Fabrication Techniques for Mems-Based Sensors: Clinical Perspective

Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

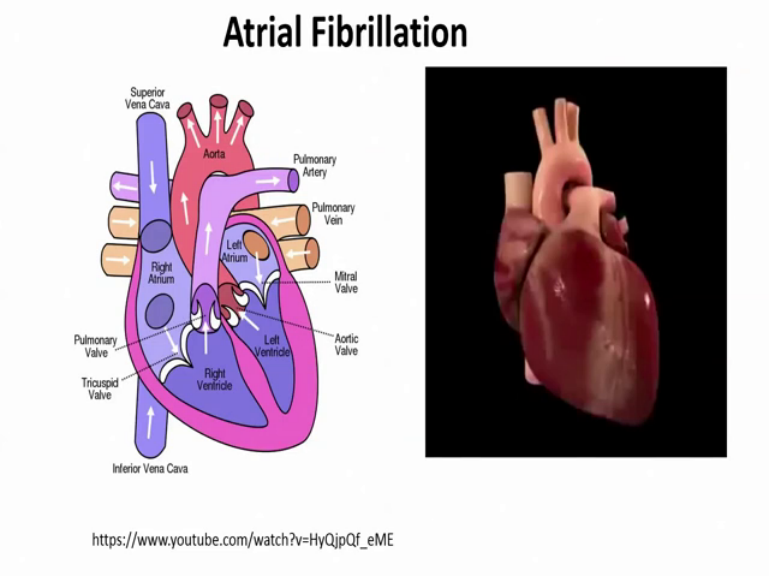
Module - 9
Lecture - 30
Smart Catheter

Hi, Today we will be learning a very important application of micro engineering or micro technology and that will be force sensing. Now, it may come to your mind that why force sensing is so important, because you have been looking at or you may be looking at a lot of force sensors available around you right, but if I say that this force sensor plays a vital role when a heart surgery is performed or during a heart surgery. So, the first question that comes to our mind is how, right? And how come force sensing is used in a heart surgery?

So, when we talk about heart, right. We you see that whenever you work out right, whenever you climb the stairs, run, your heart beats faster. So, faster beating of heart when you are performing a physical activity it is normal. Faster beating of heart when you are static can be a corresponding or can be a signature to a particular disease. It can be arrhythmia; however, if the heart pumps unevenly; rapid, then slow, suddenly rapid, normal, again rapid, again normal, then that will cause a bigger problem. Because, it may cause a clot in the blood and the clot can travel to other part of the body including brain and cause brain damage. So, that beating of heart, uneven beating of heart is called fibrillation, particularly atrial fibrillation.

So, what exactly is atrial fibrillation? What are the techniques to cure atrial fibrillation? And how we can make the tool that is used in curing atrial fibrillation smarter? So, the tool that is used in curing the atrial fibrillation is called catheter. Is a tube that is inserted from the groin area and reaches the heart and ablates the tissue. So, when I when I talk about ablation is nothing but, burning, burns the tissue. Now, why suddenly burning comes into picture? Why we have to burn the tissue and that too heart I will talk about this things in detail once we go through the slides. So, if you see the slide you can see that today, we will be talking about smart catheters or how can we make catheters smarter.

(Refer Slide Time: 04:04)



So, we have also read about heart. There is a superior vena cava, right atrium, left atrium, a left ventricle, a right ventricle, pulmonary valve, right. Tricuspid valve, aortic valve. Same way we have, pulmonary artery, we have pulmonary vein correct. This is and of course we have aorta. This is a general structures, general structure of heart that we all know. Now, the electrical signals, they are generated from superior vena cava and travels through pulmonary veins PVI. So, that can cause misfiring. That the, that is uniform generally. When the electrical signals are pumping into the heart, they have a uniform fashion, right always. And we know that, there is a rhythmic movement of heart, not uneven beating, but a uniform beating.

But when this electrical signals does not form a particular pattern and misfires in random direction, this will cause uneven beating of heart. So, how we can treat this particular disease? Let us see how our heart looks like. So, you can see right actual heart pumping and right. So, you can here, clearly see what we are talking about, we are talking about aorta which is here, right. You can see its right over here aorta, right, pulmonary artery, pulmonary veins, superior vena cava, inferior vena cava, right. And this is how our heart actually looks like guys.

So, it is not something that is we used to represent, right fancy version of the heart. Actual heart when you see [laughter] you will not really like it right. And, but, having

said that this is nothing but a pumping organism, upon pumping organ. And pumping organ which is, extremely important for us to live right.

(Refer Slide Time: 07:14)

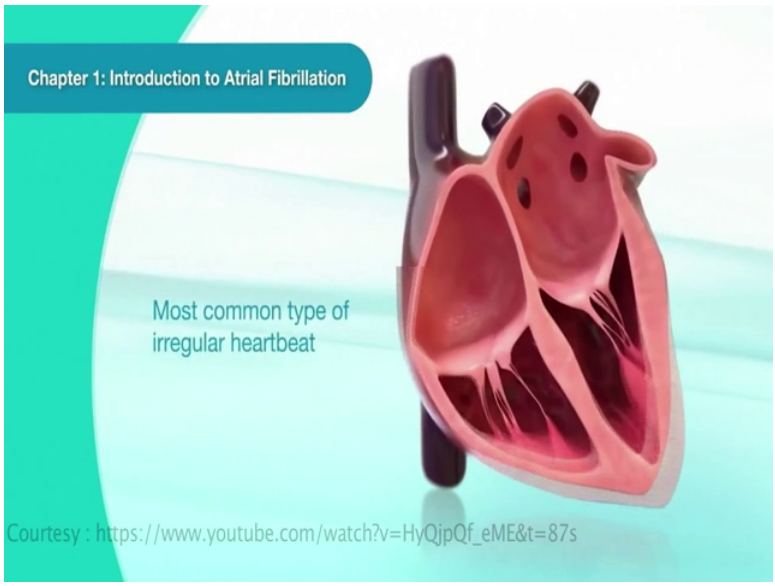
Now, let us first understand what exactly is atrial fibrillation and its role in causing the difficulty in the heart to pump, as well as possible curing mechanism. So, let us see this video.

(Refer Slide Time: 07:37)

Atrial fibrillation or AFib, is a heart condition that causes the heart to race and beat in an irregular rhythm. People often say that when I have an episode of AFib they feel as

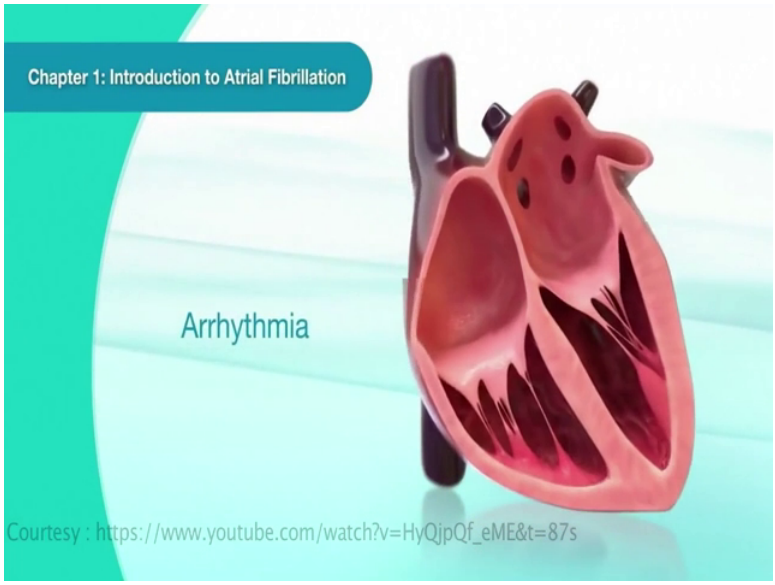
though a fish is flopping around in their chest or that their heart feels like it will explode. AFib can increase your risk of heart failure, stroke and even death. Because of these risks and because AFib can get worse over time it is important to have it diagnosed early and cared for appropriately.

