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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Albumin cobalt binding test for the diagnosis of acute coronary syndrome in patients with heart failure

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SUMMARY

Introduction/Objective Patients with acute coronary syndrome (ACS) and a history of heart failure (HF) constitute a distinct high-risk subgroup requiring continuous monitoring due to a greater propensity for complications. This study aimed to evaluate the diagnostic accuracy of the albumin cobalt binding (ACB) test for detecting ACS in patients with HF who presented to the hospital with acute chest pain.

Methods Patients with chest pain suggestive of ACS and either known or newly diagnosed HF were included and stratified into HF with and without ACS. Diagnostic accuracy of the ACB test was assessed statistically.

Results Among 71 patients, 26 had ACS and 45 did not. ACB test values were significantly higher in the HF with ACS group ($p < 0.0001$). The ACB test demonstrated an area under the ROC curve of 0.99 ($p < 0.0001$), with sensitivity and specificity of 96.15% and 100%, respectively. The positive predictive value was 100%, and the negative predictive value was 97.8%.

Conclusion: The ACB test appears to be a promising complementary biomarker rather than a replacement for troponin for identifying ACS in HF patients presenting with acute chest pain.

Keywords: albumin cobalt binding test; heart failure; acute coronary syndrome

INTRODUCTION

Heart failure (HF) represents a complex clinical syndrome characterized by symptoms and signs arising from structural or functional cardiac abnormalities, manifesting when the heart is unable to pump blood forward sufficiently to meet the body's metabolic needs – even when ventricular filling pressures are elevated [1].

Although acute coronary syndrome (ACS) remains a frequent precipitant of hospitalization in patients with HF, distinguishing ACS from other HF-related symptoms is challenging – clinical features and often even biomarkers (like troponins) may be inconclusive. Up to one-third of acute HF cases are precipitated by an undiagnosed ACS, highlighting the urgent need for accurate diagnostic tools to detect ACS in the context of HF. [2].

Oxidative stress plays a critical role in the development and progression of HF, particularly during ischemia–reperfusion, where excessive production of reactive oxygen species (ROS) overwhelms antioxidant systems. This redox imbalance contributes to myocardial injury through mechanisms including lipid peroxidation, oxidative modification of proteins, and DNA damage, ultimately promoting cardiomyocyte dysfunction and ventricular remodeling [3–6]. These oxidative alterations also modify the N-terminal region of serum albumin, reducing its cobalt-binding capacity, a change that can be quantified using the albumin cobalt binding (ACB) test as a surrogate for ischemia-modified albumin (IMA).

Previous studies have demonstrated elevated serum IMA levels in various cardiovascular conditions, including ACS, percutaneous coronary intervention, and HF with reduced ejection fraction [4–7]. However, there is limited evidence regarding the diagnostic utility of the ACB test specifically in HF patients with acute chest pain. Therefore, the aim of this study was to evaluate the diagnostic accuracy of the ACB test for detecting ACS in HF patients presenting with acute chest pain.

METHODS

This prospective study included patients presenting with acute chest pain suggestive of ACS who were admitted to the Coronary Care Unit of the Medical Center in Kosovska Mitrovica.

Inclusion criteria required the onset of chest pain within six hours prior to admission, and pre-established (documented in the medical record) diagnosis of HF or newly diagnosed using the Killip classification [8].

The final diagnosis of ACS was used as the reference standard. Two independent cardiologists, blinded to the ACB test results, reviewed all clinical data and assigned the diagnosis of ACS according to established guidelines [9, 10].

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Based on the presence or absence of ACS, HF patients were categorized into two groups: HF with ACS, and HF without ACS. Demographic and clinical characteristics were recorded at admission, including hypertension, diabetes mellitus, hyperlipidemia, smoking status, and previous myocardial infarction.

Upon admission, a 5 mL venous blood sample was collected and centrifuged at 3000 rpm for 15 minutes to obtain serum for routine biochemical analyses.

ACB test was conducted following the protocol described by Bar-Or et al. [11]. Briefly, patient serum was incubated with a cobalt chloride solution, followed by the addition of dithiothreitol to initiate a colorimetric reaction, which was subsequently halted using saline. The absorbance of the final mixture was measured at 470 nm using an ultraviolet-visible spectrophotometer. This approach indirectly assesses IMA levels based on its reduced binding affinity for cobalt under oxidative conditions. Within-run precision was assessed by analyzing 10 replicates of pooled serum near the optimal cut-off value, while between-day precision was determined by measuring the same sample over five consecutive days.

