ELEVATED TROPONIN OF NON-CORONARY ETIOLOGY A REVIEW

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Abstract: Elevated troponin levels are traditionally associated with acute myocardial infarction (AMI) and are widely used as a specific marker for the diagnosis of ischemic myocardial injury. However, recent studies have shown that elevated troponin levels can occur in several non-coronary conditions, requiring a more careful diagnostic approach to avoid misinterpretations and inadequate management. This study aimed to perform a systematic review of the literature on the non-coronary causes of elevated troponin levels, seeking to identify the main associated clinical conditions and discuss their prognostic value in different contexts. To this end, a systematic review of articles published between 2014 and 2024 was conducted using the PubMed, Scopus and Web of Science databases. The results revealed that conditions such as sepsis, pulmonary embolism (PE), chronic renal failure (CRF), chronic obstructive pulmonary disease (COPD) and tachyarrhythmias are the main non-coronary causes of elevated troponin levels. It is concluded that elevated troponin levels of non-coronary etiology are an important marker of severity and poor prognosis in several systemic conditions. Troponin levels should be interpreted carefully, taking into account the clinical context and underlying conditions of each patient.

Keywords: Troponin, Non-coronary etiology, Sepsis, Chronic renal failure, COPD, Prognosis.

INTRODUCTION

Troponins are essential proteins that participate in the mechanism of regulating muscle contraction in striated and cardiac muscles. These proteins include three subtypes: Troponin T (cTnT),

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Troponin I (cTnI), and Troponin C, which are present in both skeletal and cardiac muscle and are encoded by distinct genes.

According to Motta (2009), Troponin C has the fundamental function of reversibly binding to calcium, triggering structural changes in the actin filaments that allow muscle contraction. This protein has two main domains, called N and C terminals, which are connected by a central ligand and have calcium-binding points.

Troponin I, in turn, is a monomeric protein with a molecular weight of 23.5 kDa, and acts as an inhibitory component of the troponin complex, suppressing muscle contraction when calcium levels are low in plasma. Martins (2009) explains that Troponin I has, like Troponin C, an N terminal (which plays an inhibitory role) and a C terminal (responsible for binding to actin). The interaction between actin and the inhibitory domain of troponin I results in the inhibition of myosin ATP-ase activation, promoting muscle relaxation, thus, Troponin I (cTnI) and Troponin T (cTnT) are often cited as proteins of high specificity and importance in the evaluation of myocardial damage.

The most important isoforms of troponins for the diagnosis of acute myocardial infarction (AMI) are Troponin T (cTnT) and Troponin I (cTnI). According to Motta (2009), these troponins are considered early markers of AMI and remain elevated for a longer period, and can be detected for up to 24 hours after the onset of symptoms. Compared to the isoenzyme CK-MB (creatine kinase MB), troponins are significantly more sensitive markers.

The choice between troponin T or I depends on the equipment and assays available in the laboratory. Normality values can vary with the assay kit used, making it challenging to establish a universal gold standard for the diagnosis of infarction. Although CK-MB and troponins have similar diagnostic performance in the first 12 to 24 hours of infarct progression, the accuracy of troponins makes them more useful for more sensitive and ongoing evaluation.

In recent years, De Lemos (2013) has highlighted that assays for the detection of troponins have evolved significantly, becoming ultra-sensitive and capable of detecting very low concentrations of these proteins in the blood, which provides an early and high-precision diagnosis.

Although troponins T and I are highly specific for cardiac myocytes, these proteins can be released in a variety of non-cardiac conditions, such as sepsis, chronic kidney disease, hypertensive emergencies, gastrointestinal bleeding, stroke, and rhabdomyolysis. In such cases, troponin elevation may reflect the release of a small fraction of the cytosolic component due to myocyte cell turnover, the release of degradation products, or increased cell membrane permeability (Sheyin, 2015). These factors highlight the importance of interpreting troponin elevation with caution, taking into account the patient's clinical context.

According to Harada and Potter (2023), the Troponin C subunit binds to calcium, triggering structural changes that allow the interaction between actin and myosin, which results in muscle contraction. Troponin C is present in both skeletal muscle fibers and cardiac fibers, which makes it less specific for the diagnosis of myocardial injury. In contrast, the Troponin I and Troponin T subunits are highly specific for the heart, and are therefore used as markers of myocardial injury.

