HHS Public Access

Author manuscript

World Neurosurg. Author manuscript; available in PMC 2015 June 15.

Published in final edited form as:

World Neurosurg. 2015 June ; 83(6): 880–885. doi:10.1016/j.wneu.2015.01.013.

Neurogenic Stress Cardiomyopathy After Aneurysmal Subarachnoid Hemorrhage

Athar N. Malik, Ph.D., **Bradley A. Gross, M.D.**, **Pui Man Rosalind Lai, B.S.**, **Ziev B. Moses, M.D.**, and **Rose Du, M.D., Ph.D.**

Department of Neurological Surgery, Brigham and Women's Hospital and Harvard Medical School, Boston, MA 02115

Abstract

Objective—Neurogenic stress cardiomyopathy (NSC) is a known complication of aneurysmal subarachnoid hemorrhage (aSAH). Detailed analyses of risk factors for its occurrence across large cohorts are relatively sparse.

Methods—We reviewed a consecutive group of 300 patients with aSAH, evaluating for the presence of markers of myocardial injury including EKG changes (long QT, TWI), elevated plasma troponin levels (>=0.1), and echocardiogram findings (decreased ejection fraction and wall motion abnormalities). Neurogenic stress cardiomyopathy (NSC) was defined as the presence of at least one marker of myocardial injury. Univariate and multivariate analyses were conducted to assess the correlation of NSC as well as individual markers of myocardial injury with age, gender, medical comorbidities, medications, current smoking status, Hunt-Hess (HH) grade, and Fisher grade. Medical comorbidities were assessed based on reported medical history or reported use of comorbidity-specific medications at the time of presentation.

Results—Across the cohort, 27% of patients had a plasma troponin elevation of at least 0.1, 13% a prolonged QT interval, 16% new T wave inversions, 18% a depressed ejection fraction (less than 55%), and 15% echocardiographic wall motion abnormalities. After a multivariate analysis, significant risk factors for NSC included higher HH grade on presentation (OR 2.33, $p = 4.52 \times 10^{-6}$), current smoking status (OR 2.00, p = 0.030), and older age (OR 1.03, p = 0.048). Hypertension was protective against NSC (OR 0.48, p = 0.031). Patient gender, hyperlipidemia, diabetes, coronary artery disease, statin usage, beta blocker usage, ACE-inhibitor usage, aspirin usage, and thicker SAH (Fisher 3) were not significant risk factors for NSC.

Conclusion—Higher HH grade, current smoking status, lack of hypertension and older age were the strongest predictors of neurogenic stress cardiomyopathy.

Please address correspondence to: Bradley A. Gross MD, Department of Neurological Surgery, Brigham and Women's Hospital and Harvard Medical School, 75 Francis St, Boston, MA 02115, bgross1@partners.org, Tel: 617-732-5500.

Disclosure/Conflict of Interest Statement:

The authors have no conflicts of interest pertaining to this submission, and there is no financial disclosure from the authors.

Keywords

aneurysm; subarachnoid hemorrhage; neurogenic stress cardiomyopathy; myocardial; troponin; stress; stunning

Introduction

Myocardial injury is a known complication of aneurysmal subarachnoid hemorrhage (aSAH) (9). The elevation in intracranial pressure due to aSAH is thought to cause sympathetic activation resulting in hypercontraction of cardiac myocytes and subsequent myocardial injury (9). While this phenomenon has been described by various names, including neurogenic myocardial stunning (8) and neurocardiogenic injury (14), it is now commonly referred to as neurogenic stress cardiomyopathy (NSC) to more accurately reflect the accepted underlying pathophysiology (9). Clinically, NSC may manifest as EKG changes including prolonged QT interval and T wave changes (6), elevated troponin levels (11), or echocardiographic findings including reduced ejection fraction and wall motion abnormalities (12). Detailed analyses of risk factors for its occurrence across large cohorts are relatively sparse and no studies to date have evaluated the impact of medical comorbidities, current medications, and current smoking status on the development of NSC. In this report, we evaluated a single institutional cohort to further elucidate risk factors for NSC after aSAH.

