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Original Article

Correlation of ECG Changes at High Altitude with Findings on Coronary Angiogram

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ABSTRACT

Objective: To highlight association of coronary artery disease on angiograms and high altitude-related ECG abnormalities that is thought to be ischemic in origin.

Study Design: Cross sectional study.

Place and Duration of Study: Armed Force Institute of Cardiology/National Institute of Heart Disease, Rawalpindi-Pakistan, from Oct 2016 to Oct 2021.

Methodology: A total of 103 patients at a range of 9000 to 22000 feet in altitude, with new ECG changes were selected via consecutive sampling. Data was analyzed by SPSS version-23. Descriptive statistics were run to present categorical data in frequencies and percentages. Chi-square and Fisher Exact Test was applied to find the association between study variables at 95% CI and 5% margin of error (α= 5%).

Results: The data was collected from a total of 103 respondents, mean age (years) of the respondents was 30.57±6.27, and mean duration of stay (days) at high altitude was 64.8±68.3 (Table-I). ECG changes that were recorded were: T-wave inversion in anterior leads (V1, V2, V3) were reported in n=33(32%), T- wave inversion in Inferior leads (II, III, aVF) in 21(20.3%), T-wave inversion in lateral leads (V3-V6) 10(9.7%). Normal Ejection fraction was observed in 97% of the study participants while only 3% had mild left ventricular systolic impairment. Angiographic findings were found to be normal in n=92 (89.30%), minor coronary artery disease (CAD) in n=9 (8.70%), muscle bridge in LAD in n=2 (1.90%). Our results also showed that amongst other final diagnosis, of note were vasovagal syncope (n=5; 4.8%), pulmonary embolism (n=5; 4.8%) and pulmonary arterial hypertension (n=3; 2.9%).

Conclusion: Our work leads us to the conclusion that ECG abnormalities at high altitude do not indicate coronary artery disease since they do not reflect a delay in electrical conduction or ischemia. These patients should be treated separately based on their high altitude disease symptoms (HAI).

Keywords: Coronary angiography, ECG changes, High altitude, pulmonary hypertension.

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INTRODUCTION

High-altitude illnesses result in considerable morbidity and frequent hospital admissions.[1,2] Even internationally, studies involving high altitude and mountain medicine are not common because of access and presence of population at those heights. Various studies are now being performed to understand mountain medicine and effects of hypobaric hypoxia on individuals at high altitude.[4] Military, rescue, and other professional personnel may also be called upon to ascend to high altitudes with little or no time for acclimatization. Such rapid ascends place the un-acclimatized traveler at risk for developing high altitude illness (HAI).[5] Acute mountain sickness (AMS), high-altitude cerebral edema (HACE), and high-altitude pulmonary edema (HAPE) are all illnesses that occur in people who travel to high-altitude settings. Hypobaric hypoxia causes high-altitude sickness, which is unrelated to age or physical fitness and is treatable in mild forms[6].

Changes in physiological functions during high altitude exposure vary given an individual's physical fitness, rate of ascent, severity and/or duration of exposure, cultural habits, geographical locations, and genetic variation[7]. For a long time, the evidence for myocardial ischemia/hypoxia and thromboembolism at high altitude and its possible impact on heart function in normal individuals has been argued upon.[8]

High altitude (HA) exposure has long been known to cause cardiovascular stress. Right ventricular hypertrophy, hypoxic pulmonary hypertension, severe hypoxemia, and/or right heart failure have all been well-documented effects of chronic or prolonged HA

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exposure. Contrarily, acute or short-term HA exposure can result in a range of cardiovascular adaptive responses, including an increase in heart rate (HR) both at rest and during exercise, a gradual rise in blood pressure in both hypertensive and healthy patients, a brief constriction of the pulmonary blood vessels, and a gradual change in cardiac contractility and cardiac output.[9] The typical cardiac response to acute hypoxia is mediated by carotid body stimulation, which results in adrenergic system activation and an increase in circulating catecholamines. At rest and at a certain degree of exercise intensity, this activation causes tachycardia.[9-10]

Chest pain is the most common presenting complaint in patients at high altitude.[1,2] Electrocardiogram (ECG) is readily available and a relatively simple test done at first medical contact.[3] Interpretation of that ECG becomes important in deciding the urgency to evacuate patients from high altitude. Patients are often advised and are started on antiplatelet therapy which can put the patients at increased risk of bleeding. We designed a study to highlight association of coronary artery disease on angiogram and high altituderelated ECG abnormalities that is thought to be ischemic in origin done in a tertiary care facility.