Troponin I acts as a contraction inhibitor by binding to actin and preventing the interaction between actin and myosin in the absence of calcium, as reported by Wagner et al. (2024). This action prevents muscle contraction until calcium binds to Troponin C, allowing contraction to begin. Troponin T, on the other hand, binds directly to tropomyosin, facilitating the binding of actin filaments and contributing to the stability of the contractile complex (Harada; Potter, 2023).

In recent years, the development of ultrasensitive assays for the detection of troponin has made it possible to measure extremely low concentrations of this protein in the blood, considerably increasing the accuracy and sensitivity in the diagnosis of cardiac lesions (Muller, et al., 2023). This ability to detect small amounts of troponin in the blood is essential, as it allows for the early identification of myocardial lesions that would not be detectable with other biomarkers, such as CK-MB, which is less specific for cardiac tissue.

As mentioned by Long et al. (2019), troponin remains one of the most relevant markers for the diagnosis of acute myocardial infarction, due to its specificity and its ability to remain elevated for long periods after myocardial injury. The accuracy of ultrasensitive assays reinforces troponin as a reliable

marker for the assessment of cardiac damage and an important indicator for patient follow-up, providing a solid foundation for faster and more appropriate clinical interventions.

According to the guidelines of the European Society of Cardiology (ESC), American College of Cardiology Foundation (ACCF), American Heart Association (AHA) and World Heart Federation (WHF), the universal definition of acute myocardial infarction (AMI) highlights the rise and/or fall of troponin levels as essential criteria for diagnosis, as long as they are associated with the patient's clinical context (Thygesen et al., 2019). This definition reinforces the importance of troponins as highly specific and sensitive biomarkers for the detection of myocardial injury.

After an AMI, several proteins, including myoglobin, troponin I, troponin T, and creatine kinase (CK), are released into the bloodstream. These markers help in the rapid and accurate diagnosis of infarction (Thygesen; Jaffe, 2020). In the case of troponin T, healthy individuals usually have levels below 0.01 ng/mL, while levels above 0.3 ng/mL after a few hours of an acute event are indicative of infarction (Thygesen; Jaffe, 2020).

Also, according to Jatene et al. (2022), in patients with compensated heart failure, high-sensitivity troponin T (hsTnT) can be found at levels close to the limits of clinical decision, around 14 ng/L. These values need to be carefully evaluated, especially in patients with multiple comorbidities, since small elevations can be related to both ischemic events and systemic conditions (Jatene et al., 2022).

Traditional methods used for the detection of troponin T include electrochemiluminescence assays (ECLIA) and enzyme-linked immunosorbent assays (ELISA). However, recent studies point to the limitation of these methods in the context of medical emergency, since they are not portable and require specific laboratory infrastructure. In this scenario, immunosensors based on nanomaterials and biomolecules have emerged as a promising alternative, especially due to the speed of results and the possibility of portability (Chen et al., 2019).

On the other hand, it is important to emphasize that elevated troponin levels, detected by means of ultrasensitive assays, are not always indicative of acute myocardial infarction. According to

the most recent studies, elevated troponin levels can be detected in several non-ischemic conditions, such as sepsis, renal failure, and hypertensive emergencies, which led to the development of the fourth universal definition of myocardial infarction, which aims to improve diagnostic accuracy and avoid false associations (Thygesen et al., 2019).

Finally, regarding the reference values of troponin levels, according to Thygesen; Jaffe (2020), the following parameters are used as a reference: for cardiac Troponin T (cTnT), normal values are below 0.014 ng/mL, while for cardiac Troponin I (cTnI), normal values are below 19.8 pg/mL for men and 11.6 pg/mL for women. Troponin elevation begins between 3 and 6 hours after the onset of myocardial injury, reaches a peak in 24 hours, and may take 7 to 14 days to normalize (Thygesen; Jaffe, 2022).

METHODOLOGY

This study used a systematic review of the literature with the objective of identifying the main non-coronary causes of elevated troponin levels. To this end, searches were carried out in the PubMed, Scopus, and Web of Science databases between January 2014 and December 2024. The keywords used included “elevated troponin”, “non-coronary etiology”, “sepsis”, “renal failure”, “pulmonary embolism” and “tachyarrhythmias”, combined by Boolean operators such as “AND” and “OR”.

