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*Original Research Article*

# Do Troponin Titter and CK-MB Predict Severity and In-Hospital Mortality in Patients with Ischemic Stroke?

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**Abstract**

**Elevation of serum cardiac troponin is a specific marker of the acute coronary syndrome. Serum troponin titer can be elevated in patients with acute ischemic stroke, but its clinical implications remain unclear. Several mechanisms can result in elevated serum troponin levels during the early phase of ischemic strokes, such as primary myocardial injury with secondary cardioembolic cerebral ischemia or primary cerebral ischemia with secondary myocardial damage attributable to activation of the sympathoadrenal system. CK-MB is an enzyme found primarily in the heart muscle but also in the tongue, diaphragm, uterus, prostate, and skeletal muscle. It is considered an important marker for acute myocardial infarction, but it has not been thoroughly studied in stroke. The literature shows insufficient data regarding the association and prediction of morbidity and mortality following acute ischemic stroke and serum cardiac markers. This study aims to measure serum troponin and CK-MB levels in patients with acute stroke and their relation to stroke severity and hospital mortality. An eleven-month cross-sectional study on 100 patients was done in Basrah Teaching Hospital from February to December 2018, involving acute ischemic stroke patients in the neurological and medical wards who presented within 24 hours. Serum troponin and CK-MB titers were measured; a brain CT scan was done to diagnose ischemic stroke. Out of 100 patients, 14 (14%) had a positive troponin titer, 29 (29%) had a positive CK-MB, and ten (10%) had a severe stroke based on their NIHSS score at admission. Those with severe stroke were (60%) and (70%) positive for troponin titers and CK-MB, respectively, with a mortality rate of 40%. The study concludes that serum troponin titer and CK-MB are significantly associated with the severity and mortality of acute ischemic stroke.**

**Keywords:** CKMB, Ischemic stroke, Serum troponin titer

## INTRODUCTION

Stroke is the leading cause of disability worldwide, the second most common cause of dementia, the third leading cause of death worldwide (Bakhai, 2004), and the fifth leading cause of death in the United States (Towfighi and Saver, 2011). Each year, approximately 795,000 people in the United States experience a new (610,000 people) or recurrent (185,000 people) stroke (Mozaffarian et al., 2015). It has enormous clinical, social, and economic implications. It demands a significant effort from both basic scientists and clinicians to understand the underlying pathogenetic mechanisms and thereby adopt suitable preventive measures and successful therapies beyond thrombolysis, which is available to less than 5% of all patients (Heuschmann et al., 2003). Owing to its high prevalence, high burden of illness and economic cost, well-defined modifiable risk factors, and effective prevention measures, stroke is well suited for prevention. However, negative trends in the stroke risk

factor profile; lack of awareness among the general public and medical fraternity; misapplication or underutilization of stroke preventative programs; and a lack of emphasis on preventive training in medical school and postgraduate programmes around the world have resulted in high stroke rates and a widening of the stroke prevention gap (Gorelick, 2002). The two broad categories of stroke, haemorrhage and ischemia, are diametrically opposite conditions. Epidemiologic studies indicate that 82–92% of strokes in the United States are ischemic. These categories can be divided into subtypes with somewhat different causes, clinical pictures, clinical courses, outcomes, and treatment strategies. Ischemic stroke is characterised by the sudden loss of blood circulation to an area of the brain, resulting in a corresponding loss of neurologic function. Acute ischemic stroke is caused by thrombotic or embolic occlusion of a cerebral artery or systemic hypoperfusion, which is more common than hemorrhagic stroke. Although a range of thresholds has been described, irreversible neuronal ischemia and injury are generally thought to begin at blood flow rates of less than 18 mL/100 g of tissue/min, with cell death occurring rapidly at rates below 10 mL/100 g of tissue/min. There are three main subtypes of brain ischemia (Caplan, 2009): Firstly, a thrombosis, which is a local in situ obstruction of an artery, may be due to disease of the arterial wall, such as arteriosclerosis, dissection, or fibromuscular dysplasia; there may or may not be superimposed thrombosis. Secondly, embolism refers to particles of debris originating elsewhere that block arterial access to a particular brain region (Caplan and Mannin, 2006). Third, systemic hypoperfusion is a more general circulatory problem, manifesting itself in the brain and perhaps other organs.

