Case Report

Instant Electrocardiographic Diagnosis of Neonatal Atrial Flutter Using Inter-QRS Segment Pattern Recognition

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Abstract

Neonatal atrial flutter (NAF) is a rare type of macroreentrant supraventricular tachycardia. In this report, we describe a case of atrial flutter in an 8-day-old neonate with a total anomalous pulmonary venous connection. Additionally, we introduce a diagnostic triad for ECG identification of this condition. This triad is composed of 3 components: similar shapes of inter-QRS segments (SIS) in leads II, III, and aVF, different shapes of inter-QRS segments (DIS) in lead I, and the occurrence of 1 or multiple stretched M or inverted V shapes in the inter-QRS (IQS) segment in leads II, III, and aVF. We assessed the effectiveness of this triad through a validation cohort, using previously reported cases of NAF from the literature. The sensitivity rates for detecting SIS and DIS patterns and the singular or multiple reversed W or V signs were 100%, 81%, and 100%, respectively. Furthermore, all 3 components of the triad were found in 81% of neonates diagnosed with atrial flutter. The emergence of this triad can be attributed to the elimination of the isoelectric segment in ECG, caused by the extended duration of flutter waves originating from macroreentry within the atrium and the rapid atrial rate characteristic of atrial flutter.

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Introduction

Neonatal atrial flutter (NAF) is an uncommon macroreentrant supraventricular tachycardia that more commonly arises from the right atrium.[1] NAF occurs most widely in the first 2 days after birth.[2] The atrial rate is usually 300 to 500 per minute, and the ventricular rate varies depending on the degree of the atrioventricular block (AVB).[3] The diagnosis is straightforward if 3:1 AVB or more is present because of the characteristic sawtooth flutter waves. However, in lesser degrees of AVB, diagnosis may be challenging at first glance.

NAF may lead to heart failure and cardiomyopathy if not diagnosed and treated early.[4] We report atrial flutter in an 8-day-old male neonate with supracardiac total anomalous pulmonary venous connection (TAPVC) and introduce a triad for immediate ECG diagnosis.

Case Report

A 2-day-old neonate was admitted for cardiac surgery

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with a diagnosis of supracardiac TAPVC. The initial ECG and chest X-ray showed no significant findings (Figure 1). An echocardiographic examination, however, revealed enlargement of the right atrium and ventricle due to the unobstructed supracardiac TAPVC (Videos 1 and 2). On the eighth day, the neonate experienced an episode of narrow-QRS tachycardia, maintaining stable hemodynamics. Intravenous adenosine was administered in successive doses of 0.1 mg/kg, 0.2 mg/kg, and 0.3 mg/kg at 2-minute intervals. Following the third dose, typical sawtooth flutter waves emerged and were converted to normal sinus rhythm after DC cardioversion (Figure 2).

A thorough analysis of the patient's ECG identified 3 distinct signs, forming a triad useful for immediate ECG di-