The inclusion criteria included articles in English, Portuguese, or Spanish, published in the last ten years, that discussed troponin elevation in contexts unrelated to coronary ischemia, including systematic reviews, meta-analyses, and observational studies. Articles that focused exclusively on the diagnosis of type 1 myocardial infarction, as well as those that presented non-representative samples or inadequate methodological analyses, were excluded.

The PRISMA method was used to conduct the systematic analysis of the studies, ensuring transparency and reproducibility in the selection of articles. Initially, 312 articles were identified, of which 198 were excluded after the initial screening, focusing only on abstracts. Of the remaining 114 articles, 79 were removed after full reading because they did not meet the established criteria, resulting

in a total of 35 articles included for analysis.

The selected articles were grouped into thematic categories, such as sepsis, COPD, chronic renal failure, and tachyarrhythmias, discussing the pathophysiological mechanisms involved and the prognostic value of troponin in these non-ischemic situations. This process enabled a comprehensive analysis of the factors that contribute to troponin elevation in contexts unrelated to myocardial infarction, providing a solid basis for the discussion of clinical outcomes and implications for the management of these patients.

FINDINGS

Initially, two studies on elevated troponin in hospitalized patients with COVID-19 were selected, which the studies pointed out to be associated with greater disease severity and increased mortality, even in the absence of type 1 myocardial infarction. The study by Bardají et al. (2021) analyzed 1,032 patients, of which 273 had troponin elevation. Patients with elevated troponin had higher complication rates, such as the need for mechanical ventilation (45.7% versus 22.3% in patients with normal troponin), septic shock (18.3% versus 5.4%), and ICU admission (33.2% versus 16.9%).

In-hospital mortality was significantly higher in the troponin elevation group (34.6% compared with 12.8% in patients without troponin elevation; $p < 0.001$). Elevated troponin, therefore, stood out as an independent predictor of mortality, reinforcing its importance in the risk stratification of patients with COVID-19 (BARDAJÍ et al., 2021).

In addition, elevated troponin levels were associated with an increase in inflammatory markers, such as interleukin-6 (IL-6) and C-reactive protein (CRP), suggesting that systemic inflammation and cytokine storm are important mechanisms underlying myocardial injury in these patients (ZHOU et al., 2020; BARDAJÍ et al., 2021). Inflammation and prolonged hypoxemia resulting from respiratory failure caused by COVID-19 were highlighted as the main factors responsible for troponin elevation, without the presence of significant coronary ischemia.

The data also indicated that even after adjusting for comorbidities such as heart failure and chronic kidney disease, elevated troponin remained an independent risk factor for worse prognosis. In this sense, monitoring troponin levels should be an integral part of the evaluation and management of patients with COVID-19, considering its strong correlation with adverse outcomes (ZHOU et al., 2020).

Other studies show that the relationship between troponin elevation and pulmonary embolism (PE) has been a topic of growing interest in the medical literature, since the elevation of this biomarker, traditionally associated with ischemic myocardial injury, is also observed in non-coronary conditions, such as PE. The article by López-Morales et al., (2021) investigated the correlation between troponin-I elevation and echocardiographic findings in patients with hemodynamically stable pulmonary embolism. Patients with troponin-I elevation had significant right ventricular dysfunction, as evidenced by both echocardiography and computed tomography angiography (PCI). Right ventricular overload was considered the main mechanism of myocardial injury in these patients.

Elevated troponin-I was observed in 44% of patients with hemodynamically stable PE and was associated with a higher prevalence of right ventricular dysfunction and, consequently, a higher risk of progression to hemodynamic instability. This study demonstrated that, although these patients did not have symptoms of myocardial infarction, troponin-I elevation served as an early indicator of decompensation and worse prognosis, suggesting the need for closer monitoring and, in some cases, more aggressive therapeutic interventions, such as thrombolysis (LÓPEZ-MORALES et al., 2021).

Another study that establishes this relationship between troponin and PE is that of Rodrigues et al., (2023) which provides a broader analysis, observing troponin elevation in patients with PE, regardless of hemodynamic stability where troponin elevation was observed in 54% of patients, with higher levels correlated with higher mortality. Right ventricular dysfunction, as measured by echocardiography, was significantly more common in these patients, suggesting that pressure overload in the right ventricle resulting from pulmonary arterial obstruction is one of the main factors responsible for troponin elevation.

