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Elevated Cardiac Troponin I and Functional Recovery and Disability in Patients After Aneurysmal Subarachnoid Hemorrhage

Joyce K. Miketic, RN, MBA, Marilyn Hravnak, PhD, ACNP-BC, Susan M. Sereika, MPH, PhD, and Elizabeth A. Crago, RN, MSN

Joyce K. Miketic is a graduate student researcher, Marilyn Hravnak is a professor, and Elizabeth A. Crago is a clinical coordinator in the Department of Acute and Tertiary Care at the University of Pittsburgh, School of Nursing, Pittsburgh, Pennsylvania. Susan M. Sereika is an associate professor in the Department of Health and Community Systems in the School of Nursing and the Department of Biostatistics in the Graduate School of Public Health at the University of Pittsburgh

Abstract

Background—Patients with aneurysmal subarachnoid hemorrhage experience myocardial injury at the time of rupture, but its effect on functional recovery and disability is unclear.

Objective—To describe the prevalence of myocardial injury, as indicated by high serum levels of cardiac troponin I (≥ 0.3 ng/mL), within the first 5 days after aneurysmal subarachnoid hemorrhage and the effect of the injury on 3-month functional recovery and disability.

Methods—In a prospective longitudinal study, 239 patients with Hunt/Hess grade 3 or greater and/or Fisher grade 2 or greater at admission had serum level of troponin I measured on days 0 to 5. Patients were interviewed at 3 months to evaluate functional recovery (Glasgow Outcome Scale) and functional disability (Modified Rankin Scale). Statistics included χ^2 analysis, *t* tests, and binary logistic regression.

Results—Troponin values were elevated in 33.5% of the patients, and few patients in either group had a history of coronary artery disease (7.4% with troponin levels ≥ 0.3 ng/mL vs 2.7% with levels < 0.3 ng/mL, $P = .12$). Higher troponin levels were significantly related to age and Hunt/Hess and Fisher grades, but not race, and were significantly associated with poorer functional recovery ($P < .001$) and more functional disability ($P < .001$). Even after controls for age, race, and more severe Hunt/Hess grades, higher levels remained a significant predictor of poorer functional recovery ($P = .04$) and disability ($P = .01$).

Conclusion—Elevated levels of cardiac troponin I after aneurysmal subarachnoid hemorrhage are common in patients with no cardiac history, are associated with severity of the hemorrhage, and are independently predictive of poorer functional recovery and increased disability.

Aneurysmal subarachnoid hemorrhage (aSAH) affects up to 33000 patients each year in the United States, usually in middle age (mean age at diagnosis, 55 years) and more often in women (1.6 times greater incidence than in men) and African Americans (2.1 times greater

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Corresponding author: Joyce K. Miketic, RN, MBA, PhD(c), Department of Acute and Tertiary Care, University of Pittsburgh School of Nursing, 3500 Victoria Street, Pittsburgh, PA 15261 (jkm10@pitt.edu).

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incidence than in whites).¹ patients experience a primary brain injury at the time of initial aneurysmal rupture, but additional injury may occur in the minutes, hours, days, or weeks after the rupture.² Mechanisms of other secondary injuries include symptomatic cerebral vasospasm, hydrocephalus, and rebleeding.¹ Myocardial injury after aSAH has been noted in other studies^{2,3}; the reported prevalence ranged from 20% to 40%.³

Many reasons for myocardial injury in patients with aSAH have been suggested, such as coronary vasospasm or extreme hypertension at the time of the initial bleeding injury. A more current explanation for these developments is a catecholamine surge at the time of rupture.^{4,5} Macmillan et al⁶ described a “catecholamine storm” that resulted in a prolonged and massive sympathetic nervous activation. They further suggested that the elevation in level of cardiac troponin I (cTnI) may be manifested as an acute reversible cardiac injury ranging from hypokinesia with a normal cardiac index to low-output cardiac failure. The findings of Tung et al⁷ further supported the theory that myocardial injury after aSAH might be due to an excessive release of catecholamines, notably norepinephrine, from the cardiac sympathetic nerves at the time of the initial aneurysmal rupture as a neurocardiac interaction, resulting in a subendocardial contraction band necrosis. However, no consensus exists about the prevalence of myocardial injury after aSAH or about the relationship of the cardiac injury to patients' outcomes.

