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Assessment of Lactate Levels as Prognostic and Predictive Markers in Patients with Complete Atrioventricular Block

Laktat Düzeylerinin Atriyoventriküler Tam Bloklu Hastalarda Prognostik ve Prediktif Belirteç Olarak Değerlendirilmesi

ABSTRACT

Objective: Complete atrioventricular (AV) block complicates management decisions, particularly regarding temporary pacemaker (TP) insertion. Lactate, an anaerobic byproduct, may reflect inadequate cardiac output and help guide this decision. We analyzed the prognostic value of lactate in patients with complete AV block.

Method: We retrospectively evaluated the medical records of adult patients presenting with complete AV block to our coronary care unit. Initial and subsequent venous blood lactate levels were analyzed for associations with adverse in-hospital outcomes, defined as renal injury, cardiac mortality, or the need for TP prior to permanent pacemaker implantation.

Results: The study included 140 patients (46.4% female; median age: 76 years, range: 32–96). Poor outcomes were observed in 22.9% of patients (n = 32), who exhibited significantly higher initial lactate levels (median: 3.1 vs. 2.0 mmol/L; P < 0.001). A lactate cutoff > 1.8 mmol/L predicted poor outcomes with 90.6% sensitivity and 43.5% specificity. Elevated baseline and follow-up lactate levels remained significant predictors, with 83.3% sensitivity and 85.5% specificity compared to normal baseline and follow-up lactate levels.

Conclusion: Increased lactate levels are independent determinants of poor in-hospital outcomes in patients with complete AV block. Lactate measurement may aid decision-making regarding TP even in hemodynamically stable patients. However, these results are hypothesis-generating, and prospective studies are needed to confirm clinical utility.

Keywords: Complete atrioventricular block, temporary pacemaker, venous blood lactate level

ÖZET

Amaç: Atriyoventriküler (AV) tam blok yönetiminde, özellikle geçici pacemaker (GP) endikasyonunun belirlenmesinde karar verme süreci zordur. Anaerobik metabolizmanın bir yan ürünü olan laktat, yetersiz kardiyak debiyi yansıtabilir ve bu süreçte yol gösterici olabilir. Bu çalışmada, AV tam bloklu hastalarda laktat düzeylerinin prognostik değerini ve olumsuz klinik gidişi öngörmedeki rolünü değerlendirmeyi amaçladık.

Yöntem: Koroner yoğun bakım ünitemize kabul edilen AV tam blok tanılı erişkin hastaların kayıtları retrospektif olarak incelendi. Bazal ve takip venöz kan laktat düzeyleri ile kötü hastane içi klinik sonuçlar arasındaki ilişki değerlendirildi. Kötü klinik sonuç; renal hasar, kardiyak nedenli mortalite veya kalıcı pacemaker öncesi GP gereksinimi olarak tanımlandı.

Bulgular: Çalışmaya 140 hasta (yaş ortancası 76 [32–96] yıl; %46,4 kadın) dahil edildi. Kötü klinik gidiş %22,9 (n=32) oranında izlendi. Bu hastalarda bazal laktat düzeyleri anlamlı olarak daha yüksekti (ortanca 3,1 vs. 2,0 mmol/L; P < 0,001). Laktat > 1,8 mmol/L, kötü klinik sonucu %90,6 duyarlılık ve %43,5 özgüllükle öngördü. Normal bazal ve takip laktat düzeylerine kıyasla yüksek bazal ve takip laktat düzeyleri, kötü klinik gidişi %83,3 duyarlılık ve %85,5 özgüllükle öngördü.

Sonuç: Laktat düzeyi, tam AV bloklu hastalarda kötü hastane içi klinik gidişin bağımsız bir öngördürücüsüdür. Hemodinamik olarak stabil hastalarda bile GP gerekliliğine karar verme sürecinde laktat ölçümü yol gösterici olabilir. Ancak bu bulgular hipotez üreten niteliktedir ve klinik faydayı doğrulamak için prospektif çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Atriyoventriküler tam blok, geçici kalp pili, venöz kan laktat düzeyi

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Managing complete atrioventricular (AV) blocks is challenging, especially when determining the need and timing for temporary pacing. Although immediate temporary pacing is not necessary for all patients with complete AV block, careful clinical assessment is essential.[1-4] Temporary pacing, although a relatively simple intervention, is not without complications, including malfunction, infection, thromboembolic events, and cardiac perforation.[5,6] The inherent risks associated with routine temporary pacing emphasize the need for a cautious and selective approach. Nevertheless, the negative consequences of delayed or omitted temporary pacing should not be disregarded.[7] Maintaining this delicate balance requires careful patient selection. Thorough evaluation of clinical indicators, reversible causes, and the potential for complications is therefore crucial when determining the need and timing of temporary pacing.[8-10]

Lactate, a metabolite generated during both aerobic and anaerobic metabolism, has gained recognition as a valuable biomarker across various medical conditions.[11] Elevated lactate levels may serve as a key indicator of compromised cardiac output and inadequate tissue perfusion, helping to inform decisions regarding the need for temporary pacing in patients with complete AV block.[12] Previous research has demonstrated a strong association between elevated lactate concentrations and mortality in patients with septic shock.[13,14] Likewise, admission lactate levels have been linked to adverse outcomes in individuals with acute coronary syndrome and heart failure.[15,16] Despite these findings, the prognostic significance of lactate in the setting of complete AV block has not been systematically examined. The present study aims to evaluate the prognostic value of lactate levels in this population and to explore their potential role in guiding the timing of temporary pacemaker implantation.

ABBREVIATIONS

AC	Alternating current
AV	Atrioventricular
ECG	Electrocardiogram
KDIGO	The Kidney Disease: Improving Global Outcomes
LVEF	Left ventricular ejection fraction
TP	Temporary pacemaker

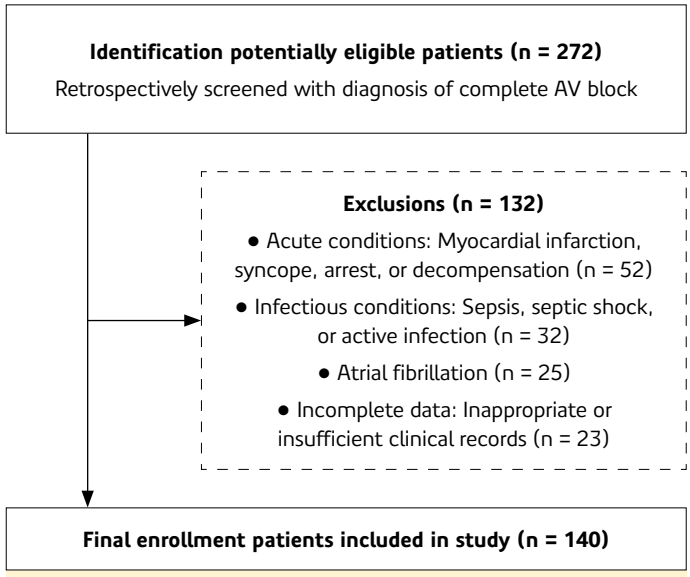


Figure 1. STROBE-style study flow diagram.

