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Cardiac Troponins I and T as Biomarkers of Cardiomyocyte Injury—Advantages and Disadvantages of Each

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Abstract: Measurement of cardiac troponin in serum is an essential part of diagnosing myocardial infarction in the emergency department. The guidelines suggest that high-sensitivity techniques should be used for measuring cardiac troponin I (cTnI) or cardiac troponin T (cTnT). The aim of our study was to correlate the values of both troponins, and to ascertain which type of troponin is more in agreement with the diagnosis. The patients were classified into four groups: 43 patients in non-ST-elevation myocardial infarction (NSTEMI), 7 in ST-elevation myocardial infarction (STEMI), 48 in Type 2 myocardial infarction, and 21 in the control group. A significant correlation between cTnI and cTnT was found in the NSTEMI (r = 0.70) and Type 2 (r = 0.75) groups while in the control group there was no association (r = −0.06). The ratios of cTnI and cTnT relative to their cut-off values were lower in Type 2 myocardial infarction compared to NSTEMI. This difference can be attributed to the pathophysiology of these two types of heart conditions. The ratio in the NSTEMI group was higher in female than in male patients (53.3 vs. 24.6 ng/L); the same difference was found for the ratio of cTnT (20.8 vs. 13.1 ng/L). In the same manner, the ratios in the Type 2 group were higher in female than in male patients for cTnI (25.6 vs. 12.7 ng/L) as well as for cTnT (19.0 vs. 6.73 ng/L). These differences could be due to biological differences, but they could also be influenced by other factors contributing to different damage responses.

Keywords: cardiac troponin I; cardiac troponin T; myocardial infarction

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1. Introduction

Diagnosing cardiac emergencies is one of the most crucial tasks in the emergency department. It is imperative to expeditiously and precisely narrow down the wide differential diagnosis of chest discomfort in order to administer the necessary life-saving treatments to patients [1]. To distinguish between the various causes of chest discomfort, a number of crucial diagnostic instruments are employed in addition to the history and physical examination [2]. Troponins are regulatory proteins in muscle tissue and their measurement is a tool that is now crucial to cardiac workups and diagnosis [3].

Troponins are located in the cytosol of the myocyte as a small free pool as well as structural proteins [4]. There are three different molecular forms of troponin that are associated with different isotypes that are present in heart tissue, slow-twitch skeletal muscle, and fast-twitch skeletal muscle [5]. The cardiac isotype exhibits about 40% sequence heterogeneity with respect to the skeletal isotypes and has an additional 31 residues at the amino terminus [6]

Cardiac troponin T (cTnT) and cardiac troponin I (cTnI) are crucial protein molecules involved in muscle contraction, particularly in the regulation of cardiac and skeletal muscles. However, there are several key differences between the two: cTnI has not been identified outside the myocardium, indicating its specificity to the heart muscle. On the other hand,

cTnT is expressed to a small extent in skeletal muscle, but the current cTnT assays do not detect skeletal troponins [7]. There are also some differences in function: cTnI binds to actin in thin microfilaments to hold the troponin–tropomyosin complex, and it inhibits ATPase activity of actomyosin. Meanwhile, cTnT binds to tropomyosin, interlocking them to form a troponin–tropomyosin complex, and it regulates the interaction of the troponin complex with thin filaments.

Since cardiac troponin is not a constitutive blood protein, healthy subjects without heart injury will have extremely low blood levels of this protein. Therefore, the clinical interest in cardiac troponin levels is limited to elevated levels, unlike many other blood indicators that can demonstrate both unusually low and high levels.