The purpose of our study was to determine both the prevalence of myocardial injury as indicated by elevated serum levels of cTnI (≥ 0.3 ng/mL) and the impact of the injury on patients' outcomes after aSAH. The research questions were as follows:

- What is the prevalence of cTnI levels of 0.3ng/mL or greater in patients within 5 days of aSAH?
- Does a relationship exist between cTnI levels of 0.3 ng/mL or greater within 5 days of aSAH and patients' characteristics (age, sex, race, neurological status on hospital admission) and aSAH severity according to symptom findings as indicated by the Hunt/Hess grade and the amount of bleeding evident on computed tomography scans as indicated by the Fisher grade?
- Does a relationship exist between elevated cTnI levels and poor functional recovery and more functional disability 3 months after an aSAH?

Myocardial injury after aneurysmal subarachnoid hemorrhage may be due to excess catecholamines.

Methods

Patient Population and Design

This prospective, longitudinal study was conducted on the neurosurgical intensive care unit at the University of Pittsburgh Medical Center in Pittsburgh, Pennsylvania. Patients were recruited from May 2004 to January 2007. Inclusion criteria were age 18 to 75 years, admission to the neurovascular intensive care unit, diagnosis of aSAH by computed tomography or digital subtraction angiography (0-12 hours after admission and diagnosis determined after review by both the case radiologist and neurosurgeon), and severe aSAH signs and symptoms as indicated by a Hunt/Hess grade of 3 or greater and/or a Fisher grade of 2 or greater (evaluated on admission to the emergency department; score assigned by the neurosurgeon).^{8,9} patients were excluded if they had preexisting neurological deficits or SAH due to trauma or arteriovenous malformation, severe renal insufficiency/disease, or a recent history of myocardial infarction before the aneurysmal event. patients or their proxies were approached for participation in the study, and consent was obtained as approved by the appropriate institutional review board.

No consensus has been reached about the relationship of myocardial injury after hemorrhage to patients' outcomes.

Clinical Management

All patients with aSAH were managed according to local practice guidelines based on national standards for aSAH patients and the protocol of the neurovascular intensive care unit. Aneurysms were secured in the operating room by placement of surgical clips or in the interventional radiology suite by using an endovascular coil and embolization.

Three-month functional outcomes were assessed with the Glasgow Outcome Scale and the Modified Rankin Scale.

Data Elements and Collection

Clinical data were acquired from the medical records by trained research staff members, who used standardized data forms. Demographic information included age, race, sex, and previous medical history. A physician assigned the admission score on the Glasgow Coma Scale (GCS), and aSAH severity as indicated by the Hunt/Hess and Fisher grade scores. The GCS is a standard neurological scale used to describe the conscious state of a patient; scores range from 3 to 15. A GCS score of 13 or greater correlates with mild brain injury; 9 to 12, moderate brain injury; and 8 or less, severe brain injury.¹⁰ The Hunt/Hess grade is based on the severity of signs and symptoms: 0 = unruptured aneurysm; 1 = symptomatic, mild headache or slight nuchal rigidity; 2 = moderate to severe headache with nuchal rigidity and no neurological deficit other than cranial nerve palsy; 3 = drowsiness, confusion, mild focal neurologic deficit; 4 = stupor, moderate to severe hemiparesis, and early decerebrate posturing; and 5 = deep coma with decerebrate posturing or moribund appearance.¹¹ The Fisher grade indicates the degree of blood evident on computed tomography scans: 0 = no scan done; 1 = no blood detected; 2 = diffuse or vertical layers of blood 1 mm or thicker; 3 = localized clot and/or vertical layers of blood 1 mm or thicker; and 4 = diffuse or no SAH but intraventricular or intraparenchymal clot.⁹

Myocardial injury was indicated by levels of cardiac troponin I exceeding 0.3 ng/mL in 33.5% of patients.