(Refer Slide Time: 08:08)

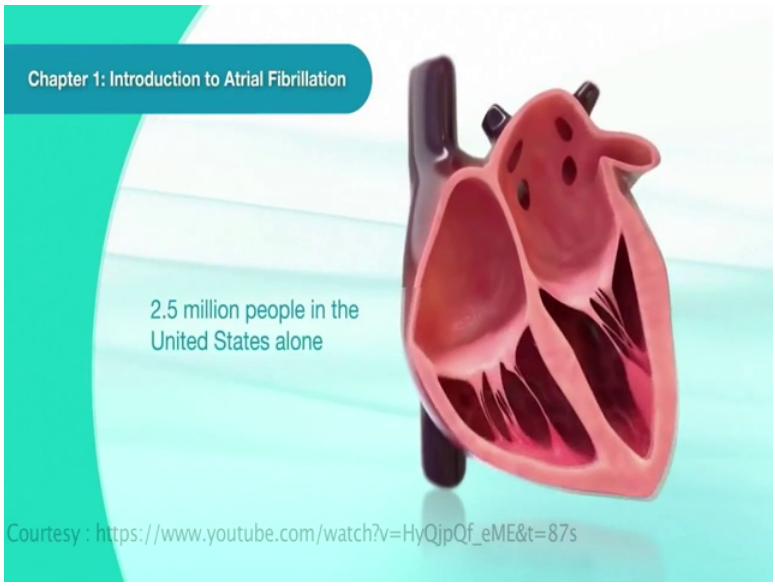


AFib is the most common type of irregular heartbeat or arrhythmia.

(Refer Slide Time: 08:11)

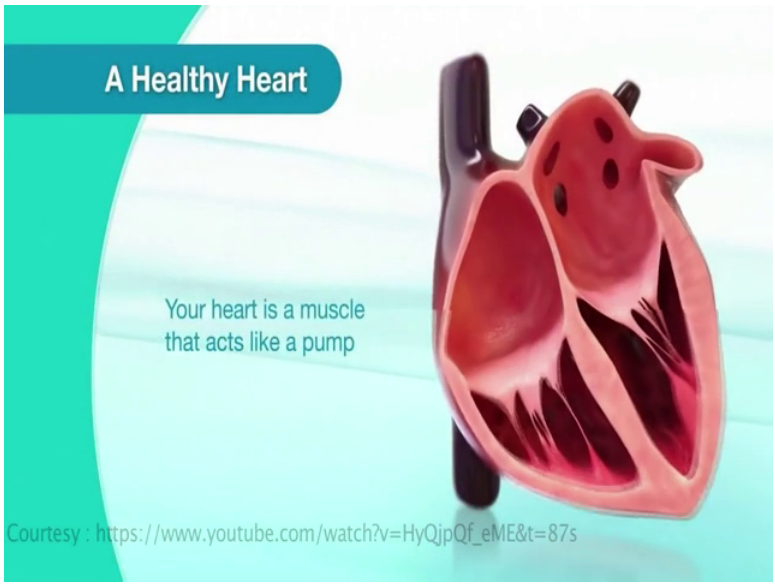


(Refer Slide Time: 08:13)



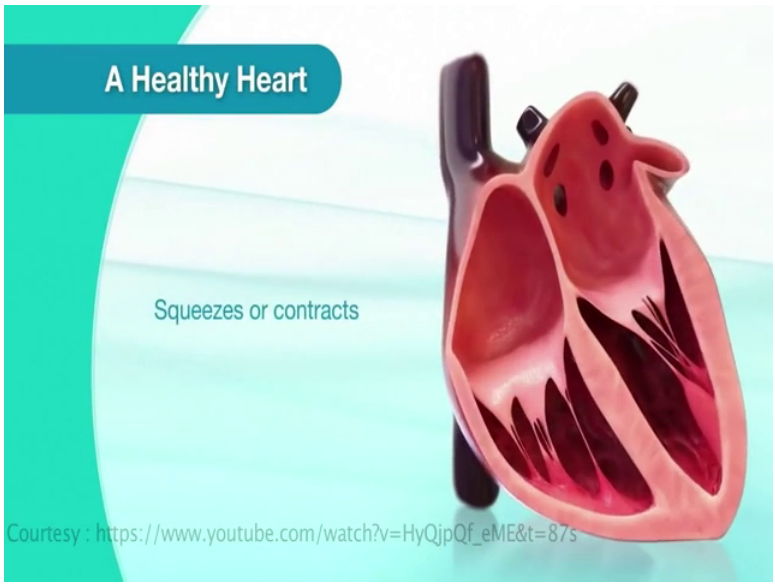
It affects over 2.5 million people in the United States alone.

(Refer Slide Time: 08:19)



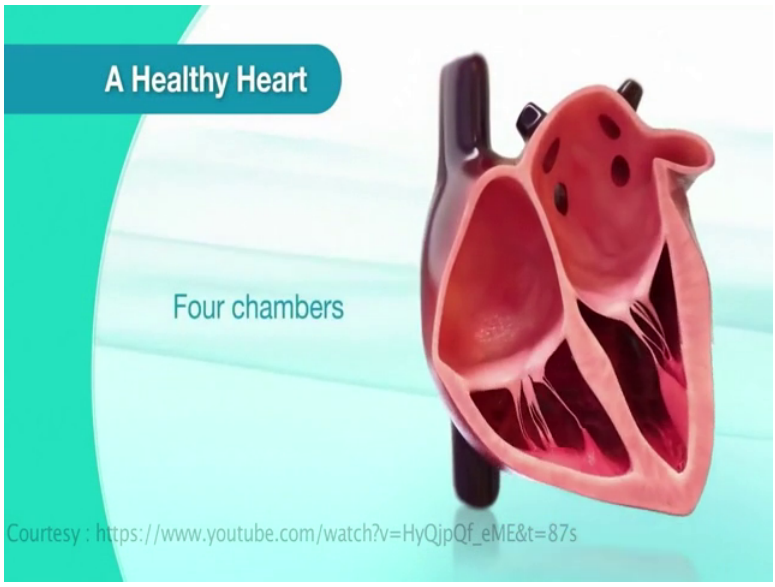
Your heart is a muscle that acts like a pump.

(Refer Slide Time: 08:23)



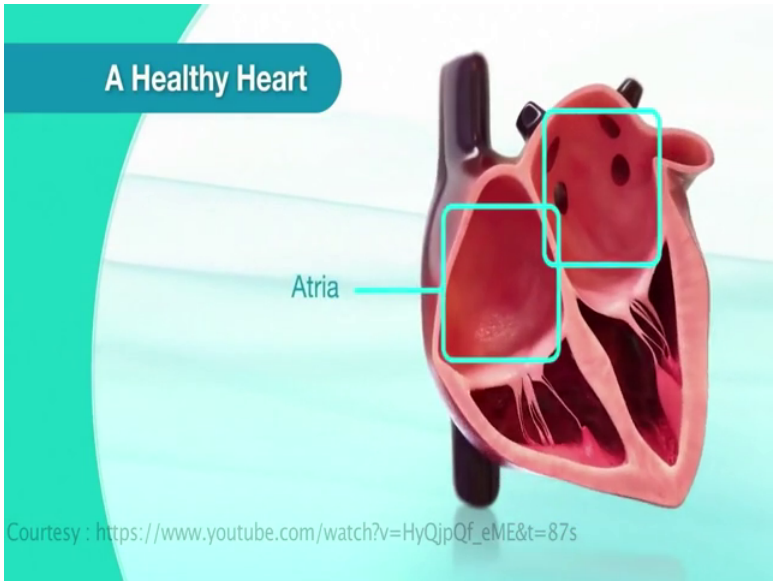
With each beat it, squeezes or contracts to push blood to the rest of your body.

