CONDUCTION SYSTEM OF THE HEART
(THE CARDIAC IMPULSE)

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THE CONDUCTION SYSTEM OF THE HEART

The cardiac conduction system is a group of specialized cardiac muscle cells. These cells are capable of generating and conducting Action Potential.

The conduction system of the heart comprises of:

1. The Sino-atrial node (SA node).
2. The Atrio-ventricular node (AV node).
3. The Bundle of His (atrioventricular bundle).
4. Purkinje fibers.

Figure 10-1 Sinus node and the Purkinje system of the heart, showing also the A-V node, atrial internodal pathways, and ventricular bundle branches.
The sinus node (also called **sinoatrial node**) is a small, flattened, ellipsoid strip of specialized cardiac muscle, 3 X 15 X 1 mm.

It is located in the superior posterolateral wall of the right atrium immediately below and slightly lateral to the opening of the superior vena cava.

SA node has almost **no** contractile muscle filaments.

SA nodal fibres **connect** directly with the atrial muscle fibres so that any action potential that begins in the SA node spreads immediately to the adjacent atrial muscle.

SA node generates a **Pacemaker potential**.
Role of Internodal Pathways & the spread of the AP to both Atria

Special bands are present b/w SA node & AV node and the velocity of conduction in these **Inter nodal Pathways** is about 1 m/sec.

There are 3 Atrial Internodal Pathways:

1. Anterior Internodal Pathway or **Bachmann’s Bundle**
2. Middle Internodal Pathway or **Wenkhebach Bundle**
3. Posterior Internodal Pathway or **Tract of Thorel**

If the AP can spread directly from the SA node to the atrial muscle why, is there the presence of Interatrial bands?

Velocity of conduction in most atrial muscle is about 0.3 m/sec. These specialized bands conduct the AP at a speed of 1 m/sec (due to presence of specialized conduction fibers).
The atrial conduction system is organized so that the cardiac impulse does not travel from the atria into the ventricles too rapidly; there is, in fact, a delay.

This delay allows time for the atria to empty their blood into the ventricles before ventricular contraction begins.
The Atrioventricular Node (AV Node)

The A-V node is located in the posterior wall of the right atrium immediately behind the tricuspid valve.

The Atrio Ventricular node continues into the AV bundle also called the Bundle of HIS.

The Impulse **slows** down at the AV node & the Bundle of HIS so that there is a delay here before it enters into the ventricles.
What is AV Nodal Delay?

It is the delay at the AV node to transmit the cardiac impulse forward. It is app. 0.09 second. If delay at the AV Bundle (0.04 sec) is also included, then it equals 0.13 sec.

- What causes the AV Nodal Delay?
WHAT CAUSES THE AV NODAL DELAY?

- Decreased number of gap junctions
- Greater resistance to conduction of ions
- Smaller fibres
Why should the cardiac impulse travel from the atria into the ventricles after a certain delay?
Because the delay will allow time for the atria to empty the blood into the ventricles & thus, complete ventricular filling, before ventricular contraction begins.
How long does it take for the Cardiac Impulse to reach the ventricles?
How long does it take for the Cardiac Impulse to reach the ventricles?

- From SA node to the Av node: 0.03 sec
- At the AV node: 0.09 sec
- AV Bundle of HIS: 0.04 sec

- Time taken for the impulse to reach from the SA node to the ventricles: **0.16 sec**
Figure 10-3 Organization of the A-V node. The numbers represent the interval of time from the origin of the impulse in the sinus node. The values have been extrapolated to human beings.
AV BUNDLE ALLOWS ONLY ONE-WAY CONDUCTION.