Consistent with the standard of care on the neurological intensive care unit, all patients with aSAH had blood samples collected on admission and then daily (between 7 and 9 AM). Serum samples were analyzed for cTnI levels for 0 to 5 days after the initial aSAH injury by using a standard fluorescent enzyme immunoassay (Bayer Heath Care, Tarrytown, New York) at the health center laboratory, which meets cTnI quality control extraction procedures set by the American Association of Laboratory Measurements and Standards. Cardiac TnI is considered to have equal sensitivity but greater specificity for myocardial injury than creatine kinase MB levels.¹² The Bayer cTnI assay can detect myocardial cellular disruption with 88% sensitivity and 75% specificity.¹³ The laboratory detection limit of cTnI is 0.08 ng/mL. The peak cTnI value obtained for each patient was used for analysis; an indication of myocardial injury was defined as a peak cTnI level of 0.3 ng/mL or greater according to the local clinical standard for injury.¹⁴ Cut points of cTnI of 0.3 to 0.4 ng/mL have been used by other researchers^{5,15} as an indication of myocardial injury.

The 3-month functional outcomes were evaluated by patient interview (face to face or by telephone) by using the Glasgow Outcome Scale (GOS) for perception of functional recovery and the Modified Rankin Scale (MRS) for perception of functional disability. The GOS is used for self-appraisal of functional recovery after brain injury. It complements the GSC and has 5 levels: 1 = death, 2 = persistent vegetative state, 3 = severely disabled, 4 = moderately disabled, and 5 = good recovery.⁸ Interrater reliability for the GOS in a structured interview format is $\kappa = 0.92$.¹⁶

The MRS is used for self-appraisal of functional disability and includes both mental and physical adaptations. It is widely used in stroke trials and contains 6 levels: 0 = no symptoms at all, 1 = no significant disability despite symptoms, 2 = slight disability (unable to perform all activities), 3 = moderate disability (able to walk without assistance), 4 = moderate severe disability (unable to walk without assistance), 5 = severe disability (bedridden, incontinent, in nursing home), and 6 = death.¹⁷ Interrater reliability for the MRS in a structured interview format is $\kappa = 0.81$, $\kappa(w) \geq 0.94$.¹⁸ If patients were unable to complete the interview, a family member or caregiver answered the questions.

Statistical Analysis

SPSS, version 16.0 (SPSS Inc, Chicago, Illinois), was used for data analysis. After data screening, assessments of missing values and remedial efforts such as a review of an individual patient's medical record to resolve data discrepancies, descriptive statistics, measures of central tendency, dispersion, distribution, and correlation were generated for each patient's demographic and clinical parameters. These measures were used to assess group size and characterize the demographics (age, sex, race, cardiovascular comorbid conditions) of patients in the sample. Univariate analyses were performed for demographic and clinical parameters by using the χ^2 test of independence or the Fisher exact test for categorical variables and a *t* test for continuous variables.

The severity of injury and 3-month outcomes were dichotomized for statistical analysis.¹⁹ Hunt/Hess grades were coded as less severe aSAH (grades 1-2) and severe aSAH (grades 3-5). Fisher grades were coded as less severe aSAH (grades 1-2) and severe aSAH (grades 3-4). GOS was coded as good (GOS 4-5) and poor (GOS 1-3) functional recovery. MRS functional disability was coded as good (MRS 1-3) and poor (MRS 4-6). A hierarchical binary logistic regression was performed by using the stepwise method with the following order pattern: cTnI 0.3 ng/mL or greater, Hunt/Hess grade, race, sex, and age. A *P* value less than .05 was considered significant in all analyses.

Results

We enrolled 239 aSAH patients. The total sample was primarily female (72%, *n* = 172) and white (89.5%, *n* = 214), with a mean age of 54.4 years (SD, 11.1; range, 24-82).