METHODOLOGY

We conducted an initial pilot study of 40 patients in similar settings. Due to useful and clinically significant results, another study was designed which included retrospective collection of larger data set from 5 years. This study was conducted in the Cardiology department of Armed Force Institute of Cardiology/ National Institute of Heart Diesease, Rawalpindi, from October 2016 to October 2021, after the approval of Institutional Ethical Review Board committee of AFIC/ NIHD (IERB ltr no. 10/2/R&D/2022/ 158).

Sample Size: All the patients fulfilling the inclusion criteria during study period were selected as study participants and they accounted to n=103.

Inclusion Criteria: Males, aged 20-45 years with new ECG changes were included in the study

Exclusion Criteria: Those with previous coronary artery disease history and with pre-existing ECG changes were excluded.

Data Collection was done through a self-structured questionnaire. All respondents who presented with signs and symptoms of high altitude illness had their electrocardiogram (ECG) done at first medical contact. If they were found to have significant ECG changes, they were evacuated to tertiary care cardiac facility where they had investigations done including coronary angiography.

While conducting this study, informed consent from all patients was taken verbally. Participation was voluntary and the respondents were informed that they can withdraw at any time and that all data will be treated confidentially. Patients were given a broad outline of the research, the reasons why the research was being carried out and how the information which they provide will be used.

Data was analyzed using SPSS-23. Mean±SD was calculated for continuous variables. Categorical variables were expressed in frequency/ percentages. Chi-square was used to determine association between variables of interest.

RESULT

The data was collected from a total of 103 respondents, mean age (years) of the respondents was 30.57±6.27, and mean duration of stay (days) at high altitude was 64.8±68.3 (Table-I).

Table-I: Descriptive Statistics of Study

Variables	Means/SD	
Duration of stay (Days)	64.8± 68.3	
Age(Years)	30.57±6.28	
Hemoglobin (mg/dl)	16.7±1.62	
Systolic BP (mmHg)	125.7±20.0	
Diastolic BP(mmHg)	80.3±16.9	
Left Ventricular Ejection Fraction (% of patients)	Normal (50%-70%)	100(97%)
	Mild LV systolic impairment (40%-49%)	3(3%)

Out of 103 respondents, n=53(51.4%) presented with chest pain, n=12(11.6%) had both chest pain as well as shortness of breath, n=11(10.6%) presented with shortness of breath (SOB) only, while presentation with loss of consciousness and headache was n=6(5.8%) and n=7(6.7%) respectively (Figure-I).

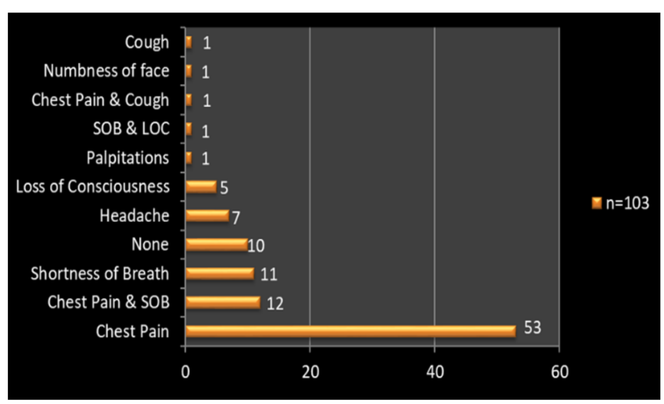

Figure-I: Presenting Symptoms

ECG changes recorded were: T-wave inversion in anterior leads (V1, V2, V3) were reported in n=33 (32%), T-wave inversion in Inferior leads (II, III, aVF) in 21(20.3%), T-wave inversion in lateral leads (V3-V6) 10(9.7%), Right Bundle Branch block and Left Bundle Branch Block in 6(5.8%), 3(2.9%) respectively (Table-II).