Data were analyzed using MedCalc version 12.3.0.0 (MedCalc Software, Ostend, Belgium). No formal sample size calculation was performed, as this was an exploratory pilot study. Measures of central tendency and variability were calculated. The Kolmogorov–Smirnov test assessed normality. For normally distributed continuous variables: results were presented as mean ± standard deviation (SD), and Student's t-test was used. For non-normally distributed variables: results were expressed as median and interquartile range (Q1-Q3), and analyzed using the Mann–Whitney U test. Categorical data were expressed as counts and percentages. The χ^2 test was applied for comparisons. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance of the ACB test in detecting ACS among HF patients. The optimal cut-off value was determined from the ROC curve based on the maximum Youden index: J = max (sensitivity + specificity – 1). Bootstrapped 95% confidence intervals were calculated for the Youden index and its associated cut-off.

The area under the ROC curve (AUC) with bootstrapped 95% CI was used to quantify test accuracy. Sensitivity, specificity, positive and negative predictive values, and likelihood ratios were calculated along with 95% CI. A value of $p < 0.05$ was considered statistically significant.

Ethics: The study was conducted in accordance with the Declaration of Helsinki (1975) and approved by the Ethics Committee of the Faculty of Medicine Priština – Kosovska Mitrovica (No. 05-197/9) and by the Medical Center in Kosovska Mitrovica (No. 1234). Informed consent was obtained from all participants.

RESULTS

A total of 96 patients met the initial inclusion criteria. However, 25 were excluded due to missing data, inadequate sample quality, or lack of informed consent. The final cohort consisted of 71 individuals with HF, of whom 26 were diagnosed with ACS, while 45 were not.

Baseline characteristics – including age, sex, smoking status, history of hypertension, diabetes mellitus, dyslipidemia, and previous myocardial infarction – did not significantly differ between HF patients with and without ACS (Table 1). Sex distribution was similar across all groups.

Serum ACB test results were significantly higher in HF patients with ACS compared to both the HF without ACS group. These results are summarized in Table 2. Additionally, serum albumin concentrations did not significantly differ between HF patients with and without ACS. No significant correlation was found between albumin concentrations and ACB test values ($r = –0.201$, $p = 0.22$).

Table 1. Patient characteristics

Variables	HF patients with ACS n = 26	HF patients without ACS n = 45	p
Age (years)	67 ± 9	64 ± 7	0.146
Male (%)	54%	51%	0.981
Smoking (%)	54%	49%	0.875
Hypertension (%)	70%	73%	0.923
Diabetes mellitus (%)	35%	29%	0.813
Hyperlipidemia (%)	38%	31%	0.711
Previous MI (%)	34%	13%	0.069

Data presented as mean ± standard deviation (SD) or percentage; differences between groups were calculated with t-test or χ^2 test; HF – heart failure; ACS – acute coronary syndrome; n – number of patients in group; MI – myocardial infarction

Table 2. ACB test and albumin levels

Parameter	HF with ACS (n = 26)	HF without ACS (n = 45)	p
ACB Test (ABSU)	0.86 (0.63–1.01)*	0.38 (0.28–0.42)	p < 0.0001
Albumin (g/L)	45.1 (43.0–49.6)	49.2 (46.2–51.5)	p = 0.06

Data are presented as median and interquartile range (Q1–Q3); differences between groups were calculated with Mann–Whitney test; HF – heart failure; ACS –acute coronary syndrome; n – number of participants in group; ACB test – albumin cobalt binding test; ABSU – absorbance unit

ROC curve analysis of the ACB test's diagnostic accuracy for identifying ACS among HF patients yielded an area under the ROC curve of 0.99 (95% bootstrap CI: 0.924–1.0; $p < 0.0001$) (Figure 1). The optimal diagnostic threshold was determined as 0.48 absorbance unit (95% bootstrap CI: > 0.47 to > 0.48), corresponding to a Youden index of 0.961 (95% bootstrap CI: 0.807–1.0). At this cutoff, sensitivity, specificity, positive and negative predictive values were calculated and presented in Table 3.

Analytical precision of ACB test was also confirmed. The intra-assay coefficient of variation was 4.1% at a mean value of 0.49 absorbance unit, while the inter-assay coefficient of variation was 3.6% at 0.48 absorbance unit-both measured near the established ROC cutoff.