Prevalence of cTnI of 0.3 ng/mL or Greater Within 5 Days of an aSAH

The mean peak cTnI level for the entire sample was 1.53 ng/mL (SD, 4.7). A total of 80 patients (33.5%) had myocardial injury as indicated by cTnI of 0.3 ng/mL or greater, whereas 159 patients (66.5%) had cTnI less than 0.3 ng/mL (odds ratio, 1.7; 95% confidence interval, 0.7-3.6; *P* = .24).

Relationship Between cTnI Levels, Patient Characteristics, and aSAH Severity

The demographics and characteristics of the 239 patients are presented in Table 1. A significant relationship existed between cTnI of 0.3 ng/mL or greater and age ($\geq$ cTnI 0.3 ng/mL, 53.61 years [SD, 10.3] vs cTnI <0.3 ng/mL, 58.0 years [SD, 11.3]; *P* = .004) but not between cTnI of 0.3 ng/mL or greater and sex (*P* = .90) or race (*P* = .29). Patients with cTnI of 0.3 ng/mL or greater had a lower mean admission GCS score indicative of a more severe injury (GCS score, 10.4; SD, 4.47) than did patients with cTnI less than 0.3 ng/mL (GCS score, 13.38; SD, 2.98; *P* < .001). For aSAH severity indicated by Hunt/Hess grade, 80% of patients with cTnI of 0.3 ng/mL or greater and 48% of patients with cTnI less than 0.3 ng/mL were in the more severe category (*P* < .001). A total of 85% of patients with cTnI of 0.3 ng/mL or greater and 66% of patients with cTnI less than 0.3 ng/mL had more severe aSAH

as indicated by Fisher grades ($P = .002$). Few patients in either group had a history of coronary artery disease (cTnI ≥ 0.3 ng/mL, 7% vs cTnI < 0.3 ng/mL, 3%; $P = .12$).

A cardiac troponin I level exceeding 0.3 ng/mL is a significant predictor of poorer functional outcome.

Relationship Between cTnI Levels and Functional Recovery and Functional Disability

Functional outcome data at 3 months were available for only 203 patients; of these 143 (70%) had cTnI of 0.3 ng/mL or greater, and 60 (29%) had cTnI less than 0.3 ng/mL. A total of 35 patients did not have outcome data because they withdrew from the study or could not be contacted for the 3-month outcome assessment.

At 3 months, 47% of patients with cTnI of 0.3 ng/mL or greater and 22% with cTnI less than 0.3 ng/mL reported poorer functional recovery as indicated by GOS scores ($P < .001$; Table 2). Similarly, when MRS scores were used to denote functional disability, 45% of patients with cTnI of 0.3 ng/mL or greater and only 18% with cTnI less than 0.3 ng/mL perceived that they had a poor outcome ($P < .001$).

Hierarchical binary logistic regression method (Table 3) revealed that even when adjustments were made for the severity of bleeding variables, race, sex, and age, cTnI levels of 0.3 ng/mL or greater remained a significant predictor of poorer functional outcome as indicated by the GOS score (odds ratio, 2.7; 95% confidence interval, 1.2-5.8; $P = .01$), and more severe functional disability by the MRS score (odds ratio, 2.2; 95% confidence interval, 1.0-4.6; $P = .04$).

Discussion

Myocardial injury and dysfunction after SAH has become a major phenomenon of interest recently.^{20,21} Our findings corroborate the results of other investigators^{7,22} who also found a high prevalence of elevated cTnI after aSAH. Tung et al⁷ found a prevalence of 20% in 223 patients when a cTnI cut point of 1.0 ng/mL was used. In a sample of 83 patients, Ramappa et al²² found a prevalence of 37% when a cTnI cut point of 2.0 ng/mL was used. Thus, although results between studies vary somewhat, the common finding is that elevations in markers of myocardial injury occur quite commonly after aSAH; we confirmed this finding in the largest sample of patients.

