Indonesian Journal of Global Health Research
Volume 7 Number 4, August 2025
e-ISSN 2715-1972; p-ISSN 2714-9749
http://jurnal.globalhealthsciencegroup.com/index.php/IJGHR

ABNORMAL CARDIAC ELECTROPHYSIOLOGICAL ACTIVITY IN THE SUKU ANAK DALAM LIVING IN A MALARIA-ENDEMIC AREA

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ABSTRACT
Malaria is a life-threatening parasitic disease. Although the annual incidence of the parasite has decreased, malaria continues to be a health concern. The incidence of malaria remains high in tropical regions. The Suku Anak Dalam is the indigenous population of Jambi who live in the tropical forest. With limited access to healthcare, low levels of education, poor socio-economic status, and a nomadic lifestyle, the Suku Anak Dalam are vulnerable to malaria infections. Malaria infections trigger immune responses that cause issues with capillary blood vessels and the heart. Changes in the electrocardiogram are considered indicative of cardiac problems. This study aims to understand the electrocardiogram patterns of the Suku Anak Dalam community living in malaria-endemic areas, in order to support preventive measures regarding cardiac issues in populations residing in such regions. This research employed a descriptive cross-sectional design, utilising accidental sampling of nine adult members of the Suku Anak Dalam community who reside in the forest area of Sungai Terap Jelutih village, Batin XXIV Sub-district, Batanghari Regency, Jambi Province, and who consented to undergo electrocardiogram (ECG) recording. The ECG results were subsequently analysed descriptively by a ECG specialist, and the findings were then summarised. The results of electrocardiogram recordings from nine respondents showed Left Bundle Branch Block, along with signs of anaemia and hypertension. The conclusion is that the presence of Left Bundle Branch Block may be due to malaria infection, which triggers immune disturbances resulting in capillary and cardiac complications. Continuous cardiac examinations are necessary in endemic areas as a preventive measure.

Keywords: cardiac desease; left budle bruch block; malaria; suku anak dalam

How to cite (in APA style)
Suryaman, A., Fahmi, I., Sarbaini, S., Nurachmah, E., Anwar, C., & Handayani, D. (2025). Abnormal Cardiac Electrophysiological Activity in the Suku Anak Dalam Living in A Malaria-Endemic Area. Indonesian Journal of Global Health Research, 7(4), 631-640. Retrieved from https://jurnal.globalhealthsciencegroup.com/index.php/IJGHR/article/view/6411.

INTRODUCTION

Malaria is transmitted through the bite of the Anopheles mosquito, a vector commonly found in endemic regions, particularly in remote areas with poor sanitation (Gupta et al., 2021). Malaria is caused by protozoan species such as Plasmodium falciparum, vivax, ovale, and knowlesi, which are transmitted via infected Anopheles mosquitoes (Kumpitak et al., 2024). In addition to mosquito vectors, poor sanitation, high poverty levels, limited access to healthcare, and close contact with animals contribute to the transmission of malaria from Anopheles mosquitoes to humans (Gupta et al.,2021) Malaria remains a life-threatening parasitic disease, particularly in tropical and subtropical regions (Zhang

et al., 2020). According to a WHO report in 2019, there were approximately 228 million malaria cases worldwide, resulting in 405,000 deaths. The highest burden was recorded in Africa, with around 57 million cases (Bayode & Siegmund, 2022). In Indonesia, the malaria prevalence has declined to approximately 0.99 per 1,000 people. Nevertheless, malaria is still considered a significant public health issue that requires serious attention (Suryaman et al., 2021).

The Orang Rimba, more widely known as the Suku Anak Dalam (SAD), continue to inhabit the remote forest regions of Jambi Province. Due to the absence of recent dedicated studies on the population size of the Suku Anak Dalam, the most recent available data is drawn from the 2010 publication by the Central Bureau of Statistics of Jambi Province (Badan Pusat Statistik – BPS), which recorded a total of 3,205 individuals from the SAD community. These individuals are dispersed across several regencies, including Sarolangun, Batanghari, Merangin, Tanjung Jabung Barat, Tebo, and Bungo. Malaria remains a significant public health concern in the remote villages of Jambi, particularly among the SAD, owing to their limited awareness of the disease and their open living environments. In 2021, the malaria incidence rate was estimated at approximately 0.03 per 1,000 population, with 121 individuals confirmed positive (Badan Pusat Statistik, 2010; Suryaman et al., 2021, 2020). A prevalence study in Batanghari found that 33% of 345 SAD residents were infected with malaria (Listautin & Nurzia, 2020). Previous research using PCR-based testing found that SAD residents in Jelutih Village, Batanghari Regency, experienced asymptomatic malaria, where individuals did not report the classical malaria triad of symptoms. However, Nested PCR tests revealed that 35% of the 99 blood samples tested were positive for asymptomatic malaria (Suryaman et al., 2021).