In this study, patients with elevated troponin had a mortality rate of 28%, compared with 8% in

patients without biomarker elevation. Troponin has been identified as a marker of worse prognosis, even in those patients with hemodynamically stable pulmonary embolism. The elevation was correlated with the need for intensive interventions, such as thrombolysis, mechanical ventilation, and in some cases, circulatory support. This suggests that troponin not only reflects myocardial injury but also acts as a marker of PE severity (Rodrigues et al., 2023).

It should be noted here that both studies emphasize the usefulness of troponin as a prognostic marker in patients with PE, regardless of typical ischemic symptoms. Right ventricular dysfunction, caused by pressure overload, has been identified as the main mechanism underlying troponin elevation. In both studies, elevated troponin was consistently associated with a worse prognosis, including a higher risk of death, need for ICU admission, and more aggressive therapeutic interventions.

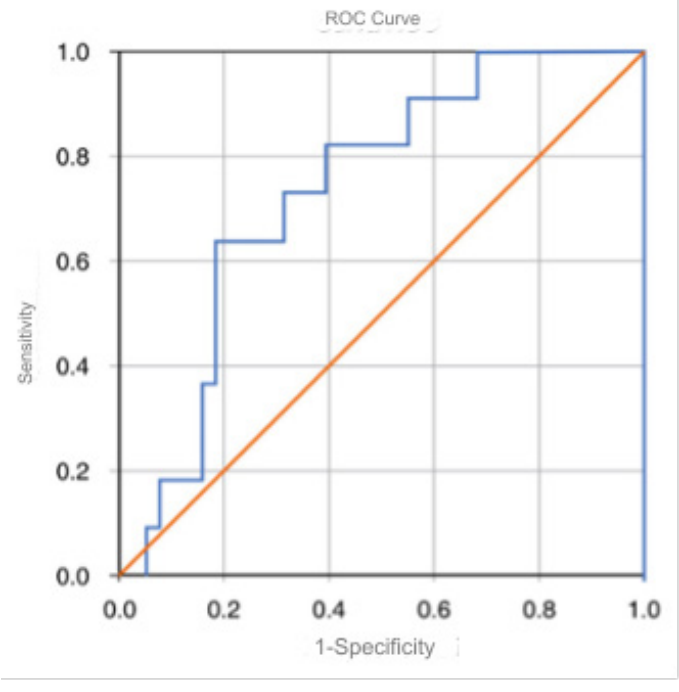
The study by Bolaños et al. (2023) provided clear evidence on the relationship between troponin elevation and adverse hospital outcomes in patients with septic shock. The research demonstrated that elevated troponin, identified within the first 24 hours of hospitalization, was a predictive marker of high sensitivity for mortality and significant clinical worsening in patients with septic shock. Among the patients evaluated, those with elevated troponin levels had a mortality rate of 33%, compared to 26% in patients with normal troponin, confirming that troponin is a robust indicator of risk in these cases.

The article also discussed that myocardial dysfunction caused by septic shock does not necessarily imply a classic coronary ischemic event, but rather a myocardial injury secondary to the exacerbated systemic inflammatory response, as suggested by the underlying mechanisms of direct endotoxin and cytokine toxicity, hypoperfusion, and coronary flow dysregulation (BOLAÑOS et al., 2023). These findings are in line with data in the literature, which point to an increase in troponin in approximately 30% to 55% of septic patients, and highlight that this increase is associated with a worse prognosis, both in terms of mortality and in the need for intensive therapeutic interventions (JAVED et al., 2022).

Another relevant point discussed in the study by Bolaños et al. (2023) was the usefulness of the ROC (Receiver Operating Characteristic) curve, which is a graphical representation of the performance

of a diagnostic test, which shows the relationship between sensitivity (true positives) and specificity (false positives), allowing the evaluation of the test's ability to discriminate between positive and negative results, which demonstrated that a troponin cut-off value of 50 ng/dL had a sensitivity of 73% to predict mortality in patients with septic shock.

Figure 1: Results of ROC troponin I curve.



Source: BOLAÑOS et al., 2023

These data reinforce the role of troponin as a key marker in risk stratification and directing the clinical management of septic patients.