In our sample, patients with cTnI of 0.3 ng/mL or greater were slightly older (58 years) than patients with cTnI less than 0.3 ng/mL (53 years), a finding that has been documented in other studies^{23,24} of aSAH patients with myocardial injury. Of interest, however, despite the statistical difference in ages between our groups, overall our patients were still younger than those who typically have myocardial injury due to coronary artery disease.²⁵ In addition, in our sample, few patients in either group had a history of coronary artery disease. These findings lend credence to the hypothesis that a mechanism other than coronary ischemia is responsible for the myocardial cellular damage. Like other researchers,^{2,7,26} we did not find a difference between myocardial injury after aSAH by either sex or race. Nevertheless, our sample size is the largest in which these specific patient characteristics were examined and therefore provides a stronger determination of these specific results.

Patients with elevated cTnI had more severe aSAH symptoms as indicated by the Hunt/Hess grade and a greater amount of bleeding as indicated by the Fisher grade. Although most current researchers did not use both the Hunt/Hess and Fisher grade scales as primary evaluative tools, our finding corroborates those of both Tung et al⁷ and Banki et al.⁵ Possibly, the hypothesized catechol amine surge with aSAH is incrementally related to the severity of injury. However, the exact physiological mechanism for myocardial cellular

disruption, with worsening related to aSAH severity, is still unknown. Coronary artery occlusion or spasm probably is not the cause, because previous studies of abnormalities in ventricular wall motion indicated that the pattern of damage is not in the distribution of the coronary arteries.²⁷ Also, some patients do not have elevated cTnI. We found elevated cTnI levels in only one-third of our patients. If, as the literature suggests, the damage is due to myocardial cellular disruption as a consequence of a massive catecholamine surge at the time of aneurysmal rupture, then the dissimilarity in patients' responses may be due to the variation in patients' sensitivity to catecholamine and warrants further exploration.

Interestingly, elevated cTnI also has been linked to poorer outcomes in patients with intracerebral hemorrhage and ischemic stroke.²³ Elevated cTnI also has been found in the following conditions without any indication of overt ischemic cardiac disease: trauma, noncardiac surgery without complications, renal failure, severe asthma, drug intoxication, inflammatory disease, burns, and transplant-related vasculopathy.²⁸ This information suggests that several pathophysiological processes that have a stress state in common can produce myocardial cellular disruption.

Our study is unique because we evaluated functional recovery and disability in all aSAH subjects at 3 months, not just at hospital discharge. We found a similar relationship between cardiac injury and poor functional recovery and functional disability in an earlier study²⁹ we conducted with a much smaller sample size. We now report that the same findings are upheld with a much larger sample size.

Poor Hunt/Hess grades have been correlated with poor outcomes in aSAH patients. In our large sample we found that cTnI of 0.3 ng/mL or greater is an independent predictor of poorer functional outcomes even after adjustments for other potentially confounding factors such as race, sex, age, and, most importantly, aSAH severity. Strikingly, our patients with elevated cTnI had nearly a 3-fold greater risk for poorer functional recovery and a 2-fold greater risk for more functional disability than did those without elevated cTnI, and these risks were independent of aSAH severity. Schuiling et al²⁴ also found that aSAH patients with elevated cTnI had poorer neurological outcomes at 3 months than did patients without elevated troponin levels, although the tool used in that study was the World Federation of Neurological Surgeons scale, and the sample was much smaller (n = 68). In a sample of 180 patients, only slightly smaller than our sample of 203, Naidech et al³ also found that compared with patients without elevated cTnI, those with elevated cTnI had more 3-month functional disability according to MRS scores. Therefore, we join Naidech in confirming that in studies with a large sample size, elevated cTnI is independently predictive of more severe disability at 3 months, even when the aSAH severity is taken into account.

Nevertheless, the exact mechanism by which elevated cTnI contributes to these poorer outcomes remains unclear. Some evidence³⁰ suggests that elevated cTnI after aSAH is related to cardiac arrhythmia, including ventricular arrhythmia, as well as abnormalities in ventricular wall motion. Although the degree of both arrhythmia and wall motion abnormality is generally modest, these factors singly or in concert may contribute to the functional outcomes we noted, and further study is indicated to explore both causation and consequences of elevated cTnI further.