The inflammatory process caused by malaria infection can lead to an increase in cytokines within the blood vessels, which may trigger cardiovascular diseases. A study has shown that untreated malaria can result in cardiac complications such as reduced cardiac output, arrhythmias, myocarditis, pericarditis, cardiac tamponade, and even heart failure (Gupta et al., 2021). Another study highlighted that untreated malaria can infect the heart's capillaries, causing obstruction in coronary blood flow (Langdon, Abdlaziz, Rhodes, & Clarke, 2022). Electrocardiographic examination serves as an initial diagnostic tool to detect changes in heart rhythm disorders among individuals infected with either symptomatic or asymptomatic malaria, potentially preventing the risk of ongoing cardiac complications (Aryal, Mainali, & Aryal, 2024; Chan et al., 2020; Langdon et al., 2022; Olatunji et al., 2025). Clinical findings in malaria patients often reveal electrocardiographic abnormalities, particularly in the ST segment and irregularities in the Q and T intervals. A cohort study found that, out of 100 individuals, 17 experienced cardiovascular disorders detected via electrocardiographic examination (Gupta et al., 2021).

A cross-sectional study conducted on the Suku Anak Dalam (SAD) in Nyogan Village, Jambi Province, reported that 4.32% of the SAD population were suffering from hypertension (Kalsum, Lesmana, & Pertiwi, 2019). Previous malaria research in Sungai Terap, Jelutih Village, Batanghari Regency, Jambi Province, indicated that SAD individuals living in the area were affected by both symptomatic and asymptomatic malaria, with a prevalence rate reaching 43.3%, based on results from Rapid Diagnostic Tests, microscopy, and Nested Polymerase Chain Reaction (Suryaman et al., 2021). The areas inhabited by the SAD show high malaria infection rates. Their residences in the forest, combined with environmental and geographical conditions that support Anopheles

mosquito breeding, their nomadic lifestyle, low educational background, poor socio-economic status, and limited access to healthcare services as well as previous findings indicating a high proportion of asymptomatic and symptomatic malaria form a strong basis for conducting research. This study aims to identify whether there are abnormal cardiac electrophysiological activities among the SAD population living in endemic regions with a high prevalence of asymptomatic malaria, by means of electrocardiographic examination.

METHOD

This research is a descriptive cross-sectional study with a case study approach. The population of this study comprised the indigenous people of Jambi, namely the Suku Anak Dalam, who reside in a malaria-endemic area within the forest of Sungai Terap Jelutih Village, Bathin XXIV Sub-district, Batanghari Regency, Jambi Province. The inclusion criteria for respondents were individuals from the Suku Anak Dalam community who were willing to undergo an examination of cardiac electrical activity using an electrocardiogram (ECG) machine, and who demonstrated cooperation during the ECG recording procedure. Informed consent was obtained through a mediator, and respondents who agreed to participate confirmed their consent by affixing a thumbprint to the consent form. Exclusion criteria included individuals who were not members of the Suku Anak Dalam community, as well as those members of the community who resided outside the forest area. Sampling was conducted using an accidental sampling technique, resulting in the inclusion of nine respondents. The ECG examination was performed using a 12-lead configuration, with electrodes placed on both the precordial region and extremities. Aqua gel was applied to ensure proper electrode contact. The ECG recordings were conducted with the respondents lying on an emergency stretcher that did not touch the ground. The ECG machine was powered by a portable electric generator and a voltage stabiliser. Data were obtained in the form of ECG tracings that met readability criteria, and these recordings were subsequently interpreted by a qualified ECG specialist for analysis and conclusion.

