Original Research Article

Association of serum cardiac Troponin I and short term outcome in patients with Subarachnoid Haemorrhage; a single center experience

ABSTRACT

Background: Subarachnoid hemorrhage (SAH) is a catastrophic neurological event, which is associated with significant medical complications. Cardiac troponin I release occurs frequently after SAH and has been associated with a neurogenic form of myocardial injury. The aim of the study was to find out the association of serum cardiac troponin I and short term outcome in patients with Subarachnoid haemorrhage.

Methods: This prospective observational study was carried out in the department of Neurology, Neurosurgery and Medicine in Dhaka Medical College & Hospital, Dhaka, Bangladesh from July, 2022 to June, 2024. A total of 95 patients suffering from subarachnoid haemorrhage confirmed by CT scan of head were included in this study. The patients were divided in to the Group I= SAH with cTnI <0.3 ng/ml; n=47 and Group II= SAH with cTnI ≥ 0.3 ng/ml; n=48 groups, according to Troponin I level measured within 72 hours after the incident.

Results: The mean age of study population in Group I and Group II were 50.51±9.13 vs 57.58±10.63 years (p=0.001). The mean GCS in Group I and Group II were 13.85±1.41 vs 12.20±2.68 (p=0.001). The mean Hunt and Hess scale were 2.55±0.65 vs 3.15±0.77 (p=0.001) in Group I and Group II respectively. The mean serum cardiac troponin I was 0.12±0.05 vs 0.65±0.36 (p=0.001) in Group I and Group II and 0.25±0.22 in independent, 0.35±0.24 dependent and 0.86±0.45 in death (p=0.001). Majority (83.0%) patients had good outcome in serum cardiac troponin I <0.30 and 57.4% in serum cardiac troponin I ≥0.30. The difference of was statistically significant between two groups and OR=3.79 with 95%CI 1.34-11.00 (p<0.05).

Conclusion: Measurements of serum troponin I reveal a higher incidence of myocardial injury in patients with SAH. Raised serum cardiac troponin I is associated with more severe neurological injury.

Key words: *Troponin I, short term outcome, Subarachnoid Haemorrhage*

Introduction:

Subarachnoid haemorrhage (SAH) is the bleeding in the subarachnoid space-the area between the arachnoid mater and the pia mater surrounding the brain. This may occur spontaneously, usually from a ruptured cerebral aneurysm or may result from head injury (Ropper and Samuels, 2009).It is a form of stroke and comprises 1 to 7 % of all strokes and affects about 6/100,000 of the population and women are affected more commonly than men, usually present before the age of 65 (Feigin et al. 2005; Colledge et al. 2010). Up to half of all cases are fatal and 10-15% dies before reaching to the hospital and those who survive often have neurological or cognitive impairment (Van Gijn et al. 2007; Suarez et al.2006). Ruptured "berry" aneurysm is the most common among the aneurysmal SAH and is responsible for 85% of cases (Colledge et al. 2010).

A wide variety of cerebral pathology, from acute ischemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage (SAH), or even rare entities such as transient global amnesia, has been associated with transient cardiac dysfunction with electrocardiographic (ECG) changes and simultaneous release of cardiac biomarkers (Murthy et al. 2014; Jalanko et al. 2015; Wybraniec et al. 2014). These two findings, as well as left ventricular systolic dysfunction, constitute cardiac abnormalities that have been reported after SAH (Kothavale et al. 2006). In the hours to days following SAH, excessive sympathetic activation can cause neurogenic stress cardiomyopathy, which is displayed by an increased cardiac troponin as a biomarker of cardiac injury (Zhang et al. 2015; Naidech et al. 2005). In up to half of all SAH patients, elevated troponins are reported and several studies have shown the prognostic relevance of elevated troponin early after admission for poor neurological outcome and mortality (Zhang et al. 2015; Naidech et al. 2005; Oras et al. 2015).