Myocardial injury occurs commonly in patients without cardiac history after aneurysmal subarachnoid hemorrhage.

Study Limitations

Our study had several limitations. We used reports from the medical records of previous medical conditions, and we did not actually measure or physiologically corroborate the

presence or absence of these conditions. We did not have outcome data on the full sample of 239 patients; nevertheless, the proportion of patients in the regression analysis with elevated cTnI was still similar (33% for 239 patients and 29% for the 203 patients in the outcome analysis) and the sample size was large. Therefore, having outcome data on the full complement of patients probably would not have altered the findings. Furthermore, our data were collected in a single center. The most notable limitation could be that our outcomes of functional status are based on the patients' self-perception of disability rather than on an objective evaluation by a researcher. Nevertheless, a patient's own perception of the disability imposed by aSAH may be as important as, if not more important than, those assigned by an observer, because the perception provides information about how aSAH has affected the patient's outlook and situation. Lastly, linking elevated cTnI to other indicators of cardiac function would have been helpful but was beyond the scope of this study.

Myocardial injury is associated with both severity of the aneurysmal subarachnoid hemorrhage and poorer patient outcomes.

Conclusion

Our findings indicate that myocardial injury, as indicated by elevated cTnI levels, occurs quite commonly in aSAH patients who are relatively young and have no history of cardiac disease. Thus, we recommend that nurses caring for aSAH patients be cognizant of the independent role that neurocardiac injury has on patients' outcomes and the importance of monitoring for neurocardiac injury during the acute phase of aSAH. Elevations in cTnI may alert nurses to aSAH patients who are at risk for poorer functional recovery and more severe functional disability. We suggest that cTnI measurement should become a standard practice in the treatment of patients with aSAH. In addition, further research is needed to investigate and identify the mechanistic links between elevated cTnI and poorer function after aSAH in order to develop effective cardioprotective care.

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References

1. Suarez JJ, Tarr RW, Selman WR. Aneurysmal subarachnoid hemorrhage. *N Engl J Med*. 2006; 354(4):387–396. [PubMed: 16436770]
2. Parekh N, Venkatesh B, Cross D, et al. Cardiac troponin I predicts myocardial dysfunction in aneurysmal subarachnoid hemorrhage. *J Am Coll Cardiol*. 2000; 36(4):1328–1335. [PubMed: 11028491]
3. Naidech AN, Kreiter KT, Janjua N, et al. Cardiac troponin elevation, cardiovascular morbidity, and outcome after subarachnoid hemorrhage. *Circulation*. 2005; 112(18):2851–2856. [PubMed: 16267258]
4. Smith M. Intensive care management of patients with subarachnoid haemorrhage. *Curr Opin Anesthesiol*. 2007; 20:400–407.
5. Banki N, Kopelnik A, Dae M, et al. Acute neurocardiogenic injury after subarachnoid hemorrhage. *Circulation*. 2005; 112:3314–3319. [PubMed: 16286583]
6. Macmillan CSA, Grant IS, Andrews PJD. Pulmonary and cardiac sequelae of subarachnoid haemorrhage: time for active management. *Intensive Care Med*. 2002; 28(8):1012–1023. [PubMed: 12185419]
7. Tung P, Kopelnik A, Banki N, et al. Predictors of neurocardiogenic injury after subarachnoid hemorrhage. *Stroke*. 2004; 35:548–553. [PubMed: 14739408]