RESULT

Malaria is a disease caused by protozoan species *Plasmodium falciparum*, *P. vivax*, and *P. ovale*, which are transmitted by infected *Anopheles* mosquitoes. It is estimated that there are 247 million cases of malaria and 619,000 deaths across 84 endemic countries. Malaria is classified as a tropical disease, with the highest annual incidence reported in sub-Saharan Africa and Southeast Asia (Jeanne Rini Poespoprodjo, et al, 2023).The *Suku Anak Dalam* (SAD) are an indigenous ethnic group of Jambi Province who reside in remote forested areas, with a recorded population of 2,951 households. They are spread across several regions, including Batang Hari, Tebo, Sarolangun, and Merangin (Fitria, 2022). The SAD lead a nomadic lifestyle within tropical forests and rely heavily on the forest environment for survival. Their open and unsheltered living conditions increase their vulnerability to malaria infection. Due to the remote nature of their settlements and the limited accessibility of healthcare services, SAD individuals are often unaware of their malaria infection status. The continued presence of malaria cases among the SAD, combined with their restricted access to health services, raises concerns over the elevated risk of malaria-related cardiovascular complications (Suryaman et al., 2020).

Previous research conducted on the same population and in the same area confirmed the presence of asymptomatic malaria among SAD individuals. Using Nested PCR, infections with *P. falciparum* were identified (Suryaman et al., 2021). In areas with high malaria transmission, individuals may receive an infective mosquito bite daily, potentially exposing the entire population to repeated infections. However, the greatest disease burden tends to fall

on young children. As children grow, their immune systems gradually develop the ability to control the disease, leading to most infections during adolescence and adulthood becoming asymptomatic or subclinical (Agaba et al., 2022; Nzoumbou-boko et al., 2025).

Table 1.

Respondent characteristics (n=9)

Sex	Age	Fever and Headache	Anaemic Conjunctiva	Blood Pressure (mmHg)	Comorbidity
Laki-laki	47	Present	Present	140/100	Unknown
Laki-laki	49	Present	Present	130/90	Unknown
Laki-laki	45	Present	Present	136/90	Unknown
Laki-laki	44	Present	Present	150/100	Unknown
Laki-laki	48	Present	Present	135/90	Unknown
Laki-laki	50	Present	Present	145/80	COPD
Laki-laki	53	Present	Present	130/90	Unknown
Laki-laki	49	Present	Present	145/90	Unknown
Laki-laki	43	Present	Present	140/90	Unknown