The connection between the central nervous system (CNS) and the heart was first described by Cushing at the turn of the previous century (Cushing, 1903). The mechanisms of cardiac dysfunction after SAH used to be controversial until recently (Kothavale et al. 2006). Historically, cardiac necrosis after SAH has been attributed to coronary artery disease, coronary vasospasm or oxygen supply-demand mismatch. Experimental evidence, however, indicated that excessive

release of norepinephrine from the myocardial sympathetic nerves was the most likely cause (Tung et al. 2004) .Now-a-days it was evident that acute left ventricular dysfunction associated with SAH can be the expression of a stress –related cardiomyopathy (Richard, 2011). Neurogenic stunned myocardium (also known as apical balloting syndrome or Takotsubo syndrome) is a frequent complication of SAH, with a significant impact on disease course. The presumed cause is catecholamine surge at the time of aneurysm rupture (Liang et al. 2013). A possible mechanism is that hypothalamic ischemia causes increased sympathetic tone and resultant catecholamine surge producing subendocardial ischemia or coronary artery vasospasm (Greenberg, 2006). The massive surge of catecholamines after SAH likely induces various degrees of cardiac injury, as evidenced by increased serum troponin levels, ECG changes and sometimes severe cardiac wall motion abnormalities (Eddleman et al. 2012).

Cardiac Troponin I release occurs frequently after SAH and has been associated with a neurogenic form of myocardial injury (Naidech et al. 2005; Spears et al. 2011). Elevated Troponin I has been reported in up to 68% of SAH patients (Spears et al. 2011). Troponin elevation, is an early and specific marker for cardiac involvement after SAH and its levels peak about two days after SAH (Ahmedian et al. 2013; Kumar et al. 2011). SAH is a relatively common neurological condition with high mortality and morbidity. About 10 to 15% patient had died before reaching to the hospital. Detection of elevated cardiac troponin I is appropriate to categorize the patients into high risk group. Multidisciplinary team management can reduce the mortality, morbidity and improved poor neurological outcome. Therefore, the aim of this study was to evaluate the association of serum cardiac Troponin I and short term outcome in patients with SAH in Dhaka Medical College Hospital, Dhaka, Bangladesh.

Materials and method:

This prospective observational study was carried out in the department of Neurology, Neurosurgery and Medicine in Dhaka Medical College & Hospital (DMCH), Dhaka, Bangladesh from July, 2022 to June, 2024. A total of 95 patients suffering from subarachnoid haemorrhage confirmed by CT scan of head were included in this study after purposive sampling. The patients were divided in to the Group I= SAH with cTnI <0.3 ng/ml; n=47 and Group II= SAH with cTnI ≥ 0.3 ng/ml; n=48 groups, according to Troponin I level measured within 72 hours after the incident.

Inclusion criteria:

1) Age > 18 year of both gender
2) Non traumatic SAH
3) Within 3 days after the onset of SAH
4) Patients willing to give informed written consent

Exclusion criteria:

1) Traumatic SAH.
2) Recurrent history of SAH.
3) History of myocardial Infarction, cardiac surgery within 3 months.
4) Intracerebral haemorrhage with ventricular extension, Subdural/ extradural haematoma and ischaemic stroke.
5) Patients on anticoagulant medications.

All patients with confirmed Subarachnoid haemorrhage (SAH) diagnosed by CT scan of head, admitted in the neurology, neurosurgery and medicine department of Dhaka Medical College and Hospital, Dhaka, who fulfill the inclusion and exclusion criteria were considered primarily for the study. The study protocol was approved by the Ethical Review Committee of DMCH. Informed written consent was taken from each patient or their legal guardian before enrollment. Meticulous history was taken and detailed clinical examination was performed and recorded in redesigned

structured format. Demographic data such as age, gender were recorded. Risk factors profile including hypertension, smoking, DM and previous history of IHD were noted. Laboratory investigation was done. Estimation of serum cardiac troponin I was performed with taking 3 ml blood, collected from each patient within 72 hours after the incident.