The clinical significance of cTnI and cTnT levels lies in their ability to indicate heart muscle damage, particularly as a result of a myocardial infarction or other heart-related problems. These proteins, which are specific to the heart, are normally found inside cardiac muscle cells. However, when cardiac muscle damage occurs, such as during a myocardial infarction, these proteins leak into the bloodstream. Therefore, higher levels of cTnI or cTnT in the blood indicate more severe heart damage. Additionally, troponin levels can be used to estimate the extent of heart damage. The more damage there is to the heart, the greater the amount of cTnI and cTnT there will be in the blood. A multicenter study involving 2226 patients reported that both troponins, despite differences in biochemical characteristics and release kinetics, have high diagnostic accuracy for acute myocardial infarction [8].

Cardiac troponins are released into the circulation as a consequence of an acute cardiac shock and a brief period of local ischemia. Patients usually experience a dull discomfort in their arms or chest within the first several hours following the trauma. Usually, between two and three hours after the onset of chest discomfort, troponin levels in the blood begin to rise. The levels will continue to rise until a peak is reached, generally between 12 and 48 h [9]. However, the peak can appear anywhere between 6 h and 3 days, depending on the kind of myocardial infarction [10]. Blood levels of cTnI often rise much higher than that of cTnT in myocardial infarction, whereas cTnT is often higher in patients with stable conditions such as atrial fibrillation [11]. When measured six to twelve hours after the onset of chest pain, troponin tests were found to have nearly 100% sensitivity and a considerably better specificity for cardiac muscle injury than earlier biomarkers [4]. Over the following four to ten days, the troponin level will return to normal, assuming no new cardiac injury occurs in the interim, but it can occasionally take as long as a few weeks for cardiac troponin levels to drop to baseline [9,10].

Troponin T is found in a 3-unit complex of the contractile apparatus in myofibrils, and there is also a cytosolic pool of unbound troponin that is released acutely, mimicking the appearance kinetics of other cytosolic proteins. This pool represents about 6% of cTnT, which explains the late but not early release of troponin. The increased overall amount of troponin in the heart is not why troponin is more sensitive than other proteins. The increased early sensitivity likely reflects the fact that the percentage of troponin released that reaches the blood after cardiac injury is greater for troponin than for other proteins. The unique release kinetics and the presence of a cytosolic pool of unbound cTnT may contribute to the observed pattern of cTnT concentration, characterized by an initial drop, a plateau, and then another drop [12].

Both cTnI and cTnT have a short half-life in plasma, lasting around two hours. The apparent half-life is 24 h, with cTnT being slightly longer, due to the ongoing release of troponin from the necrotic myocardium [13].

Troponins have been measured using a variety of methods over time, each with unique benefits in terms of sensitivity and specificity. The clinical situation and the ideal balance between sensitivity and specificity—both necessary for a correct diagnosis—often influence the assay selection. Antibodies used in immunoassays can detect very low troponin concentrations with great sensitivity and specificity. Chemiluminescent detection is the most common choice and together with automated analysis provides quick results.

Point-of-care testing (POCT), which offers rapid diagnostic results close to patient treatment sites, can have variable sensitivity and specificity and are less frequently used.

The most recent international guidelines [14] suggest that high-sensitivity techniques should be used for measuring cardiac cTnI and cTnT in order to detect myocardial damage and differentiate between acute coronary syndromes. Acute myocardial infarction diagnosis requires the presence of myocardial damage, which is a separate condition. The 2018 Fourth Universal Definition of Myocardial Infarction states that myocardial injury is detected when at least one value above the 99th percentile upper reference limit is measured in a patient with high-sensitivity methods for cTnI or cTnT [15,16].

However, the primary justification for utilizing the 99th percentile upper reference limit is the current deficiency in standardization and harmony among the many cardiac troponin assays. This means that a single numerical cut-off cannot be used as a physiological threshold for myocardial injury [17,18].

With the development of troponin assays, the 99th percentiles of the assays became ever lower, and the sensitivity became ever higher. In addition to providing a CV $\leq$ 10% at the 99th percentile, the most recent generation of high-sensitivity assays can now measure troponin concentrations above the level of detection in more than 50% of the healthy population. Additionally, gender-specific 99th percentiles have been set with the value for females usually lower than for males.