Methods

With approval of our local institutional review board, we reviewed the records of a consecutive series of 300 patients with aneurysmal subarachnoid hemorrhage. We extracted patient age, gender, pertinent medical comorbidities (hypertension, hyperlipidemia, diabetes, coronary artery disease), medication usage on presentation (statin, beta-blocker, ACE-inhibitor, aspirin), current smoking status, presenting Hunt-Hess (HH) grade, and SAH thickness. Medical comorbidities were considered present based on based on reported medical history or reported use of comorbidity-specific medications at the time of presentation. We noted pertinent EKG findings on presentation (prolonged QT interval, T wave changes), maximum troponin-I levels within 72 hours of presentation, and pertinent echocardiogram findings within 72 hours of presentation (ejection fraction and wall motion abnormalities). EKG and echocardiogram findings are based on the results reported in the medical records as reviewed by a cardiologist. Outcome was measured by the modified Rankin Scale (mRS). An mRS of greater than or equal to 3 at discharge was defined as poor outcome.

Statistical analysis was performed using R (version 3.0.2). Neurogenic stress cardiomyopathy (NSC) was defined as the presence of at least one marker of myocardial injury (troponin ≥ 0.1, EF < 55%, long QT, T wave inversions, wall motion abnormalities). Univariate and multivariate logistic regressions were conducted to assess risk factors for QT prolongation, T wave inversions, elevated plasma troponin, depressed ejection fraction (EF < 55%), wall motion abnormalities, and overall NSC. The following variables were evaluated: age, gender, medical comorbidities, current medications, current smoking status,

clinical grade (Hunt and Hess), and radiographic grade (Fisher). Missing data were excluded from the analysis. Statistical significance was defined as $p < 0.05$.

Results

Of 300 consecutive patients seen at our institution with confirmed aneurysmal subarachnoid hemorrhage, fourteen did not have early post-hemorrhage troponin and echocardiographic data and were thus excluded from the analysis. Mean age for the overall evaluated cohort was 54.9 ± 14.2 years with a female predilection (76%). Associated medical conditions included hypertension in 47% of patients, hyperlipidemia in 20%, diabetes mellitus in 6% and coronary artery disease in 7%. Medications taken included statins (11%), beta blockers (14%), ACE-inhibitors (10%), and aspirin (13%). Thirty-nine percent of patients were current smokers. Poor clinical grade at presentation (Hunt-Hess 4–5) was seen in 27% of patients. Thick subarachnoid clot (Fisher grade of 3, at least 1 mm thick) was seen on computed tomography (CT) in 67% of patients (Table 1).

EKG changes

Thirteen percent of patients had QT prolongation on initial EKG and 16% had T-wave changes. After multivariate analysis (Table 2), age, gender, prior medical conditions (hypertension, hyperlipidemia, diabetes, coronary artery disease), medication usage (statin, beta blocker, ace-inhibitor, aspirin), current smoking status, HH and Fisher grades were not significantly associated with QT prolongation. T wave inversion was positively correlated with HH grade (OR 2.24, $p = 4.7\times10^{-4}$), usage of beta blockers (OR 5.85, $p = 0.007$), and female gender (OR 5.51, $p = 0.007$). T wave inversion was negatively correlated with use of statins (OR 0.03, $p = 0.032$). Other factors such as age, prior medical conditions (hypertension, hyperlipidemia, diabetes, coronary artery disease), other medication usage (ACE-inhibitor, aspirin), current smoking status and Fisher grade were not significant risk factors for the occurrence of T wave inversions at presentation.

Elevated Plasma Troponin-I

Overall, 37% of patients had an elevated plasma troponin-I within 72 hours of presentation. Ten percent of patients had a minimal elevation (Tn-I 0.01–0.1), 15% a moderate elevation (Tn-I 0.1–1.0) and 12% a significant elevation (Tn-I > 1.0) (Table 1). In multivariate analysis (Table 2), a significant troponin-I elevation (Tn-I >= 0.1) was positively correlated with HH grade (OR 2.45, $p = 7.6\times10^{-6}$) and age (OR 1.03, $p = 0.032$) but negatively correlated with hypertension (OR 0.47, $p = 0.047$). Gender, other medical conditions (hyperlipidemia, diabetes, coronary artery disease), medication usage (statin, beta blocker, ACE-inhibitor, aspirin), current smoking status, and Fisher grade were not significant risk factors for a significant troponin elevation (Tn-I >= 0.1).

