Chapter

ECG Approach to Narrow QRS Complex Supraventricular Tachycardia

Behram Ahmed Khan and Umashankar Lakshmanadoss

Abstract

Supraventricular tachycardia (SVT) is an irregular heart rhythm in which the focus of impulse lies above the bundle of His, i.e., the sinus node, the atria, and the atrioventricular node (AVN). There are two types of SVT: Narrow QRS complex tachycardia and wide QRS complex tachycardia. Narrow QRS complexe tachycardias can further be divided as regular or irregular based on R–R intervals. There is further classification that can be made in regular rhythms in terms of RP interval. The most common tachycardias that are characterized by a long RP interval include sinus tachycardia, atrial tachycardia, and atrioventricular reentrant tachycardia. Short RP interval tachycardias mainly Atrioventricular nodal reentrant tachycardia (AVNRT), junctional tachycardia (JT) and permanent junctional reciprocating tachycardia (PJRT). On the other hand, irregular SVTs usually include atrial fibrillation, atrial flutter, and multifocal atrial tachycardia.

Keywords: Supraventricular tachycardia, Narrow QRS complex tachycardia, Wide QRS complex tachycardia, Atrioventricular reentrant tachycardia, Junctional rhythm, Permanent junctional reciprocating tachycardia, Atrial fibrillation

1. Introduction

Supraventricular tachycardia (SVT) is a type of arrhythmia that originates from areas above the bundles of His, i.e., the sinus node, atria, and atrioventricular node (AVN), manifesting with heart rate > 100 beats/min. In terms of duration, it can be sustained, non-sustained (<30 seconds), paroxysmal, and persistent. Tachycardias are usually classified according to anatomical structure like atrial, AV nodal, and due to accessory pathway. Nonetheless, since an electrocardiogram (ECG) is used for diagnosis, it is better to approach the diagnosis and classify SVTs according to the characteristics of the ECG. Generally, SVTs fall into two categories; narrow QRS complexes and wide QRS complexes. This chapter will focus on ECG approach to narrow QRS complex SVTs, **Figure 1**.

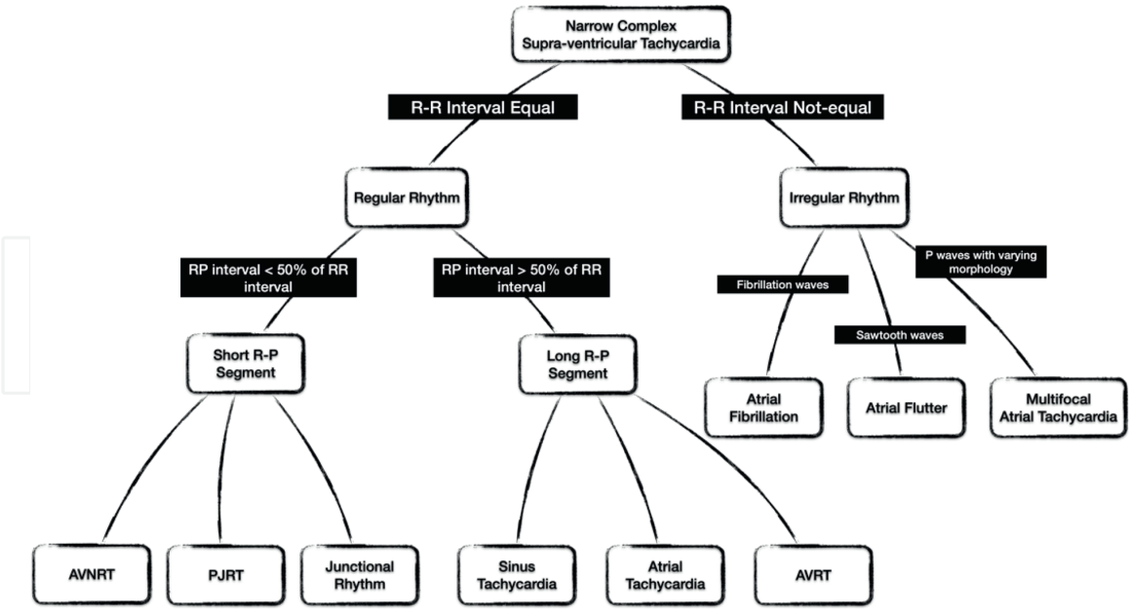

Figure 1.
Algorithm to define the supraventricular tachycardia.