The risk factors for ischemic stroke include modifiable conditions (Goldstein et al., 2011) like hypertension (the most important), diabetes mellitus, cardiac disease, hypercholesterolemia, transient ischemic attacks (TIA), and carotid stenosis. In addition to the nonmodifiable conditions like age, race, sex, ethnicity, and history of migraine headaches (Brooks, 2014), and heredities, such as a family history of stroke or transient ischemic attacks (TIAs), identifying risk factors in each patient can provide information about the cause of the stroke as well as the best treatment and secondary prevention plan.

The release of cardiac enzymes in acute ischemic stroke was first documented as early as the late 1970s (Kiranmayi and Tagore, 2015). Elevation of serum cardiac troponin T (cTnT) is a specific marker of the acute coronary syndrome. Troponin titter can be increased in patients with acute ischemic stroke, but its clinical implications remain unclear. Several mechanisms can result in a high titer of serum troponin during the early phase of ischemic strokes, such as primary myocardial damage with secondary cardioembolic cerebral ischemia or primary cerebral ischemia with secondary cardiac injury attributable to activation of the sympathoadrenal system (Song et al., 2008). Troponins are protein molecules that are part of cardiac and skeletal muscles, while smooth muscle cells do not contain troponins. Three types of troponins are present: troponin I, troponin T, and troponin C. Each subunit has a unique function: troponin T binds the troponin components to tropomyosin, troponin I inhibits the interaction of myosin with actin, and troponin C contains the binding sites for $Ca^{2+}$ that help initiate contraction (Ganong's Review of Human physiology, 2012).

Generally, troponins are undetectable in healthy patients. The absolute abnormal value varies depending on the clinical setting in which the patient is evaluated and the assay used. Other causes of troponin elevation other than MI include the following: all patients with established acute coronary disease or cardiac surgery; patients with renal failure; sepsis; infiltrative diseases such as amyloidosis; and medications and toxins such as doxorubicin, trastuzumab, and snake venom. Troponin is a highly sensitive and specific marker for myocardial injury used in the diagnosis and prognosis of people with acute coronary syndrome. However, elevated troponin levels have been observed in various clinical settings, including SAH, traumatic and space-occupied lesions, and ischemic stroke in the absence of ACS (Agewall et al., 2010).

Creatinine Kinase is found in the mitochondria and cytoplasm of skeletal muscle (predominantly), cardiac muscle, the brain, and other visceral tissues. Its primary function is generating and facilitating the transportation of high-energy phosphates. *Creatinine Kinase* is a dimeric molecule composed of M and B subunits. The two subunits can form three isozymes: CK-MM, CK-MB, and CK-BB. Skeletal muscle, myocardium, and neuronal tissue are the major sources of CK-MM, CK-MB, and CK-BB, respectively.

CKMB activity has been shown to increase in certain patients with ischemic stroke, subarachnoid hemorrhage, and head trauma without any clinically evident acute coronary syndrome. A continuing low-grade myocardial necrosis suggestive of myocytolysis, the pathological hallmark of stroke-related cardiac damage distinguished by foci of swollen myocytes, interstitial bleeding, and mononuclear infiltration in the vicinity of cardiac nerves, has been implicated as the cause of CKMB elevations (Ay et al., 2002). The CK-MB isoenzyme exists as two isoforms: CK-MB1 and CK-MB2. Laboratory investigations of CK-MB represent the sum of the isoforms CK-MB1 and CK-MB2. CK-MB2 is the tissue form initially released from the myocardium after myocardial infarction. It is converted peripherally in the serum to the CK-MB1 isoform rapidly after symptom onset. Because the primary source of CK-MB is the myocardium, the CK-MB elevation level indicates myocardial injury, including acute myocardial infarction, myocarditis, cardiac trauma, cardiac surgery, and endomyocardial biopsy. However, CK-MB makes up 5–