The levels of cTnI and cTnT can provide valuable insights into different types of myocardial infarction. ST-elevation myocardial infarction (STEMI) causes a larger blockage of one or more coronary arteries, leading to a complete deprivation of blood to the heart. On the other hand, non-ST-elevation myocardial infarction (NSTEMI) causes only partial or incomplete blockage of a coronary artery. STEMI is considered a more serious event than NSTEMI due to the larger blockage and the resulting impact on the heart's blood supply. This results in more long-term heart health problems and increases the risk of death in the short term. The severity of myocardial injury in STEMI is typically more extensive due to the complete blockage of a coronary artery.

In STEMI, both cTnI and cTnT levels are typically elevated at presentation and are associated with a worse prognosis in terms of both short-term and long-term mortality. Higher troponin values generally correlate with a larger infarct, providing an estimate of the infarct size and the severity of myocardial damage. In NSTEMI, elevated levels of cTnI and cTnT at presentation are also associated with a worse prognosis in terms of both short-term and long-term mortality. Peak troponin values can provide an estimate of the infarct size and the severity of myocardial damage, with higher values generally correlating with a larger infarct.

In Type 2 myocardial infarction, an elevated troponin in the first blood sample is expected in patients with renal failure. A rising concentration of troponin indicates acute injury and may be due to an acute myocardial infarction. It is crucial to classify the etiology of a troponin elevation and treat patients accordingly [19].

Particularly in the current era of high-sensitivity troponin tests, the number of situations known to cause myocardial injury by pathways other than myocardial ischemia is increasing [20]. Elevated troponin levels can be indicative of heart damage, but they are not specific to myocardial infarction. Other conditions, such as congestive heart failure, abnormally fast heartbeat, and kidney disease, can also cause elevated troponin levels, leading to potential misinterpretation. Elevated troponin levels can also result from conditions such as acute coronary syndrome, acute myocarditis, and infiltrative diseases like amyloidosis. Additionally, medications, toxins, transplant vasculopathy, and critical illness can also lead to elevated troponin levels. Acute ventricular wall stretch or strain is typically the cause of acute (or chronic) systolic or diastolic heart failure. Troponin trajectories are typically more indolent, with milder troponin increases. Myocardial inflammation directly causes pericarditis and myocarditis. Cardiopulmonary resuscitation is another possibility, where the heart injury can be caused by electrical shocks from an external defibrillator or by mechanical chest compressions. Stress-induced release of neurohormonal hormones

and catecholamines also results in myocyte damage and temporary dilation of the ventricle, which is known as stress-induced cardiomyopathy. Acute pulmonary embolism is not from cardiac ischemia, but rather from an acute stretch or strain of the right ventricle. Renal failure due to chronic kidney disease or severe renal injury is at least somewhat associated with decreased troponin clearance from the kidneys.

Both cTnI and cTnT were associated with adverse classical cardiovascular disease (CVD) risk factors. The Spearman correlation coefficient between cTnT and cTnI was found to be 0.443 ($p < 0.001$) [21]. Previous cohort studies have examined either cTnI or cTnT but rarely both of them, most likely due to the assumption that assays can be interchanged in diagnosis of an acute cardiac event. This has resulted in an evidence base that does not directly show which biomarker is actually better. A meta-analysis, which included 13 studies that measured cTnI and 7 studies that measured cTnT—none of which measured both—reflects this. The risk of future CVD events was greater for cTnT than cTnI in the top versus bottom third of the distribution (hazard ratio = 1.60 versus 1.36; $p = 0.171$), and cTnT was more significantly related to fatal CVD ($p = 0.027$) [22].

The aim of our study was to determine cTnI and cTnT in patients admitted to the emergency department with chest pain and to correlate the results of the two troponins. Furthermore, we wanted to determine which form of troponin was more consistent with the diagnosis. For this purpose, we analyzed the disease course of those patients in whom the results of both troponins were not consistent.