1.1 Narrow QRS complex supraventricular tachycardia

While approaching an SVT, the first step would be to determine whether it's a narrow or wide QRS complex. If the QRS complex is <120 ms (<3 small boxes on the ECG) it is narrow complex and it is >120 ms (>3 small boxes on the ECG) it is defined as wide QRS complex.

1.2 Regular rhythm vs. irregular rhythm

The next step would be to determine if the rhythm is regular or irregular. The RR interval can be used to decide if the rhythm is regular or irregular ECG. If the rhythm is regular,

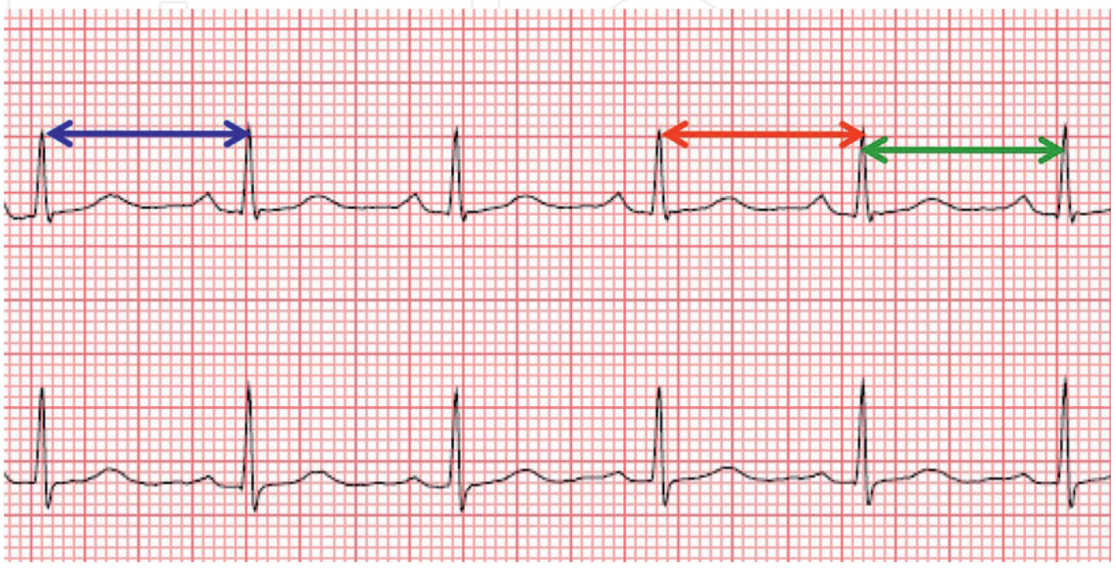

Figure 2.
Regular RR interval. The length of blue, red and green arrows are equal showing the regularity of the RR interval.

Figure 3.
Irregular RR interval. The length of blue, red and green arrows are not equal showing the irregularity of the RR interval.