Materials and Methods

Study Population

In this retrospective study, we examined the association between serum lactate levels and prognosis in individuals diagnosed with complete AV block. The study initially evaluated data from 272 consecutive patients diagnosed with complete AV block. Exclusion criteria included acute coronary syndrome, atrial fibrillation, active infection or sepsis, decompensated heart failure, the need for inotropes, cardiac arrest, early (< 24 hours) permanent pacemaker implantation, and insufficient clinical or laboratory data (Figure 1). These exclusions were applied to reduce major confounding causes of lactate elevation. In addition, some of these conditions required urgent temporary pacing, leaving no meaningful pre-pacing observation period for analysis. After applying the exclusion criteria, a total of 140 patients were included in the final analysis. The study was conducted in accordance with the Declaration of Helsinki and received approval from Health Sciences University Dışkapı Yıldırım Beyazıt Training and Research Hospital Clinical Research Ethics Committee (Approval Number: 56/14, Date: 12.11.2018). Given its retrospective design, the requirement for informed patient consent was waived. This study did not involve the use of artificial intelligence–based technologies, including but not limited to large language models, chatbots, or image-generation tools.

Baseline patient characteristics, including age, sex, comorbidities, and laboratory parameters, were obtained from the hospital database. Patients who underwent temporary pacing were identified. Twelve-lead electrocardiograms (ECGs) were independently evaluated by two cardiologists. ECG recordings were obtained using a filter range of 0.15–100 Hz, an alternating current (AC) filter of 60 Hz, a speed of 25 mm/s, and a sensitivity of 10 mm/millivolt. Echocardiographic examinations were performed using a Philips Healthcare iE33 echocardiography system (xMATRIX, Philips Medical System, Andover, MA, USA) equipped with an S5-1 transducer. Left ventricular ejection fraction (LVEF) was calculated using the modified Simpson method (biplane method of disks). For the entire study population, the occurrence of acute kidney injury and cardiac-related mortality, as well as the presence of hemodynamic compromise, symptoms, or findings necessitating temporary pacing prior to permanent pacemaker implantation, were regarded as indicators of poor in-hospital clinical outcomes. The Kidney Disease: Improving Global Outcomes (KDIGO) criteria were used for the diagnosis of acute kidney injury.[17] Acute kidney injury was defined by the presence of any one of the following criteria: an increase in serum creatinine of ≥ 0.3 mg/dL within 48 hours; an increase in serum creatinine to ≥ 1.5 times the known baseline within the previous seven days; or a urine output < 0.5 mL/kg/h for at least 6 hours. Altered mental status, chest pain, worsening bradycardia, or the onset of pulmonary edema were also considered indicators of poor in-hospital clinical outcomes. Conversely, the absence of these conditions during follow-up was considered indicative of a favorable clinical outcome.

Laboratory Analysis

Laboratory analyses included a comprehensive set of parameters recorded at the time of hospital admission, including hemoglobin, creatinine, sodium, potassium, alanine aminotransferase, total bilirubin, low-density lipoprotein, thyroid-stimulating hormone, troponin, and lactate levels. Lactate levels in venous blood gas samples were quantified using a spectrophotometric measurement method on the ABL 800 FLEX device (Radiometer Medical, Denmark). To monitor dynamic changes, follow-up assessments of creatinine and lactate levels were conducted at 12 and 24 hours after admission. Admission lactate was defined as the first lactate measurement obtained at presentation to the emergency department. Follow-up lactate values were defined as measurements obtained approximately 12 and 24 hours after the admission sample based on laboratory timestamps; analyses at each time point included all available cases. For delta lactate, an "increase" was defined as any rise at either follow-up time point compared with the admission value. The maximum delta lactate was calculated using the highest follow-up lactate value (whichever was higher at 12 or 24 hours).

Data Analysis

Statistical analyses were performed using SPSS (version 20.0, IBM Corp., Armonk, NY, USA) and MedCalc (version 22.0, MedCalc Software Ltd., Ostend, Belgium). Data distribution was assessed using the Kolmogorov–Smirnov test. Continuous variables with a normal distribution were presented as mean ± standard deviation, whereas non-normally distributed variables were reported as median (min-max). Categorical variables were presented as counts and percentages. To evaluate differences in numerical variables between groups with poor and good clinical outcomes, the Student's t-test was used for normally distributed variables and the Mann-Whitney U test for non-normally distributed variables. The chi-square test and Fisher's exact test were used to compare categorical data. Multivariable logistic regression analysis was performed to identify independent predictors of poor clinical outcomes from a set of potential risk factors. To evaluate the predictive performance of lactate levels for poor clinical outcomes, receiver operating characteristic (ROC) curve analysis was conducted. The predictive value was then determined using the Youden index. Internal validation was performed using bootstrap resampling. In each bootstrap sample, the multivariable logistic regression model was refitted, and discrimination was assessed by the area under the receiver operating characteristic curve (AUC). Optimism-corrected AUC values with 95% confidence intervals (CI) were derived from the bootstrap distribution. Calibration was evaluated using the calibration intercept and calibration slope. A p-value < 0.05 was considered statistically significant.

Results

During the study period, 272 consecutive patients with complete atrioventricular block were screened; 132 were excluded (acute conditions, n = 52; atrial fibrillation, n = 25; sepsis or active infection, n = 32; inadequate records, n = 23). The final cohort included 140 patients (female, n = 65 [46.4%]; median age 76 years [range: 32–96]). Pre-existing conditions included diabetes mellitus in 17.9% of patients, hypertension in 81.9%, and coronary artery disease in 52.9%. The mean heart rate was 36.0 ± 7.6 beats per minute. At presentation, the mean systolic blood pressure was 124.0 ± 22.6 mmHg in the overall cohort, 125.4 ± 23.4 mmHg in patients with good outcomes, and 119.1 ± 19.4 mmHg in patients with poor outcomes (P = 0.163). Mean diastolic blood pressure was 67.1 ± 14.3 mmHg overall, 67.1 ± 14.2 mmHg in the good-outcome group, and 67.2 ± 14.9 mmHg in the poor-outcome group (P = 0.971). Mean arterial pressure was 86.1 ± 15.9 mmHg overall, 86.5 ± 15.9 mmHg in the good-outcome group, and 84.5 ± 15.8 mmHg in the poor-outcome group (P = 0.523). Senile degeneration was the most common etiological cause (87.9%), followed by drug-related causes (11.4%) and myocarditis (0.7%). On admission, the median serum creatinine level was 1.2 mg/dL (range: 0.6-4.0), increasing to 1.5 mg/dL (range: 1.0-5.1) at follow-up. Serum lactate levels at admission were 2.1 mmol/L (range: 0.7-14.5), with a follow-up median of 2.0 mmol/L (range: 0.5-18.0). The overall rate of poor clinical outcomes was 22.9% (n = 32). During follow-up, acute kidney injury occurred in 13.6% of patients, mortality in 6.4%, and temporary pacing was required in 2.9% of initially untreated patients. A complete overview of the study population's baseline characteristics and clinical outcomes is provided in Table 1.