During hospitalization period every patients were treated by respective clinical experts of each department. During discharge, patients were examined and categorized as independent (0,1,2,3), dependent (4,5) and death (6) by using Modified Rankin scale (MRS).

The Modified Rankin Scale (MRS) is the most widely used outcome measure in stroke clinical trials.

0	No symptoms
1	No significant disability, despite symptoms; able to perform all usual duties and activities
2	Slight disability; unable to perform all previous activities but able to look after own affairs without assistance
3	Moderate disability; requires some help, but able to walk without assistance
4	Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe disability; bedridden, incontinent, and requires constant nursing care and attention
6	Death

Table-1: The Modified Rankin Scale (MRS)

This Modified Rankin scale (MRS) was categorized as two groups.

A) Those with good outcome (independent) MRS 0 to 3.

B) Those with poor outcome (dependent, MRS 4,5 and death, MRS 6).

Follow up was given at the end of 3 months either by direct examination or over telephone by using Modified Rankin scale (MRS) and categorized as good (independent-0,1,2,3) versus poor outcome (dependent-4,5 and death-6). At the end of 3 months during followed up, three patients from group I and two patients from group II had lost to follow up. So total study subjects were 95, in Group I =47 and Group II= 48.

The data obtained from the study was analyzed and significance of differences were estimated by using statistical methods. Quantitative variables were presented as mean±SD and analyzed using

student t-test or ANOVA test. Categorical variables were presented as frequency and percentages and analyzed using Chi-square test or Fisher exact test. Multivariate logistic regression analysis was performed to determine the independent predictors of poor outcome group. All statistical studies were carried out using the Statistical Package for Social Sciences (SPSS -22) software. Two tailed p values <0.05 were considered statistically significant.

Results:

A total of 95 patients suffering from subarachnoid haemorrhage confirmed by CT scan of head in the department of Neurology, Neurosurgery and Medicine of Dhaka Medical College & Hospital, Dhaka, from July, 2018 to June, 2020, were included in this study. It was observed that almost two third (61.6%) patients belonged to age <50 years in group I and 11(22.9%) in group II. The mean age was 50.51±9.13 years in group I and 57.58±10.63 years in group II. The difference was statistically significant (p<0.05) between two groups(Table-1). More than half 27(57.4%) patients were female in group I and 28(58.3%) in group II. The difference was statistically not significant (p>0.05) between two groups. Besides, more than one third 18(38.3%) patients had hypertension in group I and 29(60.4%) in group II. More than one third 16(34.0%) patients had smoker in group I and 20(41.7%) in group II. Five (10.6%) patients had diabetes mellitus in group I and 5(10.4%) in group II. Two (4.3%) patients had history of IHD in group I and 5(10.4%) in group II. The difference of hypertension was statistically significant (p<0.05) between two groups.

The mean GCS was 13.85±1.41 in group I and 12.20±2.68 in group II. The mean SBP was 149.79±20.56 mm of Hg in group I and 154.58±27.97 mm of Hg in group II. The mean DBP was 93.30±9.11 mm of Hg in group I and 96.56±16.22 mm of Hg in group II. The mean pulse was 73.98±5.67 per minute in group I and 74.83±10.43 per minute in group II. More than half (79%) patients had more severe in group II and 22(47%) in group I. The difference of GCS and Hunt and Hess scale were statistically significant (p<0.05) between two groups(table-2).