Low Ejection Fraction (EF < 50%)

Of the 286 patients with Tn-I data, 169 underwent echocardiography (59%) (Table 1). Of these 169 patients, 82 did not have a Tn-I elevation (49%), 22 had a minimal Tn-I elevation (13%, 0.01–0.1), 35 had a moderate Tn-I elevation (21%, 0.1–1.0), and 30 had a Tn-I elevation of at least 1.0 (18%). Thirty-one patients had an ejection fraction less than 55%

(18% of cases); four of these patients had an ejection fraction of 30% or less. Thirteen of these patients demonstrated T-wave changes on EKG (42%). In a multivariate analysis (Table 2), reduced ejection fraction (< 55%) was positively correlated with HH grade (OR 1.91, p = 0.033) and statin usage (OR 19.8, p = 0.043), and negatively correlated with hypertension (OR 0.12, p=0.006). Patient age, gender, other medical conditions (hyperlipidemia, diabetes, coronary artery disease), other medication usage (beta-blocker, ACE-inhibitor, statin), current smoking status, and Fisher grade were not significant risk factors for a depressed ejection fraction on echocardiography.

Wall Motion Abnormalities

Of the 169 patients who underwent echocardiography, 25 exhibited wall motion abnormalities (15%) (Table 1). Nearly half demonstrated T-wave inversions on EKG (12/25, 48%), and most had thick SAH (Fisher 3, 23/25, 92%). In a multivariate analysis (Table 2), the presence of wall motion abnormalities was positively correlated with HH grade (OR 2.05, p=0.036) and negatively correlated with hypertension (OR 0.14, p = 0.021). Patient age, gender, other medical conditions (hyperlipidemia, diabetes, coronary artery disease), medication usage (statin, beta-blocker, ACE-inhibitor, statin), current smoking status, and Fisher grade were not significant risk factors for the presence of wall motion abnormalities.

Of these 25 patients with wall motion abnormalities, 7 patients exhibited apical hypokinesis (Takotskubo's, 28%), 12 patients exhibited nonapical hypokinesis (48%), and 6 patients exhibited global hypokinesis (24%) (Table 3). Interestingly, all 7 patients with apical hypokinesis were female, all had thick SAH, and the mean age of these patients was 74.6 (SD 9.3). Background and demographic characteristics of patients with nonapical hypokinesis and global hypokinesis did not significantly differ from our general cohort (Table 3).

Neurogenic stress cardiomyopathy (NSC)

Neurogenic stress cardiomyopathy (NSC) was defined as the presence of at least one marker of myocardial injury among the following markers: troponin ≥ 0.1, EF < 55%, long QT, T wave inversions, and wall motion abnormalities. In multivariate analysis (Table 4), NSC was positively correlated with HH grade (OR 2.33, $p = 4.52 \times 10^{-6}$), current smoking status (OR 2.00, p = 0.030), and older age (OR 1.03, p = 0.048). NSC was negatively correlated with hypertension (OR 0.48, p = 0.031). Patient gender, other medical conditions (hyperlipidemia, diabetes, coronary artery disease), medication usage (statin, beta blocker, aspirin), and thicker SAH (Fisher 3) were not significant risk factors for NSC in this cohort.

Outcome

Outcome at discharge was adversely affected by age (OR 1.08, $p = 2.31 \times 10^{-4}$) and HH grade (OR 2.15, p = 0.006) but not by NSC in multivariate analysis.

Discussion

Aneurysmal subarachnoid hemorrhage (aSAH) is a devastating condition that is associated with mortality rates of up to 50% (3,4). While initial hemorrhage (2) and subsequent delayed

cerebral ischemia (13) are major contributors to mortality, a recent study found that neurogenic stress cardiomyopathy (NSC) after aSAH was also associated with higher mortality and poorer long-term functional outcomes even after correction for Hunt-Hess grade (7). As a result, better understanding the risk factors for the development of NSC after aSAH may aid in the early recognition and treatment of NSC and improve patient outcome.

Detailed analyses of risk factors for occurrence of NSC after aSAH across large cohorts are relatively sparse. However, previous studies have identified severity of neurological injury as a major predictor of NSC after aSAH, with patients presenting as Hunt-Hess > 3 having higher risk (5,7,14). Our study found that NSC was positively correlated with HH grade (OR 2.33, $p = 4.52 \times 10^{-6}$), and thus is in line with these previous reports. This association supports the hypothesis that cardiac injury after subarachnoid hemorrhage is a neurally mediated process. Previous studies have also reported female gender as a risk factor for NSC after aSAH (10,14). In our study, while female gender was not a statistically significant risk factor for NSC (OR 1.32, p = 0.454), it was a significant risk factor for T wave inversions (OR 5.51, p = 0.007). Our study also found that NSC was positively correlated with increasing age (multivariate OR 1.03, p = 0.048). This result has not been previously reported but may reflect the reduced ability of older myocardium to withstand neurogenic stress in the context of aSAH.