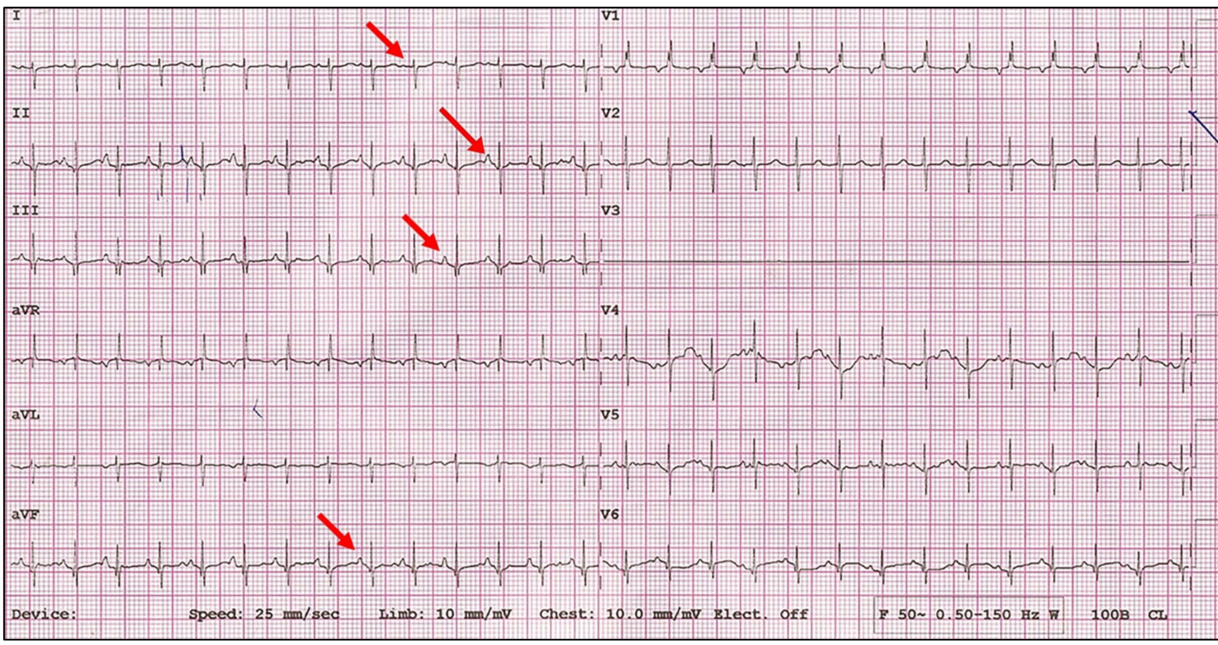

Figure 1. The patient's ECG, upon admission, exhibits a normal sinus rhythm. The P wave appears normal in both amplitude and duration. An RSR' pattern is observed in lead V1, indicative of right ventricular hypertrophy. The red arrows show normal P waves.

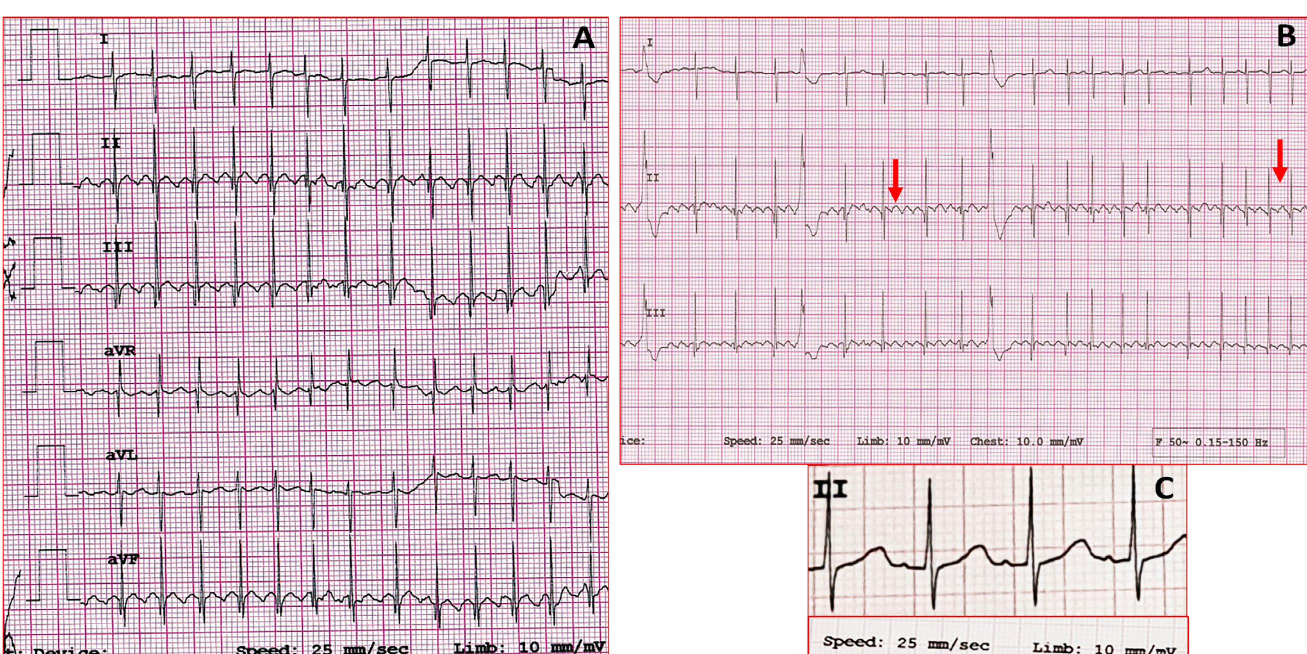

Figure 2. A) The image depicts the neonate's supraventricular tachycardia, characterized by a ventricular rate of 214 beats per minute and an RR interval of 0.28 seconds, captured before adenosine administration.
B) The image showcases distinctive sawtooth flutter waves emerging after the third dose of adenosine, exhibiting an atrial rate and variable atrioventricular block, as indicated by red arrows. The red arrows show the flutter waves. C) The image illustrates the patient's normal P wave.

agnosis even before administering adenosine to the neonate (Figure 3):