(Refer Slide Time: 08:28)



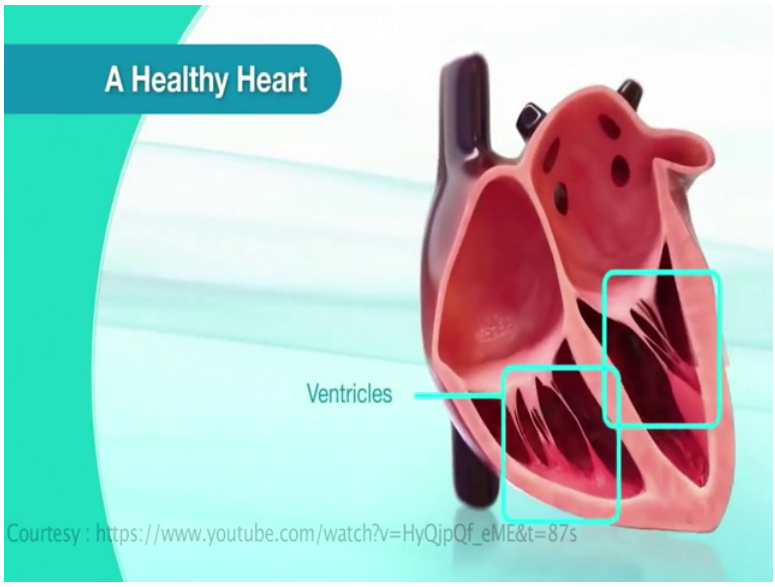
Your heart has four chambers.

(Refer Slide Time: 08:32)



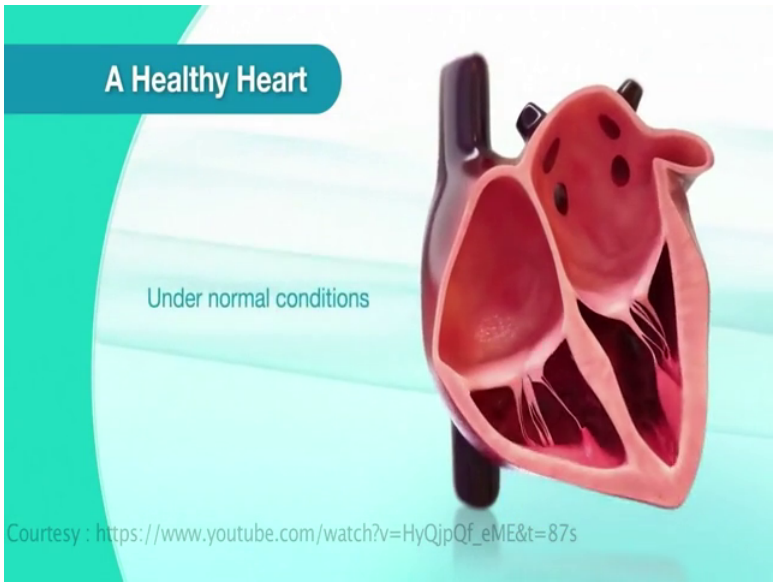
The two upper chambers are called Atria.

(Refer Slide Time: 08:34)



The two lower chambers are called ventricles.

(Refer Slide Time: 08:37)

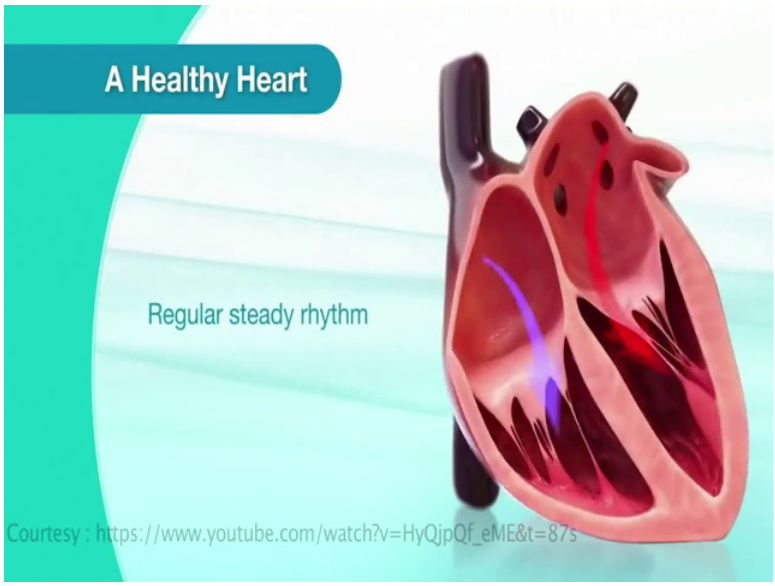


Under normal conditions.

(Refer Slide Time: 08:39)

The upper and lower chambers of the heart work together to pump blood throughout the body. The blood stream enters the atrium where, blood is pumped to the ventricles in a regular and coordinated way. From there, blood is pumped from the ventricles to various parts of the body.

(Refer Slide Time: 08:55)

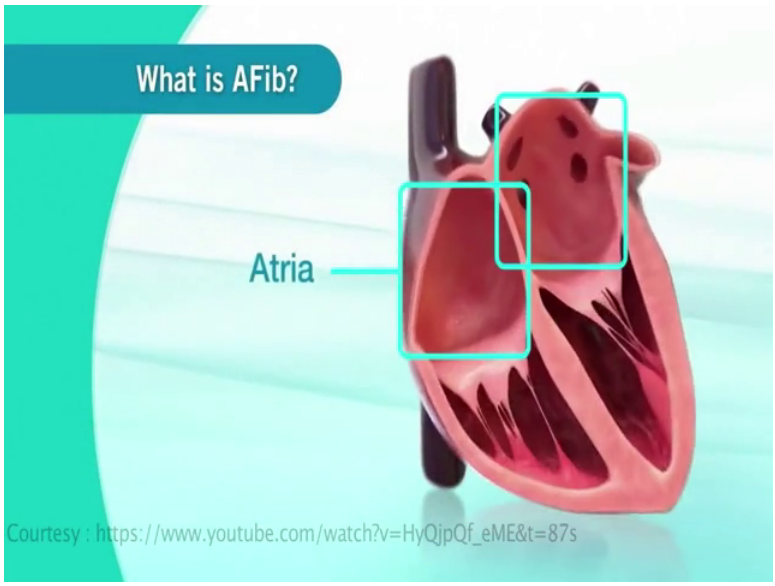


The healthy heart beats in a regular steady rhythm or pattern.

(Refer Slide Time: 09:00)

Notice that, the heart beats evenly and uniformly. In a healthy heart electrical signals travels through the heart in a regular pattern as seen here. These electrical impulses originate in a special section of the atrium and travel through the heart in a regular pattern. Each signal ultimately causes the heart to beat.

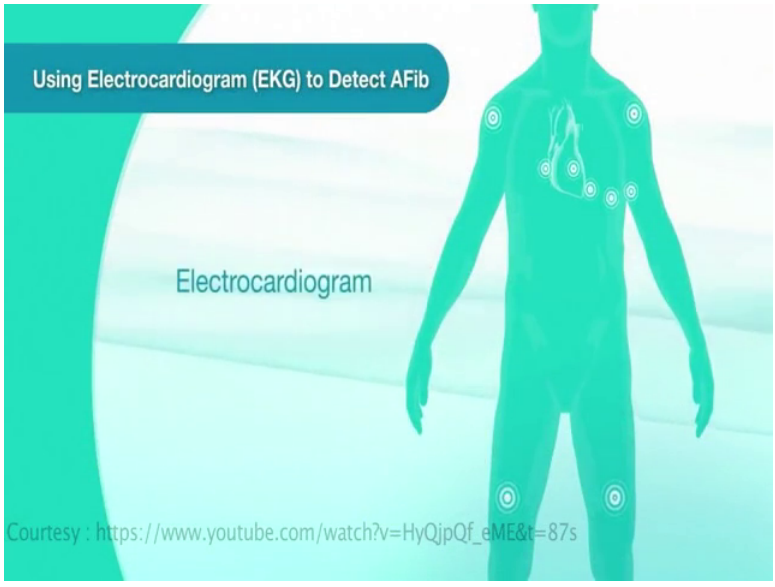
(Refer Slide Time: 09:25)



In AFib, the top 2 chambers of the heart or atria beat very fast and in an irregular pattern that is out of rhythm. Notice, how the atria appear to quiver and are uncoordinated. Due to this irregular pattern the atria do not coordinate with the ventricles and the heart is out of rhythm.