In patients with poor clinical outcomes, LVEF was significantly lower compared to those with good outcomes (44.0 ± 12.1% vs. 50.3 ± 13.1%; P = 0.016). Notably, in patients with poor clinical outcomes, there was no significant change in lactate levels during follow-up (3.1 mmol/L vs. 3.3 mmol/L; P = 0.468). In contrast, patients with good clinical outcomes demonstrated a significant decrease in lactate levels during follow-up (2.0 mmol/L vs. 1.5 mmol/L; P < 0.001). At admission, patients with poor clinical outcomes had significantly higher serum creatinine levels [1.4 (0.8–3.8) mg/dL vs. 1.2 (0.6–4.0) mg/dL; P = 0.042] and lactate levels [3.1 (0.8–14.5) mmol/L vs. 2.0 (0.7–9.0) mmol/L; P < 0.001] compared to those with good outcomes. Similarly, follow-up assessments revealed significantly higher serum creatinine [2.2 (1.5–5.0) mg/dL vs. 1.3 (1.0–5.1) mg/dL; P < 0.001] and lactate [3.3 (1.0–18.0) mmol/L vs. 1.5 (0.5–12) mmol/L; P < 0.001] levels in patients with poor outcomes (Figure 2). In the good clinical outcome group (n = 108), the median admission lactate level was 2.0 mmol/L (range: 0.7–9.0) and the median follow-up lactate level was 1.5 mmol/L (range: 0.5–12.0). Compared with this group, the mortality subgroup (n = 9) had significantly higher admission and follow-up lactate levels (7.0 [2.8–14.5] and 8.0 [3.6–18.0], respectively; both P < 0.001). The acute kidney injury subgroup (n = 19) also showed higher lactate values at admission (2.3 [1.5–9.0]; P = 0.024) and at follow-up (3.0 [1.0–6.0]; P = 0.002). In contrast, lactate levels in patients requiring temporary pacing (n = 4) were not significantly different from those in the no-event group at admission (2.7 [0.8–5.6]; P = 0.615) or at follow-up (2.1 [1.0–4.0]; P = 0.370). Comparisons of serial lactate levels between the no-event group and adverse outcome subgroups are summarized in Table 2.

The analysis revealed several factors associated with poor clinical outcomes, as detailed in Table 3. Specifically, LVEF (odds ratio [OR]: 0.96, 95% CI: 0.94–0.99; P = 0.018), lactate level at admission (OR: 1.44, 95% CI: 1.17–1.76; P < 0.001), follow-up lactate level (OR: 1.52, 95% CI: 1.23–1.88;

Table 1. Clinical, echocardiographic, and laboratory parameters stratified by clinical course

Parameters	All patients (n = 140)	Patients with good outcomes (n = 108)	Patients with poor outcomes (n = 32)	*P*
Age (years), mean ± SD	74.6 ± 13.1	73.5 ± 13.2	78.1 ± 12.5	0.082
Female, n (%)	65 (46.4)	50 (46.3)	15 (46.9)	0.998
Smoking, n (%)	80 (53.6)	64 (59.3)	16 (50.0)	0.468
Diabetes, n (%)	25 (17.9)	19 (17.6)	6 (18.8)	0.997
Hypertension, n (%)	114 (81.9)	86 (79.6)	28 (87.5)	0.455
CAD, n (%)	74 (52.9)	56 (51.9)	18 (56.2)	0.813
Systolic BP (mmHg), mean ± SD	124.0 ± 22.6	125.4 ± 23.4	119.1 ± 19.4	0.163
Diastolic BP (mmHg), mean ± SD	67.1 ± 14.3	67.1 ± 14.2	67.2 ± 14.9	0.971
Mean BP (mmHg), mean ± SD	86.1 ± 15.9	86.5 ± 15.9	84.5 ± 15.8	0.523
Heart rate (bpm), mean ± SD	36.0 ± 7.6	35.8 ± 8.2	36.0 ± 5.5	0.883
Senile degenerative block, n (%)	123 (87.9)	93 (86.1)	30 (93.8)	0.488
Wide QRS, n (%)	78 (55.7)	61 (56.5)	17 (53.1)	0.840
LVEF (%), mean ± SD	48.0 ± 13.1	50.3 ± 13.1	44.0 ± 12.1	0.016
Hemoglobin (g/dL), mean ± SD	12.7 ± 2.1	12.9 ± 2.0	12.1 ± 2.4	0.069
Potassium (mEq/L), mean ± SD	4.1 ± 0.8	4.0 ± 0.8	4.2 ± 0.9	0.405
LDL (mg/dL), mean ± SD	148.7 ± 42.4	151 ± 42.1	140.9 ± 42.8	0.236
TSH (mIU/L), median (min-max)	1.1 (0.01–9.0)	1.1 (0.01–9.0)	1.1 (0.1–3.2)	0.344
ALT (U/L), median (min-max)	32.0 (8.0–432.0)	32 (8–432)	30 (12–321)	0.994
Total bilirubin (mg/dL), median (min-max)	1.0 (0.2–6.7)	1 (0.2–3.3)	0.9 (0.2–6.7)	0.594
Troponin (pg/mL), median (min-max)	0 (0–1.2)	0 (0–1.2)	0.01 (0–0.9)	0.769
Creatinine (mg/dL), median (min-max)	1.2 (0.6–4.0)	1.2 (0.6–4.0)	1.4 (0.8–3.8)	0.042
Baseline lactate level (mmol/L), median (min-max)	2.1 (0.7–14.5)	2.0 (0.7–9.0)	3.1 (0.8–14.5)	< 0.001
Follow-up lactate level (mmol/L), median (min-max)	2.0 (0.5–18.0)	1.5 (0.5–12)	3.3 (1.0–18.0)	< 0.001

ALT, Alanine aminotransferase; CAD, Coronary artery disease; LDL, Low-density lipoprotein; LVEF, Left ventricular ejection fraction; SD, Standard deviation; TSH, Thyroid-stimulating hormone.