Table-II: Association of ECG Changes with CAD

ECG Changes	Coro Angiogram Findings			*p*-value
	Normal	Muscle Bridge LAD	Not Done	
Normal	20	-	1	
T- wave inversion (V1, V2, V3)- anterior leads	22	-	-	
T-wave inversion (II, III, aVF) - Inferior leads	11	-	-	
T-wave inversion (V3-V6) - lateral leads	9	1	-	
ST-depression in II, III & aVF	2	-	-	
RBBB	6	-	-	
LBBB	3	-	-	
VPB's	4	-	1	
SInus Tachycardia	3	-	-	
Poor R-wave Progression	1	-	-	
LVH	2	-	-	.329
1st Dgeree AV-Block	1	-	-	
RBBB+T- wave inversion (V1, V2, V3)	3	-	-	
ST-depression in II, III & aVF + V3-V6 inversion	2	1	-	
WPW	1	-	-	
T-wave Inversion V1-V6	1	-	-	
T-Wave Inv Ant+Inf leads	2	-	-	

RBBB=Right Bundle Branch block, LBBB=Left Bundle Branch Block, VPB's=Ventricular Premature Beats, LVH=Left Ventricular Hypertrophy, AV-Block=Atrioventricular Block, IWMI=Inferior wall myocardial infarction, WPW=Wolff-Parkinson-White Syndrome

There were no risk factors reported in 93% of the respondents, while 3.8% were smokers and 1% had hypertension and Ischemic heart disease. Normal ejection fraction (EF) was observed in 97% of the study participants while only 3% had mild LV systolic impairment. (Table-I) Angiographic findings were found to be normal in n=92 (89.30%), minor CAD in n=9(8.70%), muscle bridge in LAD in n=2(1.90%) (Figure-II).

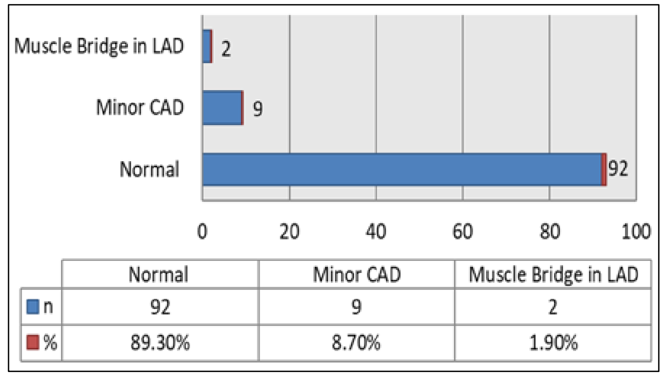

Figure-II: Coronary Angiography Findings

It was concluded that ECG changes at high altitude were not significantly associated with obstructive coronary artery disease. *p*-value ≥0.05. Our results showed that amongst other final diagnosis, of note were vasovagal syncope (n=5; 4.8%), pulmonary embolism (n=5; 4.8%) and pulmonary arterial hypertension (n=3; 2.9%) (Figure-3).

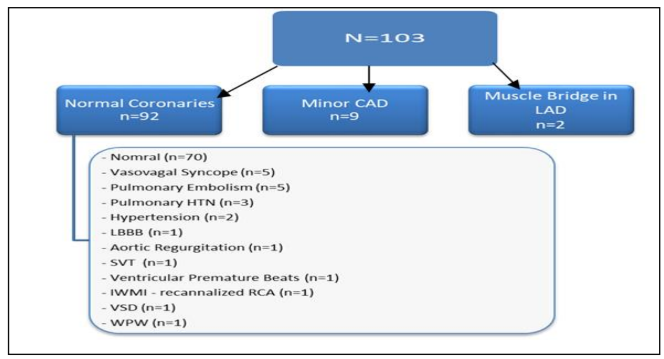

Figure-III: Final Outcome

HTN=Hypertension, LBBB=Left Bundle Branch Block, SVT= Supra-ventricular Tachycardia, IWMI=Inferior Wall Myocardial Infarction, VSD=Ventri-cular Septal Defect, WPW=Wolff-Parkinson-White

DISCUSSION

High altitude (HA) exposure has long been known to cause cardiovascular stress. Acute exposure without acclimatization can cause variety of physiological responses including reflex tachycardia and transient pulmonary vasoconstriction which can lead to variation in cardiac contractility and cardiac output. However, long term exposure can cause variety of high altitude related illnesses including pulmonary hypertension, right ventricular hypertrophy and right heart failure.