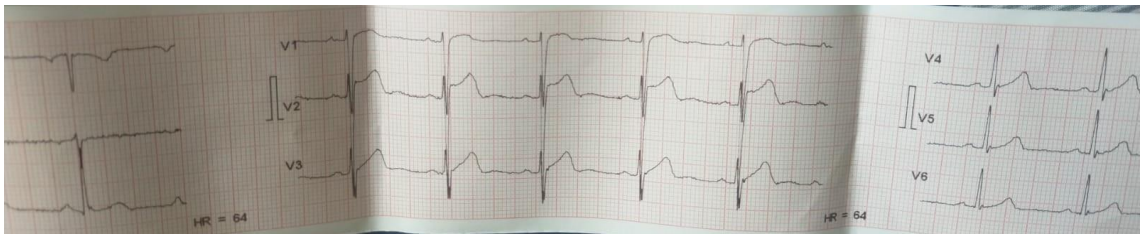

Figure 1. Electrocardiographic Findings of the Respondents

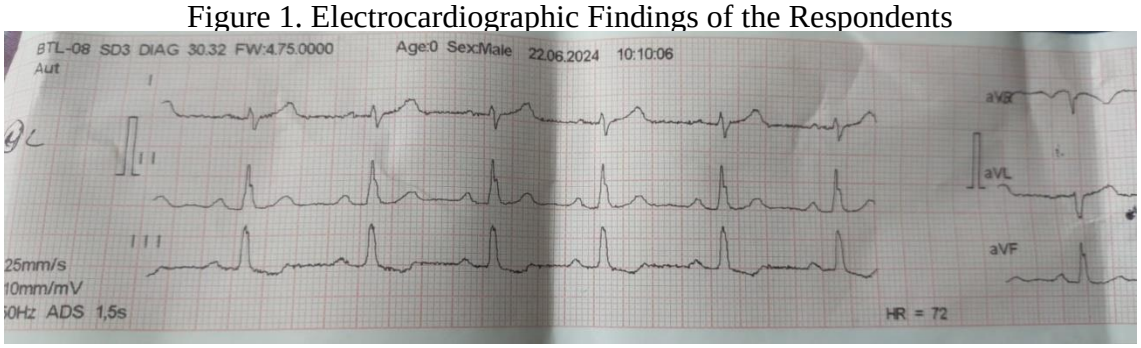

Figure 2. Electrocardiographic Findings of the Respondents

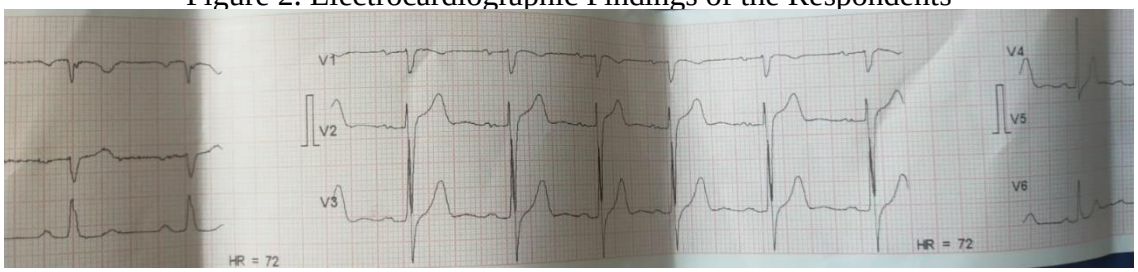

Figure 3. Electrocardiographic Findings of the Respondents

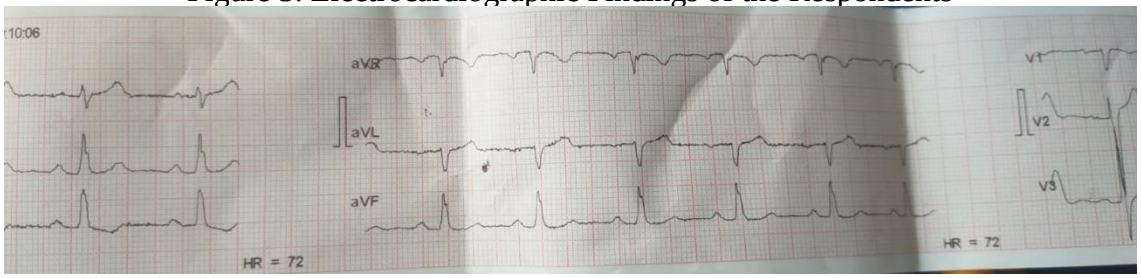

Figure 4. Electrocardiographic Findings of the Respondents

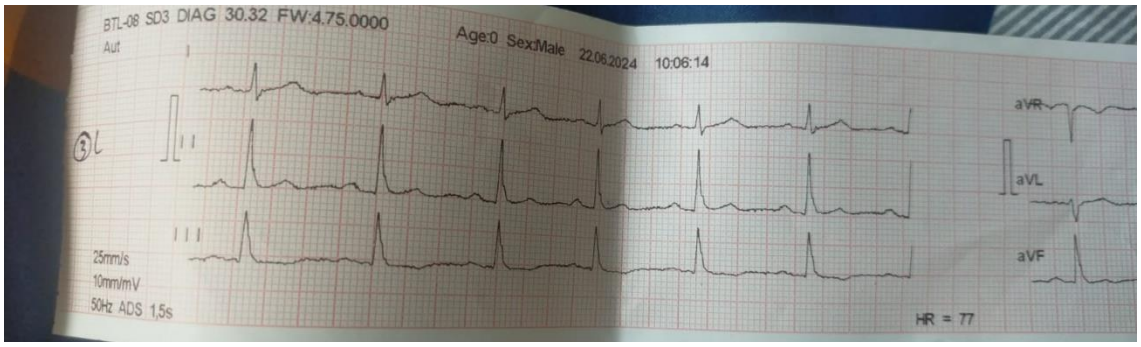

Figure 5. Electrocardiographic Findings of the Respondents

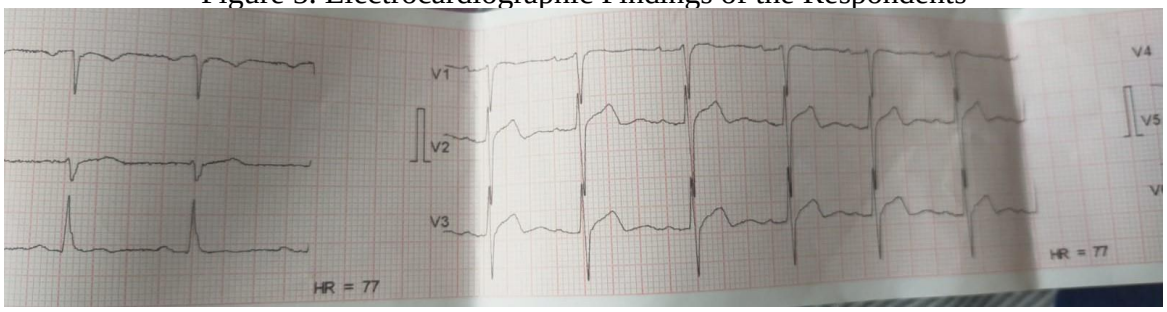

Figure 6. Electrocardiographic Findings of the Respondents

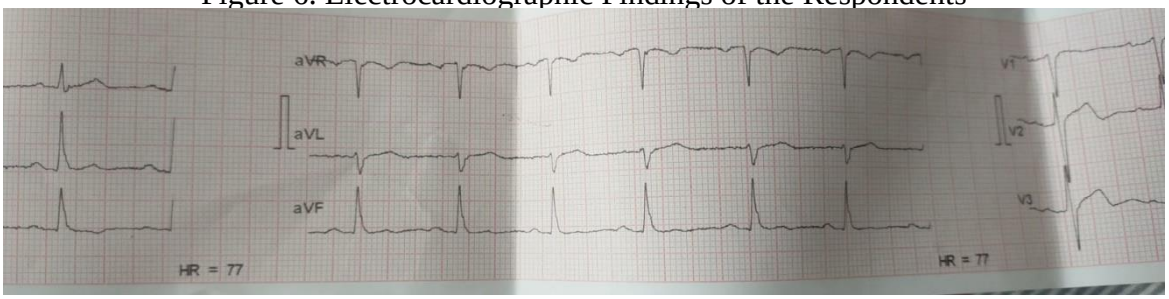

Figure 7. Electrocardiographic Findings of the Respondents

DISCUSSION

In this study, nine respondents were all male and reported complaints of fever and headache. Clinical examination revealed conjunctival pallor in all participants, and electrocardiogram (ECG) recordings showed the presence of Left Bundle Branch Block (LBBB). Although malaria is known to affect multiple organ systems, cardiovascular involvement is rarely highlighted. However, such involvement may contribute significantly to increased morbidity and mortality (Bhardwaj, Sanadhya, Sindhur, Setia, & Sharma, 2024; Costedoat-Chalumeau et al., 2007; Gupta et al., 2021). The pathophysiological mechanisms linking malaria to cardiovascular consequences remain poorly understood. Nonetheless, ECG abnormalities are presumed to be related to imbalanced