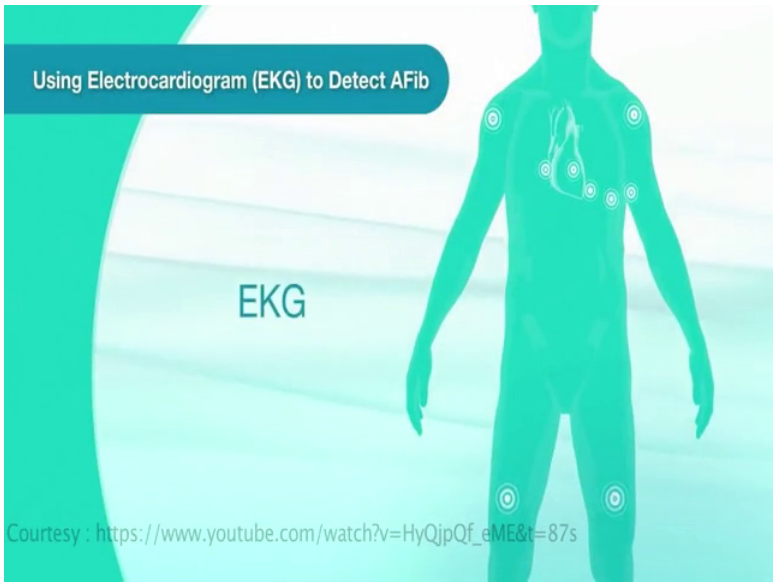
AFib occurs when electrical signals start in the wrong place and misfire. The faulty signals cause the atria to quiver and not contracts completely. Notice how the signals spread in a rapid disorganized way.

(Refer Slide Time: 09:57)



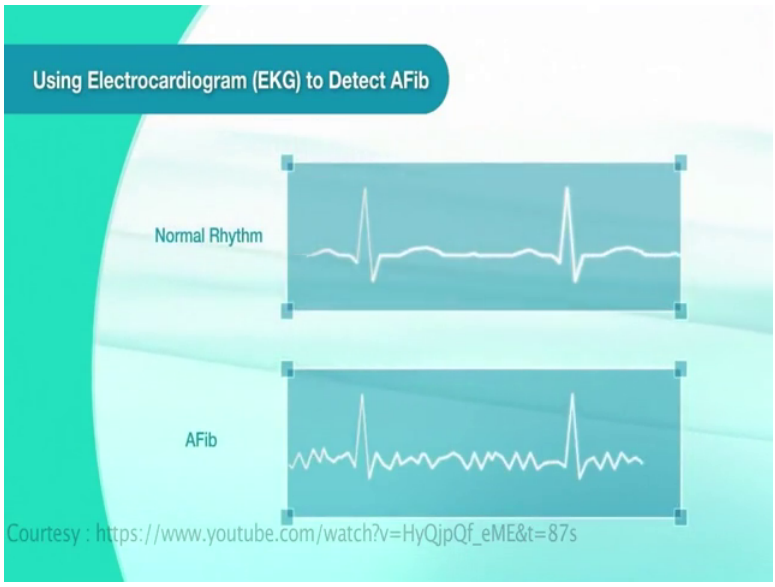
Your doctor may perform a test called an electrocardiogram.

(Refer Slide Time: 10:02)



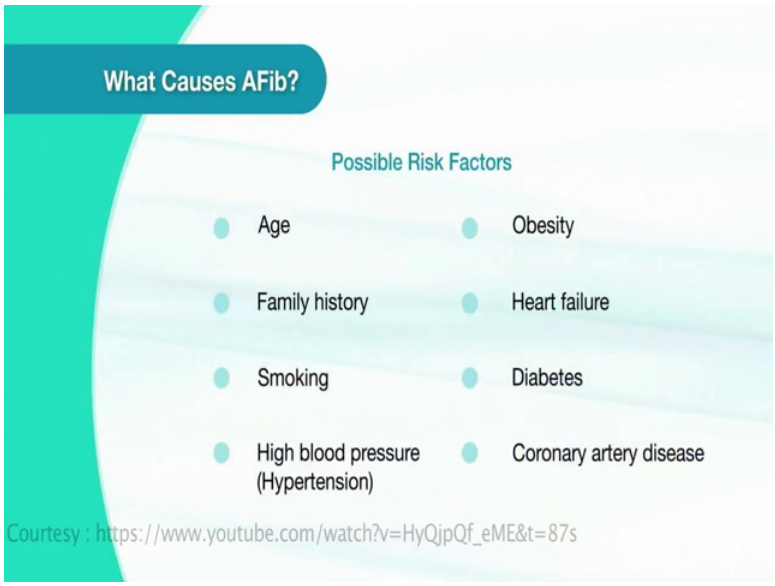
Or an EKG, to see your heart's electrical activity and rhythm. During an EKG, small electrodes are placed on specific parts of your arms, chest and legs using small stickers.

(Refer Slide Time: 10:14)



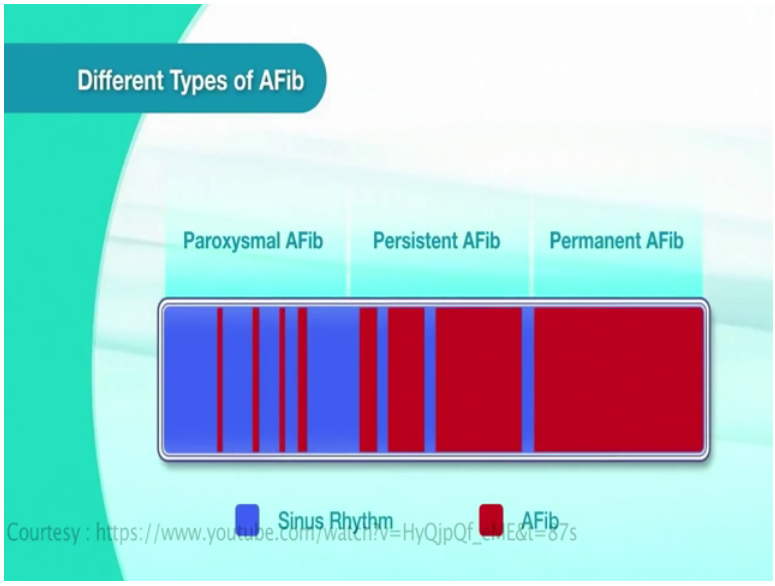
When the heart beats, the electrode sends signals to the EKG machine. The EKG, measures the electrical impulses or waves, shown here as lines. See the differences between a healthy heart and a heart in AFib. In a normal heart, beats are evenly spaced and show a regular pattern. In AFib, the waves appear more chaotic and random.

(Refer Slide Time: 10:41)



While the causes of AFib are often unknown, there are a number of things that increase the chances you might get it. Some of these include age, family history, smoking, high blood pressure or hypertension and obesity. Also if you have any of the following conditions you are more at risk of AFib heart failure, diabetes or coronary artery disease. The more of these risk factors you have, the more likely it is you might experience AFib. Be sure to discuss your full medical history with you health care provider.