The next study, Toledo (2022) evaluated serum troponin I levels in patients with chronic kidney disease (CKD) without clinical evidence of myocardial injury, with the aim of analyzing the occurrence of "false positive" results. The samples tested included 60 patients with CKD on hemodialysis and 10 healthy individuals (control group). The results showed that 17.1% of the patients with CKD had elevations in troponin I levels, while 8.6% had elevations in CK-MB levels and 1.4% showed simultaneous

increases in troponin I and CK-MB.

These findings are consistent with previous studies, which indicate the possibility of elevations unrelated to cardiac injury in patients with CKD, suggesting that troponin I may be elevated even in the absence of overt cardiac events. The main hypothesis for this elevation is related to decreased renal troponin clearance and chronic renal dysfunction, which makes these biomarkers less specific for the diagnosis of myocardial injury in renal patients (Robitaille et al., 2006).

In addition, the T-test performed for troponin I levels showed a statistically significant difference between the control group and the group of chronic kidney patients ($p = 0.023$). This data reinforces the need to reevaluate the interpretation of troponin I in these patients, since the elevation may be due to renal factors and not directly related to cardiac damage.

For CK-MB, the T-test did not reveal a statistically significant difference ($p = 0.225$), suggesting that this marker is less susceptible to variations associated with renal dysfunction compared to troponin I.

The presence of chronic inflammation, hemodynamic alterations, and the proinflammatory state in patients with chronic kidney disease may also contribute to troponin release without direct myocardial injury. These factors can trigger changes in the permeability of the myocyte cell membrane, allowing the release of troponin into the circulation (Robitaille et al., 2006). In addition, oxidative stress and tissue hypoxia common in patients with CKD are also important factors for this non-myocardial elevation (Martins, 2009).

In the study by Acosta et al. (2020), published in Cureus, the researchers conducted a retrospective analysis of patients admitted with hypertensive crisis to an emergency room. It was found that about 33% of the patients had troponin elevation without evidence of myocardial infarction or typical ischemic injury. The presence of elevated troponin in these patients was attributed to a process of secondary myocardial dysfunction, resulting from pressure overload induced by severe hypertension.

Hypertensive crisis is characterized by an abrupt and critical increase in blood pressure, which leads to significant overload of the left ventricle. This increase in intracavitary pressure can result in

subendocardial ischemia due to reduced perfusion time and increased myocardial oxygen demand, even in the absence of coronary occlusion. The troponin elevation seen in these patients, therefore, is interpreted as a response to tissue hypoxia and ventricular wall stress, rather than as a type 1 (ischemic) myocardial infarction event (Acosta et al., 2020).

The study also demonstrated that patients with elevated troponin had a greater need for prolonged hospitalization and required more intensive therapeutic interventions compared to those who did not have elevated troponin. These findings are particularly important because they highlight the role of troponin as a prognostic marker in non-coronary conditions. The presence of elevated troponin in hypertensive crisis indicated an increased risk of adverse outcomes, even in the absence of acute coronary injury, suggesting that these patients are more likely to develop complications, such as decompensated heart failure (Acosta et al., 2020).

The results of this study were inspired by a later study conducted by Lindner et al. (2014), where troponin elevation was evaluated in patients admitted to the emergency room, without the presence of a diagnosed myocardial infarction. The results showed that, in 69% of the cases, troponin elevation was not associated with an acute myocardial infarction. The main cause of the elevation was attributed to hemodynamic overload conditions, such as heart failure, uncontrolled hypertension, and sepsis.

These states of hemodynamic overload result in increased myocardial oxygen demand and reduce perfusion time during diastole, especially in patients with severe hypertension or decompensated heart failure. These factors contribute to subendocardial ischemia, which is a less severe type of myocardial injury, but which can result in the release of troponin. Thus, even in the absence of a significant coronary obstruction, mechanical stress and hypoxia can trigger the release of this biomarker (Lindner et al. 2014).

The authors suggest that troponin monitoring may be a useful tool for risk stratification in patients with hypertensive crisis. Patients with troponin elevation should be monitored more intensively and may require therapy adjustments, including the use of cardioprotective medications such as beta-blockers and ACE inhibitors. Elevated troponin in conditions of hemodynamic overload such as

hypertensive crisis is correlated with a poor prognosis, similar to that observed in other situations of non-ischemic myocardial stress, such as sepsis and chronic renal failure.