We assessed the impact of medical comorbidities, current medications, current smoking status, and radiographic SAH grade (Fisher) on development of NSC after aSAH. We found that current smoking status was a risk factor for NSC (OR 2.00, p = 0.030) and hypertension was protective against NSC (OR 0.48, p = 0.031). Other medical conditions (hyperlipidemia, diabetes, coronary artery disease), medication usage (statin, beta blocker, ACE-inhibitor, aspirin), and thicker SAH (Fisher 3) were not significant risk factors for NSC in this cohort.

In addition to finding a negative correlation between hypertension and NSC, we found that a history of hypertension was also negatively correlated with the individual markers of myocardial injury including elevated troponin levels (Tn>=0.1, OR 0.47, p = 0.047) and reduced ejection fraction (OR 0.12, p = 0.006). While it may be assumed that a history of hypertension would place a patient at increased rather than decreased risk for myocardial injury after aSAH, our results suggest otherwise. It is possible that a history of hypertension may result in preconditioning of the myocardium that makes it more resistant to the stress encountered during NSC. Interestingly, a previous study of the risk factors of NSC after aSAH also found that lower systolic blood pressure was an independent predictor of troponin elevation (14). Additional studies will be needed to better understand this association.

We did not observe a significant effect of NSC on outcome at discharge. This is in contrast to previous results by Kilbourn et al. where neurogenic stress cardiomyopathy was associated with poorer long-term functional outcomes (7). This may be secondary to the differences in the interval of followup, as well as, the difference in the definition of myocardial dysfunction.

Study Design and Limitations

This study is limited by its single-center, retrospective design. Furthermore, it is impacted by not controlling for approximate time to presentation to our institution. As a result, there may bias introduced by the variability in the time after aSAH at which point clinical data were collected at our institution. Because NSC is a generally transient state (1), we may have in some instances missed peak occurrences of clinical indicators of NSC. Another limitation of our study may be the definition used to define and quantify NSC. In this study NSC was a binary variable, defined by the presence of at least one marker of myocardial injury, including QT prolongation on EKG, T wave inversion on EKG, elevated troponin-I levels (>=0.1), reduced ejection fraction (<55%), and wall motion abnormalities. We employed this definition to encompass the multiple variables that serve as clinical indicators of myocardial injury in NSC. Since this precise definition was not used in previous studies of NSC (5,7,14), the results of our study may not be directly comparable with prior studies. Importantly, we did explore alternative methods of quantifying NSC. For example, we defined NSC not as a binary variable but instead as the sum of the number of individual markers of myocardial injury present. With this analysis, we obtained similar major results to those described. Hence, our results appear to be robust to the exact definition of NSC used. Finally, our results may be affected by interobserver variability in Hunt and Hess grades.

Conclusion

This study illustrates a statistically significant association of higher Hunt-Hess grade, current smoking status, older age, and lack of hypertension with the risk of developing neurogenic stress cardiomyopathy after aneurysmal subarachnoid hemorrhage. These findings build upon previous studies that have investigated risk factors for neurogenic stress cardiomyopathy after aneurysmal subarachnoid hemorrhage, and support the hypothesis that cardiac injury after subarachnoid hemorrhage is a neurally mediated process.

References

1. Banki N, Kopelnik A, Tung P, Lawton MT, Gress D, Drew B, Dae M, Foster E, Parmley W, Zaroff J. Prospective analysis of prevalence, distribution, and rate of recovery of left ventricular systolic dysfunction in patients with subarachnoid hemorrhage. J Neurosurg. 2006; 105:15–20. [PubMed: 16871878]
2. Broderick JP, Brott TG, Duldner JE, Tomsick T, Leach A. Initial and recurrent bleeding are the major causes of death following subarachnoid hemorrhage. Stroke. 1994; 25:1342–1347. [PubMed: 8023347]
3. Hijdra A, Braakman R, van Gijn J, Vermeulen M, van Crevel H. Aneurysmal subarachnoid hemorrhage. Complications and outcome in a hospital population. Stroke. 1987; 18:1061–1067. [PubMed: 3686578]
4. Hop JW, Rinkel GJ, Algra A, van Gijn J. Case-fatality rates and functional outcome after subarachnoid hemorrhage: a systematic review. Stroke. 1997; 28:660–664. [PubMed: 9056628]
5. Hravnak M, Frangiskakis JM, Crago EA, Chang Y, Tanabe M, Gorcsan J 3rd, Horowitz MB. Elevated cardiac troponin I and relationship to persistence of electrocardiographic and echocardiographic abnormalities after aneurysmal subarachnoid hemorrhage. Stroke. 2009; 40:3478–3484. [PubMed: 19713541]
6. Khechinashvili G, Asplund K. Electrocardiographic changes in patients with acute stroke: a systematic review. Cerebrovasc Dis. 2002; 14:67–76. [PubMed: 12187009]