7% of CK in skeletal muscle. Therefore, skeletal muscle injury can sometimes lead to elevated CK-MB levels, causing misinterpretation. In addition, a recent study shows that CK-MB is related to elevated blood pressure as elevated adenosine triphosphate in endothelium can cause vasoconstriction and antagonise nitric-mediated vasodilatation (Brewster et al., 2006).

## METHODS

This is a cross-sectional study carried out on the patients admitted to the neurological and medical wards in Basrah Teaching Hospital from February to December 2018. The study was approved by the Iraqi Committee of Medical Specialization. The patient's relatives were informed about the aim of the study, and informed consent was obtained from them.

The study included 100 patients diagnosed with acute ischemic stroke using a brain CT scan, with 47 males and 53 females ranging in age from 26–90 years, with a mean of (62.71±11.75) years. All patients have had a complete clinical evaluation (including history and clinical examination) and a follow-up evaluation during their hospital stay. The severity of stroke has been assessed according to the National Institutes of Health Stroke Scale (NIHSS) (Lyden, 2017).

The exclusion criteria include ischemic heart disease, heart failure, major cardiac surgery, chronic atrial fibrillation, renal impairment, hemorrhagic stroke, and traumatic and space-occupying lesions of cerebro-vascular diseases.

Investigation requests include a brain CT scan (Phillips Brilliance 64 slice). Serum troponin titer is estimated using the COBAS e 411 device, which depends on the Elecsys Electro Chemi-Luminescence ECL technique in analysing results with a normal value of less than 0.1 ng/mL. CKMB will be measured using the Advanced ELISA method with a COBAS e 411 device, with a normal value range of 0–25 U/L. Complete blood count, electrocardiogram, blood sugar level, lipid profile, and renal function tests.

The statistical analysis was done using IBM SPSS (a statistical package for the social sciences) version 25. Continuous data was presented as a mean and standard deviation. The comparison between the means of study groups was made by using the one-way ANOVA test (analysis of variance) to compare continuous variables. For categorical variables, the chi-squared test was used. A P value of less than 0.05 was considered significant.

## RESULTS

Out of 100 patients, there were six patients (6 %) with minor stroke and seventy-five patients (75%) with moderate stroke; nine patients (9 %) with moderately severe stroke; and ten patients (10 %) with severe stroke as shown in Table 1. Fourteen patients (14%) were found to have positive serum troponin titers at admission, with a mean level of (0.678±0.602) ng/mL and a median level of (0.312) ng/mL.

Interestingly, this study revealed that there was a significant relationship between stroke severity and troponin titter (P-value was < 0.001), since there were 60 % of patients with severe stroke, 55.6 % of patients with moderately severe stroke, and only 4 % of patients with moderate stroke who had high serum troponin titter, and troponin titter was not raised in the minor form of stroke patients, as shown in Table 2.

As demonstrated in Figure 1, the mean serum troponin titer was high in patients with severe and moderately severe strokes (0.499±0.705 ng/mL) and (0.351±0.487 ng/mL), respectively, while it is in the normal range among patients with moderate and minor strokes (0.035±0.123 ng/mL) and (0.0175±0.016 ng/mL), respectively. Statistically, these differences were highly significant (P value = 0.001).

In regard to CKMB, 29 (29%) patients had been found to be positive with a mean level of 54.90±23.34 U/L and the median level was 49.08 U/L.