In the study conducted by O'Donnell and Laveneziana (2023), it was clear that hypoxia and increased lung pressure associated with Chronic Obstructive Pulmonary Disease (COPD) play a key role in elevating troponin levels. During severe exacerbations of COPD, there is an increase in pulmonary pressure and a consequent overload on the right ventricle, leading to myocardial hypoperfusion and subendocardial ischemia, which results in the release of troponin.

Long et al. (2019) corroborate these findings by discussing troponin elevation in conditions unrelated to coronary ischemia, such as COPD. According to the authors, troponin can be elevated due to myocardial hypoperfusion and increased oxygen demand, which is in line with the mechanism observed in patients with COPD, where pulmonary hyperinflation and hypoxia contribute to cardiac perfusion impairment, without direct coronary artery occlusion (LONG et al., 2019).

The presence of elevated troponin in these patients is often associated with a poorer prognosis, including higher rates of hospitalization and mortality compared with those who do not have elevated biomarker. This reinforces the use of troponin as a risk marker for cardiovascular complications in patients with COPD, even in the absence of ischemic injury.

Therefore, troponin elevation in patients with COPD is often a reflection of subendocardial myocardial injury resulting from the combination of prolonged hypoxia, increased pulmonary pressure, and hyperinflation, which compromise cardiac filling and myocardial perfusion. These factors make troponin a relevant marker not only for the diagnosis of severe exacerbations, but also for risk stratification of cardiovascular complications, providing an opportunity for early interventions and improvement of clinical management.

FINAL CONSIDERATIONS

The analysis of the selected studies showed that elevated troponin has been shown to be a

highly relevant prognostic marker in different clinical settings, consistently associated with worse outcomes and higher risk of mortality. In patients with sepsis, troponin elevation is correlated with the severity of the inflammatory condition and higher in-hospital mortality, which indicates the presence of myocardial injury secondary to systemic involvement. In cases of pulmonary embolism, elevated troponin is related to right ventricular overload, which is indicative of a higher risk of complications and worse clinical outcome.

In the context of chronic renal failure, the presence of elevated troponin often reflects not only a possible myocardial injury, but also a decrease in the renal clearance of this protein, making its interpretation particularly complex. In patients with COPD, troponin elevation can be attributed to chronic hypoxia and pulmonary hyperinflation, which result in right ventricular overload and increased myocardial oxygen demand, and is therefore an important marker for the assessment of cardiovascular risk in these patients.

High-sensitivity assays for troponin detection have allowed considerable advances in the early diagnosis of myocardial lesions, but have also introduced challenges regarding the proper interpretation of this biomarker in non-coronary settings. Elevated troponin, in these cases, should be understood as a marker of severity that can indicate either direct myocardial injury or hemodynamic or systemic compromise. Therefore, the interpretation of troponin levels should always be performed based on the patient's clinical presentation, considering the underlying conditions and other complementary tests.

It is concluded that elevated troponin in non-coronary etiologies is a relevant indicator of risk and prognosis, which should be used as part of a comprehensive approach to patient evaluation. Its detection in different clinical conditions, such as sepsis, renal failure, and COPD, is associated with worse outcomes and higher mortality rates, highlighting the importance of early and appropriate management. Thus, this study reinforces the need for a careful interpretation of troponin levels, aiming to ensure accurate risk stratification and effective treatment, contributing to the improvement of clinical outcomes in medical practice.

REFERENCES

ACOSTA, Giancarlo et al. Clinical determinants of myocardial injury, detectable and serial troponin levels among patients with hypertensive crisis. Cureus, v. 12, n. 1, 2020.

BOLAÑOS, Hans de Jesús Cruz et al. Mortality prediction with the use of inflammatory biomarkers in patients with septic shock. Medicina Crítica, v. 37, n. 3, p. 198-202, 2023.

CHEN, Yuqi et al. Diagnostic and prognostic value of biomarkers in acute myocardial infarction. Postgraduate Medical Journal, v. 95, n. 1122, p. 210-216, 2019.

COLLINSON, Paul O. et al. High sensitivity, contemporary and point-of-care cardiac troponin assays: educational aids developed by the IFCC Committee on Clinical Application of Cardiac Bio-Markers. Clinical Chemistry and Laboratory Medicine (CCLM), v. 57, n. 5, p. 623-632, 2019.