2. Materials and Methods

2.1. Patients

The observational, prospective, single-center study was conducted between March and May 2023 at the University Medical Centre Ljubljana, which is the regional referral for ACS patients. The study protocol was approved by the National Ethics Committee and was performed in accordance with the principles set out in the Declaration of Helsinki.

All adult patients arriving at the emergency medical unit triage room (Manchester triage system) have standardized pre-examination laboratory testing according to the clinical syndromes. We included consecutive patients who came to the emergency department complaining about chest discomfort or dyspnea and had increased values of cTnI. The patients were included regardless of the potential previous clinical history.

The total number of patients included in the study was 119 of whom 74 are men and 45 are women, aged between 31 and 93 years. After screening in the triage room, the patients were classified into the following main groups: 43 patients in NSTEMI, 7 in STEMI (STEMI patients go directly in the catheter lab, they do not stop in the emergency department), and 48 in Type 2 myocardial infarction. At the same time, a control group was formed, consisting of 21 individuals who were defined as “other conditions” and also had a negative troponin concentration.

2.2. Methods

Blood samples were taken into additive-free tubes with or without added gel. After centrifugation, serum was used for the measurement of the concentrations of cTnI and cTnT. Serum concentrations of cTnI were measured with Advia Centaur XP analyzer (Siemens Healthcare, Erlangen, Germany), and serum concentrations of cTnT were measured using Cobas e411 analyzer (Roche Diagnostics, Mannheim, Germany). Both methods are based on the principle of the immunochemical ‘sandwich’ method using chemiluminescence detection. Briefly, a biotinylated cTnT-specific antibody and a cTnT-specific antibody labeled with a ruthenium complex formed a sandwich complex with the analyte. The complex was bound to the streptavidin-coated microparticles. After the removal of unbound substances, electrochemiluminescent emission was measured. A similar principle with slightly different detection was applied for cTnI. Instead of ruthenium complex and electro-chemiluminescent detection, acridinium ester and chemiluminescent detection was used. Specifications of both methods used for the measurement of troponins are presented in Table 1.

Table 1. Specifications of methods used for the measurement of troponins.

	cTnI in Serum (ADVIA Centaur XP)	cTnT in Serum (Cobas e411)
Intra-assay variation [%] (repeatability)	1.5–6.1	0.8–7.1
Inter-assay variation [%] (intermediate precision)	2.3–8.7	1.4–7.9
Limit of detection [ng/L]	2.21	2.54
Limit of quantification [ng/L]	2.50 (at CV = 20%)	7.45 (at CV = 10%)
Cut-off [ng/L] (99th percentile)	F 39.6 M 58.0 (population mean 46.5)	F 9.0 M 16.8 (population mean 14.0)

2.3. Statistical Analyses

Statistical analyses were performed using the SPSS statistical software v22 (IBM, Armonk, NY, USA). First, we performed a test for the normality of the distribution using the Shapiro–Wilk test. Based on this, we decided to use the non-parametric Kruskal–Wallis test and then performed a post hoc analysis of the pairwise comparison of diagnoses using the non-parametric Dwass–Steel–Critchlow–Fligner pairwise comparison test. Finally, we calculated the proportion of patients whose cTnI and cTnT levels did not match.

3. Results

Spearman's test showed that there was a significant association between cTnI and cTnT in NSTEMI (r = 0.70) and Type 2 (r = 0.75) groups with a p-value below the 0.05 statistical significance level. No correlation was found in the control group (r = −0.06). The correlation was not calculated for the STEMI group since the number of patients was too low.

Mean values and ratios relative to respective cut-offs are presented in Table 2. For the STEMI group, the data are not presented. Nevertheless, the calculation was performed as additional information. The means and ratios for cTnI and cTnT were 9998 ng/L (ratio 172) and 286 ng/L (ratio 17.0) for males. For females means and ratios for cTnI and cTnT were 6115 ng/L (ratio 153) and 176 ng/L (ratio 19.5), respectively.