Examination findings	Group I (n=47)	Group II (n=48)	*p* value
GCS	13.85±1.41	12.20±2.68	0.003
SBP (mm of Hg)	149.79±20.56	154.58±27.97	0.923
DBP (mm of Hg)	93.30±9.11	96.56±16.22	0.344
Pulse (per minute)	73.98±5.67	74.83±10.43	0.231
Hunt and Hess scale			
Less severe (n%)	25(53.2%)	10(20.8%)	0.001
More severe(n%)	22(46.8%)	38(79.2%)	

Table 2: Distribution of the study patients by examination findings (n=95)

Almost two third (63.8%) patients had normal ECG finding in group I and 10(20.8%) in group II. The difference was statistically significant ($p<0.05$) between two groups. The mean serum cardiac troponin I was 0.12±0.05 in group I and 0.65±0.36 in group II. The RBG was 6.09±1.82 in group I and 9.94±3.17 in group II. The mean serum creatinine was 1.09±0.2 in group I and 1.14±0.18 in group II. The difference of serum cardiac troponin I was statistically significant ($p<0.05$) between two groups (table-3). The mean Serum cardiac troponin I was 0.24±0.21 in independent, 0.35±0.24 in dependent and 0.85±0.43 in death. The difference was statistically significant ($p<0.05$) among the groups.

ECG finding	Group-I (n=47)		Group-II (n=48)		*p* value
	n	%	n	%	
Normal	30	63.8	10	20.8	0.001[s]
Abnormal (T-wave inversion, ST-T change, Prolong QT, Arrythmia)	17	36.2	38	79.2	

Laboratory findings	Group I (n=47)	Group II (n=48)	*p* value
Serum cardiac troponin I (ng/ml)	0.12±0.05	0.65±0.36	0.001
RBG (mmol/L)	6.09±1.82	6.94±3.17	0.115
Serum creatinine (mg/dl)	1.09±0.2	1.14±0.18	0.203

Table-3: Investigation profile of the study population

It was observed that in Group I, majority (89.4%) patients belonged to independent in at discharge and 39(83.0%) in at 3 month according to modified Rankin Scale. In Group II, more than two third 33(68.7%) subjects were in the independent group during discharge and 27(56.3%) in at 3 month. But 18(37.5%) patients were in dead category according to MRS in Group-II after 3 months. The difference was statistically significant ($p<0.05$).

Modified Rankin Scale	**Group-I (n=47)**					**Group-II (n=48)**				
	At discharge		**At 3 month**		***p* value**	**At discharge**		**At 3 month**		***p* value**
	n	**%**	**n**	**%**		**n**	**%**	**n**	**%**	
Independent	42	89.4	39	83.0		33	68.7	27	56.3	
Dependent	4	8.5	5	10.6	0.543	9	18.8	3	6.3	0.008
Dead	1	2.1	3	6.4		6	12.5	18	37.5	

Table-4 Comparison of outcome assessed by Modified Rankin Scale (MRS) at discharge and at the end of 3 month (n=95)

21(44.7%) patients had poor outcome in serum in group –II (cardiac troponin I > 0.30) and only 8(17%) patients in group-I (serum cardiac troponin I <0.30). The difference of was statistically significant ($p<0.05$) between two groups.

Modified Rankin Scale (MRS)	**Serum cardiac troponin I**				**OR (95% CI)**	***p* value**
	Group-I (n=47)		**Group-II (n=48)**			
	n	**%**	**n**	**%**		
Good outcome	39	83.0	27	57.4	3.79(1.34-11.00)	0.005
Poor outcome	8	17.0	21	44.7		

Table-5 showing association between Modified Rankin Scale (MRS) and Serum cardiac troponin I of the study patients at the end of 3 months

Receiver-operator characteristic (ROC) was constructed using Serum cardiac troponin I had area under the curve 0.883, showed with a cut off value of >0.3 having 85.7% sensitivity and 72.0% specificity for prediction of death in patients with Subarachnoid Haemorrhage (Fig-1).