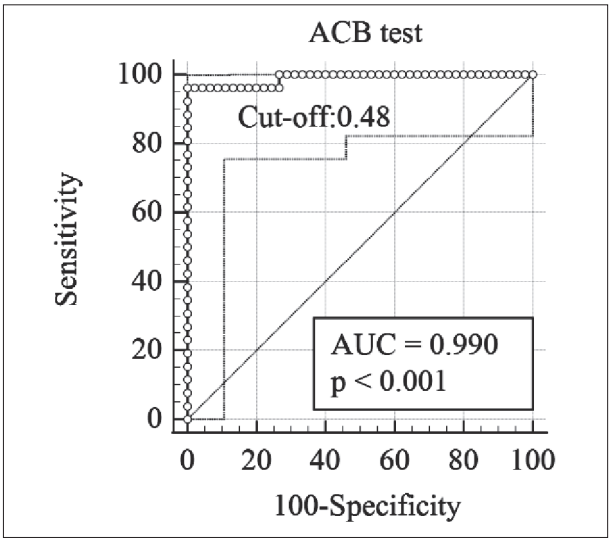

Figure 1. Receiver operating characteristic (ROC) curve of albumin cobalt binding test (ACB) test was derived for heart failure (HF) patients with acute coronary syndrome (ACS) vs. HF patients without ACS; AUC – area under the ROC curve

Table 3. Diagnostic performance of the ACB test in HF with ACS vs. HF without ACS

Parameter	Value (95% CI)
Sensitivity	96.15 (80.4–99.9)
Specificity	100 (92.1–100)
Positive predictive value	100
Negative predictive value	97.8 (86.8–99.7)
Area under ROC curve	0.99 (0.93–0.997)

Values of sensitivity, specificity, negative, and positive predictive value are presented in percentage; values in parentheses represent 95% confidence interval (CI); ACB test – albumin cobalt binding test; ACS – acute coronary syndrome; HF – heart failure

DISCUSSION

The primary finding of this exploratory study is that the ACB test shows promise for detecting ACS in patients with HF presenting with acute chest pain. In this population, where clinical symptoms may overlap and confound diagnosis, the ACB test may serve as a valuable adjunct diagnostic tool.

Patients with HF often present with symptoms indistinguishable from those of ACS, making differential diagnosis challenging. Although troponin T (cTnT) remains a cornerstone in the diagnostic assessment of ACS, its specificity is limited in the context of HF. Elevated troponin levels can occur in patients without acute ischemia, particularly in those with chronic or decompensated HF, as a result of ongoing cardiomyocyte injury and mechanical stress [12, 13, 14]. This overlap complicates clinical decision-making and underscores the need for complementary diagnostic tools capable of differentiating ischemia from other causes of biomarker elevation.

To our knowledge, this is the first study to report that the ACB test is significantly elevated in HF patients with concurrent ACS, compared to HF patients without ACS. This result supports the utility of the ACB test as a marker of myocardial ischemia [5] and left ventricular systolic dysfunction [7].

Ischemic conditions lead to oxidative alterations in the N-terminal region of human serum albumin, resulting in reduced binding affinity for metal ions such as cobalt. These structural changes are primarily attributed to increased ROS activity during ischemia and reperfusion, which modify amino acid residues essential for metal coordination. The ACB test exploits this biochemical shift as an indirect indicator of myocardial ischemia, reflecting oxidative stress-induced albumin dysfunction [5, 15, 16].

There is a growing body of evidence implicating oxidative stress in the pathogenesis of various cardiovascular conditions, including myocardial ischemia-reperfusion injury, atherosclerosis, cardiac hypertrophy, hypertension, diabetic cardiomyopathy, and atrial fibrillation [17]. The transition from myocardial hypertrophy to HF is associated with progressive oxidative damage, highlighting the role of ROS in disease progression [18]. While the etiological background of HF is heterogeneous, factors such as coronary artery disease, diabetes, and hypertension are major contributors to the observed oxidative alterations [19]. Notably, oxidative stress is elevated in both ischemic and non-ischemic HF [20]. During ischemia-reperfusion, the excessive generation of oxygen radicals can overwhelm antioxidant defenses, resulting in significant tissue damage [21]. These changes may further impair the albumin-metal binding capacity, which is the basis of the ACB test.

Patients with HF and concomitant ACS represent a high-risk subgroup with greater rates of complications, prolonged hospital stays, and increased mortality during hospitalization and at follow-up intervals of 30 days and one year [2, 22]. Early identification of ACS in these patients is thus of paramount clinical importance.