7. Kilbourn KJ, Levy S, Staff I, Kureshi I, McCullough L. Clinical characteristics and outcomes of neurogenic stress cadiomyopathy in aneurysmal subarachnoid hemorrhage. Clin Neurol Neurosurg. 2013; 115:909–914. [PubMed: 23021080]
8. Kono T, Morita H, Kuroiwa T, Onaka H, Takatsuka H, Fujiwara A. Left ventricular wall motion abnormalities in patients with subarachnoid hemorrhage: neurogenic stunned myocardium. J Am Coll Cardiol. 1994; 24:636–640. [PubMed: 8077532]
9. Lee VH, Oh JK, Mulvagh SL, Wijdicks EF. Mechanisms in neurogenic stress cardiomyopathy after aneurysmal subarachnoid hemorrhage. Neurocrit Care. 2006; 5:243–249. [PubMed: 17290097]
10. Mayer SA, Lin J, Homma S, Solomon RA, Lennihan L, Sherman D, Fink ME, Beckford A, Klebanoff LM. Myocardial injury and left ventricular performance after subarachnoid hemorrhage. Stroke. 1999; 30:780–786. [PubMed: 10187879]
11. Parekh N, Venkatesh B, Cross D, Leditschke A, Atherton J, Miles W, Winning A, Clague A, Rickard C. Cardiac troponin I predicts myocardial dysfunction in aneurysmal subarachnoid hemorrhage. J Am Coll Cardiol. 2000; 36:1328–1335. [PubMed: 11028491]
12. Pollick C, Cujec B, Parker S, Tator C. Left ventricular wall motion abnormalities in subarachnoid hemorrhage: an echocardiographic study. J Am Coll Cardiol. 1988; 12:600–605. [PubMed: 3403818]
13. Qureshi AI, Sung GY, Razumovsky AY, Lane K, Straw RN, Ulatowski JA. Early identification of patients at risk for symptomatic vasospasm after aneurysmal subarachnoid hemorrhage. Crit Care Med. 2000; 28:984–990. [PubMed: 10809270]
14. Tung P, Kopelnik A, Banki N, Ong K, Ko N, Lawton MT, Gress D, Drew B, Foster E, Parmley W, Zaroff J. Predictors of neurocardiogenic injury after subarachnoid hemorrhage. Stroke. 2004; 35:548–551. [PubMed: 14739408]

Abbreviations

NSC	Neurogenic Stress Cardiomyopathy
aSAH	Aneurysmal Subarachnoid Hemorrhage
HH	Hunt-Hess
OR	Odds Ratio
ACE	Angiotensin-Converting Enzyme
CT	Computed Tomography
Tn	Troponin
EF	Ejection Fraction

Highlights

- Significant risk factors for Neurogenic Stunned Myocardium included higher HH grade (OR 2.33, $p = 4.52 \times 10^{-6}$), current smoking (OR 2.00, p = 0.030), and older age (OR 1.03, p = 0.048).
- Hypertension was protective against NSC (OR 0.48, p = 0.031).
- Patient gender, hyperlipidemia, diabetes, coronary artery disease, statin usage, beta blocker usage, ACE-inhibitor usage, aspirin usage, and thicker SAH (Fisher 3) were not significant risk factors for NSC.