This is due to the fibrous skeleton of the heart.
• **Heart Skeleton**
  - Consists of plate of fibrous connective tissue between atria and ventricles
  - Fibrous rings around valves to support
  - Serves as electrical insulation between atria and ventricles
  - Provides site for muscle attachment
The Bundle Branches and the Purkinje Fibres

• Bundle of HIS extends from the AV node into the ventricles.
• After about 10-15 mm it divides into the Left and Right Bundle branches.
• They move towards the apex of the heart.
• Purkinje fibres emerge from the Bundle of HIS supply the ventricular muscle.
• Purkinje fibres are very large fibres transmitting action potentials at a velocity of 1.5 to 4 m/sec. The cause of the increased speed of conduction is:
  - Large sized fibres,
  - Increased no. of gap junctions, and
  - fewer myofibrils for contraction.
• Once impulse reaches the ends of Purkinje fibres (0.03 sec later), it is transmitted through the ventricular muscle mass by the ventricular muscle fibres themselves. (velocity of conduction: 0.3 to 0.5 m/sec)
• Impulse travels from the endocardium to the epicardium (0.03 sec)
• Total time from Bundle of HIS to last of ventricular muscle fibre: 0.06 sec.
Purkinje Fibres ensure the synchronous contraction of the ventricular muscle.
Electrical signaling begins in the SA node.

1. SA node depolarizes.
2. Electrical activity goes rapidly to AV node via internodal pathways.
3. Depolarization spreads more slowly across atria. Conduction slows through AV node.
4. Depolarization moves rapidly through ventricular conducting system to the apex of the heart.
5. Depolarization wave spreads upward from the apex.

**THE CONDUCTING SYSTEM OF THE HEART**

**SA node**

**Internodal pathways**

**AV node**

**AV bundle**

**Bundle branches**

**Purkinje fibers**

**Figure Question**

What would happen to conduction if the AV node malfunctioned and could no longer depolarize?
**Time taken for the impulse**

- From SA node to the AV node: 0.03 sec
- AV nodal delay: 0.13 sec
  - 0.09 sec at AV node
  - 0.04 sec at Bundle of HIS

Thus, time taken for the impulse to reach from SA node to the ventricles: 0.16 sec

- From Bundle branches to Purkinje fibers: 0.03 sec
- From endocardium to the epicardium (after the Purkinje fibers): 0.03 sec
ELECTRICAL CONDUCTION IN MYOCARDIAL CELLS

Autorhythmic cells spontaneously fire action potentials. Depolarizations of the autorhythmic cells then spread rapidly to adjacent contractile cells through gap junctions.

Cells of SA node

Electrical current

Action potentials of autorhythmic cells

Action potentials of contractile cells

Intercalated disk with gap junctions

Contractile cell
Figure 10-2  Rhythmical discharge of a sinus nodal fiber. Also, the sinus nodal action potential is compared with that of a ventricular muscle fiber.
Why does the SA node rather than the AV node or the Purkinje fibers control the heart’s rhythmicity?
Why does SA node rather than the AV node or the Purkinje fibers control the heart’s rhythmicity?

Because its rate of rhythmical discharge is faster than that of any other part of the heart.
Who is the real pacemaker?

<table>
<thead>
<tr>
<th>Parts of conducting system</th>
<th>Pacing rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA Node</td>
<td>75 times/min</td>
</tr>
<tr>
<td>AV Node</td>
<td>60-50 times/min</td>
</tr>
<tr>
<td>Bundle of His &amp; Purkinje fibers</td>
<td>20-30 times/min</td>
</tr>
</tbody>
</table>

- The **discharge rate of the sinus node is faster** than discharge rate of either the A-V node or the Purkinje fibers.

- The sinus node discharges again before either the A-V node or the Purkinje fibers can reach their own thresholds.

- Rate of rhythmic discharge **in SA Node is faster** than any other part.
Whole train will go 70 mph (heart rate set by SA node, the fastest autorhythmic tissue).

SA node "derailed"

Train will go 50 mph (the next fastest autorhythmic tissue, the AV node, will set the heart rate).

AV node "derailed"

First part of train will go 70 mph; last part will go 30 mph (atria will be driven by SA node; ventricles will assume own, much slower rhythm).

Ectopic focus

Train will be driven by ectopic focus, which is now going faster than the SA node (the whole heart will be driven more rapidly by an abnormal pacemaker).
What is an Ectopic Pacemaker?

An Ectopic pacemaker of the heart is a pacemaker elsewhere than the Sinus Node.
Question

Transmission of impulse from SA to AV node is blocked. Thus, SA node discharges at its own rate while AV node becomes the new pacemaker and discharges at its own rate. Why is this dangerous?
Question

What is Stokes Adams Syndrome?

(Guyton, 13th Ed. Page: 127)