(Refer Slide Time: 11:17)

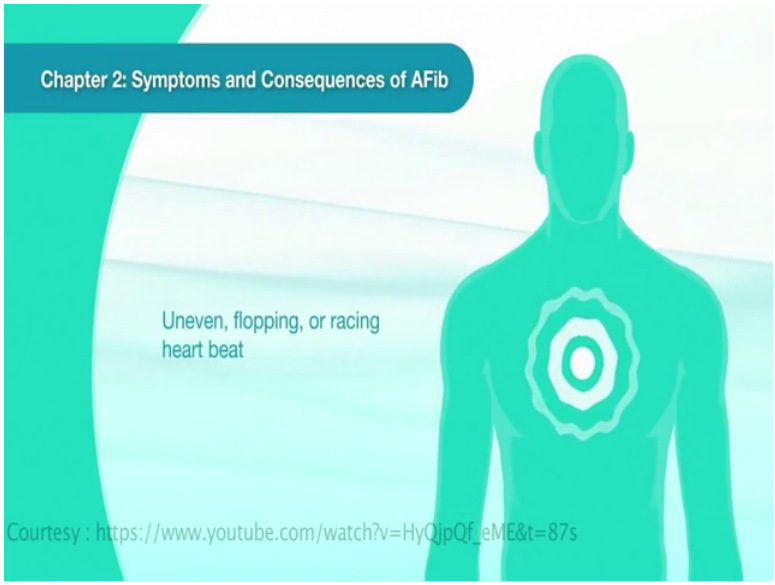


AFib often gets worse as time goes on. It's important to take care of it early. Because, the longer your heartbeat is out of rhythm, the harder it is to return to normal. In this chart, the red lines represent AFib episodes and the blue lines represent times when the heart is in rhythm. When many patients are first diagnosed, they experience periods of AFib that may come and go. These episodes may be momentary or last for days. But, generally go away on their own, this is called paroxysmal AFib.

In some situations AFib may not go away on its own. Your doctor may need to perform a procedure or provide medicine for a cardio version to bring your heart back to normal rhythm this is called persistent AFib. In some people who have had AFib for a long time, the heart may not be able to return to a normal rhythm at all, this is called permanent AFib.

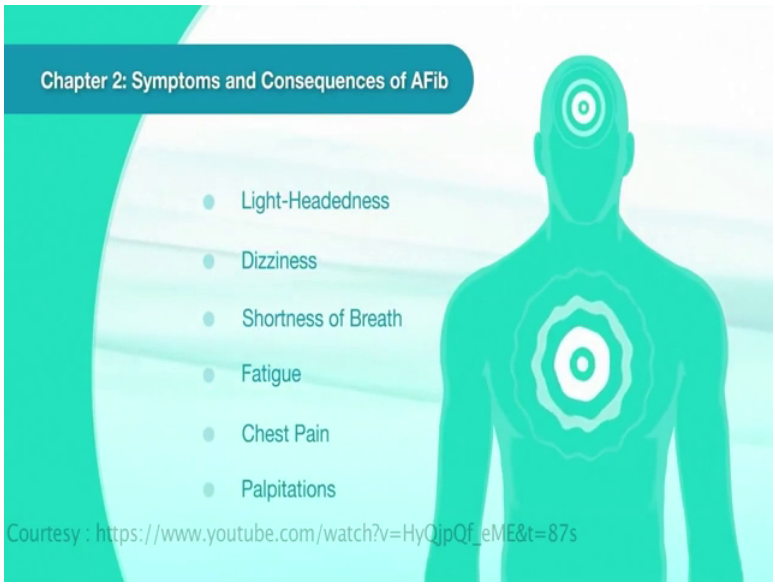
Notice that over time the red areas are larger and more frequent. This is why it is important to talk to your health care provider to be sure that you are doing all you can to keep your heart in rhythm.

(Refer Slide Time: 12:30)



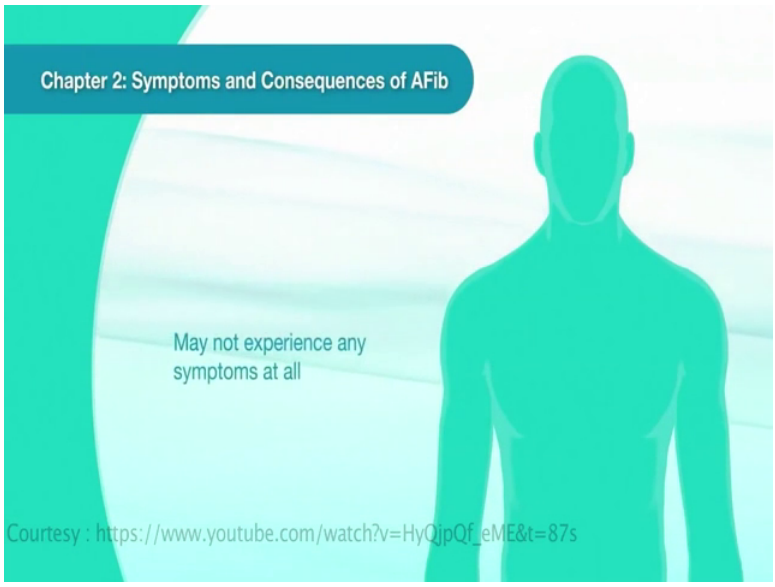
There are many signs and symptoms of AFib, many describe an uneven, flopping or racing heartbeat.

(Refer Slide Time: 12:38)



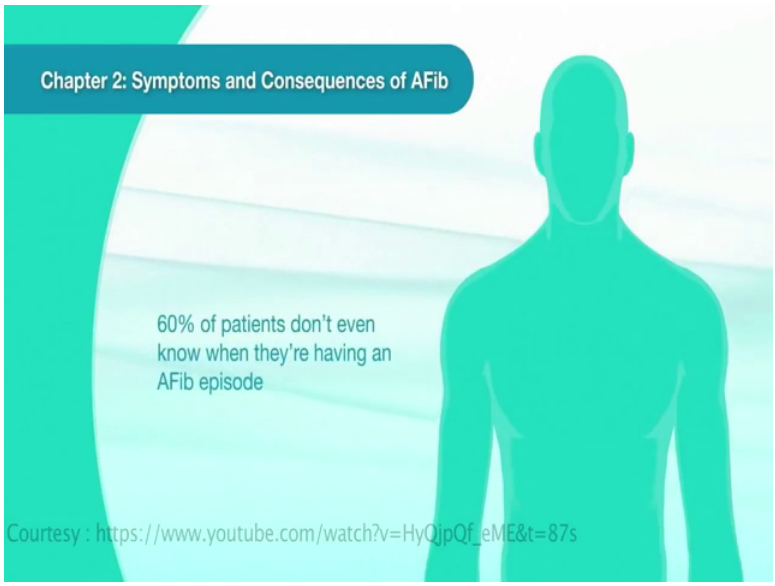
AFib can make you feel light headed, dizzy or even short of breath. Some people feel tired or weak, others experience chest pain or discomfort such as, palpitations. These symptoms might be sudden or severe.

(Refer Slide Time: 12:54)



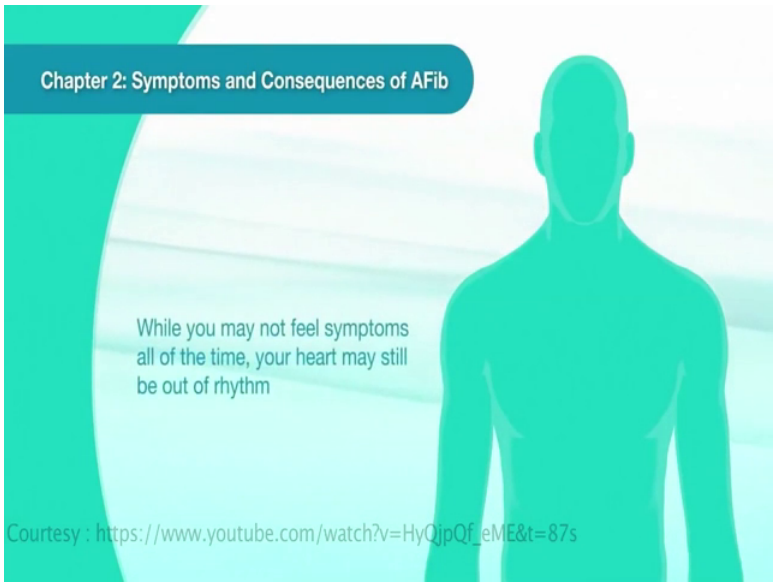
And they may come and go and you may not experience any symptoms at all.