This study shows a significant association between stroke severity and CKMB

as 70% of severe stroke cases were found to have elevated CKMB, while (66,7%) and (21.3%) among those with moderate and moderately severe categorical groups, respectively, as shown in Table 3. (P value <0.001). Interestingly, among moderate stroke patients where the serum troponin level was negative, there was a significant rise in CKMB level as shown in tables 2 and 3.

Figure 2 demonstrates that the mean level of CKMB was higher among those with severe stroke (46.91±27.85) U/L versus (40.73±20.24) U/L and (26.79±18.95) U/L among moderate and minor stroke respectively (P-value =0.005). Furthermore, (8%) of all patients have positive serum troponin and CKMB represents (57.1%) of all positive troponin patients and (27.6%) of all positive CKMB patients. On the other hand, 65% of patients have both negative serum troponin and CKMB, representing (75.6%) and (91.5%) among both negative troponin and CKMB, as illustrated in Figure 3 (P value 0.004).

The mortality rate was 6% among all patients. Two patients were with moderately severe strokes and four patients were with severe strokes that had died. All of them had high serum troponin and CKMB levels.

## DISCUSSION

This study, among a few previous ones, was designed to show any association between serum troponin and CKMB with severity and mortality in patients with acute ischemic stroke. We accepted the study investigators'

**Table 1.** Classification of the patients according to the stroke severity

| Stroke severity | No. of patients |
|---|---|
| Minor | 6 |
| Moderate | 75 |
| Moderately severe | 9 |
| Severe | 10 |
| Total | 100 |

**Table 2.** The association between troponin and the stroke severity

| Stroke Severity | | Troponin | | Total | |
|---|---|---|---|---|---|
| | | Negative | Positive | | |
| Minor | No. | 6 | 0 | 6 | |
| | % with stroke severity | 100.0% | 0.0% | 100.0% | |
| | % with troponin | 7.0% | 0.0% | 6.0% | |
| Moderate | No. | 72 | 3 | 75 | |
| | % with stroke severity | 96.0% | 4.0% | 100.0% | |
| | % with troponin | 83.7% | 21.4% | 75.0% | **P value** |
| Moderately severe | No. | 4 | 5 | 9 | |
| | % with stroke severity | 44.4% | 55.6% | 100.0% | **0.001** |
| | % with troponin | 4.7% | 35.7% | 9.0% | |
| Severe | No. | 4 | 6 | 10 | |
| | % with stroke severity | 40.0% | 60.0% | 100.0% | |
| | % with troponin | 4.7% | 42.9% | 10.0% | |
| Total | No. | 86 | 14 | 100 | |
| | % with stroke severity | 86.0% | 14.0% | 100.0% | |
| | % with troponin | 100.0% | 100.0% | 100.0% | |