1. Similarity in the shape of the inter-QRS segment (IQS) in leads II, III, and aVF, known as the SIS pattern
2. A different shape of the IQS in lead I, termed the DIS pattern
3. The presence of single or multiple stretched M signs or reverse V signs in the IQS of leads II, III, and aVF, which vary with the degree of AVB. Notably, each reversed V sign represents an atrial flutter wave. The formation of a

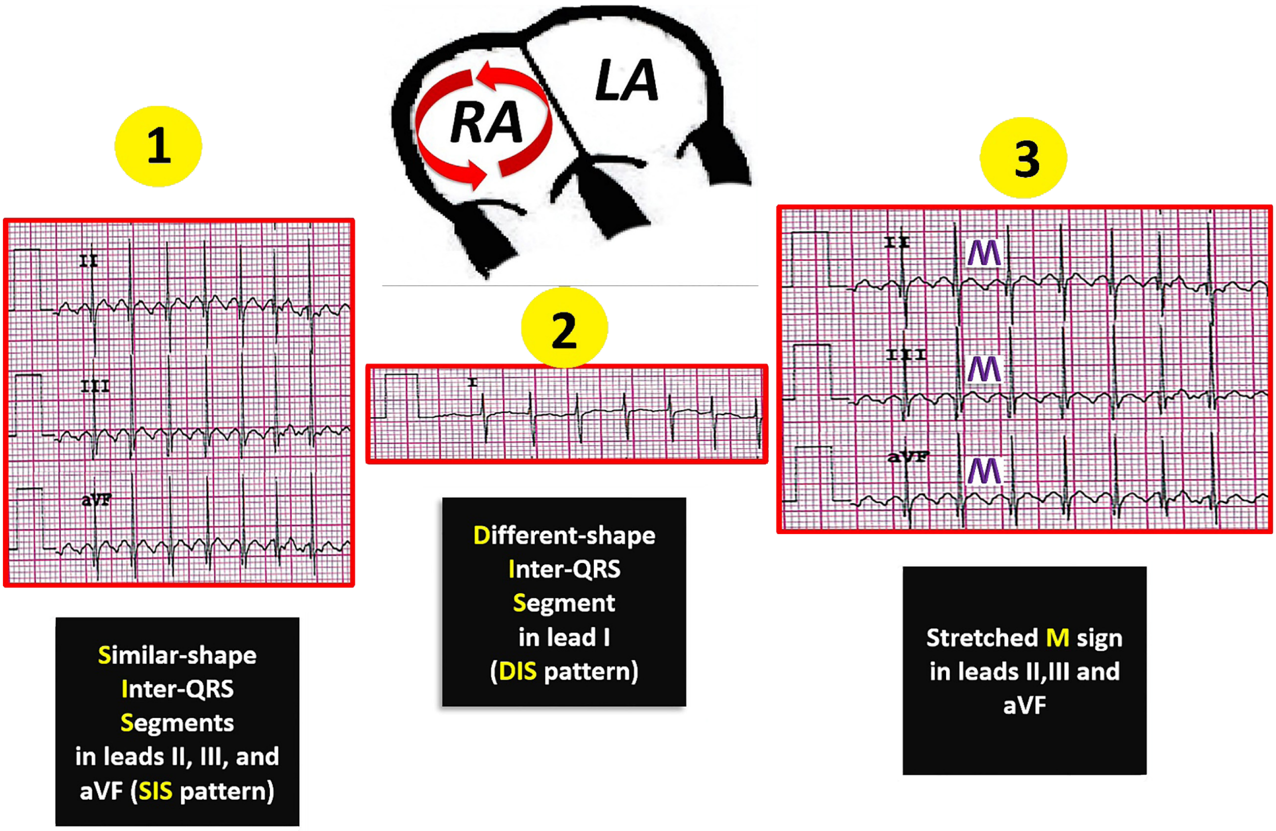

Figure 3. This figure illustrates the 3 components of the novel atrial flutter triad for immediate electrocardiographic diagnosis.

Table 1. Validation cohort for detecting the sensitivity of the novel ECG triad for immediate diagnosis of neonatal atrial flutter