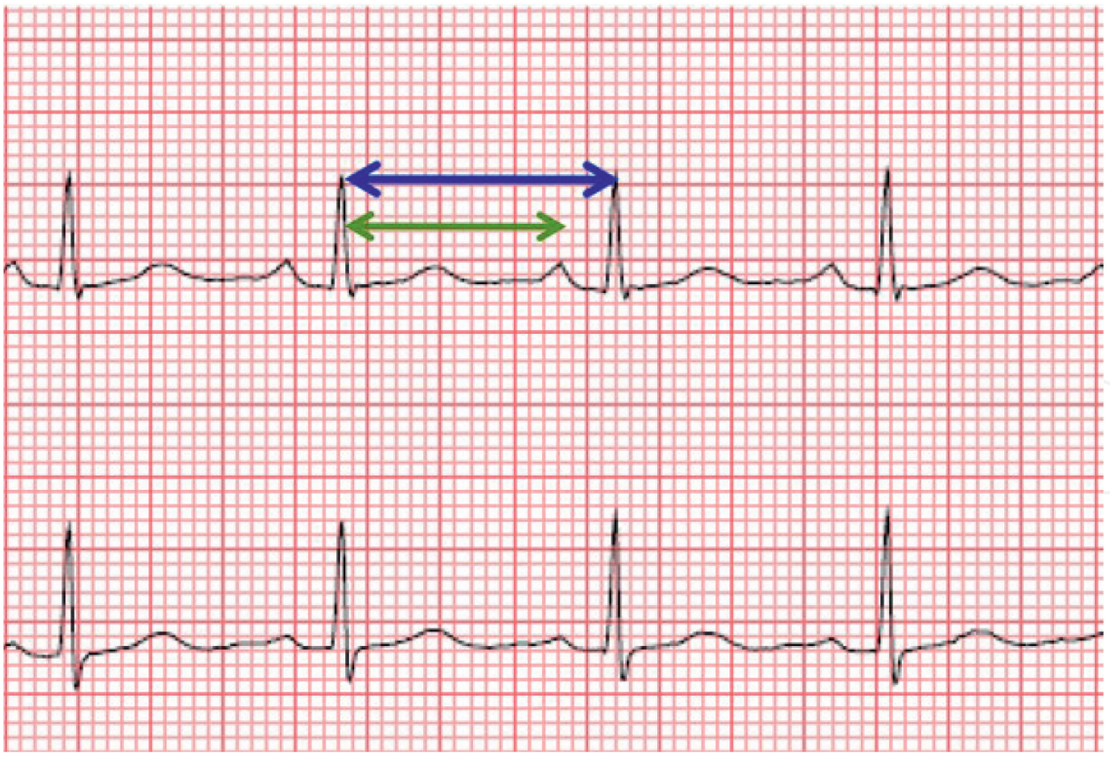

Figure 4.
Long RP interval. The RP interval (green arrow) is more than half of RR interval (blue arrow).

the RR intervals will be equal, but if it is irregular, the RR intervals will be anything but equal. If the RR interval is regular, it's a regular narrow QRS complex rhythm, **Figure 2**. If the RR interval is irregular, it's an irregular narrow QRS complex rhythm, **Figure 3**.

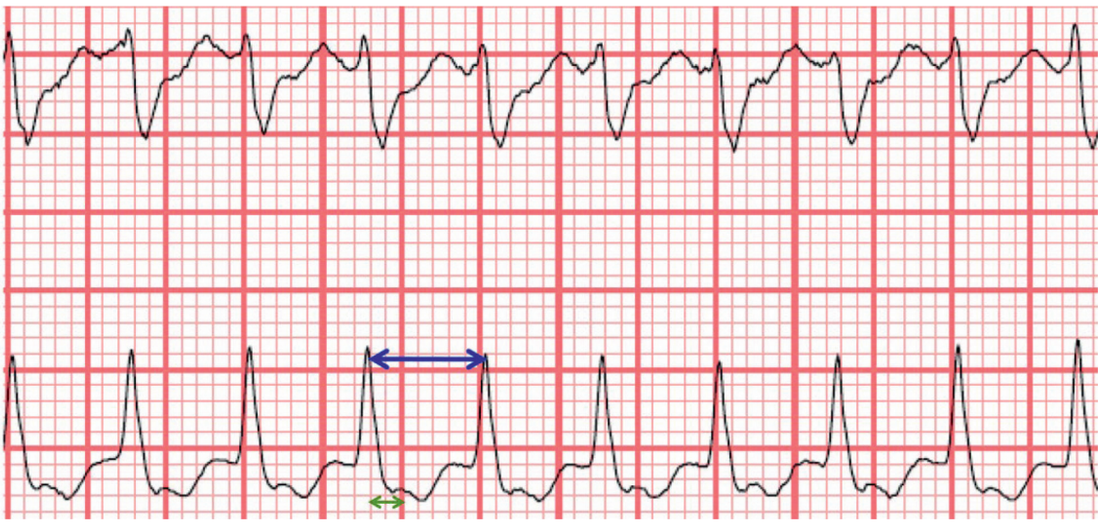

Figure 5.
Short RP interval. The RP interval (green arrow) is less than half of RR interval (blue arrow).