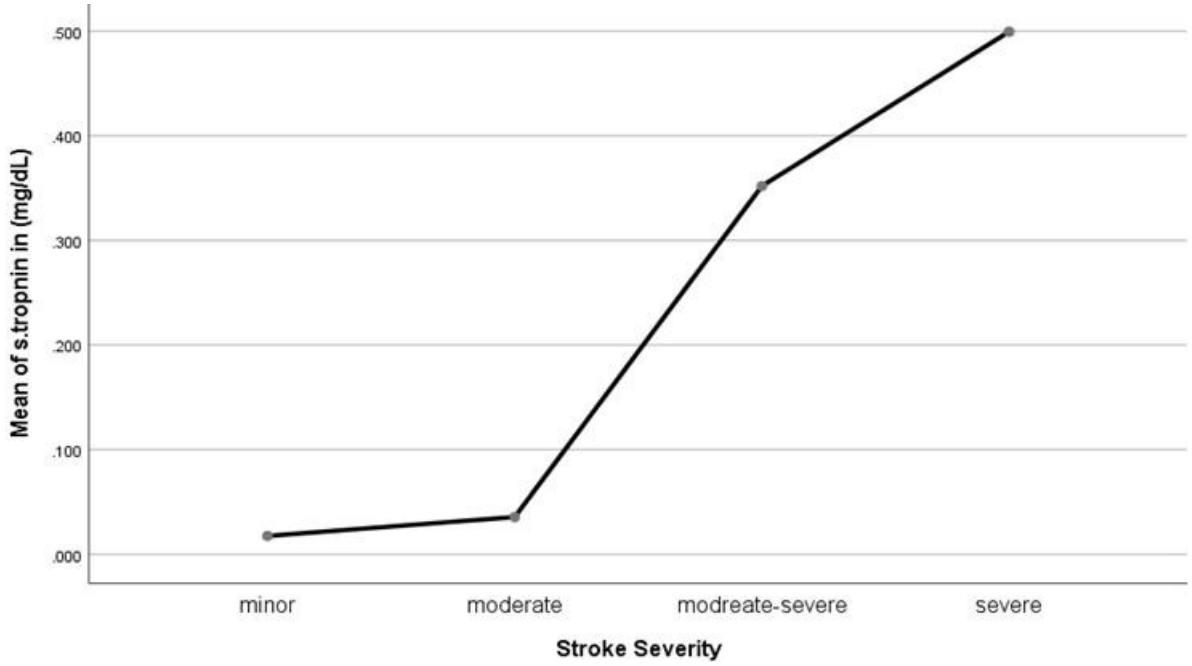


**Figure 1.** The association between the mean of troponin titter and the stroke severity

**Table 3.** The association between CKMB and the stroke severity

| Stroke Severity | | CKMB | | Total | P value |
|---|---|---|---|---|---|
| | | Positive | Negative | | |
| Minor | No. | 0 | 6 | 6 | |
| | % with stroke severity | 0.0% | 100.0% | 100.0% | |
| | % with CKMB | 0.0% | 8.5% | 6.0% | |
| Moderate | No. | 16 | 59 | 75 | |
| | % with stroke severity | 21.3% | 78.7% | 100.0% | |
| | % with CKMB | 55.2% | 83.1% | 75.0% | |
| Moderately severe | No. | 6 | 3 | 9 | |
| | % with stroke severity | 66.7% | 33.3% | 100.0% | |
| | % with CKMB | 20.7% | 4.2% | 9.0% | |
| Severe | No. | 7 | 3 | 10 | |
| | % with stroke severity | 70.0% | 30.0% | 100.0% | |
| | % with CKMB | 24.1% | 4.2% | 10.0% | |
| Total | No. | 29 | 71 | 100 | |
| | % with stroke severity | 29.0% | 71.0% | 100.0% | |
| | % with CKMB | 100.0% | 100.0% | 100.0% | |