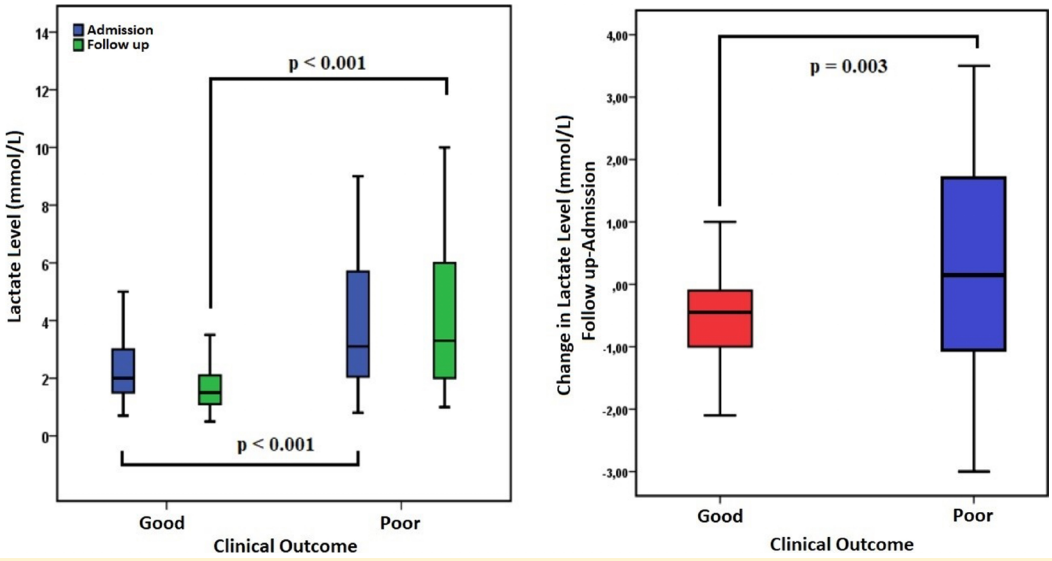


Figure 2. Admission and follow-up lactate levels and lactate change according to clinical outcome.

P < 0.001), and ΔLactate (OR: 1.60, 95% CI: 1.15–2.23; P = 0.005) were associated with poor clinical outcomes. A lactate level > 1.8 mmol/L predicted poor clinical outcomes with 90.6% sensitivity and 43.5% specificity, yielding a positive predictive value of 30.9% and a negative predictive value of 95.3%. When analyzed as a continuous variable, admission

Table 2. Comparison of lactate levels between the good-outcome group and poor-outcome subgroups

Group	n	Lactate at admission	*P*	Lactate at follow-up	*P*
No event	108	2.0 (0.7–9.0)		1.5 (0.5–12.0)	
Mortality	9	7.0 (2.8–14.5)	< 0.001	8.0 (3.6–18.0)	< 0.001
Acute kidney injury	19	2.3 (1.5–9.0)	0.024	3.0 (1.0–6.0)	0.002
Need for temporary pacing	4	2.7 (0.8–5.6)	0.615	2.1 (1.0–4.0)	0.370

P values represent comparisons between each subgroup and the no-event group. Follow-up lactate level refers to the higher value observed at approximately 12 or 24 hours. Lactate levels are reported as median (min–max) in mmol/L.

Table 3. Risk factors associated with poor clinical outcomes

Parameters	OR	95% CI	*P*
LVEF, %	0.96	0.94–0.99	0.018
Admission lactate (mmol/L)	1.44	1.17–1.76	< 0.001
Follow-up lactate (mmol/L)	1.52	1.23–1.88	< 0.001
ΔLactate, (mmol/L)	1.60	1.15–2.23	0.005

OR, Odds ratio; CI, Confidence interval; LVEF, Left Ventricular Ejection Fraction; Δ, Difference between follow-up and admission values.

lactate demonstrated good discrimination, with an area under the receiver operating characteristic curve of 0.712 (95% CI: 0.637–0.792) (Figure 3). The proportion of patients with a baseline lactate level ≤ 1.8 mmol/L and no increase in lactate at follow-up was 25.7%. A baseline lactate level ≤ 1.8 mmol/L with an increase in lactate at follow-up was observed in 10% of patients. The proportion of patients with a baseline lactate level > 1.8 mmol/L and no increase in lactate at follow-up was 47.9%, whereas 16.4% of patients had a baseline lactate level > 1.8 mmol/L with an increase in lactate at follow-up. The proportion of patients with a baseline lactate level > 1.8 mmol/L and an increase in lactate at follow-up was significantly higher among patients with poor outcomes (P < 0.001) (Figure 4). In multivariable regression analysis, Model 1 identified baseline LVEF (OR: 0.97, 95% CI: 0.94–0.99; P = 0.037) and baseline lactate level (OR: 1.39, 95% CI: 1.13–1.70; P = 0.002) as independent predictors of poor clinical outcome. In Model 2, ΔLactate (OR: 1.52, 95% CI: 1.10–2.13; P = 0.010) was identified as an independent predictor of poor clinical outcome. In Model 3, lactate level patterns were categorized as follows: "admission high, no increase at follow-up" (OR: 4.14, 95% CI: 1.12–15.30; P = 0.033) and "admission high, increase at follow-up" (OR: 29.38, 95% CI: 6.90–125.06; P < 0.001). Both patterns were independent predictors of poor clinical outcome. Model 3 demonstrated better performance in explaining poor clinical outcomes compared to the other regression models (Nagelkerke R^2 = 0.523) (Table 4). Relative to a normal admission lactate level, the "admission high, increase at follow-up" lactate pattern demonstrated strong predictive capacity for poor clinical outcomes, with a sensitivity of 83.3% and a specificity of 85.5%. Model 1 (LVEF + admission lactate) showed an optimism-corrected AUC of 0.721 (95% CI: 0.628–0.819) with a calibration slope of 0.948. Model 2 (LVEF + Δlactate) had an optimism-corrected AUC of 0.659 (95% CI: 0.555–0.777) with a calibration slope 0.937. Model 3 (LVEF + lactate pattern) yielded an optimism-corrected AUC of 0.796 (95% CI: 0.715–0.895) with a calibration slope of 0.859.

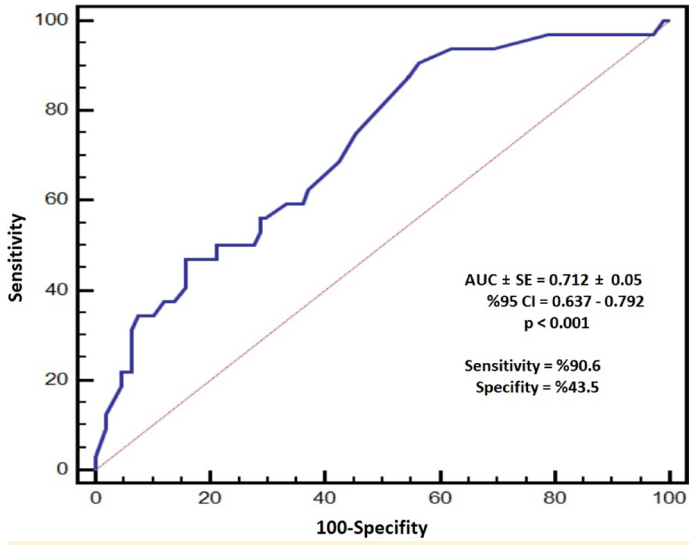


Figure 3. Prediction of poor clinical outcomes by lactate level > 1.8 mmol/L.