1.3 Long RP interval vs. short RP interval

The third step would be to determine the RP interval. SVT can be classified into two categories based on RP interval: Short RP (RP interval less than half of RR interval) and long RP (RP interval greater than half of RR interval) **Figures 4** and **5**. The RP interval is defined as the time interval between ventricular and atrial activation. On an ECG, an RP interval is the distance between the onset of the QRS complex and the end of the P wave. An approximate assumption would be that rhythms which originate from the AV node or perinodal tissue have a short RP interval and rhythms that originate elsewhere would have a long RP interval.

2. Regular rhythm

2.1 Sinus tachycardia

2.1.1 Narrow QRS complex, regular rhythm with long RP interval

In general, sinus tachycardia occurs as an appropriate response of the body to stress (illness, exercise, pulmonary embolism, hypovolemia, pain) or as a pathological abnormality of the SA node (sinus node re-entry tachycardia) [1]. Typically in this type of arrhythmia, there is an increased rate of firing of the SA node. This is demonstrated by an impulse that starts from the SA node and moves to the right atrium then to the left atrium and finally reaching the AV node, **Figure 6**.

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Long RP interval (RP interval > half of RR interval) → Upright P wave in leads I, II and aVL (showing sinus origin), and a negative P wave in lead aVR.

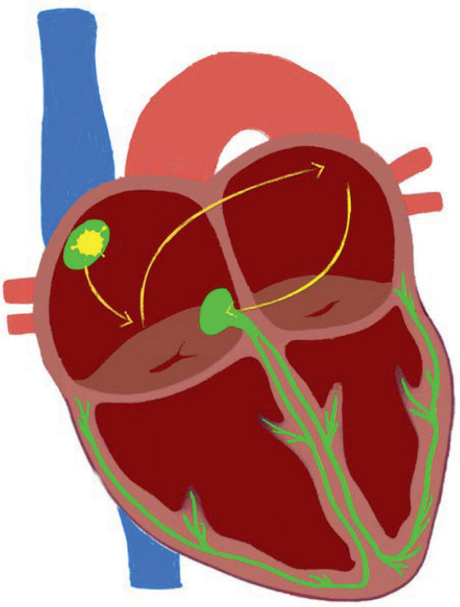

Figure 6.
The impulse is generated in the sinus node (yellow drop sign), followed by a normal conduction pathway to the atria (yellow arrow) and ultimately to the AVN.

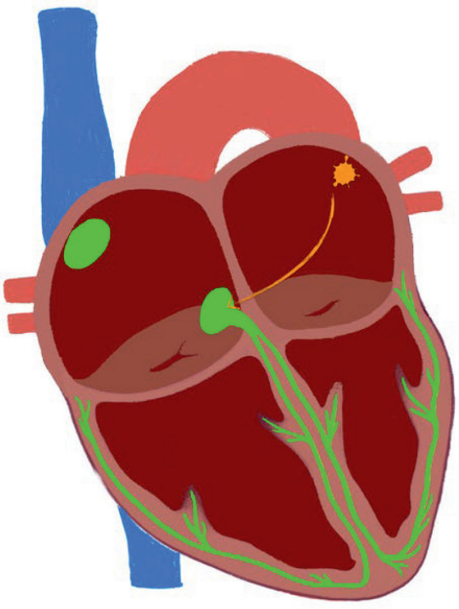

Figure 7.
An impulse is generated in the atria but not in the sinus node (the orange drop signs), which travels to the AVN.

2.2 Atrial tachycardia (focal atrial tachycardia)

2.2.1 Narrow QRS complex, regular rhythm with long RP interval

The term atrial tachycardia, also known as atrial ectopic tachycardia, refers to an arrhythmia that originates from an atrial site other than the SA node and it is

commonly paroxysmal in nature. Focal atrial tachycardia (Focal AT) is relatively uncommon, accounting for between 5% – 15% of arrhythmias in adults [2]. The most common sites of activation are the crista terminalis, tricuspid annulus, and pulmonary vein. Atrial myocytes (any focal site) are activated (either by an automatic, triggered, or micro-reentrant event) and spread centrifugally to reach the AV node, **Figure 7** [3].

