# Atrial Fibrillation and the Maze Operation

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In this document, I want to explain some basic aspects of atrial fibrillation, describe how the maze operation works, and present our results to date. We will begin by describing how normal sinus rhythm works, then explain what atrial fibrillation is and how it causes symptoms, and finally proceed to the concepts of the maze operation. Here at the beginning, let me remind you that the heart consists of two upper chambers, the atria, and two lower chambers, the ventricles. The right and left atria are storage containers for blood coming back from the body and the lungs respectively. The right and left ventricles relax to allow atrial blood to flow into them, and then they contract forcefully to deliver blood under pressure to the lungs and the body respectively. I want to explain how this rhythmic contraction of the heart is controlled.

## What is normal?

All muscular contractions, whether in your arm muscle or your heart muscle, begin with a wave of electrical activity that causes the muscle to squeeze. In the case of the arm muscle, an electrical signal comes from the brain and travels down the spinal cord to nerves that distribute electrical stimulation to the muscle. If the nerves or spinal cord are cut, electricity can't flow, and the muscle cannot contract. Instead of relying on the brain, the heart has its own much simpler, but highly effective electrical system that tells the heart when to contract. This system begins with a special set of cells, called the **sinus node**, in the right atrium that regularly discharge electrical messages to the heart. Each message quickly spreads over both right and left atria causing them to contract once.

This electrical message then passes to the next key part of the electrical system, called the **AV node**. This structure is a bridge that delays the signal for a brief moment and then sends it to the ventricles. The delay is very important because it protects the ventricles from being stimulated too frequently. Remember that the ventricles pump by squeezing the blood inside them and then relaxing so the next load of blood can enter. If they are simulated too frequently, they don't have enough time to fill or empty, so they can't move blood. The delay in the AV node prevents this from happening.

After a delay at this tollgate, the electrical message passes quickly to the ventricles, and they contract synchronously to squeeze blood and thus maintain blood pressure and provide oxygen. In very abbreviated form, this explains how a single normal heartbeat occurs.

## What is atrial fibrillation?

To understand atrial fibrillation, you have to begin with an even simpler question that reveals a fundamental idea about the heart. Once the sinus node releases a packet of electrical activity to the atria, why doesn't the electricity just keep wandering around the heart? Why does the heart quiet down after each stimulation? Every cell in the heart is designed so that normally after each stimulation (also known as a **depolarization**) there is a period during which the cells absolutely cannot be stimulated again. This is called the **refractory period**. Therefore once the atria have been depolarized, they cannot be further stimulated for a while and the electricity has nowhere to go. After this rest, the atria regain their ability to be depolarized again so they are ready for the beginning of the next heartbeat. But what happens if the atria are very large? Under these conditions, some portion of the atria might recover while the impulse is still traveling through the atria. Then the electrical impulse could always find a place that could be depolarized, and the electrical activity would be continuous, not intermittent. That is, the electrical impulse could always find a place ready to depolarize, and therefore electricity would continue to wander around the atrium. The same sequence of events could happen if the atria were diseased and therefore slowed the passage of the original stimulation through the heart. Once again, by the time electricity spread slowly over the atria, enough time might pass so that some part has recovered (repolarized), then another, and the original signal could continue wandering around the atria finding a repolarized spot.

## What does atrial fibrillation do to patients?

Most patients with atrial fibrillation have one or both of these problems: the atria are enlarged and/or they conduct slowly. These problems permit an electrical impulse to wander endlessly around the heart. The electrical energy is said to **re-enter** the places where it has been on the previous beat, and thus atrial fibrillation is a re-entry abnormality. This continuous electrical activity has several effects: first, the atria quiver irregularly and second, the ventricles, although protected by the AV node, beat irregularly. Let's examine the effects of each of these on the patient. When the atria quiver in response to continuous electrical activity, they do not squeeze effectively, blood passes through them turbulently, and turbulent flow promotes clot formation in the atria. When these clots are washed into the ventricle, they can end up in the brain, causing a stroke. People with atrial fibrillation take the blood thinner coumadin to diminish the chance of clot formation. This treatment is effective but does nothing for the atrial fibrillation and exposes patients to the risk of bleeding. When the sinus node cannot control heart rate, the AV node does what it can to prevent too many electrical signals from going to the ventricles, but the normal way we control our heart rate doesn't work, we tend to go too fast or too slowly, and we don't adjust to our level of activity. Some of us sense irregular heart beats as "palpitations". Medicines such as digoxin and the antiarrhythmics can help, but rarely cure atrial fibrillation. Finally, when the atria quiver they do not squeeze blood into the ventricles. This decreases the effectiveness of the heart as a pump.

## The Maze Operation

Now that you have some basic concepts about the electrical activity of the heart, I can provide some ideas about the surgical cure of atrial fibrillation. Once you have read this, take a look at the slide show that follows. It was written for medical personnel, so it is more detailed, but it presents a complete view of the maze as well as our results with this operation.

Since atrial fibrillation is a **re-entry** abnormality, we can cure it if we block re-entry. We can do this by placing a series of strategically located incisions in the atria and then sewing them up. Electrical activity cannot cross such incisions even after they heal. The key idea in the maze is to place these incisions in the locations where re-entry is most likely, but leave the **sinus node** in electrical touch with most of the atrium. In this way the sinus node can continue to control heart rate, but re-entry is less likely. In addition, the maze detaches and reattaches the pulmonary veins to the left atrium. This prevents premature atrial beats that originate in these veins from initiating atrial fib. The slide presentation will add some depth to this brief outline, and specifically credit the key research of my colleague and friend, Dr James Cox who made this effective operation possible.