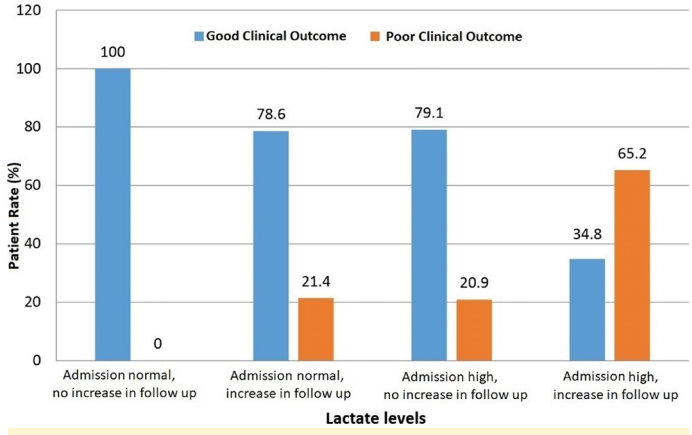


Figure 4. Proportion of patients according to lactate levels at admission and follow-up.

Discussion

This study demonstrates the substantial impact of lactate levels on clinical outcomes in patients with complete AV block, highlighting the association between elevated lactate levels at admission and a subsequent rise in lactate levels during follow-up with poorer in-hospital outcomes. In particular, the lactate profile characterized as "admission high, increase at follow-up" emerged as the most reliable indicator of unfavorable clinical outcomes.

Table 4. Independent predictors of poor clinical outcome

Parameters	OR	95% CI	*P*
Model 1			
LVEF	0.97	0.94–0.99	0.037
Lactate	1.39	1.13–1.70	0.002
Nagelkerke R^2 = 0.352; P < 0.001			
Model 2			
LVEF	0.97	0.94–0.99	0.038
ΔLactate	1.52	1.10–2.13	0.010
Nagelkerke R^2 = 0.411; P < 0.001			
Model 3			
LVEF	0.96	0.93–0.98	0.042
Lactate			
Admission normal	Ref		
Admission high, no increase at follow-up	4.14	1.12–15.30	0.033
Admission high, increase at follow-up	29.38	6.90–125.06	< 0.001
Nagelkerke R^2 = 0.523; P < 0.001			

OR, Odds ratio; CI, Confidence interval; LVEF, Left ventricular ejection fraction; Δ, Difference between follow-up and admission values.

Since its discovery, lactate has traditionally been regarded as a byproduct of glycolysis, viewed primarily as a metabolic waste product with limited physiological significance.[18] However, subsequent research has shed light on the complex role of lactate, revealing its importance beyond that of a mere metabolic byproduct. Lactate is now recognized as a key mediator in organ growth and development, as well as in the coordination of vascular development and progenitor cell behavior during brain development.[19] Moreover, lactate serves as a precursor for gluconeogenesis and can directly or indirectly enter the mitochondrial matrix to contribute to energy production.[20] Lactate also serves as a significant energy source for vital organs such as the heart, brain, and skeletal muscles. Notably, during periods of physical exertion, lactate can supply more than 50% of the energy required by cardiomyocytes. As exercise progresses, lactate production increases to accommodate the heightened metabolic demands.[21]

Lactate production is a complex biochemical process involving multiple tissues, with skeletal muscle being a primary source. Under normal aerobic conditions, pyruvate—produced through glycolysis—enters the Krebs cycle via conversion to acetyl-coenzyme A (acetyl-CoA), allowing efficient energy production without lactate accumulation. However, when oxygen supply is limited—such as in cases of complete AV block where cardiac output is severely compromised—pyruvate is converted to lactate by the enzyme lactate dehydrogenase, facilitating anaerobic glycolysis. This metabolic shift not only results in increased lactate levels but also reflects the severity of tissue hypoxia and systemic perfusion deficits.[22,23]

Clinical and experimental studies have demonstrated significant alterations in lactate levels in several cardiovascular diseases, including atherosclerosis, heart failure, atrial fibrillation, and myocardial infarction.[24-26] Numerous studies have consistently shown that elevated lactate levels are associated with a poor prognosis in patients with heart failure. Specifically, elevated lactate levels at hospital admission are strongly associated with higher mortality rates in patients with acute decompensated heart failure.[25] This rise in blood lactate is primarily caused by several factors, including decreased oxygen delivery to peripheral tissues, impaired tissue oxygen utilization, activation of the neurohumoral system (including the adrenal and sympathetic nervous systems), increased oxygen demand, and organ dysfunction such as liver or kidney issues, which reduce the body's ability to clear lactate.[27-30] During myocardial infarction, coronary occlusion results in a significant reduction in oxygen supply to myocardial cells, impairing mitochondrial oxidative phosphorylation and accelerating glycolysis within the heart muscle.[24,31] This shift leads to increased lactate production in cardiomyocytes, a finding supported by some clinical studies reporting elevated circulating lactate levels in patients with myocardial infarction. It has been consistently demonstrated across multiple studies that circulating lactate levels have substantial prognostic value in predicting unfavorable clinical outcomes in these patients.[32,33] Moreover, compared to initial lactate values, the 24-hour lactate level and lactate clearance rate provide superior predictive power for in-hospital mortality in patients with myocardial infarction.[34] Atrial fibrillation, another common cardiovascular condition, has also been studied in relation to lactate metabolism. Research has shown that lactate levels are elevated in atrial myocytes of patients with atrial fibrillation, a phenomenon associated with oxidative stress-induced damage and cardiomyocyte apoptosis. These findings indicate that this metabolic pathway may contribute to the development and progression of atrial fibrillation by promoting atrial remodeling.[35-38] Atherosclerosis is a chronic inflammatory condition involving multiple cell types, including vascular endothelial cells, monocytes, macrophages, and lymphocytes. In recent years, studies have highlighted the important role of lactate in the development of atherosclerosis. A cross-sectional study demonstrated a positive association between elevated blood lactate levels and carotid atherosclerosis, a finding that remained significant after adjustment for other cardiovascular risk factors.[39,40] In addition, exercise is a well-known protective factor against several cardiovascular diseases, such as atherosclerosis.[41] Recent studies suggest that lactate-induced lactylation may decrease the risk of atherosclerosis by inhibiting lipogenesis and attenuating vascular inflammatory responses.[42] Lactate also exerts similar effects on lipid metabolism in adipose tissue. These findings suggest that the rise in lactate during high-intensity interval training may reduce the risk of atherosclerosis by inhibiting lipogenesis.[43,44]

Profound bradycardia and AV dissociation observed in individuals with complete AV block precipitate a decline in cardiac output. As a result, reduced oxygen delivery to tissues may lead to tissue hypoxia.[45] This physiological state enhances the conversion of pyruvate to lactate through anaerobic glycolysis. Consequently, adverse outcomes such as acute kidney injury and cardiac-related mortality may be more common in individuals with elevated lactate levels. Moreover, patients with good clinical outcomes demonstrated a significant decrease in lactate levels

during follow-up, whereas no such decline was observed in patients with poor clinical outcomes. Therefore, the absence of a decrease in lactate levels during follow-up in a patient with complete AV block may indicate the need for closer clinical monitoring due to the potential risk of clinical complications.[1,2,46]