Table 1

Characteristics of all patients, and those with Tn leaks, EF < 55% and wall motion abnormalities.[a]

	Overall	Tn leak	EF < 55%	Any WMA
Patients	286	107/286 (37%)	31/169 (18%)	25/169 (15%)
Age (Mean +/− SD)	54.9 (14.2)	58.9 (14.3)	60.4 (15.8)	58.8 (15.5)
Female Gender	216/286 (76%)	83/107 (78%)	26/31 (84%)	20/25 (80%)
Medical History:				
Hypertension	135/286 (47%)	48/107 (45%)	8/31 (26%)	6/25 (24%)
Hyperlipidemia	56/286 (20%)	19/107 (18%)	4/31 (13%)	2/25 (8%)
Diabetes	18/286 (6%)	7/107 (7%)	2/31 (6%)	1/25 (4%)
CAD	20/286 (7%)	10/107 (9%)	4/31 (13%)	3/25 (12%)
Medications:				
Statin	32/286 (11%)	12/107 (11%)	5/31 (16%)	3/25 (12%)
Beta Blocker	39/286 (14%)	16/107 (15%)	6/31 (19%)	4/25 (16%)
ACE-Inhibitor	28/286 (10%)	10/107 (9%)	1/31 (3%)	1/25 (4%)
Aspirin	38/286 (13%)	14/107 (13%)	2/31 (6%)	1/25 (4%)
Current Smoker	112/286 (39%)	44/107 (41%)	12/31 (39%)	10/25 (40%)
Hunt-Hess 4–5	77/286 (27%)	56/107 (52%)	20/31 (65%)	18/25 (72%)
Thick SAH (Fisher 3)	193/286 (67%)	91/107 (85%)	28/31 (90%)	23/25 (92%)
EKG Changes:				
QT Prolonged	36/286 (13%)	22/107 (21%)	5/31 (16%)	3/25 (12%)
T-wave changes	45/286 (16%)	40/107 (37%)	13/31 (42%)	12/25 (48%)

[a] Tn, troponin; EF, ejection fraction; WMA, wall motion abnormality; SD, standard deviation; CAD, coronary artery disease; SAH, subarachnoid hemorrhage; ICA, internal carotid artery; ACA, anterior cerebral artery; MCA, middle cerebral artery.

Table 2

Results of multivariate analysis of risk factors for individual markers of myocardial injury including QT prolongation, T-wave inversion, Troponin leak (>= 0.1), depressed ejection fraction (less than 55%), and wall motion abnormalities. P values meeting statistical significance ($p < 0.05$) are shown in bold.[a]

	Long QT			TWI			Tn >= 0.1			EF <55%			WMA		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Age	1.00	0.97–1.04	0.852	1.01	0.97–1.04	0.718	1.03	1.00–1.06	**0.032**	1.04	1.00–1.10	0.083	1.03	0.98–1.09	0.244
Female Gender	0.75	0.29–2.06	0.565	5.51	1.77–22.2	**0.007**	1.96	0.85–4.79	0.124	1.47	0.45–5.43	0.539	1.31	0.37–5.47	0.688
Medical History:															
Hypertension	0.76	0.27–1.99	0.585	0.51	0.20–1.22	0.141	0.47	0.22–0.98	**0.047**	0.12	0.02–0.46	**0.006**	0.14	0.02–0.61	**0.021**
Hyperlipidemia	1.79	0.44–6.59	0.392	2.43	0.54–9.86	0.224	1.50	0.46–4.68	0.490	0.13	0.00–1.17	0.119	0.40	0.01–4.41	0.498
Diabetes	0.45	0.02–2.89	0.478	1.67	0.31–8.02	0.527	0.71	0.15–2.91	0.641	6.40	0.55–69.2	0.119	2.60	0.07–45.8	0.531
CAD	0.37	0.02–3.31	0.427	3.18	0.24–40.4	0.351	3.04	0.52–18.6	0.214	1.51	0.05–25.0	0.775	6.37	0.17–341	0.291
Medications:															
Statin	0.57	0.10–2.98	0.504	0.03	0.00–0.43	**0.032**	0.41	0.08–1.85	0.254	19.8	1.51–706	**0.043**	5.05	0.28–159	0.286
Beta-Blocker	0.25	0.03–1.24	0.132	5.85	1.62–21.9	**0.007**	0.86	0.24–2.79	0.802	1.60	0.29–7.85	0.564	2.63	0.38–16.1	0.297
ACE-Inhibitor	4.01	0.95–16.4	0.052	0.82	0.08–4.83	0.845	0.73	0.16–2.91	0.667	0.47	0.01–7.05	0.630	3.92	0.15–57.8	0.323
Aspirin	3.21	0.92–10.7	0.060	0.09	0.00–0.74	0.071	0.44	0.11–1.52	0.219	0.09	0.00–1.46	0.155	7.9×10^{-9}	$0–3.2\times10^{24}$	0.988
Current Smoker	1.13	0.47–2.68	0.786	1.50	0.66–3.44	0.336	1.57	0.79–3.17	0.199	1.88	0.65–5.65	0.247	2.25	0.69–7.90	0.188
Hunt-Hess 4–5	1.44	0.90–2.36	0.137	2.24	1.45–3.61	**4.7×10^{-4}**	2.45	1.68–3.71	**7.6×10^{-6}**	1.91	1.08–3.63	**0.033**	2.05	1.09–4.24	**0.036**
Thick SAH	2.26	0.66–9.27	0.216	1.66	0.54–5.52	0.383	1.54	0.60–4.15	0.377	0.89	0.17–5.51	0.895	1.05	0.16–9.57	0.959