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Long RP interval (RP interval > half of RR interval) → if origin is near SA node, there will be an upright P wave in leads I, II and aVL and a negative P wave in lead aVR.

It is important to compare the P wave morphology with the previous ECG, particularly in leads V1 and II, to be able to differentiate the etiology. Secondly, even though focal ATs are regular, the heart rate may increase in the first few beats of the tachycardia and gradually decelerate in the last few beats (warming up phenomenon). Notably, if there is an abrupt onset or termination of the AT (e.g., over a period of three to four beats), it is more suggestive of focal atrial tachycardia [4].

Moreover, it can be diagnosed with the greatest degree of accuracy if two or more of the following findings are present: (a) RP/PR ratio ≥ 1.65, (b) no P waves in inferior leads, and (c) P wave duration >96 ms [5].

Using the following approach, it is possible to determine the location of the focus of AT as well [6].

A. If there is a negative or biphasic P wave in V1 with an initially positive deflection and a terminally negative deflection, then the AT focus is probably in the right atrium, not the left atrium.

B. If there is a biphasic P wave in V1 with an initial negative/terminally positive deflection, it is likely that the AT focus is paraseptal in nature.

C. A positive P wave in V1 indicates that there is an AT focus in the left atrium.

2.3 Atrioventricular reentrant tachycardia

2.3.1 Narrow QRS complex, regular rhythm with long RP interval

Atrioventricular reentrant tachycardia (AVRT) is an anatomically defined reentrant tachycardia characterized by the presence of the normal AV conduction system and the accessory AV pathway. Atrial premature beats initiating an orthodromic AVRT are blocked in the accessory pathway but conduct antegrade to the ventricles over the AV node/His-Purkinje system. As the impulse is conducted through the ventricles, it then travels back via the AV accessory pathway into the atria in a retrograde fashion. This completes the reentrant loop, **Figure 8** [7]. This reentrant loop leads to tachycardia.

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Long RP interval (RP interval > half of RR interval).

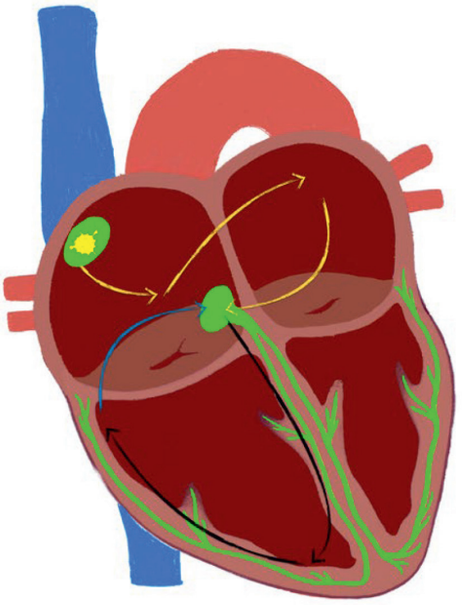

Figure 8.
An accessory pathway (blue arrow) and the AV node form a reentrant circuit.

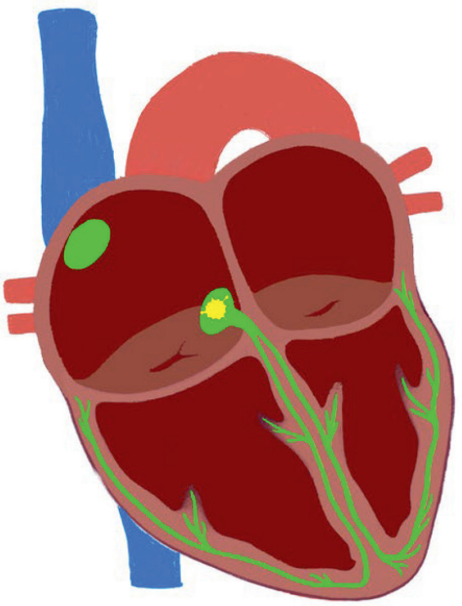

Figure 9.
AV node (yellow drop sign) generates impulses at a higher rate than sinus node.