(Refer Slide Time: 12:58)



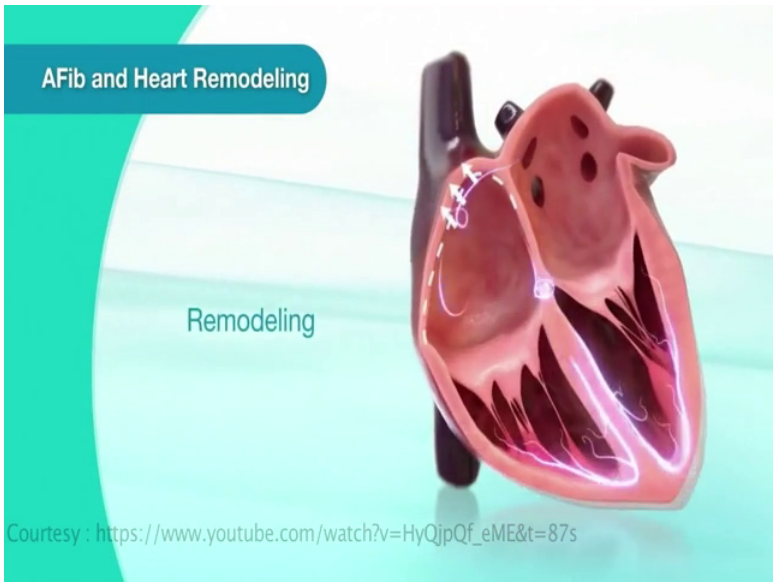
In fact, 60 percent of patients do not even know when they are having an AFib episode.

(Refer Slide Time: 13:04)



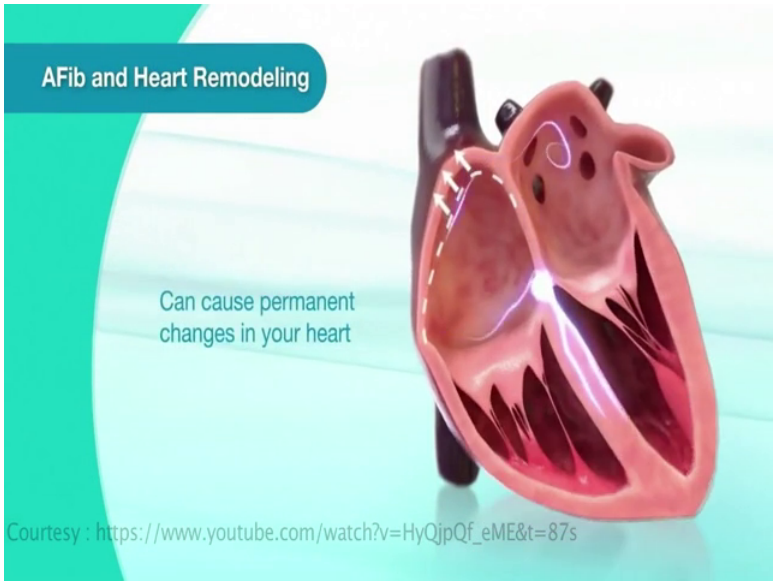
If you have AFib, it is important to know that while you may not feel symptoms all of the time, your heart may still be out of rhythm. And you are still at risk for other complications like remodeling or stroke.

(Refer Slide Time: 13:17)



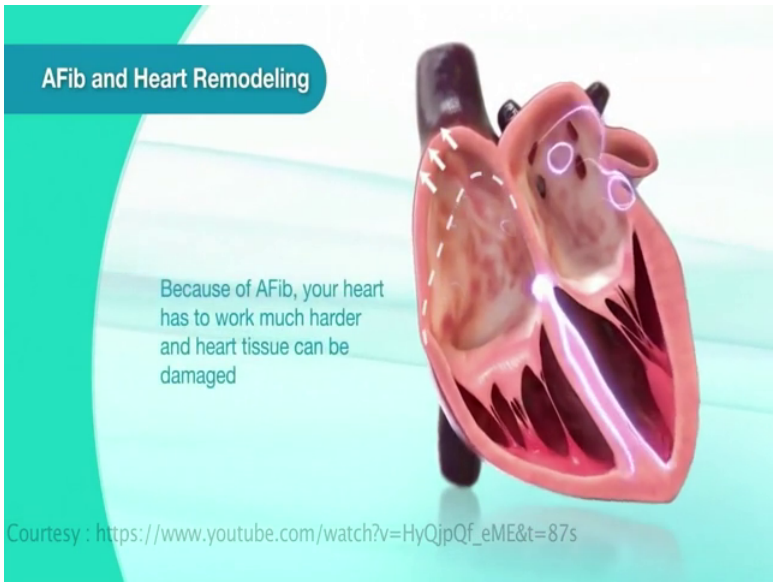
If left untreated, AFib can change the size and even the shape of your heart through a process called remodeling.

(Refer Slide Time: 13:25)



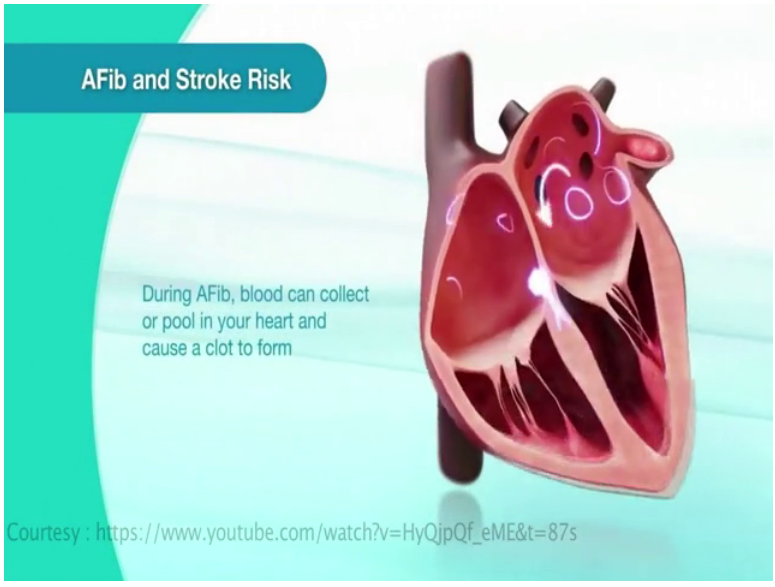
Remodeling can cause permanent changes in your heart in a very short amount of time potentially just a few days.