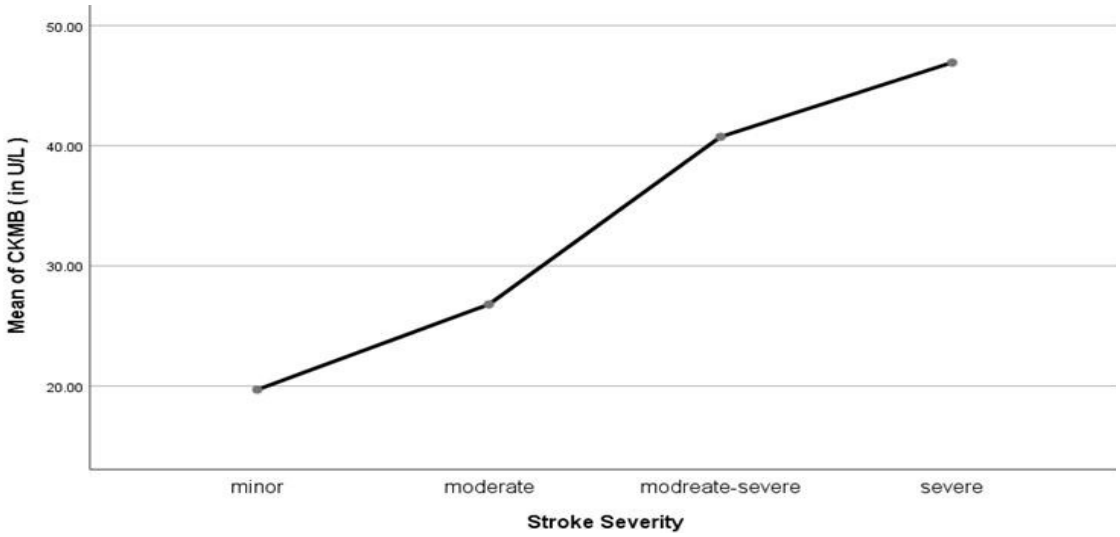


**Figure 2.** The association between the mean of CKMB and the stroke severity

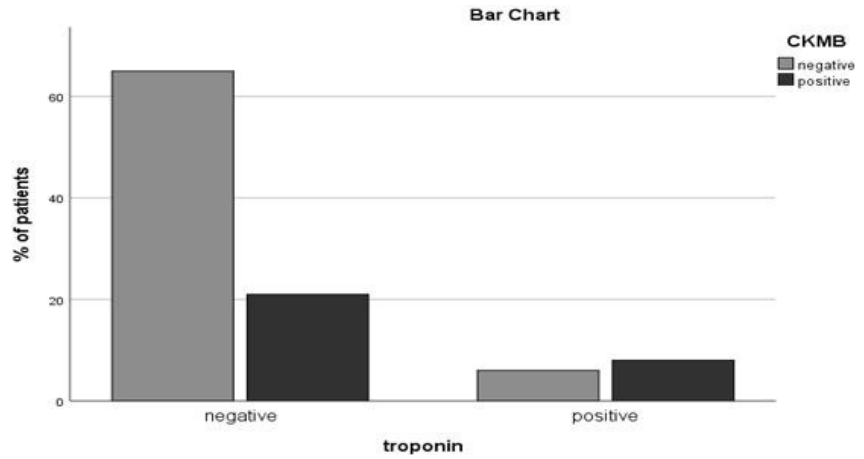


**Figure 3.** The association between troponin and CKMB

definition of troponin positivity but acknowledge that the issue of different troponin types, assays, and cutoffs is complex (Jaffe et al., 2006). It is also beyond the scope of this review to investigate the effects of different troponin types and cutoffs.

A universal finding in most studies is that patients with elevated troponin were more likely to have ECG changes suggestive of myocardial ischemia. So far, previous studies of hospitalised patients with acute ischemic stroke have shown a varying prevalence of positive troponin titters ranging from 0 to 35%, most likely due to different exclusion criteria and different troponin titer cutoffs (Kerr et al., 2009). However, our study excluded the possibility of cardiac insults, renal impairment, or other causes of elevated troponin titers.

This study found a statistically significant relationship between serum troponin levels and stroke severity as measured by the National Institutes of Health Stroke Scale score. The prognosis was poor in patients with elevated cTnT, which is consistent with previous research (Song et al., 2008; Kerr et al., 2009; Jensen et al., 2007; Banki et al., 2005).

Myofibrillar degeneration (coagulative myocytolysis and contraction band necrosis) is a common microscopic associated with elevation of circulating epinephrine in acute ischemic stroke; therefore, activation of the pathologic picture is seen in myocardial necrosis in stroke patients. The phenomenon has been explained as a neurally mediated process due to an increase in catecholamine release due to hypoperfusion of the posterior hypothalamus, causing autonomic nervous system imbalance and increased sympathetic output. Increased troponin levels in the sympathetic-adrenal system could contribute to myocardial damage in these patients. Cells die in a hyper-contracted state with prominent contraction bands, which happens within minutes and is associated with early calcification and mononuclear infiltration. This contrasts with myocardial lesions due to coronary heart disease, where the cells die in a relaxed state without prominent contraction bands known as coagulation necrosis. This process can take hours or even days with late calcification (Jensen et al., 2007). Others may have had myocytolysis with patchy myocyte damage associated with sympathoadrenal activation and stress response after stroke (Kerr et al., 2009).