2.4 Junctional rhythm

2.4.1 Narrow QRS complex, regular rhythm with short RP interval

As the name implies, an accelerated junctional rhythm (JR) occurs when the rate of an AV junctional pacemaker exceeds the rate of the sinus node. In this situation,

an increase in automaticity in the AV node occurs in conjunction with a decreasing amount of automaticity in the sinus node (**Figure 9**). There is a possibility that the retrograde impulse from the AV node may suppress the SA node.

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Short RP interval (RP interval < half of RR interval) → Retrograde P waves may be present and appear before, during or after the QRS complex.

There are usually inverted P waves in inferior leads (II, III, aVF), upright P waves in aVR and V1. If the SA node is not suppressed by retrograde AV impulses, AV dissociation may be present with the ventricular rate usually greater than the atrial rate [8].

2.5 Permanent junctional reciprocating tachycardia

2.5.1 Narrow QRS complex, regular rhythm with short RP interval

This type of tachycardia is also dependent upon the accessory pathway. As the AV node is responsible for generating impulses, these impulses are transmitted retrogradely through the accessory pathways to the atria. This results from characteristically slow conduction of the accessory pathway in permanent junctional reciprocating tachycardia (PJRT) in contrast to AVRT which has a "fast" accessory pathway, **Figure 10**.

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Long RP interval (RP interval > half of RR interval).

Retrograde P waves may be present and appear before, during or after the QRS complex. There are usually inverted P waves in inferior leads (II, III, aVF), upright P waves in aVR and V1. If the SA node is not suppressed by retrograde AV impulses, AV dissociation may be present with the ventricular rate usually greater than the atrial rate.

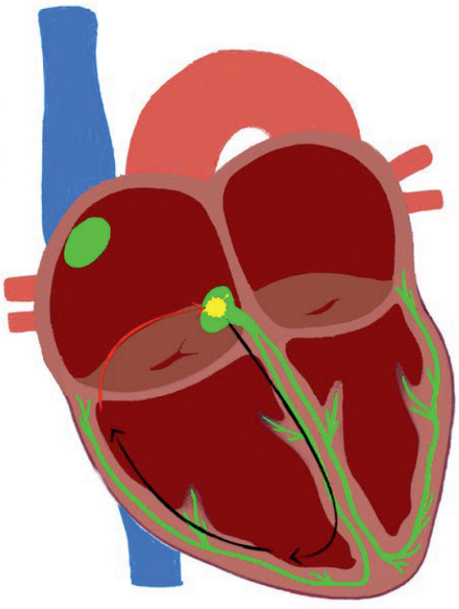

Figure 10.
Slow accessory pathways (red arrow) and the AV node form a reentrant circuit.

2.6 Atrioventricular nodal reentrant tachycardia

2.6.1 Narrow QRS complex, regular rhythm with short RP interval

Atrioventricular nodal reentrant tachycardia (AVNRT) is a regular tachycardia resulting from a reentry circuit that occurs inside the atrium and perinodal tissue. AVNRT is a paroxysmal regular tachycardia characterized by two electrical pathways (fast and slow) near or inside the AV node, **Figure 11**. Fast pathways conduct quickly and exhibit a relatively long refractory period. In contrast, the slow pathway conducts relatively slowly and has a shorter refractory period [9, 10].

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Regular RR intervals (RR intervals are equal) → Short RP interval (RP interval < half of RR interval).

If P waves are visible, they exhibit retrograde conduction with P wave inversion in leads II, III, and aVF. They may be buried within the QRS complex, visible afterward, or appear before the QRS. There will be pseudo S wave in Lead II and pseudo R wave in V1.

3. Irregular rhythm

3.1 Atrial fibrillation

Atrial fibrillation is one of the most common supraventricular tachycardias it is characterized by chaotic rapid atrial electrical activity with and without variable ventricular rate, **Figure 12**. Its pathophysiology usually varies depending upon the type of atrial fibrillation. Ectopic foci are generally the cause of paroxysmal atrial fibrillation, whereas sustained atrial fibrillation is caused by arrhythmogenic substrates formed by fibrosis of myocytes and arrhythmogenic stimulation by triggers [11].

