated with a periprocedural CVE. Hoffman et al[6] found at univariate analysis that intracoronary thrombus was more frequent in the post PCI CVEs, however this remained only as a trend (P=0.0734) when introduced into the multivariate model. In a most recent study demonstration of significantly higher rates (1.3%) of intervention-related CVEs in a primary PCI population that by definition must have an elevated thrombus burden supports our findings of the role of thrombus in intervention-related CVEs.[10] It would be extremely interesting to attempt to determine the mechanism of action of this association, particularly if the thrombus is a marker for a prothrombotic state or whether itself is the source of the subsequent embolus. Unfortunately, as our assessable end point (a clinically manifest neurological event) may be delayed by several hours, making temporal association analyses potentially misleading.

The final independent predictor was the performance of an intervention. The most recent studies assessing periprocedural CVEs have limited themselves to PCIs only.[6,11,12] Although it is clear that intervention represents a higher risk there were 2 specific reasons that we analyzed diagnostic studies in conjunction with the interventions. The first was that in the current environment of ad hoc intervention, the staff and patient facing a procedure should be aware of the potential CVE risk with a diagnostic study alone as well as that of a follow-on intervention. Second, following controlling for all other variables including, atherosclerotic burden as manifested by multiple features such as previously diagnosed carotid artery disease, PVD, and triple vessel disease, the intervention introduces the possibility of extraction of embolic material either associated with aspiration devices, on balloons or stent platforms. Based on the OR of 2.35 related to an intervention, this appears to represent a very significant mechanism of PCI-related stroke. This is supported by multiple reports[13–15] of thrombi or other filling defects having been displaced to more proximal branches or other coronary arteries following withdrawal of intracoronary devices such as aspiration catheters, balloons, and atherec-

tomy devices. Interestingly the use of eptifibatide or bivalirudin was not protective, possibly due to the intracoronary extraction mechanism not being dependent on thrombus alone as well as the ability of these agents intraprocedurally to only partially reduce the load of thrombus, often with a significant residual thrombus burden. Another important issue is the temporal impact of anticoagulant and antiplatelet administration. Unfortunately, due to the retrospective nature of this study we were unable to reliably dissect out the exact timing of administration in the total cohort severely limiting our ability to elucidate a relationship with CVEs.

Encouragingly, despite the broad adoption of these powerful intravenous antiplatelet agents that were progressively introduced over the study period, the incidence of intracerebral hemorrhage has remained remarkably low. Two of the 3 episodes were associated with the use of eptifibatide or bivalirudin, with devastating outcomes. In the third instance bivalirudin was used with a much less dramatic presentation and better outcome.

When compared to publications assessing stroke incidence postcoronary intervention in the United States such as the single center experience from the Washington Hospital Center (0.38%)[4] and more recently the Mayo Clinic (0.37%),[6] including data from the 1990s, the CVE rate of 0.23% in our study, seems relatively low. We conjecture that this may be due to the relatively early transfer from 8 and 7 French guiding catheters to a 6 French system that occurred in our center several years prior to the United States. The report from the National Cardiovascular Data Registry that studied stroke incidence in enrolling centers between the years 2004-2007 found an incidence (0.22%) similar to that in our center over the entire study period.[11] Due to the relatively small number of large catheters used we were unable to distinguish the impact of catheters greater than 6F. We found no impact of catheters smaller than 6F when compared with 6F, however it should be noted that the majority of 5F guiding catheters were used in conjunction with the radial approach presenting a confounding influence.

Previous studies[4–6] have assessed procedure-related CVEs over longer periods predominantly with in-hospital follow-up. We chose to limit the CVEs to those occurring with 24 hours of the procedure. This increases specificity but reduces sensitivity to some degree. To account for this we assessed all in-hospital CVEs in patients undergoing catheterizations and found an additional 3 CVEs in the entire population, one prior to the procedure and clearly not related. The additional 2 were postprocedure and also could not be clearly related to the procedure, although this cannot be excluded. In spite of this, the impact of these 2 additional cases on our results would be negligible and so an additional analysis was not performed.

Study Limitations

This study is a single-center, retrospective analysis of clinically evident CVEs occurring within 24 hours of a coronary cardiac catheterization. In spite of this, due to the advantage of having access to all the patients' complete records, we assessed all in in-hospital events. No procedure-related events that occurred beyond the 24-hour period were included. Furthermore, the access to a large number of procedural characteristics not available in large multicenter registries may offset to some degree the limitation of a single-center analysis. The retrospective analysis of a large number of relatively standard procedures (cardiac catheterization) precludes the inclusion of clinically silent CVEs that would provide stronger statistical power to elucidate risk factors and potential mechanisms of action. Nonetheless, the principal concern of physicians and their patients are those events that are clinically evident.

The relatively small number of CVEs limits the ability to adequately assess subgroups with any statistical power. It further can be assumed that many subclinical or very minor events were not identified. Their identification would improve the ability to further define the "at-risk" subgroups although in themselves may be of questionable clinical relevance.

In all but one instance, urgent brain imaging was performed. Imaging was limited to CT scanning. This has been the standard over the study period and in spite of the increasing use worldwide of MRI scanning it is not routinely performed for stroke assessment in Israel.[9,16] Moreover recent reports state that the sensitivity of DWI for the diagnosis of ischemic stroke is now estimated to be only 80% to 90%.[17,18] CT is very sensitive for the diagnosis of acute symptomatic ICH.[19]

Conclusion

In a single-center retrospective assessment over nearly 20 years, CVEs post-cardiac catheterization were very rare and nearly exclusively ischemic. The independent predictors for these events were found to be, not surprisingly, the performance of an intervention and those associated with increased atherosclerotic burden, specifically older age, triple vessel disease and prior stroke. Our findings however, identified an additional high-risk group with more acute coronary disease as manifest by the presence of coronary artery thrombus.

Disclosures

None.

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