Our study revealed that individuals at high altitude may present with multitude of symptoms and new onset ECG changes likely due to sympathetic overdrive. However, these symptoms may overlap with symptoms of coronary artery disease and once coupled with new onset ECG changes, pose a great challenge for clinicians to identify the true cause. We studied 103 patients who stayed at a range of 9000 to 22000 feet in altitude with new ECG changes and correlated the symptoms and ECG changes with coronary angiogram findings. All patients with ECG changes were evacuated from high altitude to tertiary care cardiology centre where they had coronary angiography done. Our results showed that these ECG changes at high altitude do not represent coronary artery disease and are likely to settle down in due course once the individual has descended to sea level.

According to our study, T-wave inversion was the commonest finding with a total of 62% patients presenting with it. T-wave inversion in inferior leads was seen in 21% of our patients evacuated from high altitude. This was comparable to Dixit *et al.* who observed T-wave inversion in inferior leads in 29.6%. Contrary to our finding, Dixit *et al.* also observed that T wave inversion in inferiorly directed frontal plane leads was the most prevalent ECG abnormality (29.6%) whereas our study concluded that T-wave inversion in anterior leads was the most prevalent finding with 32%. Dixit reported that T-wave inversion in both inferiorly directed frontal plane leads and precordial leads was n=13 (24%). This study also concluded that the majority of ECG anomalies at high altitude are temporary and benign, and do not indicate an increased risk of cardiovascular disease.[12]

Another study suggested that hypoxic pulmonary vasoconstriction causes an increase in pulmonary artery pressure and electrocardiographic morphological alterations. On ascent, right axis deviation, right bundle branch block, and variations in *p* and T wave amplitudes are typical and only resolve after descending to a low altitude.[13]

Angiographic findings in our study were found to be normal in majority (92%) of the patients. Furthermore, no significant association was established between ECG changes and Coronary angiography findings. A study published by Lal *et al.* reported that amongst previously healthy people who experience minor symptoms and ECG abnormalities at high altitude, only a small and insignificant percentage have actual coronary artery involvement on Coronary Angiogram. Asymptomatic patients with incidental ECG abnormalities but no symptoms are very less likely to have CAD.[1]

Although high-altitude populations do not have a high prevalence of coronary heart disease (CHD), electrocardiographic literature proposes that aberrant ECG abnormalities increase with altitude and risk pattern differs by ethnicity.[14] Contrary findings about the occurrence of risk factors for cardiovascular diseases in relation to altitude are found in data on cardiovascular mortality risk. Interestingly, increasing altitude was linked to a reduction in coronary heart disease due to better acclimatization and chronically reduced oxygen demand.[15]

According to epidemiological data from people permanently living at high altitude, environmental factors have a distinct impact on the development of cardiovascular disorders.[16-17] A systematic review gives ECG reference standards that clinicians may utilize. Clinicians should be aware of the implications of living at a high altitude on cardiovascular health and how these effects vary by age, ethnicity, and other factors.[18]

LIMITATIONS OF STUDY

Existing study's findings cannot be generalized as it was a single center study. We did not include patients who initially had ECG changes at first medical contact but subsequently self resolved before being reviewed in a cardiology centre. It takes time for patients to be evacuated from high altitude places to tertiary care cardiac facilities and during that time some of the ECG changes can self resolve. Moreover, even internationally, studies involving high altitude and mountain medicine are not common because of access and presence of population at those heights. There needs to be international collaboration of people involved in mountain medicine to compare findings, educated ourselves and prepare our healthcare units of potential complications.

CONCLUSION

Our work leads us to the conclusion that ECG abnormalities at high altitude do not indicate obstructive coronary artery disease since they do not reflect delays in electrical conduction or ischemia. Angiographic findings were found to be normal in n=92(89.30%), minor CAD in n=9(8.70%), muscle bridge in LAD in n=2(1.90%). It was found that ECG changes at high altitude were not significantly associated with obstructive coronary artery disease, p-value ≥(0.05). To avoid needless dual anti-platelet therapy, ECG abnormlities should be correlated with symptoms, signs, and levels of highly sensitive Troponin I (HS-Trop I). The causes of these changes is still a subject of interest and needs further studies but can likely be subjected to sympathetic overdrive, right ventricular hypertrophy and degree of pulmonary hypertension.