In critically ill patients, persistent imbalances between oxygen demand and oxygen delivery can lead to global tissue hypoxia, prompting increased anaerobic metabolism and lactate production.[14] While several randomized studies in sepsis use a lactate threshold of ≥ 4 mmol/L as an inclusion criterion, some research suggests that even lactate levels ≥ 2 mmol/L are associated with increased mortality in patients with sepsis.[2,12-15] A retrospective cohort study of 1,865 patients with acute coronary syndrome investigated the association between admission lactate levels and 30-day and 180-day mortality. Patients were categorized into three groups based on lactate levels: < 1.8 mmol/L, 1.8–2.6 mmol/L, and > 2.7 mmol/L. The study reported increased 30-day and 180-day mortality in the third group, in which admission lactate values exceeded 2.7 mmol/L.[15] Additionally, a study involving 754 patients admitted to the coronary intensive care unit with acute decompensated heart failure identified lactate level at presentation as an independent predictor of in-hospital mortality. The lactate threshold with the highest sensitivity and specificity for predicting mortality was determined to be 3.2 mmol/L.[16] Lactate levels have also been increasingly recognized as an important biomarker in cardiac transplantation, particularly in the setting of urgent heart transplantation. Preoperative hyperlactatemia, especially in patients experiencing cardiogenic shock, has been consistently associated with poorer postoperative outcomes, with some studies reporting nearly 50% mortality at one year among patients with preoperative lactate levels ≥ 2 mmol/L. This association highlights the importance of monitoring lactate levels during the perioperative period, as elevated lactate may signal an increased risk of complications, including primary graft failure and multiorgan dysfunction.[47-49] In our study, a lactate level > 1.8 mmol/L was identified as a predictor of poor clinical outcomes, with a sensitivity of 90.6% and a specificity of 43.5%. Among patients with poor outcomes, the proportion of those with a baseline lactate level > 1.8 mmol/L and a subsequent increase in lactate level during follow-up was significantly higher.

Another noteworthy prognostic parameter is LVEF. Extensive evidence has demonstrated that reduced LVEF is associated with an unfavorable prognosis in various cardiovascular diseases, including heart failure and coronary artery disease.[50–52] In our study, we observed significantly lower LVEF values in patients with complete AV block who experienced poor clinical outcomes. One possible explanation is that reduced ejection fraction may be further exacerbated by atrioventricular dissociation and bradycardia in patients with complete AV block.

Current guidelines recommend temporary transvenous pacing primarily for patients with AV block who exhibit symptoms or hemodynamic instability refractory to medical therapy.[1,2] However, a subset of patients who initially do not require temporary pacing may develop cardiac decompensation and hemodynamic deterioration during follow-up, ultimately necessitating temporary pacing. The association between elevated lactate levels and adverse outcomes observed in our study may provide useful guidance, particularly in the management of patients who do not initially require temporary pacing. An important clinical question is whether temporary pacemaker implantation should be considered in patients who, despite being asymptomatic and hemodynamically stable at presentation, exhibit lactate levels exceeding 1.8 mmol/L. Translating the findings of our study into clinical practice suggests that patients without an initial indication for temporary pacing but with elevated admission lactate levels and a subsequent increase during follow-up may require closer monitoring. Additionally, temporary pacing may be considered, particularly when lactate levels become elevated during follow-up despite initially low baseline levels. However, these observations should be considered hypothesis-generating, and prospective studies are required to determine whether incorporating serial lactate measurements into routine decision-making can improve outcomes.

This preliminary study examining the relationship between lactate levels and prognosis in patients with complete AV block has certain limitations. First, as a single-center retrospective study, the generalizability of the findings to broader populations may be limited. Second, the relatively small sample size of the study population limits the statistical power and may affect the reliability of the conclusions. Furthermore, due to its observational design, the study cannot establish a causal relationship between lactate levels and clinical outcomes. Finally, an important limitation of this retrospective study is the lack of reliable documentation regarding the time interval from symptom onset to hospital admission and to the first blood sampling. This interval may influence initial lactate and creatinine measurements and could introduce unmeasured variability into the observed associations.

Conclusion

Our study sheds light on the previously unexplored relationship between lactate levels and clinical outcomes in patients with complete AV block. Our findings highlight the potential importance of lactate as a prognostic marker and as a tool to support clinical decision-making, particularly regarding the need for a temporary pacemaker implantation. Patients with elevated admission lactate levels, especially when accompanied by a further increase during follow-up, demonstrated a higher risk of adverse clinical outcomes. However, these findings are hypothesis-generating and should not be interpreted as sufficient to justify changes in current pacing practice. Prospective, multicenter studies are needed to confirm the clinical utility of lactate measurements in this setting.

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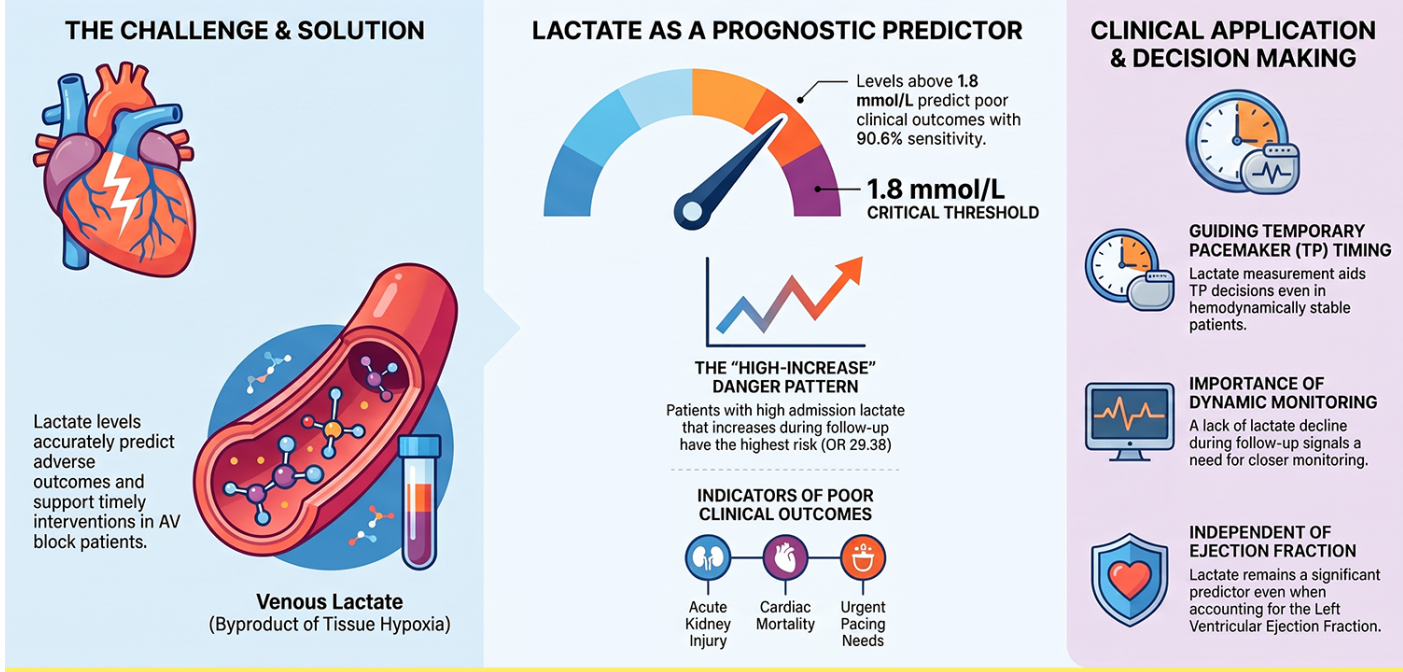
References