pro-inflammatory cytokine responses or sequestration of parasitised erythrocytes due to increased adhesion of infected red blood cells to the vascular endothelium (Fogang et al., 2024; Olatunji et al., 2025; Gupta et al., 2021).

An increase in malaria infection can lead to erythrocyte rupture, which subsequently releases pro-inflammatory cytokines such as tumour necrosis factor-α and interleukin-1β and -6 (Popa & Popa, 2021; Romero et al., 2024). These inflammatory cytokines can induce myocardial contractile dysfunction through energy depletion mediated by nitric oxide and inducible nitric oxide synthase (Popa & Popa, 2021). Plasmodial glycosylphosphatidylinositol acts as a toxin that affects genes involved in apoptosis, potentially causing programmed cell death in cardiac tissu (Sauer et al., 2023). Furthermore, endothelial dysfunction can arise due to inflammatory cytokine activity (Gupta et al., 2021). Tissue hypoxia may also occur due to capillary blockage from the adhesion of parasitised erythrocytes to the endothelium, a process promoted by cytokine release during infection (Buthelezi, Masia, Masamba, Cedric Simelane,

& Kappo, 2025). Pro-inflammatory cytokines have been shown to play a significant role in both the symptoms of malaria and cardiovascular pathology (Buthelezi et al., 2025; Olatunji et al., 2025). The entrapment of infected erythrocytes in the spleen and liver further contributes to cardiovascular involvement (Gahrn-Hansen & Pedersen, 2000).