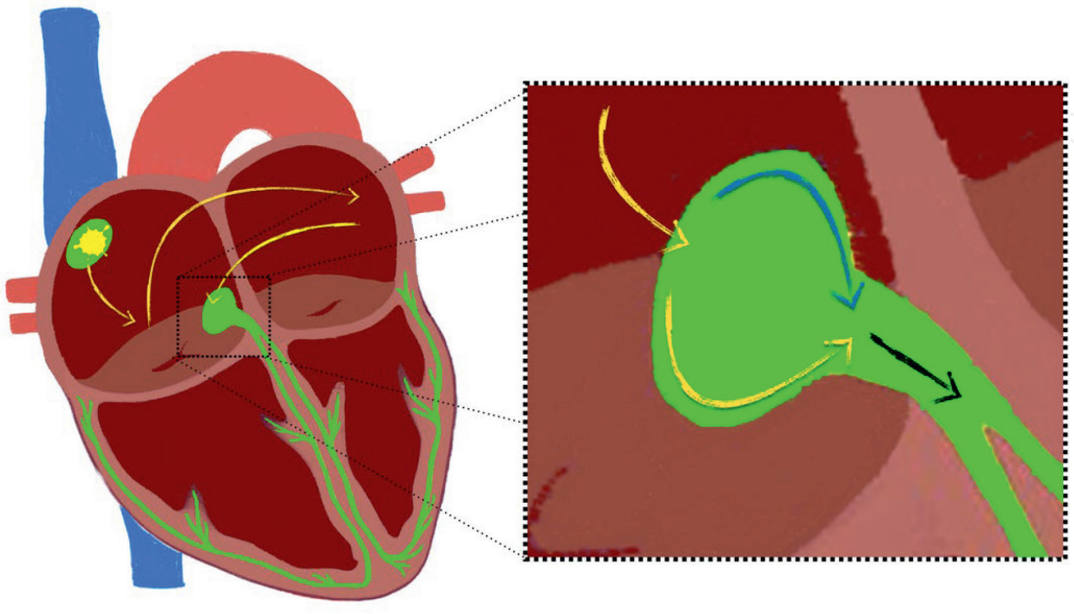

Figure 11.
A reentrant circuit forms through the normal fast atrioventricular nodal conduction pathway (yellow drop sign) and the slow perinodal accessory pathway (blue arrow).

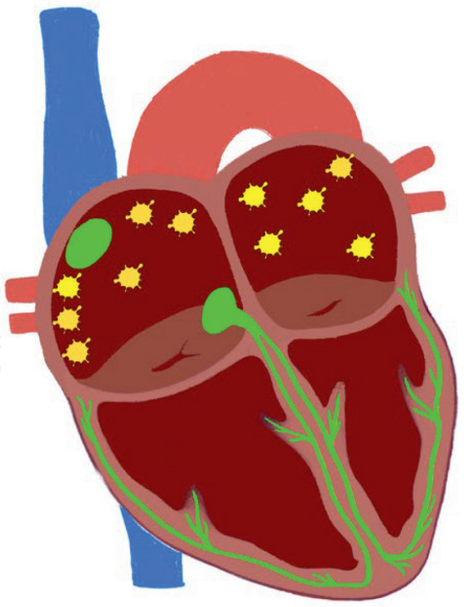

Figure 12.
Atrial tissue generates multiple impulses in a chaotic manner (yellow drop signs).

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Irregular RR intervals (RR intervals are not equal). There is no distinct presence of P waves, however chaotic fibrillation waves could be seen.

3.2 Multifocal atrial tachycardia

Multifocal atrial tachycardia (MAT) is an uncommon SVT characterized by an irregular rhythm and discrete P waves with varying morphologies, which are often observed in patients with pulmonary disease during acute exacerbations of the disease. It is the most common arrhythmia to be confused with atrial fibrillation due to varying morphology of the P waves. An increased intracellular calcium store is thought to trigger the arrhythmia from different atrial locations, which may occur as a consequence of hypokalemia, hypoxia, acidemia, and increased catecholamines, **Figure 13** [12].