8. Rosen DS, Macdonald RL. Subarachnoid hemorrhage grading scales: a systematic review. *Neurocrit Care*. 2005; 2:110–118. [PubMed: 16159052]
9. Smith ML, Abrahams JM, Chandela S, et al. Subarachnoid hemorrhage on computed tomography scanning and the development of cerebral vasospasm: the Fisher grade revisited. *Surg Neurol*. 2005; 63:229–235. [PubMed: 15734507]
10. McNett M. A review of the predictive ability of Glasgow Coma Scale in head-injured patients. *J Neurosurg Nurs*. 2007; 39:68–75.
11. Hunt WE, Hess RM. Surgical risk as related to time of intervention in the repair of intracranial aneurysms. *J Neurosurg*. 1968; 28:14–20. [PubMed: 5635959]
12. Dixit S, Castle M, Velu RP, et al. Cardiac involvement in patients with acute neurologic disease. *Arch Intern Med*. 2000; 160:3153–3158. [PubMed: 11074746]
13. Wu AH, Agee SJ, Lu QA, Todd J, Jaffe AS. Specificity of a high-sensitivity cardiac troponin I assay using single-molecule-counting technology. *Clin Chem*. 2009; 55(1):196–198. [PubMed: 19106190]
14. Christenson RH, Duh SH, Apple FS, et al. Toward standardization of cardiac troponin I measurements, II: assessing commutability of candidate reference materials and harmonization of cardiac troponin I assays. *Clin Chem*. 2006; 52:1685–1692. [PubMed: 16858078]
15. Horowitz MB, Willet D, Keffer J. The use of cardiac troponin-I (cTnI) to determine the incidence of myocardial ischemia and injury in patients with aneurysmal and presumed aneurysmal subarachnoid hemorrhage. *Acta Neurochir*. 1998; 140:87–93.
16. Pettigrew LE, Wilson JT, Teasdale GM. Reliability of ratings on the Glasgow Outcome Scale from in-person and telephone structured interviews. *J Head Trauma Rehabil*. 2003; 18(3):252–258. [PubMed: 12802167]
17. Wilson JTL, Hareendran A, Hendry A, et al. Reliability of the Modified Rankin Scale across multiple raters: benefits of a structured interview. *Stroke*. 2005; 36:777–781. [PubMed: 15718510]
18. Wilson JTL, Hareendran A, Grant M, et al. Improving the assessment of outcomes in strokes: use of a structured interview to assign grades on the Modified Rankin Scale. *Stroke*. 2002; 33:2243–2246. [PubMed: 12215594]
19. Staub F, Graf R, Gabel P, Köchling M, Klug N, Heiss WD. Multiple interstitial substances measured by microdialysis in patients with subarachnoid hemorrhage. *Neurosurgery*. 2000; 47(5):1106–1116. [PubMed: 11063103]
20. Urbaniak K, Merchant AI, Amin-Hanjani S, Roitberg B. Cardiac complications after aneurysmal subarachnoid hemorrhage. *Surg Neurol*. 2007; 67(1):21–29. [PubMed: 17210289]
21. Kopelnik A, Fisher L, Miss JC, et al. Prevalence and implications of diastolic dysfunction after subarachnoid hemorrhage. *Neurocrit Care*. 2005; 3(2):132–138. [PubMed: 16174882]
22. Ramappa P, Thatai D, Coplin W, et al. Cardiac troponin I: a predictor of prognosis in subarachnoid hemorrhage. *Neurocrit Care*. 2008; 8(3):398–403. [PubMed: 18087680]
23. Saddhu R, Aaron WS, Rajdev A, et al. Relation of cardiac troponin I levels with in-hospital mortality in patients with ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage. *Am J Cardiol*. 2008; 102(5):632–634. [PubMed: 18721527]
24. Schuiling WJ, Dennesen PJ, Tans JT, Kingma LM, Algra A, Rinkel GJ. Troponin I in predicting cardiac or pulmonary complication and outcome in subarachnoid haemorrhage. *J Neurol Neurosurg Psychiatry*. 2005; 76(11):1565–1569. [PubMed: 16227553]
25. Anand SS, Islam S, Rosengren A, et al. INTERHEART Investigators. Risk factors for myocardial infarction in women and men: insights from the INTERHEART study. *Eur Heart J*. 2008; 29(7):932–940. [PubMed: 18334475]
26. Macrea LM, Tamer MR, Walder B. Spontaneous subarachnoid hemorrhage and serious cardiopulmonary dysfunction—a systematic review. *Resuscitation*. 2005; 65:139–148. [PubMed: 15866393]
27. Tanabe M, Crago EA, Suffoletto MS, et al. Relation of elevation in cardiac troponin I to clinical severity, cardiac dysfunction, and pulmonary congestion in patients with subarachnoid hemorrhage. *Am J Cardiol*. 2008; 102:1545–1550. [PubMed: 19026312]