DE LEMOS, J. A.; MURAKAMI, M.; PANTEGHINI, M. et al. Cardiac Troponins I and T: Molecular Markers for Early Diagnosis, Prognosis, and Accurate Triaging of Patients with Acute Myocardial Infarction. Molecular Diagnosis & Therapy, v. 32, p. 126-134, 2023.

GREASER, M. L.; GERGELY, J. Troponin: Structure, Function and Dysfunction. 2023.

HARADA, K.; POTTER, J. D. Familial Hypertrophic Cardiomyopathy and Troponin Mutations. Journal of Biological Chemistry, v. 279, p. 14488-14495, 2023. DOI: 10.1016/j.jbc.2023.

JATENE, Tannas et al. Atherosclerotic burden is the pathway to cardiovascular events. Brazilian Archives of Cardiology, v. 119, n. 3, p. 400-401, 2022.

LINDNER, Gregor et al. Non-acute myocardial infarction-related causes of elevated high-sensitive troponin T in the emergency room: a cross-sectional analysis. Internal and Emergency Medicine, v. 9, p. 335-339, 2014.

LONG, B. et al. An emergency medicine approach to troponin elevation due to causes other than occlusion myocardial infarction. American Journal of Emergency Medicine, 2019.

MARTÍNEZ-SANZ, R. et al. Troponin-I in hemodynamically established pulmonary thromboembolism: correlation with echocardiography and computed tomography angiography. Revista Española de Cardiología, v. 63, n. 7, p. 874-882, 2010. DOI: 10.1016/j.rce.2010.06.014.

MARTINS, A. F.; REDWOOD, C. S. Human cardiac troponin complex: structure and functions. Biochemistry (Moscow), v. 84, p. 200-210, 2023.

MARTINS, C. S. Troponin: Structure, Pathophysiology and Clinical Importance Beyond Myocardial Ischemia. Arq Med, v. 23, n. 6, p. 221-240, 2009.

MOTTA, A.; REDWOOD, C. S.; ZAMORA, M. Troponin structure and function: a view of recent progress. Journal of Muscle Research and Cell Motility, v. 36, p. 561-580, 2016.

O'DONNELL, D.; LAVENEZIANA, P. Physiology and Consequences of Lung Hyperinflation in COPD. European Respiratory Review, 2023.

ROBITAILLE, R.; LAFRANCE, J. P.; LEBLANC, M. Altered laboratory findings associated with end-stage renal disease. Seminars in Dialysis, v. 19, n. 5, p. 373-380, 2006.

SAGGIN, B. et al. Troponin I: Mechanisms and Applications in Myocardial Injury. Advances in Cardiac Research, v. 42, 2023. DOI: 10.1080/troponin.2023.

SHEYIN, Olusegun et al. The prognostic significance of troponin elevation in patients with sepsis: a meta-analysis. Heart & Lung, v. 44, n. 1, p. 75-81, 2015.

SMITH, J. A. et al. Troponin elevation and prognosis in pulmonary embolism: A multi-center cohort study. PubMed Central, v. 22, n. 5, p. 1120-1127, 2023. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11081194/. Accessed on: 09 out. 2024.

SOEIRO, A. M. et al. Sensitive troponin I assay in patients with chest pain - Association with significant coronary lesions with or without renal failure. Brazilian Archives of Cardiology, 2017.

THYGESEN, Kristian et al. Fourth universal definition of myocardial infarction (2018). European Heart Journal, v. 40, n. 3, p. 237-269, 2019.

THYGESEN, Kristian; JAFFE, Allan S. The gloomy long-term prognosis of patients with type 2 myocardial infarction or myocardial injury. Journal of the American College of Cardiology, v. 75, n. 9, p. 1014-1016, 2020.

TOLEDO, João Gabriel Assis et al. Evaluation of serum troponin I levels in patients with chronic kidney disease. Remecs Journal - Multidisciplinary Journal of Scientific Studies in Health, v. 7, n. 12, p. 32-42, 2022.

WAGNER, Björn; WEIDNER, Norbert; HUG, Andreas. Elevated high-sensitivity cardiac troponin T serum concentration in subjects with spinal cord injury. International Journal of Cardiology, v. 391, p. 131284, 2023.