Approach to ECG findings: Heart rate > 100 → Narrow QRS complex (QRS < 120 ms) → Irregular RR intervals (RR intervals are not equal) → discrete P waves with at least three different morphologies (including the sinus P wave).

3.3 Atrial flutter with or without variable block

An atrial flutter, also known as macro-reentrant atrial tachycardia, is caused by macro reentrant circuits within the annulus of the tricuspid valve with impulse conduction along the Cavo-tricuspid isthmus, **Figure 14**. It is possible for this macro reentrant circuit to be found in other areas of the atria. Therefore, it can be a typical atrial flutter (through the Cavo-tricuspid isthmus) or an atypical atrial flutter (in another part of the atria). Usually, this circuit develops as a result of fibrosis of atrial myocytes. There is an organized atrial activity, which is commonly observed as sawtooth flutter waves with a rate exceeding 200 beats per minute. Atrial flutter may manifest as an irregular SVT if there is a variable block, however it may also manifest as a regular SVT if there is no variable block.

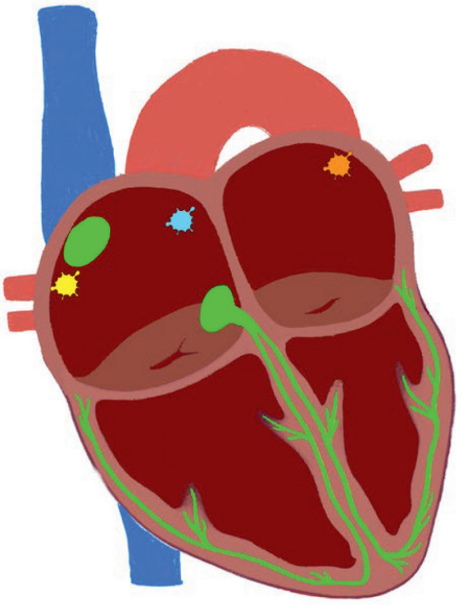

Figure 13.
The atrial tissue (drop signs) generates impulses in different places.

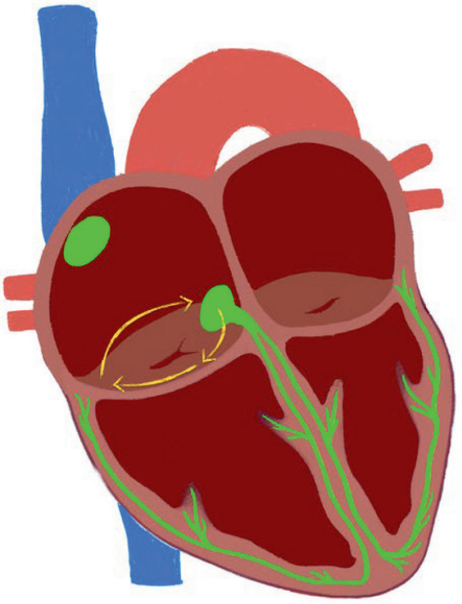

Figure 14.
A macro-reentrant circuit develops along the Cavo-tricuspid isthmus (yellow arrows).

Approach to ECG findings: Heart rate > 100 (total R waves on long lead × 6) → Narrow QRS complex (QRS < 120 ms) → Irregular RR intervals (RR intervals are not equal) → QRS complex is preceded by multiple P waves (two to three sawtooth-like waves) within a single lead with the same morphology. When the circuit is counterclockwise, it produces negative sawtooth flutter waves in leads II, III, and aVF. When the direction of the circuit is reversed, a positive P wave is produced in leads II, III, and aVF [13].

4. Conclusion

Generally, ECG findings are used to determine the type of SVT. This four-step approach can be used to identify SVTs 1. Determine if the QRS complex is narrow or wide; 2. Determine whether the rhythm is regular or irregular; 3. If the rhythm is regular, determine whether the RP interval is short or long; 4. Analyze the P wave for presence, morphology, and regularity to define supraventricular arrhythmias.

Conflict of interest

The authors declare no conflict of interest.

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