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Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

MS: Proof reading, Intellectual contribution, final approval

FUR: Manuscript writing, drafting and editing

JL: Study design, concept and critical review

US: Formatting, critical review and data collection/entry

FS: Data collection, data entry and review of article

AK: Analysis, manuscript writing and proof reading

MNK: Proofreading, Intellectual contribution, final approval

NAS: Intellectual contribution, concept & final approval

MBS: Review of article, concept and study design

JA: Proofreading, drafting and editing

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Lal K, Singh N, Kumar A, Agarwal N, Datta R, Datta R, Bhardwaj P, Chadha DS, Ghosh AK, Kumar R. Association of ischemic electrocardiographic changes in high-altitude areas with coronary angiography. Med J Armed Forces India 2021; 77(4): 403-407. doi: 10.1016/j.mjafi.2020.1101. Epub 2021 Aug 20.
2. Coustet B, Lhuissier FJ, Vincent R. Electrocardiographic changes during exercise in acute hypoxia and susceptibility to severe high-altitude illnesses. Circul 2015; 131(9): 786–794.
3. Saurenmann P. The ECG changes due to altitude and to catecholamines. Eur J Appl Physiol Occup Physiol 1984; 53(1): 35–42.
4. Windsor JS, Rodway GW, Montgomery HE. A Review of Electrocardiography in the High Altitude Environment. High Altitude Med Biol 2010; 11(1): 51–60.
5. Roach RC. High-altitude physiology. In: Wilderness Medicine, 7th ed, Auerbach PS (Ed), Elsevier, Philadelphia 2017. p.2.
6. Grimminger J, Richter M, Tello K. Thin air resulting in high pressure: mountain sickness and hypoxia-induced pulmonary hypertension. Can Respir J 2017; 2017(1): 8381653.
7. Kurtzman RA, Caruso JL. High-altitude illness death investigation. Acad Forensic Pathol 2018; 8(1): 83-97.
8. Coustet B, Lhuissier F, Vincent R, Richalet J. Electrocardiographic changes during exercise in acute hypoxia and susceptibility to severe high-altitude illnesses. Circulation 2015; 131(9): 786-794.
9. Hainsworth R, Drinkhill MJ, Rivera-Chira M. The autonomic nervous system at high altitude. Clin Auton Res 2007; 17: 13–19. doi: 10.1007/s10286-006-0395-7.
10. Windsor JS, Rodway GW, Montgomery HE. A review of electrocardiography in the high altitude environment. High Alt Med Biol 2010; 11: 51–60. doi: 10.1089/ham.2009.1065.
11. Ke J, Liu C, Yu S, Bian S. low stroke volume index in healthy young men is associated with the incidence of acute mountain sickness after an ascent by airplane: a case-control study. BioMed Res Intern 2020; 2020(1): 1-13.
12. Dixit Y, Abraham D, Prasad V. Relevance of asymptomatic electrocardiographic abnormalities at high altitude. J Assoc Phys Ind 2020; 68(4): 39-42.
13. Windsor JS, Rodway GW, Montgomery HE. A review of electrocardiography in the high altitude environment. High Alt Med Biol 2010 Spring; 11(1): 51-60. doi: 10.1089/ ham.2009.1065.
14. Aryal N, Weatherall M, Bhatta YK, Mann S. Electrocardiography in people living at high altitude of Nepal. Heart Asia 2017; 9(1): 48-53. doi: 10.1136/heartasia-2016-010838.
15. Mallet R, Burtscher J, Richalet J, Millet G, Burtscher M. Impact of high altitude on cardiovascular health: current perspectives. Vasc Health Risk Manag 2021; 17: 317-335.
16. Song C, Chongsuvivatwong V, Zhu Luo Bu O, Sang Zhuo Ma B, Sriplung H. Relationship between hypertension and geographic altitude: a cross-sectional survey among residents in Tibet. J Int Med Res 2020; 48(2): 320903645. doi:10.1177/ 0300060520903645
17. Guerra ON, Enriquez KH, Lezama JM, Chirinos JA. Systemic hypertension at high altitude. Hypertens 2018; 72(3): 567–578. doi:10.1161/hypertensionaha.118.11140
18. Parodi JB, Ramchandani R, Zhou Z, Chango DX, Acunzo R, Liblik K, et al. ANDES (Altitude non-specific distributed ECG screening) project investigators. a systematic review of electrocardiographic changes in healthy high-altitude populations. Trend Cardiovasc Med 2022: S1050-1738(22)00015-9. doi: 10.1016/j.tcm.2022.01.013. Epub ahead of print.