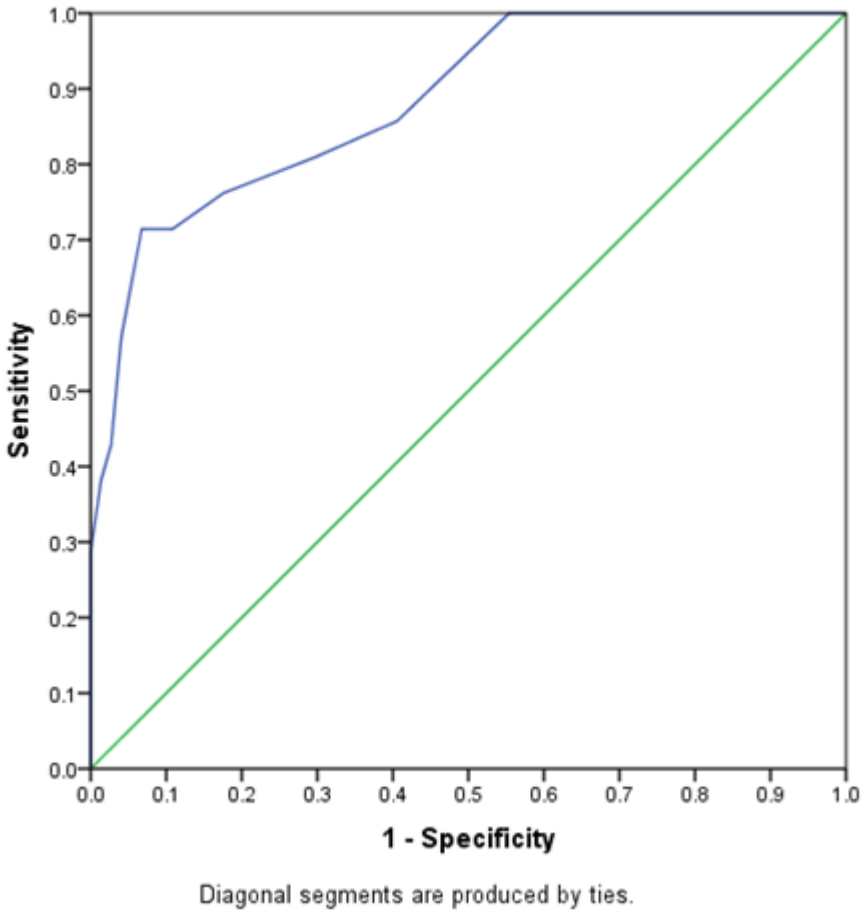

Fig-1: Receiver- operating characteristic (ROC) curve of serum cardiac troponin I for prediction of short term outcome in patients with Subarachnoid Haemorrhage

Multivariate logic regression analysis showed serum cardiac troponin I > 0.3 ng/ml, was significantly ($p<0.05$) associated with poor outcome (OR-2.29, 95% CI :1.73-23.27) in patients having Subarachnoid Haemorrhage (Table-6). Other parameters were not significantly associated with short term outcome ($p>0.05$).

	B	**S.E.**	**df**	***p* value**	**OR**	**95% C.I.**	
						Lower	**Upper**
Serum cardiac troponin I	29.400	8.24	1	0.001[s]	2.79	1.73	23.27
GCS	0.230	0.51	1	0.652 [ns]	1.26	0.46	3.43
Age (in years)	0.032	0.05	1	0.582[ns]	1.03	0.92	1.15
Hypertension	-2.280	1.56	1	0.143 [ns]	0.10	0.01	2.16
Hunt and Hess scale	-2.340	1.53	1	0.127 [ns]	0.09	0.01	1.93
ECG	0.430	0.61	1	0.352 [ns]	1.16	0.56	2.43

Table-6: Multivariate logistic regression analysis (n=95)

Discussion:

This cross sectional study was carried out with an aim to assess serum cardiac troponin I level after Subarachnoid haemorrhage (SAH) and to ascertain the mortality and morbidity in patients with Subarachnoid haemorrhage (SAH). This study also evaluates the association of serum cardiac troponin I and short term outcome in patients with subarachnoid haemorrhage (SAH) as well as to document the socio-demographic characteristics of the Subarachnoid haemorrhage (SAH) patients in our setting.