In our study, the ACB test demonstrated high diagnostic performance: sensitivity and specificity were 96.2% and 100%, respectively, with a positive predictive value of 100% and a negative predictive value of 97.8%. However, the very high AUC of 0.99 is unlikely to be replicated in larger, more heterogeneous populations. These findings suggest that the ACB test could facilitate early identification of ACS in HF patients, potentially enabling faster treatment and more efficient triage in emergency settings.

Moreover, previous studies have indicated that patients with HF undergo fewer coronary angiographies and revascularization procedures. However, when complete revascularization is achieved, outcomes are significantly improved, with reductions in HF hospitalizations and cardiovascular mortality [23]. Rapid and reliable differentiation of ACS from HF-related symptoms is essential to enable appropriate clinical interventions, such as early revascularization. Incorporating the ACB test into early diagnostic workflows could help identify high-risk patients who would benefit from timely coronary angiography and targeted therapy, ultimately improving outcomes through prompt ischemia management [22, 23].

It should be noted that this cohort was enrolled in 2014, when a third-generation cTnT assay was in use. Although high-sensitivity cardiac troponins (hs-cTn) are now the diagnostic standard, their interpretation in HF remains

problematic because chronically elevated baseline levels can mask acute ischemia. In this setting, the ACB test-capturing ischemia-driven albumin modification – could serve as a complementary marker. Our results suggest that ACB may be most useful in patients falling into the "observe" zone of accelerated 0/1-h or 0/2-h hs-cTn algorithms, and in HF patients with persistently elevated hs-cTn where additional ischemic evidence is needed [24, 25, 26]. Comparable evidence from a Serbian chest-pain cohort demonstrated that the HEART score achieved an AUROC of 0.771 (sensitivity 89.2%, specificity 57.6%) for detecting ischemic heart disease, underscoring the need for adjunct biomarkers such as ACB to improve early ACS detection in high-risk patients [27].

Taken together, the time-stable pathophysiology captured by ACB, the persistent interpretive limitations of hs-cTn in HF, and evidence that accelerated algorithms may underperform in certain high-risk patients support the continuing relevance of our results. Rather than proposing ACB as a replacement, we highlight its potential role as a complementary ischemia marker that deserves prospective validation within guideline-endorsed 0/1-h or 0/2-h hs-cTn frameworks [7, 8, 25, 26].

The limitations of this study must be acknowledged. Small sample size and single-center design reduce generalizability. Restriction to patients within six hours of symptom onset limits applicability to later presenters. No head-to-head ROC analysis of cTnT *vs*. ACB prevents direct comparative conclusions. Near-perfect ROC performance may reflect optimism bias.

CONCLUSION

This study suggests that the albumin ACB test is a promising complementary biomarker for detecting ACS in HF patients presenting with acute chest pain, based on data collected in 2014 with third-generation troponin assays. The test exhibited high sensitivity, specificity, and predictive values. However, these findings should be interpreted as preliminary, pilot-level evidence requiring validation in larger multicenter studies embedded within guideline-recommended hs-cTn diagnostic algorithms.

Conflict of interest: None declared.

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Тест везивања албумина за кобалт у дијагностици акутног коронарног синдрома код болесника са срчаном инсуфицијенцијом

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САЖЕТАК

Увод/Циљ Болесници са акутним коронарним синдромом (АКС) и историјом срчане инсуфицијенције (СИ) чине посебну подгрупу високог ризика која захтева континуирано праћење због веће склоности ка компликацијама.
Циљ ове студије био је да се процени дијагностичка тачност теста везивања кобалта за албумин (*ACB* тест) у откривању АКС код болесника са СИ који су хоспитализовани са акутним болом у грудима.

Методе У истраживање су укључени болесници са болом у грудима који је указивао на АКС, а који су имали познату или новодијагностиковану СИ. Болесници су стратификовани у групе са СИ и АКС и са СИ без АКС. Дијагностичка тачност *ACB* теста процењена је статистичком анализом.

Резултати Од укупно 71 болесника, 26 је имало АКС, док 45 није. Вредности *ACB* теста биле су значајно више у групи са СИ и АКС ($p < 0,0001$). *ACB* тест је показао површину испод *ROC* криве од 0,99 ($p < 0,0001$), са сензитивношћу и специфичношћу од 96,15% и 100%, редом. Позитивна предиктивна вредност износила је 100%, а негативна 97,8%.

Закључак Резултати указују да *ACB* тест може имати улогу комплементарног биомаркера у препознавању АКС код болесника са СИ, али да не може заменити тропонин.

Кључне речи: тест везивања албумина за кобалт; срчана инсуфицијенција; акутни коронарни синдром