(Refer Slide Time: 13:33)



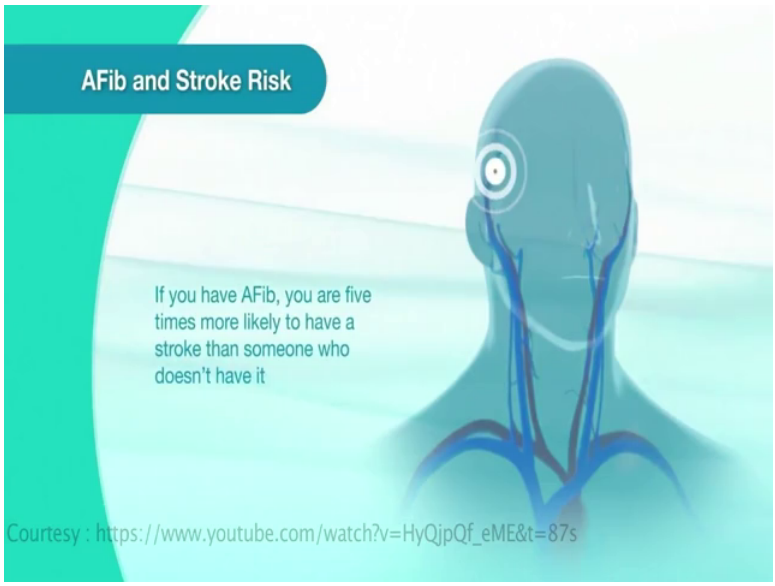
Because of AFib, your heart has to work much harder and heart tissue can be damaged. Notice how the heart increases in size and its walls thicken. Even if you are currently being treated for AFib, it is important to understand if your management program is addressing all the risks associated with the disease.

(Refer Slide Time: 13:54)



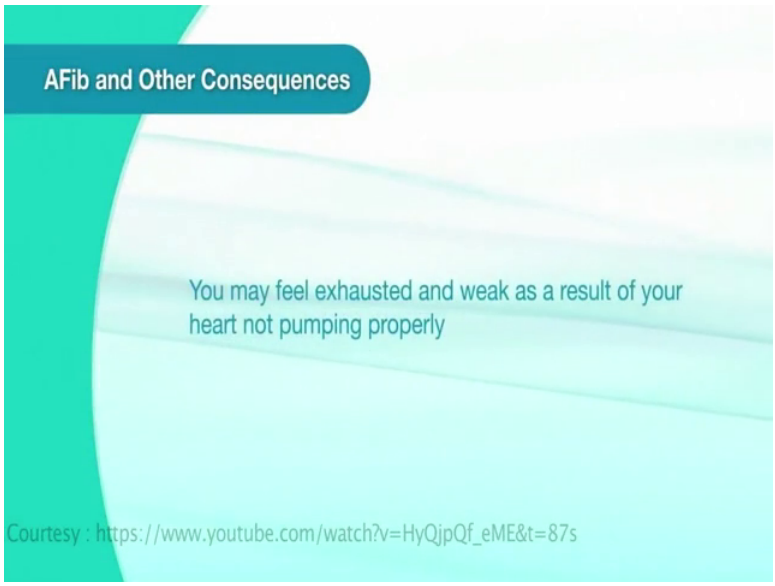
During AFib, blood can collect or pool in your heart and cause a clot to form. If this happens, the clot can travel from the heart to the brain and cause a stroke.

(Refer Slide Time: 14:06)



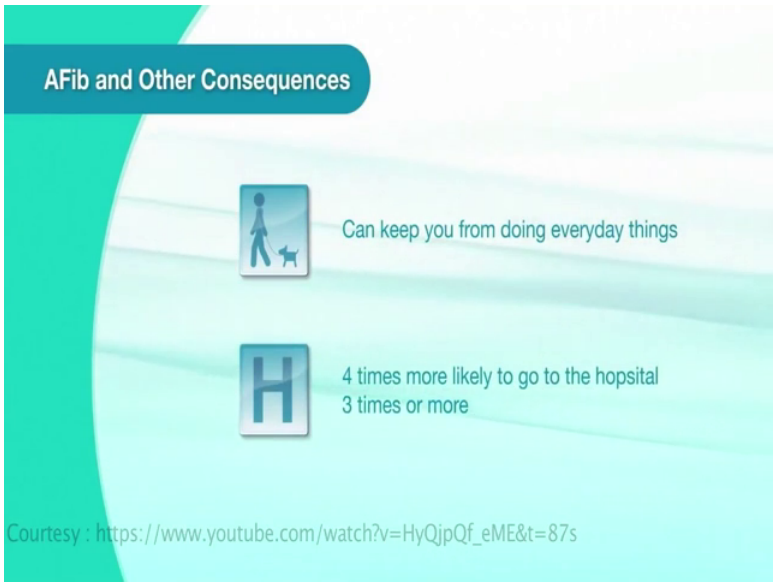
If you have AFib, you are 5 times more likely to have a stroke than someone who does not have it. It is important to talk to your health care provider about your risk of stroke and how to reduce it.

(Refer Slide Time: 14:18)



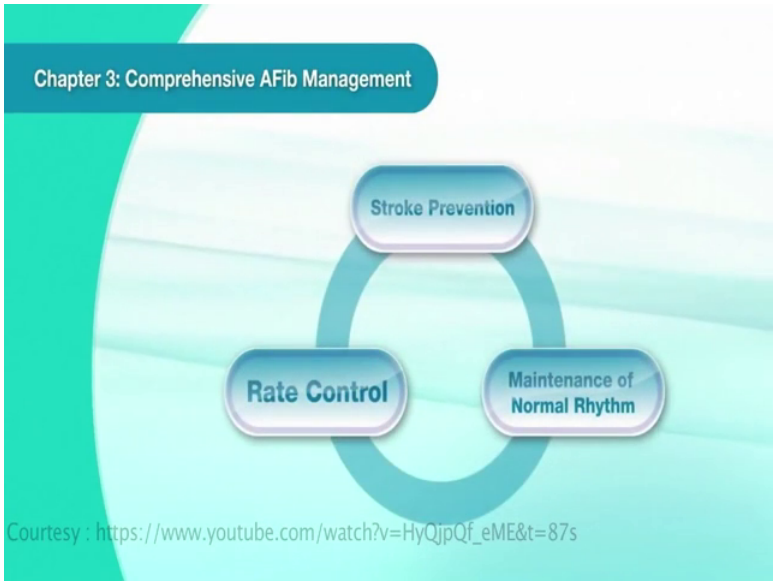
You may feel exhausted and weak as a result of your heart not pumping properly. While some people with AFib may be able to lead a normal lifestyle.

(Refer Slide Time: 14:28)



In some cases, having AFib can keep you from enjoying exercise in everyday activities. If you have AFib, you are 4 times more likely to end up in the hospital, 3 or more times than those who do not have the disease. It is important that you continue to talk to your doctor about managing your AFib, even if you are not currently experiencing symptoms.

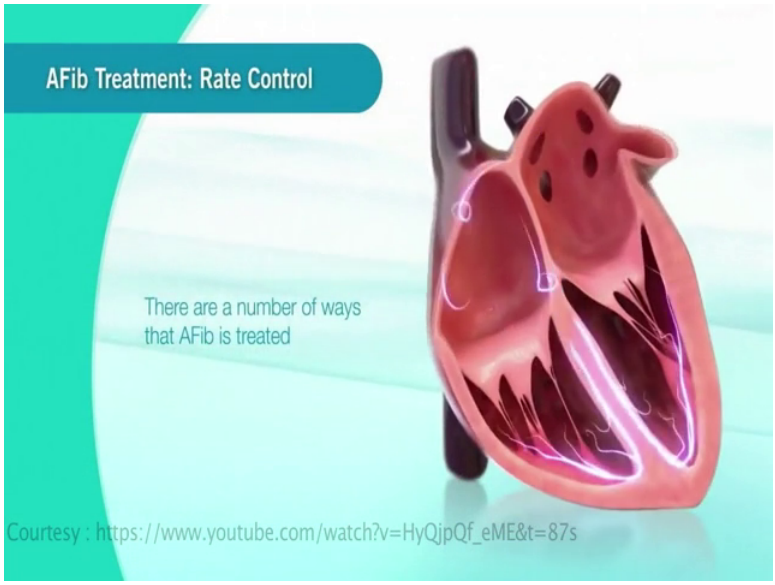
(Refer Slide Time: 14:51)



The AFib treatment guidelines for health care providers recommend a comprehensive approach to treating all the risks of AFib. The guidelines prioritize 3 treatment goals rate control, maintenance of normal rhythm and stroke prevention. Health care providers may