This study observed that the mean age was 50.51±9.13 vs 57.58±10.63 years in group I vs group II, which was significantly ($p<0.05$) higher in group II and that is similar with Miketic et al. (2010) study, where they found the mean age was 53.61±10.3 years in <0.3 and 58.0±11.3 years in≥ 0.3, that was also significantly ($p<0.05$) higher in patients with cTnI of 0.3 ng/mL or greater. The study found that 57.4% patients were female in group I and 58.3% in group II. Female patients were predominant in both groups, however, the difference was statistically not significant ($p>0.05$) between two groups. Similarly, Miketic et al. (2010) study observed that 72.0% patients female and 28.0% male were in cTnI <0.3 ng/ml, 72.0% female and 28.0% male were in cTnI ≥0.3 ng/ml respectively. In addition, the study deduced that 38.3% patients had hypertension in group I and 60.4% in group II. Hypertension was significantly ($p<0.05$) higher in group II. Naidech et al. (2005) also noticed, hypertension was significantly ($p<0.05$) higher in group II and elevated Troponin I may identify patients who are at increased risk for decompensation when hypertensive hypervolemic therapy is used.

The study also revealed that the mean GCS was 13.85±1.41 in group I and 12.20±2.68 in group II. The mean GCS was significantly ($p<0.05$) lower in group II. Miketic et al. (2010) study reported that patients with Troponin I of 0.3 ng/mL or greater had a lower mean admission GCS score(10.4±4.47) indicative of a more severe injury, than did patients with Troponin I less than 0.3 ng/mL GCS score(13.38±2.98; $P<0.05$), which is comparable with the current study.

The degree of neurological injury as measured by the Hunt-Hess grade which is a strong, independent predictor of myocardial necrosis after SAH, supporting the hypothesis that cardiac injury after SAH is a neurally mediated process (Tung et al. 2004). This study showed that 53.2%

patients had less severe in group I and 20.8% in group II. The difference was statistically significant ($p<0.05$) between two groups. Naidech et al. (2005) mentioned that admission clinical and radiographic variables predictive of increased peak troponin I levels included higher Hunt-Hess grade. The strong associations between the extent of troponin I elevation and various measures of SAH severity (e.g., Hunt-Hess grade) obtained by the authors. Ramappa et al. (2008) found Hunt and Hess scale significantly higher in group II.

The mean serum cardiac troponin I was 0.12±0.05 in group I and 0.65±0.36 in group II. The mean serum cardiac troponin I was significantly ($p<0.05$) higher in group II. A cardiac troponin I level >1.0 μg/L is independent predictor for the development of regional wall motion abnormalities, frequent after SAH (Kothavale et al. 2006). Thus left ventricular wall motion abnormalities seen on echocardiography are more common in patients with elevated troponin (Sakar et al. 2002).

This present study also demonstrated that the mean serum cardiac troponin I was 0.25±0.22 in independent, 0.35±0.24 dependent and 0.86±0.45 in death. The mean serum cardiac troponin I was significantly ($p<0.05$) higher in death patients. Receiver-operator characteristic (ROC) was constructed using serum cardiac troponin I had area under the curve 0.883, showed with a cut off value of >0.3 having 85.7% sensitivity and 72.0% specificity for prediction of death in patients with Subarachnoid Haemorrhage. Similarly, Miketic et al. (2010) study found poor outcome 45.0% in cardiac troponin I ≥0.3 ng/ml and 18.0% in cardiac troponin I <0.3 ng/ml ($p<0.05$). In another study Suwatcharangkoon et al. (2019) reported that treatment failure was associated with an increased risk of death or severe disability at 1 year modified Rankin Scale score of 4–6; 62.0% versus 25.0%; ($p<0.05$). In the same direction, Kumar et al. (2011) showed that neurological outcome was adversely related to increase in troponin I levels and Ahmadian et al. (2013) reported that associated levels of troponin I >1 μg/L are ten times higher risk of death.