1. Glikson M, Nielsen JC, Kronborg MB, et al.; ESC Scientific Document Group. 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy. *Eur Heart J*. 2021;42(35):3427-3520. Erratum in: *Eur Heart J*. 2022;43(17):1651. [CrossRef]
2. Kusumoto FM, Schoenfeld MH, Barrett C, et al. 2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. *J Am Coll Cardiol*. 2019;74(7):e51-e156. Erratum in: *J Am Coll Cardiol*. 2019;74(7):1016-1018.
3. Asil S, Aytemir K. Conduction Disturbances and Arrhythmia Risk After Septal Reduction Therapy with Alternative Agents: A Pilot Study with EVOH-DMSO and Systematic Review. *Turk Kardiyol Dern Ars*. 2023;51(1):40-49. [CrossRef]
4. Doğan M, Canpolat U. Recovery of Right Ventricular Apical Pacing-Induced Cardiomyopathy with Left Bundle Branch Pacing. *Turk Kardiyol Dern Ars*. 2024;52(5):357-361. [CrossRef]
5. Brignole M, Auricchio A, Baron-Esquivias G, et al. 2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy: the Task Force on cardiac pacing and resynchronization therapy of the European Society of Cardiology (ESC). Developed in collaboration with the European Heart Rhythm Association (EHRA). *Eur Heart J*. 2013;34(29):2281-2329. [CrossRef]
6. McCann P. A review of temporary cardiac pacing wires. *Indian Pacing Electrophysiol J*. 2007;7(1):40-49.
7. Suarez K, Banchs JE. A Review of Temporary Permanent Pacemakers and a Comparison with Conventional Temporary Pacemakers. *J Innov Card Rhythm Manag*. 2019;10(5):3652-3661. [CrossRef]
8. Çimen T, Sunman H, Erat M, et al. Sleep related bradyarrhythmic events and heart rate variability in apparently healthy individuals. *Anatol J Cardiol*. 2017;17(3):235-240. [CrossRef]
9. López Ayerbe J, Villuendas Sabaté R, García García C, et al. Temporary pacemakers: current use and complications. *Rev Esp Cardiol*. 2004;57(11):1045-1052. Spanish. [CrossRef]
10. Bozorgi A, Ahmadzadeh S, Mortazavi SH, et al. The need for permanent pacemaker after restoration of conduction following atrioventricular block: a retrospective cohort study. *Turk Kardiyol Dern Ars*. 2020;48(2):103-108. [CrossRef]
11. Cantu-Rodriguez OG, Hawing-Zarate JA, Dorsey-Trevino EG, et al. Lactate/Pyruvate Ratio as an Early Predictor of Mortality in Patients with Sepsis: A Cohort Study. *J Clin Med*. 2024;13(18):5597. [CrossRef]
12. Lee SG, Song J, Park DW, et al. Prognostic value of lactate levels and lactate clearance in sepsis and septic shock with initial hyperlactatemia: A retrospective cohort study according to the Sepsis-3 definitions. *Medicine (Baltimore)*. 2021;100(7):e24835. [CrossRef]
13. Chambers KA, Park AY, Banuelos RC, et al. Outcomes of severe sepsis and septic shock patients after stratification by initial lactate value. *World J Emerg Med*. 2018;9(2):113-117. [CrossRef]
14. Nguyen HB, Rivers EP, Knoblich BP, et al. Early lactate clearance is associated with improved outcome in severe sepsis and septic shock. *Crit Care Med*. 2004;32(8):1637-1642. [CrossRef]
15. Liang D, Zhou X, Hong X, et al. Association between admission lactate levels and mortality in patients with acute coronary syndrome: a retrospective cohort study. *Coron Artery Dis*. 2019;30(1):26-32. [CrossRef]
16. Kawase T, Toyofuku M, Higashihara T, et al. Validation of lactate level as a predictor of early mortality in acute decompensated heart failure patients who entered intensive care unit. *J Cardiol*. 2015;65(2):164-170. [CrossRef]
17. Kellum JA, Romagnani P, Ashuntantang G, Ronco C, Zarbock A, Anders HJ. Acute kidney injury. *Nat Rev Dis Primers*. 2021;7(1):52. [CrossRef]
18. Ferguson BS, Rogatzki MJ, Goodwin ML, Kane DA, Rightmire Z, Gladden LB. Lactate metabolism: historical context, prior misinterpretations, and current understanding. *Eur J Appl Physiol*. 2018;118(4):691-728. [CrossRef]
19. Dong X, Zhang Q, Yu X, et al. Metabolic lactate production coordinates vasculature development and progenitor behavior in the developing mouse neocortex. *Nat Neurosci*. 2022;25(7):865-875. [CrossRef]
20. Brooks GA. The Science and Translation of Lactate Shuttle Theory. *Cell Metab*. 2018;27(4):757-785. [CrossRef]
21. Hashimoto T, Brooks GA. Mitochondrial lactate oxidation complex and an adaptive role for lactate production. *Med Sci Sports Exerc*. 2008;40(3):486-494. [CrossRef]
22. Adamo L, Nassif ME, Novak E, LaRue SJ, Mann DL. Prevalence of lactic acidaemia in patients with advanced heart failure and depressed cardiac output. *Eur J Heart Fail*. 2017;19(8):1027-1033. [CrossRef]
23. Ouyang J, Wang H, Huang J. The role of lactate in cardiovascular diseases. *Cell Commun Signal*. 2023;21(1):317. [CrossRef]
24. Vermeulen RP, Hoekstra M, Nijsten MW, et al. Clinical correlates of arterial lactate levels in patients with ST-segment elevation myocardial infarction at admission: a descriptive study. *Crit Care*. 2010;14(5):R164. [CrossRef]
25. Zymliński R, Biegus J, Sokolski M, et al. Increased blood lactate is prevalent and identifies poor prognosis in patients with acute heart failure without overt peripheral hypoperfusion. *Eur J Heart Fail*. 2018;20(6):1011-1018. [CrossRef]
26. Biegus J, Zymliński R, Sokolski M, Jankowska EA, Banasiak W, Ponikowski P. Elevated lactate in acute heart failure patients with intracellular iron deficiency as identifier of poor outcome. *Kardiol Pol*. 2019;77(3):347-354. [CrossRef]
27. Biegus J, Zymliński R, Sokolski M, Gajewski P, Banasiak W, Ponikowski P. Clinical, respiratory, haemodynamic, and metabolic determinants of lactate in heart failure. *Kardiol Pol*. 2019;77(1):47-52. [CrossRef]
28. Garcia-Alvarez M, Marik P, Bellomo R. Stress hyperlactataemia: present understanding and controversy. *Lancet Diabetes Endocrinol*. 2014;2(4):339-347. [CrossRef]
29. Aleksandar J, Vladan P, Markovic-Jovanovic S, Stolic R, Mitic J, Smilic T. Hyperlactatemia and the Outcome of Type 2 Diabetic Patients Suffering Acute Myocardial Infarction. *J Diabetes Res*. 2016;2016:6901345. [CrossRef]
30. Sunman H, Özkan A, Yorgun H, et al. Evaluating the effects of cardiac resynchronization therapy on pathophysiological pathways of heart failure using surrogate biomarkers. *Cardiol J*. 2018;25(1):42-51. [CrossRef]
31. Dural M, Sunman H, Algül E, Hocamguliyev H, Şahan HF, Çimen T, Açıkel S, Tulmaç M. Relationship between serum bilirubin levels and presence of fragmented QRS in patients with acute coronary syndrome. *Biomark Med*. 2020;14(1):65-73. [CrossRef]
32. Davierwala PM, Leontyev S, Verevkin A, et al. Temporal Trends in Predictors of Early and Late Mortality After Emergency Coronary Artery Bypass Grafting for Cardiogenic Shock Complicating Acute Myocardial Infarction. *Circulation*. 2016;134(17):1224-1237. [CrossRef]
33. Gjesdal G, Braun OÖ, Smith JG, Scherstén F, Tydén P. Blood lactate is a predictor of short-term mortality in patients with myocardial infarction complicated by heart failure but without cardiogenic shock. *BMC Cardiovasc Disord*. 2018;18(1):8. [CrossRef]
34. Li H, Chen J, Xing X, Lou D. Association of lactate detection with in-hospital mortality in critically ill patients with acute myocardial infarction: a retrospective cohort study. *BMJ Open*. 2023;13(4):e069129. [CrossRef]