[a] TWI, T-wave inversions; Tn, troponins; EF, ejection fraction; WMA, wall motion abnormalities; CAD, coronary artery disease; Thick SAH, Fisher grade 3 subarachnoid hemorrhage.

Table 3

Characteristics of patients with different patterns of wall motion abnormalities on echocardiography.

	Apical Hypokinesis	Nonapical Hypokinesis	Global Hypokinesis
Patients	7	12	6
Age, Mean (SD)	74.6 (9.3)	52.3 (14.9)	53.5 (8.9)
Female Gender	7/7 (100%)	8/12 (67%)	5/6 (83%)
Medical History:			
Hypertension	3/7 (43%)	3/12 (25%)	0/6 (0%)
Hyperlipidemia	0/7 (0)	1/12 (8%)	1/6 (17%)
Diabetes	1/7 (14%)	0/12 (0%)	0/6 (0%)
CAD	2/7 (29%)	0/12 (0%)	1/6 (17%)
Medications:			
Statin	1/7 (14%)	1/12 (8%)	1/6 (17%)
Beta-Blocker	3/7 (43%)	0/12 (0%)	1/6 (17%)
ACE-Inhibitor	0/7 (0%)	1/12 (8%)	0/6 (0%)
Aspirin	1/7 (14%)	0/12 (0%)	0/6 (0%)
Current Smoker	1/7 (14%)	5/12 (42%)	4/6 (67%)
Hunt-Hess 4–5	4/7 (57%)	10/12 (83%)	4/6 (67%)
Thick SAH	7/7 (100%)	11/12 (92%)	5/6 (83%)
EKG Changes:			
QT Prolonged	0/7 (0%)	3/12 (25%)	0/6 (0%)
T-wave changes	5/7 (71%)	5/12 (42%)	2/6 (33%)

[a]SD, standard deviation; CAD, coronary artery disease; Thick SAH, Fisher grade 3 subarachnoid hemorrhage; ICA, internal carotid artery; ACA, anterior cerebral artery; MCA, middle cerebral artery.

Table 4

Results of multivariate analysis of risk factors for neurogenic stress cardiomyopathy (NSC), defined as the presence of at least one marker of myocardial injury. Markers of myocardial injury included QT prolongation, T-wave inversion, Troponin leak (>=0.1), depressed ejection fraction (less than 55%), and wall motion abnormalities. P values meeting statistical significance ($p < 0.05$) are shown in bold.[a]

	NSC		
	OR	**95% CI**	**p**
Age	1.03	1.00–1.05	**0.048**
Female Gender	1.32	0.64–2.78	0.454
Medical History:			
Hypertension	0.48	0.24–0.93	**0.031**
Hyperlipidemia	1.62	0.59–4.40	0.343
Diabetes	1.20	0.33–4.36	0.775
CAD	0.85	0.17–3.97	0.833
Medications:			
Statin	0.42	0.11–1.52	0.189
Beta-Blocker	1.91	0.70–5.24	0.204
ACE-Inhibitor	1.09	0.34–3.40	0.887
Aspirin	0.85	0.28–2.40	0.757
Current Smoker	2.00	1.08–3.78	**0.030**
Hunt-Hess 4–5	2.33	1.65–3.40	**4.52×10^{-6}**
Thick SAH	1.27	0.59–2.77	0.550

[a] NSC, neurogenic stress cardiomyopathy; CAD, coronary artery disease; Thick SAH, Fisher grade 3 subarachnoid hemorrhage.