In a large sample Miketic et al. (2010) found that 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, SAH severity. Strikingly, their patients with elevated cardiac troponin I 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 cardiac troponin I and these risks were independent of SAH severity which is consistent with this study.

There were some limitations of the study. It was a single centre study with a small sample size over a short period of time. Further large scale multicenter study should be done to obtain better results.

Conclusion:

The current study has showed significant association of serum cardiac troponin I and short term outcome in patients with Subarachnoid haemorrhage (SAH). Besides, elevations in serum cardiac troponin I is an independent predictor for poorer functional recovery and more severe functional disability who suffers from SAH. That's why the current study recommends that serum cardiac troponin I measurement should become a standard practice in the treatment of patients with SAH.

Disclaimer (Artificial intelligence):

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT:

Patient's informed written consent was taken to publish her case for academic purpose.

ETHICAL APPROVAL:

As per international standards or university standards written ethical approval has been collected from Institutional ethical committee and preserved by the authors.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References:

Ahmadian, A., Mizzi, A., Banasiak, M., Downes, K., Camporesi, E.M., Sullebarger, J.T., Vasan, R., Mangar, D., van Loveren, H.R. and Agazzi, S., 2013. Cardiac manifestations of subarachnoid hemorrhage. Heart, lung and vessels, 5(3), pp.168-178.

Colledge, N.R., Walker, B.R. and Ralston, S.R., 2010. Subarachnoid haemorrhage in Davidson's Principle and Practice of Medicine. 21st ed. London: Elsevier, pp.1190-1191.

Cushing, H., 1903. The blood-pressure reaction of acute cerebral compression, illustrated by cases of intracranial hemorrhage. The American Journal of the Medical Sciences (1827-1924), 125(6), p.1017.

Eddleman, C.S., Getch, C.C., Bendok, B.R. and Batjer, H.H., 2012. Intracranial aneurysms. In: Ellenbogen RG, Abdulrauf SI, Sekhar LN, editors. Principles of neurological surgery. 3rded. Philadelphia: Saunders (Elsevier) p.214.

Feigin, V.L., Rinkel, G.J., Lawes, C.M., Algra, A., Bennett, D.A., van Gijn, J. and Anderson, C.S., 2005. Risk factors for subarachnoid hemorrhage: an updated systematic review of epidemiological studies. Stroke, 36(12), pp.2773-2780.

Jalanko, M., Forsström, F. and Lassus, J., 2015. Cardiac troponin T elevation associated with transient global amnesia: another differential diagnosis of 'troponosis'. European Heart Journal: Acute Cardiovascular Care, 4(6), pp.561-564.

Greenberg, M.S., 2006. Handbook of neurosurgery. 6thed. New York: Thieme Medical Publishers, p.789.

Kothavale, A., Banki, N.M., Kopelnik, A., Yarlagadda, S., Lawton, M.T., Ko, N., Smith, W.S., Drew, B., Foster, E. and Zaroff, J.G., 2006. Predictors of left ventricular regional wall motion abnormalities after subarachnoid hemorrhage. Neurocritical Care, 4(3), pp.199-205.

Kumar, P.V., Vannemreddy, P., Kumar, D., Nanda, A. and Reddy, P., 2011. Cardiac troponin I levels are a marker of myocardial dysfunction in subarachnoid hemorrhage and predicts poor

neurologic outcome. The Journal of the Louisiana State Medical Society: official organ of the Louisiana State Medical Society, 163(5), pp.257-260.

Liang, C.W., Chen, R., Macri, E. and Naval, N., 2013. Preadmission beta-blockers are associated with decreased incidence of neurogenic stunned myocardium in aneurysmal subarachnoid hemorrhage. Journal of Stroke and Cerebrovascular Diseases, 22(5), pp.601-607.