Erythrocyte adhesion is facilitated by the pathogenicity of Plasmodium falciparum, which expresses erythrocyte membrane protein-1. After invasion, the parasite alters the morphology and characteristics of red blood cells, increasing their adhesive capacity to vascular endothelium (Lubiana et al., 2020; Oleinikov et al., 2024). The infection modifies the erythrocytes' deformability and consumes intracellular proteins, promoting sequestration, particularly in cerebral and cardiac capillaries. This cytoadherence is characteristic of P. falciparum infections, whereas such mechanisms have not been definitively observed in P. vivax infections (Adams et al., 2021; Arakawa et al., 2020; Jensen, Adams, & Hviid, 2020).While LBBB is a well-studied ECG abnormality, its pathogenesis and associated diseases remain poorly understood. It can occur in young individuals without structural heart disease and is often benign in such cases. However, major LBBB is frequently associated with hypertension, left ventricular hypertrophy, cardiomyopathy, valvular disease, heart failure, and in the context of malaria, myocardial ischaemia due to erythrocyte adhesion within coronary microvasculature (Herweg, Barold, & Vijayaraman, 2025; Tan, Witt, Oh, & Cha, 2020). LBBB is closely linked to myocardial ischaemia, either through obstructive coronary artery disease or coronary vasospasm. According to the European Society of Cardiology, new-onset LBBB with elevated cardiac necrosis enzymes may define acute myocardial infarction (Tan et al., 2020).

Although LBBB may appear in individuals without specific clinical conditions and may not independently influence prognosis, it becomes clinically significant in the presence of acute chest pain, syncope, or heart failure with reduced ejection fraction. These conditions may be associated with myocardial injury, strain, or hypertrophy (Sheikh Jan, Mohammad Tahir, Samiera, & Nusrat, 2020). Conjunctival pallor found in all respondents may indicate anaemia, which in malaria is likely due to the destruction of erythrocytes by Plasmodium parasites (Gupta et al., 2021). Anaemia may also arise from impaired erythropoiesis in the bone marrow, leading to inadequate production of red blood cells. This condition is often linked to nutritional deficiencies, bone marrow disorders, or chronic diseases affecting erythrocyte production (Cazzola, 2022).A systematic review evaluating the accuracy of non-invasive physical examination techniques for diagnosing anaemia, particularly in areas with limited healthcare resources, found that conjunctival pallor can be indicative of anaemia (Vyas et al., 2023). Iron–malaria interaction is complex. The Suku Anak Dalam (SAD) community depends on the forest for sustenance, relying on hunting and gathering. Deforestation has significantly impacted their nutritional intake. Iron deficiency is widespread in malaria-endemic areas and, although malaria does not directly cause iron deficiency, low iron levels may reduce the risk of severe malaria (Muriuki et al., 2021; Putri & Ariusmedi, 2023; Warner & Kamran, 2023). Chronic blood loss-related anaemia may lead to serious cardiac consequences. Severe iron deficiency can impair left ventricular function and cause overt heart failure (Miura, Naya, & Yamashita, 2020). Prolonged anaemia may cause cardiac muscle strain as the heart works harder to meet the body's oxygen demands (Boyette & Manna, 2018; Pereira & Sarnak, 2003), potentially leading to conduction disturbances, including LBBB (Sheikh Jan et al., 2020)

CONCLUSION

Asymptomatic malaria can occur among individuals residing in endemic areas. Abnormal findings on electrocardiographic (ECG) recordings may be associated with malaria infection.

Therefore, conducting ECG examinations in populations living in malaria-endemic regions is crucial as a preventive measure for potential cardiac complications arising from malaria infection. Further studies are necessary using gold standard diagnostic methods for malaria to confirm whether the observed cardiac abnormalities are directly attributable to malaria infection.

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