28. Babuin L, Jaffe AS. Troponin: the biomarker of choice for the detection of cardiac injury [published corrections appear in *CMAJ*. 2005;173(12):1490 and 2006;174(3):353]. *CMAJ*. 2005; 173(10):1191–1202. [PubMed: 16275971]
29. Crago EA, Kerr ME, Kong Y, et al. The impact of cardiac complications on outcome in the SAH population. *Acta Neurol Scand*. 2004; 110(4):248–253. [PubMed: 15355489]
30. Frangiskakis JM, Hravnak M, Crago EA, et al. Ventricular arrhythmia risk after subarachnoid hemorrhage. *Neurocrit Care*. 2009; 10(3):287–294. [PubMed: 19184553]

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Table 1
Demographic and clinical characteristics of 239 patients with aneurysmal subarachnoid hemorrhage^a

Characteristic	Cardiac troponin I, ng/mL			P
	<0.3 (n = 159)	≥0.3 (n = 80)	Statistic	
Age, mean (SD), y	53.61 (10.3)	58.0 (11.3)	$t_{237} = -2.946$	.004
Sex				
Female	114 (72)	58 (72)	$\chi^2_1 = 0.05$	.90
Male	45 (28)	22 (28)		
Race				
White	140 (88)	74 (92)	$\chi^2_1 = 1.1$	.29
African American	19 (12)	6 (8)		
Score on admission, Glasgow Coma Scale, mean (SD)	13.38 (2.98)	10.40 (4.47)	$t_{237} = 6.138$	<.001
Hunt/Hess grade				
Less severe (1 or 2)	83 (52)	16 (20)	$\chi^2_1 = 22.2$	<.001
More severe (3, 4, or 5)	76 (48)	63 (80)		
Fisher grade				
Less severe (0 or 1)	54 (34)	12 (15)	$\chi^2_1 = 9.4$	.002
More severe (2, 3, or 4)	104 (66)	67 (85)		
History of coronary artery disease	(n = 146)	(n = 68)		
No	142 (97)	63 (93)	$\chi^2_1 = 1.4$	.12
Yes	4 (3)	5 (7)		

^aValues are number of patients (%) unless otherwise indicated.

Table 2
Functional outcome 3 months after aneurysmal subarachnoid hemorrhage in 203 patients^a

	Cardiac troponin I, ng/mL			
Outcome measure	<0.3	≥0.3	Odds ratio (crude)	95% Confidence interval
Score on Glasgow Outcome Scale				
Good (4 or 5)	112 (78)	32 (53)	3.2	1.7-6.0
Poor (1, 2, or 3)	31 (22)	28 (47)		
Modified Rankin score				
Good (1, 2, or 3)	117 (82)	33 (55)	3.7	1.9-7.1
Poor (4, 5, or 6)	26 (18)	27 (45)		

^aValues are number of patients (%). Differences were significant at $P<.001$.

Table 3
Hierarchical binary logistic regression analysis at 3 months after aneurysmal subarachnoid hemorrhage in 203 patients

Variable	<i>P</i>	Odds ratio (adjusted)	95% Confidence interval
For poor functional outcome according to the Glasgow outcome scale			
Cardiac troponin I ≥ 0.3 ng/mL	.01	2.7	1.2-5.8
Hunt/Hess grade	<.001	14.1	4.9-41.1
Race	.007	0.2	0.1-0.6
Sex	.11	0.5	0.2-1.2
Age	.69	1.2	0.6-2.5
For more functional disability according to the modified Rankin Scale			
Cardiac troponin I ≥ 0.3 ng/mL	.04	2.2	1.0-4.6
Hunt/Hess grade	<.001	14.8	5.4-40.5
Race	.005	0.2	0.1-0.6
Sex	.06	0.5	0.2-1.0
Age	.45	1.3	0.6-2.8