Our study also found a link between CKMB and stroke severity and mortality, which is consistent with other Nigerian studies that looked at serum levels of cTnT and CK-MB in acute ischemic stroke patients concerning short- and long-term mortality (Suleiman et al., 2017).

The possibility of a secondary rise in CK-MB seen in our study might represent brain damage since the B subunit also exists in the brain as creatine kinase B isozyme brain. This was also demonstrated in the Nigerian study (Suleiman et al., 2017).

As we demonstrated in the previous chapter of this study, there was a significant increase in CKMB levels in moderately stroked patients with a negative serum troponin level. This highlights the fact that CK-MB is not a biological marker for myocytolysis. CK-MB elevations in stroke patients are likely to be noncardiac in origin (Ay et al., 2002; Suleiman et al., 2017).

We also conclude that stroke patients with raised markers have a higher mortality rate than others, especially in critically ill patients with a diagnosis other than cardiac ischemia. This fact agrees with other studies which studied elevated troponin titer in critically ill patients, including stroke (Lim et al., 2006).

Although there is a different correlation between positive serum troponin and hospital mortality of stroke patients in our study and other studies (Faiz et al., 2014; Jensen et al., 2007), others have found that there is no long-term effect of the influence of positive troponin on mortality (Whiteley et al., 2009; Etgen et al., 2005), and that also applies in regard to CKMB and long-term mortality (Suleiman et al., 2017).

The main study limitations include the lack of brain CT scanning in our hospital and its high cost outside the hospital, so we transferred all patients by ambulance to other hospitals. This limited the study sample size and might have influenced the study results. Also, the lack of both troponin titer and CKMB in the emergency department prohibits measuring them in the first hours of presentation. In addition to the lack of a serial brain CT scan during hospitalisation and at the pre-discharge time.

## CONCLUSIONS AND RECOMMENDATIONS

Both serum troponin titter and CKMB significantly rise with acute ischemic stroke and correlate significantly with in-hospital mortality. We recommend the measurement of serum troponin titer and CKMB at the emergency department for all patients with ischemic stroke. Moreover, further studies are suggested to demonstrate the influence of CKMB and troponin titter on long-term follow-up and the recurrence of ischemic stroke or their correlation to the site and size of the stroke.

**Conflicts of Interest:** None

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## REFERENCES

Agewall S, Giannitsis E, Jernberg T, Katus H (2010). Troponin elevation in coronary vs. non-coronary disease. European heart journal. Dec 18;32(4):404-11.

Ay H, Arsava EM, Sarıbas O (2002). Creatine kinase-MB elevation after stroke is not cardiac in origin: comparison with troponin T levels. Stroke. Jan 1;33(1):286-9.

Bakhai A (2004). The burden of coronary, cerebrovascular and peripheral arterial disease. Pharmacoeconomics. Dec 1; 22(4):11-8.

Banki NM, Kopelnik A, Dae MW, Miss J, Tung P, et al. (2005). Acute neurocardiogenic injury after subarachnoid hemorrhage. Circulation. Nov 22;112(21):3314-9.

Brewster LM, Mairuhu G, Bindraban NR, Koopmans RP, Clark JF, et al. (2006). Creatine kinase activity is associated with blood pressure. Circulation. Nov 7;114(19):2034-9.

Brooks M (2014). Migraine Linked to Double Risk for Silent Stroke. Medscape Medical News. Accessed: May 27

Caplan LR (2009). Basic pathology, anatomy, and pathophysiology of stroke. In: Caplan's Stroke: A Clinical Approach, 4th ed, Saunders Elsevier, Philadelphia. p.22.

Caplan LR, Mannin g W (2006). (Eds) Brain embolism Informa Healthcare, New York.