35. Algül E, Sunman H, Dural M, et al. Comparison of atrial fibrillation predictors in patients with acute coronary syndrome using ticagrelor or clopidogrel. *Turk J Med Sci*. 2019;49(5):1358-1365. [CrossRef]
36. Xu J, Xu X, Si L, et al. Intracellular lactate signaling cascade in atrial remodeling of mitral valvular patients with atrial fibrillation. *J Cardiothorac Surg*. 2013;8:34. [CrossRef]
37. Canpolat U, Oto A, Yorgun H, et al. Association of plasma fibronectin level with left atrial electrical and structural remodelling in lone paroxysmal atrial fibrillation: a cross-sectional study. *Turk Kardiyol Dern Ars*. 2015;43(3):259-268. Turkish. [CrossRef]
38. Canpolat U, Oto A, Hazirolan T, et al. A prospective DE-MRI study evaluating the role of TGF-β1 in left atrial fibrosis and implications for outcomes of cryoballoon-based catheter ablation: new insights into primary fibrotic atriocardiomyopathy. *J Cardiovasc Electrophysiol*. 2015;26(3):251-259. [CrossRef]
39. Xu R, Yuan W, Wang Z. Advances in Glycolysis Metabolism of Atherosclerosis. *J Cardiovasc Transl Res*. 2023;16(2):476-490. [CrossRef]
40. Shantha GP, Wasserman B, Astor BC, et al. Association of blood lactate with carotid atherosclerosis: the Atherosclerosis Risk in Communities (ARIC) Carotid MRI Study. *Atherosclerosis*. 2013;228(1):249-255. [CrossRef]
41. Frodermann V, Rohde D, Courties G, et al. Exercise reduces inflammatory cell production and cardiovascular inflammation via instruction of hematopoietic progenitor cells. *Nat Med*. 2019;25(11):1761-1771. [CrossRef]
42. Chen X, Huang W, Zhang J, et al. High-intensity interval training induces lactylation of fatty acid synthase to inhibit lipid synthesis. *BMC Biol*. 2023;21(1):196. [CrossRef]
43. Wang Y, Chen L, Zhang M, et al. Exercise-induced endothelial Mecp2 lactylation suppresses atherosclerosis via the Ereg/MAPK signalling pathway. *Atherosclerosis*. 2023;375:45-58. [CrossRef]
44. Zhu W, Guo S, Sun J, Zhao Y, Liu C. Lactate and lactylation in cardiovascular diseases: current progress and future perspectives. *Metabolism*. 2024;158:155957. [CrossRef]
45. Long B, Bridwell RE, DeVivo A, Gottlieb M. Transvenous Pacemaker Placement: A Review for Emergency Clinicians. *J Emerg Med*. 2024;66(4):e492-e502. [CrossRef]
46. Schiavone M, Sabato F, Gobbi C, et al. Atrioventricular and intraventricular blocks in the setting of acute coronary syndromes: a narrative review. *Rev Cardiovasc Med*. 2021;22(2):287-294. [CrossRef]
47. Algarni KD. The effect of hyperlactatemia timing on the outcomes after cardiac surgery. *Cardiothoracic Surg*. 2020;28(18):1-8. [CrossRef]
48. Couto-Mallón D, González-Vílchez F, Almenar-Bonet L, et al. Prognostic Value of Serum Lactate Levels in Patients Undergoing Urgent Heart Transplant: A Subanalysis of the ASIS-TC Spanish Multicenter Study. *Rev Esp Cardiol (Engl Ed)*. 2019;72(3):208-214. English, Spanish. [CrossRef]
49. Załęska-Kocięcka M, Dutton J, Morosin M, et al. Prognostic significance of serum lactate following cardiac transplantation. *Biomark Med*. 2022;16(8):599-611. [CrossRef]
50. Maggioni AP, Dahlström U, Filippatos G, et al.; Heart Failure Association of the European Society of Cardiology (HFA). EURObservational Research Programme: regional differences and 1-year follow-up results of the Heart Failure Pilot Survey (ESC-HF Pilot). *Eur J Heart Fail*. 2013;15(7):808-817. [CrossRef]
51. Pocock SJ, Ariti CA, McMurray JJ, et al.; Meta-Analysis Global Group in Chronic Heart Failure. Predicting survival in heart failure: a risk score based on 39 372 patients from 30 studies. *Eur Heart J*. 2013;34(19):1404-1413. [CrossRef]
52. Knuuti J, Wijns W, Saraste A, et al.; ESC Scientific Document Group. 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes. *Eur Heart J*. 2020;41(3):407-477. Erratum in: *Eur Heart J*. 2020;41(44):4242. [CrossRef]

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Lactate Levels: A Vital Prognostic Marker in Complete AV Block



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