Table 2. Mean values of cTnI and cTnT concentrations and their ratios relative to respective cut-offs (multiples of cut-off). For cTnI, the following cut-offs were used: 40 ng/L for females and 58 ng/L for males. For cTnT, the cut-offs were 9.0 ng/L for females and 16.9 ng/L for males.

	Gender	n	cTnI		cTnT	
			Mean (ng/L)	Ratio	Mean (ng/L)	Ratio
Control	M	14	38.9	0.67	50.7	3.02
	F	7	57.4	1.44	41.5	4.61
NSTEMI	M	31	1423	24.6	220.1	13.1
	F	12	2133	53.3	187.0	20.8
Type 2	M	26	733.7	12.7	113.7	6.73
	F	22	1024	25.6	171.1	19.0

In the next step, we looked into the group of patients in whose value of cTnI and cTnT did not match as expected. We found out that the elevation of cTnI and cTnT matched in 82% of cases, while in 18% of cases, only cTnI was elevated and cTnT was not. For these unmatching cases we obtained additional information on the medical history and any comorbidities. The additional diagnoses were classified into those with elevated cTnI due to coronary causes (73%) and those with elevated cTnI of non-coronary origin (27%). Causes

in this group of patients included Myocardial infarction with non-obstructive coronary arteries (MINOCA), coronary artery disease, tachycardia, cardiogenic syncope, heart failure, endocarditis, aortic stenosis, critical lower limb ischemia, bradycardia, ischemic heart disease, subacute STEMI (Table 3). Patients with known coronary disease and patients referred for coronary angiography were also included in this group. In all these conditions, the release of troponin from myocytes is due to cardiac injury, either due to reduced blood flow to the heart, inflammation, or cardiac ischemia. The subgroups were too small for statistical analysis. Nevertheless, as a preliminary information means and medians of cTnI levels were calculated. In the heart-related group the mean concentration of cTnI was 316.7 ng/L (median 190 ng/L), while in the non-heart-related group the mean concentration of cTnI was 225.9 ng/L (median 152.5 ng/L).

Table 3. Initial and final diagnoses in the subset of individuals exhibiting elevated levels of Troponin I but not Troponin T.

No	Initial Diagnosis	Final Diagnosis/Further Course of the Disease	Heart-Related
1	NSTEMI	Known coronary disease, diabetes type II, probably NSTEMI	Yes
2	NSTEMI	Coronarography, MINOCA	Yes
3	NSTEMI	Coronary artery disease, diabetes type II	No
4	TYPE 2	Tachycardia, cholangitis	No
5	NSTEMI	Cardiogenic syncope on exertion, normal cardiac MRI and ultrasound, bradycardia, pacemaker	Yes
6	TYPE 2	myocardial infarction—heart failure, diabetes type II	Yes
7	TYPE 2	Cellulitis (inflammation of the skin)	No
8	NSTEMI	Coronary angiography and cardiac ultrasound showed no evidence of coronary artery disease	No
9	NSTEMI	Ischemic heart disease with mild lateral wall contractility disorders	No
10	NSTEMI	Coronarography, MRI: no structural changes in the heart muscle	No
11	STEMI	STEMI, artificial aortic valve, pacemaker	Yes
12	TYPE 2	COVID-19 pneumonia, impaired diastolic function	No
13	TYPE 2	Heart failure, peripheral arterial disease, diabetes type II	No
14	TYPE 2	Tachycardia, spastic tetraplegia, sepsis	No
15	TYPE 2	Pneumonia, obesity, mild left ventricular enlargement	No
16	TYPE 2	Pneumonia, osteomyelitis	No
17	TYPE 2	Tachycardia, CT angiography within normal limits	No
18	TYPE 2	Infective endocarditis, fever	No
19	TYPE 2	Severe aortic stenosis, syncope, valve replacement	No
20	TYPE 2	COPD exacerbation	No
21	TYPE 2	Critical ischemia of the right lower limb	No
22	STEMI	Subacute STEMI	Yes

4. Discussion

Troponin tests have been developed over time with ever-lower 99th percentiles and ever-increasing sensitivity. As a result, more recent troponin test generations are able to identify elevated levels sooner, which is linked to heightened sensitivity for myocardial damage and quicker ACS rule-in and rule-out times.