	Author	Country	Year	No. of Neonates	All Three components of the triad	SIS pattern	DIS pattern	Single or Multiple Reversed W or V Appearances in the IQS in Leads II, III, and aVF
1	Chandraprakasam et al.[6]	India	2021	1 (Figure 3: case 2)	Present	Present	Present	Present (lead aVF was not obtained in this case.)
2	Jaile et al.11	USA	2021	1	Present	Present	Present	Present
3	Valente et al.[1]	Brazil	2020	1 (Patient 4)	Present	Present	Present	Present
4	Wojtowicz-Marzec et al.[7]	Poland	2020	1	Present	Present	Present	Present
5	Papadopoulou et al.[4]	Greece	2019	1	Present	Present	Present	Present
6	Drago et al.[8]	Italy	2018	1	Present	Present	Present	Present
7	Kawano et al.[9]	Japan	2018	1	Present	Present	Present	Present
8	Ban et al.[3]	Korea	2017	1 (Figure 6 A)	Present	Present	Present	Present
9	Yılmaz-Semerci et al.[10]	Turkey	2017	1 (Figure 2)	Present	Present	Present	Present
10	Roumiantsev et al. [12]	USA	2017	1	Present	Present	Present	Present
11	Jaeggi et al.[13]	Canada	2016	1	Absent	Present	Absent	Present
12	Kwok et al.14	Australia	2015	1	Absent	Present	Absent	Present
13	Prasad et al.[15]	USA	2013	2	Absent	Present	Absent	Present
14	Gulletta et al.[16]	Italy	2011	1	Present	Present	Present	Present
15	Ortega et al.[17]	Spain	2009	1	Present	Present	Present	Present
16	Knirsch et al.[18]	Germany	2007	1	Present	Present	Present	Present
Sensitivity					81%	100%	81%	100%

W sign, and others like it, is caused by the presence of 2 or more atrial flutter waves.

We evaluated the sensitivity of the novel triad using a validation cohort from previously reported cases of NAF. Our search encompassed terms such as “neonatal atrial flutter,” “atrial flutter AND neonate,” and “atrial flutter AND newborn” across various databases and publications, including Scopus, EMBASE, EBSCO, ClinicalKey, ScienceDirect, Wiley, Springer, SAGE, and Cambridge. We specifically included papers where the authors had acquired limb lead ECG data. The sensitivity rates of SIS and DIS patterns and the single or multiple reversed W or V signs were 100%, 81%, and 100%, respectively. All 3 components of the triad were detected in 81% of neonates diag-nosed with atrial flutter (Table 1).

Discussion

This is the first report of NAF associated with supracardiac TAPVC. We introduced a novel triad consisting of similar morphology of IQS in leads II, III, and aVF, along with different shapes of IQS in lead I, as well as single or multiple reversed W or V appearances of IQS in leads II, III, and aVF. Furthermore, we performed an extensive literature review on NAF and verified the presence of this triad in the vast majority of the 17 neonates with atrial flutter. While the triad was present in almost all cases with NAF, it was not present in cases with neonatal supra-ventricular tachycardia.[1, 3-10]

The fact that the triad is present in NAF but absent in atrioventricular reentrant tachycardia, the most common neonatal arrhythmia, is explained below.

As illustrated in Figures 1B and 1C, the duration of the atrial flutter wave was 120 milliseconds, 3 times the neonate’s P wave during normal sinus rhythm. This is because the flutter wave resulted from the macroreentry circuit in the atrium. In contrast, the patient’s normal P wave was 40 milliseconds long. Consequently, in an atrial flutter at a rate of 300 beats per minute, the flutter waves span 3600 milliseconds, leaving no isoelectric line in the ECG. This elimination of isoelectric segments in ECG makes the IQS segment a useful diagnostic tool. Hence, as the morphology of the QRS complex varies in limb leads based on the QRS axis, the appearance of the IQS segment also changes in NAF, depending on the axis of the atrial flutter wave. This variation becomes readily apparent and de-tectable when atrial flutter waves replace the isoelectric line.

Conclusion

We have introduced a new triad for the immediate ECG diagnosis of neonatal atrial flutter, comprising the SIS pattern, DIS pattern, and a distinctive reverse W or V sign. We also demonstrated the effectiveness of this triad in a validation cohort of neonates with atrial flutter. The six limb leads (I, II, III, aVR, aVL, and aVF) are essential for an immediate ECG diagnosis of atrial flutter. Furthermore, this case highlights that ECG is not sufficiently sensitive to detect right atrial enlargement in neonates.

To watch the following videos, please refer to the relevant URLs:

https://jthc.tums.ac.ir/index.php/jthc/article/view/1991/1134

Video 1. Color Doppler echocardiogram of the patient from the suprasternal view shows the drainage of the pulmonary veins into the common pulmonary venous confluence, vertical vein, left innominate vein, and superior vena cava respectively. The blue color flow in the right pulmonary artery is also seen.

https://jthc.tums.ac.ir/index.php/jthc/article/view/1991/1135

Video 2. This two-dimensional echocardiogram from the suprasternal notch view shows the connection of the pulmonary veins to the common pulmonary venous chamber and the ascending vertical vein.

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