Oras, J., Grivans, C., Bartley, A., Rydenhag, B., Ricksten, S.E. and Seeman-Lodding, H., 2015. Elevated high-sensitive troponin T on admission is an indicator of poor long-term outcome in patients with subarachnoid haemorrhage: a prospective observational study. Critical care, 20(1), p.11.

Miketic, J.K., Hravnak, M., Sereika, S.M. and Crago, E.A., 2010. Elevated cardiac troponin I and functional recovery and disability in patients after aneurysmal subarachnoid hemorrhage. American Journal of Critical Care, 19(6), pp.522-528.

Murthy, S.B., Shah, S., Rao, C.P.V., Suarez, J.I. and Bershad, E.M., 2014. Clinical characteristics of myocardial stunning in acute stroke. Journal of Clinical Neuroscience, 21(8), pp.1279-1282.

Naidech, A.M., Kreiter, K.T., Janjua, N., Ostapkovich, N.D., Parra, A., Commichau, C., Fitzsimmons, B.F.M., Connolly, E.S. and Mayer, S.A., 2005. Cardiac troponin elevation, cardiovascular morbidity, and outcome after subarachnoid hemorrhage. Circulation, 112(18), pp.2851-2856.

Ramappa, P., Thatai, D., Coplin, W., Gellman, S., Carhuapoma, J.R., Quah, R., Atkinson, B. and Marsh, J.D., 2008. Cardiac troponin-I: a predictor of prognosis in subarachnoid hemorrhage. Neurocritical Care, 8(3), pp.398-403.

Ropper, A.H. and Samuels, M.A., 2009. Cerebrovascular disease in Adams and Victor's Principles of Neurology. 9th ed. New york: McGraw- Hill, p.808-809.

Richard, C., 2011. Stress-related cardiomyopathies. Annals of intensive care, 1(1), p.39.

Sarker, A., Hoque, M.A., Khan, M.M.R., Rahman, M.K., Alam, S.M., Majumder, S., Sardar, M.A.H. and Hasan, M.A., 2014. Troponin I Changes in Patients with Subarachnoid Hemorrhage. TAJ: Journal of Teachers Association, 27(2), pp.39-43.

Spears, J., Macdonald, R.L. and Weir, B., 2011. Perioperative management of Subarachnoid Hemorrhage. In: Winn HR, editor. Youmans Neurological Surgery. 6thed. Vol. 4. Philadelphia: Saunders (Elsevier); p.3785-3786.

Suarez, J.I., Tarr, R.W. and Selman, W.R., 2006. Aneurysmal subarachnoid hemorrhage. New England Journal of Medicine, 354(4), pp.387-396.

Suwatcharangkoon, S., De Marchis, G.M., Witsch, J., Meyers, E., Velazquez, A., Falo, C., Schmidt, J.M., Agarwal, S., Connolly, E.S., Claassen, J. and Mayer, S.A., 2019. Medical treatment failure for symptomatic vasospasm after subarachnoid hemorrhage threatens long-term outcome.Stroke, 50(7), pp.1696-1702.

Tung, P., Kopelnik, A., Banki, N., Ong, K., Ko, N., Lawton, M.T., Gress, D., Drew, B., Foster, E., Parmley, W. and Zaroff, J., 2004. Predictors of neurocardiogenic injury after subarachnoid hemorrhage. Stroke, 35(2), pp.548-551.

Van Gijn, J., Kerr, R.S. and Rinkel, G.J., 2007. Subarachnoid haemorrhage. The Lancet, 369(9558), pp.306-318.

Wybraniec, M.T., Mizia-Stec, K. and Krzych, Ł., 2014. Neurocardiogenic injury in subarachnoid hemorrhage: A wide spectrum of catecholamin-mediated brain-heart interactions. Cardiology Journal, 21(3), pp.220-228.

Zhang, L., Wang, Z. and Qi, S., 2015. Cardiac troponin elevation and outcome after subarachnoid hemorrhage: a systematic review and meta-analysis. Journal of Stroke and Cerebrovascular Diseases, 24(10), pp.2375-2384.