The pattern of cTnT concentration, characterized by an initial drop, followed by a plateau, and then another drop [12] is different from cTnI. The reason for the difference may be attributed to the unique properties of cTnT and the kinetics of its release into the bloodstream.

cTnT is partially present as an unbound form or cytosolic fraction that can be released quickly after cell damage [23], but the majority of cTnT (94%) is bound to the myofibrils and is released more slowly (especially in the case of irreversible injury). This is one of the hypotheses for the biphasic curve of cTnT and not cTnI. Alternatively, immune-reactive cTnT fragments with a prolonged half-life and lack of discernibility may be the cause of the biphasic curve's shape [24].

According to the current data, troponin tests function extremely similarly in clinical settings. Combining the two biochemical signals from cTnT and cTnI may overcome preanalytical, analytical, and pathophysiological differences between the biomarkers and enhance clinical decision-making, according to the Advantageous Predictors of Acute Coronary Syndromes Evaluation (APACE) study group's hypothesis. After eliminating patients with ST-segment elevation myocardial infarction, they enrolled 2256 patients with suspected AMI; of these, 18% had an adjudicated diagnosis of AMI. At admission, the entire cohort was assessed for cTnT (Roche Diagnostics, Mannheim, Germany) and cTnI (Abbott Laboratories, Abbott Park, IL, USA), and there was a r = 0.89 correlation between the two measures. When both assays were presented, the area under the curve (diagnostic accuracy) was 0.93 (95% confidence interval, 0.92–0.94) [25].

Preliminary data from the cross-sectional Maastricht study suggests that troponin assays might not be interchangeable in the general population. The association between the aforementioned methods for cTnI and cTnT was only r = 0.54 in 1540 middle-aged members of the general population who did not have a substantial baseline disease. Although this association is obviously significant in most biological contexts, it is far from being regarded as a stand-in for assays that are purportedly detecting the same biomarker [26].

The association between cTnI and cTnT assays is clearly dependent on population. In our study, the correlation was strong in the Type 2 group (r = 0.75) and in the NSTEMI group (r = 0.70) while no correlation was found in the control group (r = −0.06). Unfortunately, the STEMI group was too small for the calculation.

Our study presents the elevation of two proteins, cTnI and cTnT, in different cardiac events. In the case of NSTEMI, which is characterized by partial blockage of the coronary artery, there is a moderate increase in the levels of both cTnI and cTnT. This is due to the damage inflicted on part of the heart muscle. On the other hand, STEMI is caused by a complete blockage of a coronary artery, leading to more extensive damage to the heart muscle. This results in a significant elevation of both cTnI and cTnT levels. Type 2 myocardial infarction, which occurs when the heart muscle demands more oxygen than the body can supply, can result in variable elevations of cTnI and cTnT. This type of event can occur in situations like severe illness, surgery, or severe emotional stress. The elevation of these proteins may not be as high as in STEMI or NSTEMI.

The ratios of cTnI and cTnT relative to their cut-off values are lower in Type 2 myocardial infarction than in NSTEMI. This difference can be attributed to the nature of these two types of heart conditions. The most common cause of NSTEMI is a partial blockage of one or more coronary arteries, which provide the heart with blood. Because of this obstruction, the heart receives less blood, which damages the heart muscle and raises blood levels of cardiac biomarkers like cTnI and cTnT. When opposed to Type 2 myocardial infarction, NSTEMI frequently has a more severe blockage and extensive heart muscle injury, which raises troponin levels and, in turn, the ratios in relation to the cut-off values.