Etgen T, H. Baum, K. Sander, and D. Sander (2005). "Cardiac troponins and N-terminal pro-brain natriuretic peptide in acute ischemic stroke do not relate to clinical prognosis," Stroke, vol. 36, no. 2, pp. 270–275

Faiz KW, Thommessen B, Einvik G, Omland T, Rønning OM (2014). Prognostic value of high-sensitivity cardiac troponin T in acute ischemic stroke. J. Stroke and Cerebrovascular Diseases. Feb 1;23(2):241-8.

*Ganong's Review of Human physiology (*2012). 24th edition, ISBN 978-0-07-178003-2: The McGraw-Hill Companies, Inc.

Goldstein LB, Bushnell CD, Adams RJ, Appel LJ, Braun LT, et al. (2011). Guidelines for the primary prevention of stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. Feb. 42(2):517-84.

Gorelick PB (2002). Stroke prevention therapy beyond antithrombotics: unifying mechanisms in ischemic stroke pathogenesis and implications for therapy: an invited review. Stroke. Mar 1;33(3):862-75

Heuschmann PU, Berger K, Misselwitz B, Hermanek P, Leffmann C, et al. (2003). Frequency of thrombolytic therapy in patients with acute ischemic stroke and the risk of in-hospital mortality: the German Stroke Registers Study Group. Stroke. May 1; 34(5):1106-12.

Jaffe AS, Babuin L, Apple FS (2006). Biomarkers in acute cardiac disease: the present and the future. Journal of the American College of Cardiology. Jul 4;48(1):1-1.

Jensen JK, Kristensen SR, Bak S, Atar D, Høilund-Carlsen PF, et al. (2007). Frequency and significance of troponin T elevation in acute ischemic stroke. The American journal of cardiology. Jan 1;99(1):108-12.

Jensen JK, Kristensen SR, Bak S, Atar D, Høilund-Carlsen PF, et al. (2007). Frequency and significance of troponin T elevation in acute ischemic stroke. Ame. J. Cardiol. Jan 1;99(1):108-12.

Kerr G, Ray G, Wu O, Stott DJ, Langhorne P (2009). Elevated troponin after stroke: a systematic review. Cerebrovascular diseases.;28(3):220-6.

Kiranmayi B, Tagore R (2015). Evaluation of CK MB levels in Acute Ischemic stroke. May -Jun. (10): P 38-42.

Lim W, Qushmaq I, Devereaux PJ, Heels-Ansdell D, Lauzier F, et al. (2006). Elevated cardiac troponin measurements in critically ill patients. Archives of internal medicine. Dec 11;166(22):2446-54.

Lyden P (2017). Using the national institutes of health stroke scale: a cautionary tale. Stroke. Feb;48(2):513-9.

Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, et al. (2015). Heart disease and stroke statistics--2015 update: a report from the American Heart Association. *Circulation*. Jan 27. 131 (4):e29-322.

Song HS, Back JH, Jin DK, Chung PW, Moon HS, et al. (2008). Cardiac troponin T elevation after stroke: relationships between elevated serum troponin T, stroke location, and prognosis. Journal of clinical neurology. Jun 1; 4(2):75-83.

Suleiman HM, Aliyu IS, Abubakar SA, Isa MS, El-Bashir JM, et al. (2017). Relationship of cardiac troponin and creatine Kinase-MB fraction at admission in acute ischemic stroke and outcome in a Tertiary Hospital in Nigeria. Annals of Tropical Pathology. Jul 1;8(2):61.

Towfighi A, Saver JL (2011). Stroke declines from third to fourth leading cause of death in the United States: historical perspective and challenges ahead. Stroke. Aug; 42(8):2351-5.

Whiteley W, Chong WL, Sengupta A, Sandercock P (2009). Blood markers for the prognosis of ischemic stroke: a systematic review. Stroke. May;40(5):e380-9.