On the other hand, disorders such as severe hypertension, tachycardia, or anemia that lead to an imbalance between the supply and demand of oxygen to the heart are typically the cause of Type 2 myocardial infarction. Although cardiac muscle damage and elevated troponin levels can also result from these disorders, the degree of damage is frequently less severe than in NSTEMI.

Despite having distinct structures and functions, cardiac troponin I and T are both sensitive and precise indicators of myocardial damage. Compared to cTnT, cTnI typically rises earlier and peaks sooner following the onset of symptoms. Variations in their intracellular location and binding characteristics within the myofilaments may be the cause of these variances in release kinetics. The underlying pathophysiological mechanisms, which include the degree of myocardial damage, the onset and duration of ischemia, and subsequent reperfusion injury, are responsible for the changes in cTnI and cTnT levels among different types of myocardial infarction [15,27]. It is essential to understand these pathways in order to properly manage patients with acute coronary syndromes and interpret troponin levels in clinical practice.

The ratios of cTnI and cTnT relative to their cut-off values in the NSTEMI group were higher in female than in male patients (53.3 vs. 24.6 ng/L); the same difference was found for the ratios of cTnT (20.8 vs. 13.1 ng/L), suggesting that women with NSTEMI have higher relative elevations of troponin levels. In the same manner, the ratios in the Type 2 group were higher in female than in male patients for cTnI (25.6 vs. 12.7 ng/L) as well as for cTnT (19.0 vs. 6.73 ng/L). These differences could be due to biological differences such as variations in heart size, and hormone levels, but they could also be influenced by other factors contributing to different damage responses.

High troponin levels at admission (more than five times above the 99th percentile) and positive ECG alterations can aid in referring patients to prompt invasive therapy when utilizing a high-sensitivity assay. When paired with a normal ECG, normal troponin values (below the 99th percentile) will facilitate the early rule-out of MI and the patient's discharge [28]. Negative troponin findings will support the exclusion of MI, particularly in the case of late arrivals (chest discomfort more than six hours prior to admission). Retesting within three to six hours is necessary if moderately positive troponin values or negative troponin results cause early arrivals [29].

The high sensitivity of troponin testing is undoubtedly one of its benefits. There is little chance of overlooking patients experiencing an acute MI when sensitivity is strong. In addition, high sensitivity promotes safe and early rule-out algorithms, even in cases where fewer patients may benefit than with the rule-out performance provided by modern troponin assays.

The high sensitivity troponin assays' enhanced sensitivity has the drawback of decreasing specificity and raising the possibility of false-positive results that indicate ACS. Even if there is less chance of missing MI when utilizing a high-sensitivity troponin assay, patients with other morbidities such as renal illness or elderly patients without ACS may still have somewhat elevated or altered troponin levels. Due to the higher number of false positives connected to high-sensitivity troponin testing, there will be a greater requirement for diagnostic follow-up and a potential danger of receiving the wrong kind of treatment.

Non-coronary causes of possible troponin elevation in our study were: cellulitis, pneumonia, COPD exacerbation, cholangitis, and diabetes. Increased troponin levels in the blood are not directly related to any of these diagnoses, but they can affect the heart and cause indirect effects that may affect troponin levels. In cellulitis, pneumonia, cholangitis, and exacerbations of COPD, troponin increases due to the systemic inflammatory response that follows. Inflammation can cause increased cardiac workload and stress on the heart muscle, which in turn can lead to increased troponin levels. Also, the lack of oxygen in the blood as a result of these conditions can put stress on the heart, which can affect its function and lead to increased troponin levels.

In the large multicenter BASEL study in Switzerland, it was shown that measuring cardiac troponin levels is helpful in predicting death among patients presenting with pneumonia to the emergency room; cTnT was found to be superior for predicting prognosis [30],

which is in contrast to our results, where cTnT was normal while cTnI was elevated in patients with this diagnosis.

In patients with chronic kidney disease, cTnT was found to be more commonly elevated. These elevations are not necessarily associated with myocardial infarction. However, they may be a sign of heart problems or damage to the cardiac muscle, which may develop as a complication of kidney disease [31].

The authors of Welsh's study concluded that while cTnI is more frequently raised as a result of coronary reasons, cTnT is more frequently linked to mortality that is not caused by coronary causes [21].

During an acute myocardial infarction, cTnI concentrations often rise to greater levels than cTnT concentrations. The molecular structures of cTnI and cTnT differ, which could have an impact on both their release and clearance from circulation. Compared to cTnT (37 kDa), cTnI has a lower molecular weight (35 kDa) and faster release kinetics. Higher amounts of cTnI relative to cTnT may be explained by this.

All of the patients have increased cTnI, which raises the possibility of cardiac injury of some kind. Normal cTnT levels, however, may suggest that the injury is either relatively recent (since cTnT levels may not have had time to develop) or not severe enough to result in a noticeable increase in cTnT levels.

Our study has some limitations. Because of the small number of patients in the STEMI subgroup, the statistical comparisons for this group were not performed. As this was a single-center study with no external validity, the applicability of the results to different populations or clinical settings would still have to be confirmed.

Future research could include long-term follow-up, which might provide insights into the prognostic value of troponin measurements. The present analytical challenges could give an opportunity to alternative technologies [32], which include POCT with shorter turn-around times. Today, no single marker satisfies all of the requirements for being a perfect biomarker of myocardial infarction. Novel promising biomarkers, such as urine and salivary cardiac troponins, heart-type fatty acid binding protein, and miRNAs [33] could reduce the amount of time that passes between myocardial infarction and suggested treatment. The novel biomarkers have been the subject of relatively few clinical trials and have not yet been used in emergency departments.

5. Conclusions

Based on our results and findings, we can confirm a good correlation between troponins T and I in different forms of ACS. Both cTnI and cTnT are good markers of myocardial ischemia, as our study showed that both are most frequently elevated when a diagnosis of myocardial infarction is made. The more specific marker of myocardial ischemia was cTnI, as it appears more rapidly in the blood after cardiac injury. We observed that all patients with different troponin elevation levels had elevated cTnI only, regardless of the final diagnosis. It is important to note that our findings were reached by analyzing a small patient population (n = 119), so the results do not give a completely correct picture of cardiac troponin elevation in acute coronary events. A larger study including a larger number of patients would be needed for a more accurate assessment.

Troponin I may be a more helpful marker of myocardial damage than cTnT in some particular situations. The troponin test has become much more sensitive in recent years, and it can now detect much lower levels of troponin in the blood than in the past. This enhanced sensitivity allows for quicker diagnosis of a heart attack and is especially helpful in cases where patients' symptoms are ill-defined or other tests yield conflicting results.

Both cTnI and cTnT have similar detection efficiencies, particularly when these biomarkers are measured with high-sensitivity techniques. The latest global guidelines advise employing high-sensitivity techniques to evaluate both cTnI and cTnT in order to differentiate between acute coronary syndromes and detect myocardial damage. The ability of these high-sensitivity techniques to identify even minute variations in these biomarkers' concentrations enables a more accurate evaluation of heart damage.

The accurate detection of both cTnI and T in the blood is ensured by the use of monoclonal antibodies specific for cardiac troponin, which have very little cross-reactivity with troponins from skeletal muscle. Their effectiveness in identifying cardiac damage is attributed to their specificity and accuracy.

For this aim, elevations in cTnT and cTnI are valuable diagnostic tools in acute clinical situations, and the majority of the evidence indicates that the tests function similarly in patients. The general public's interest in using these assays to anticipate future occurrences is, nevertheless, beginning to develop. It's still unclear what the best strategy is for using the troponin assay wisely to enhance care for people who appear to be in good health. On the other hand, new data implies that choosing a specific troponin test for a certain clinical task could play a significant role in future clinical decision-making.

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