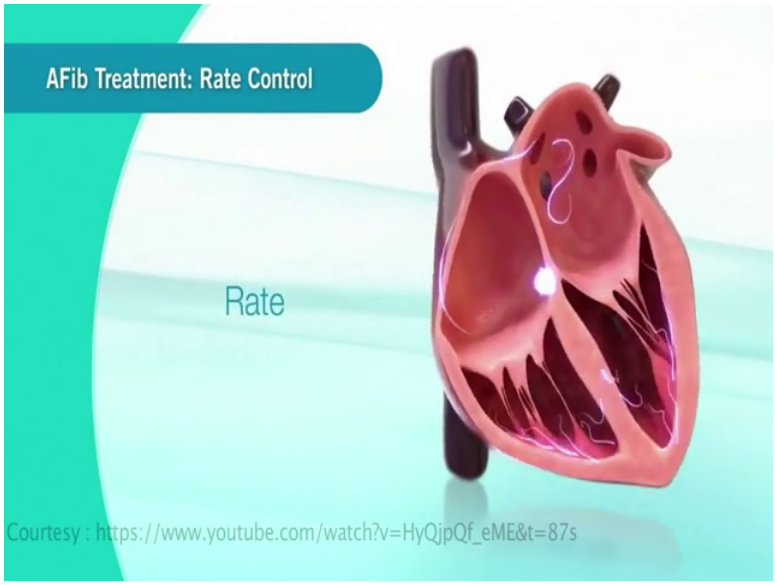
provide a range of treatments to jointly manage the different risks and symptoms of AFib.

(Refer Slide Time: 15:14)

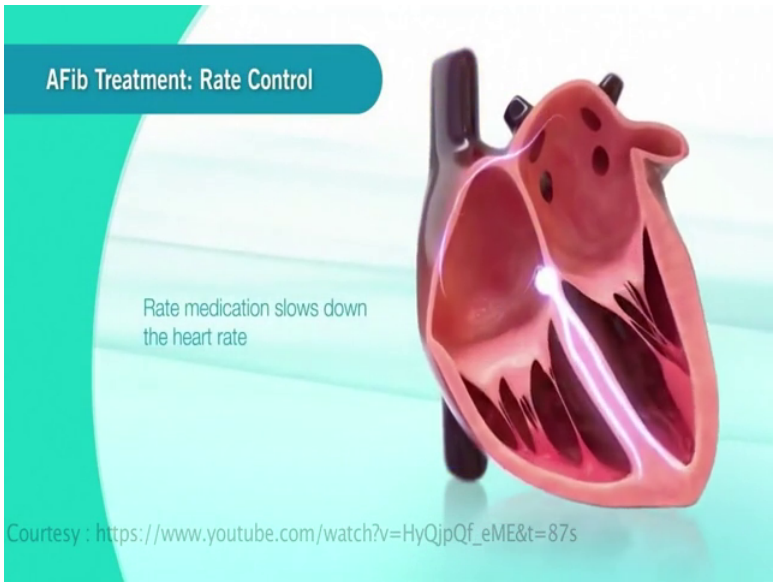


There are a number of ways that AFib is treated. Your doctor may prescribe a medication to slow down the pace or rate at which your heart beats.

(Refer Slide Time: 15:20)

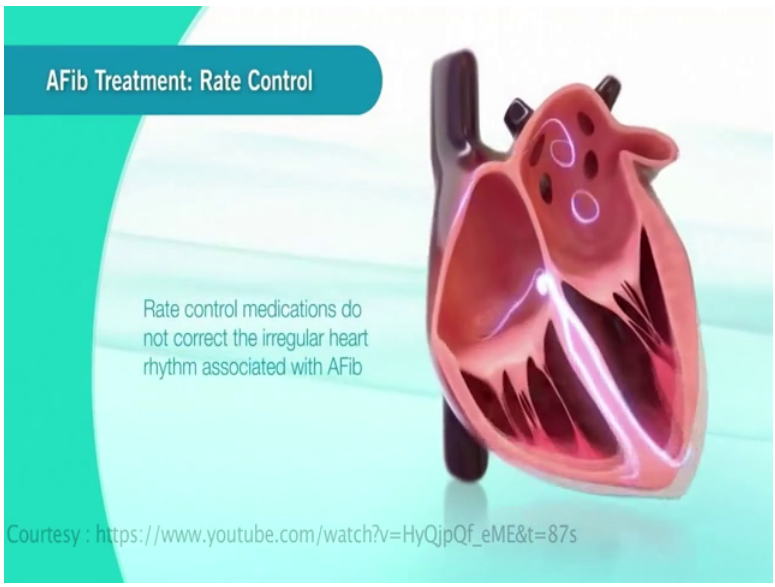


(Refer Slide Time: 15:23)



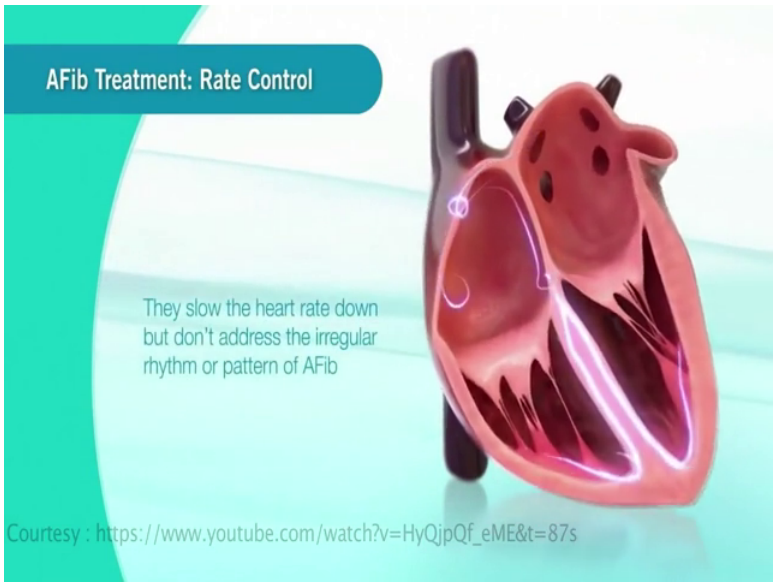
Notice that the rate medication slows down the heart rate; however, the heart continues to beat irregularly and out of rhythm.

(Refer Slide Time: 15:32)



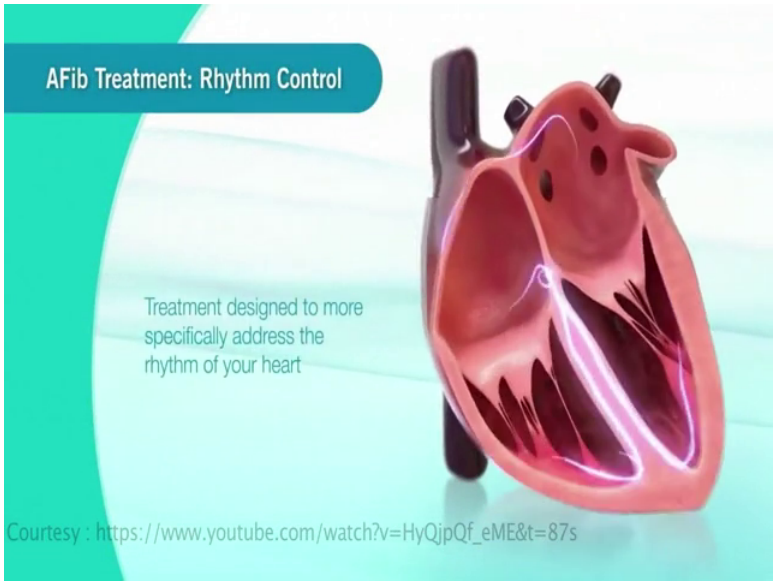
Rate control medications do not correct the irregular heart rhythm associated with AFib.

(Refer Slide Time: 15:37)



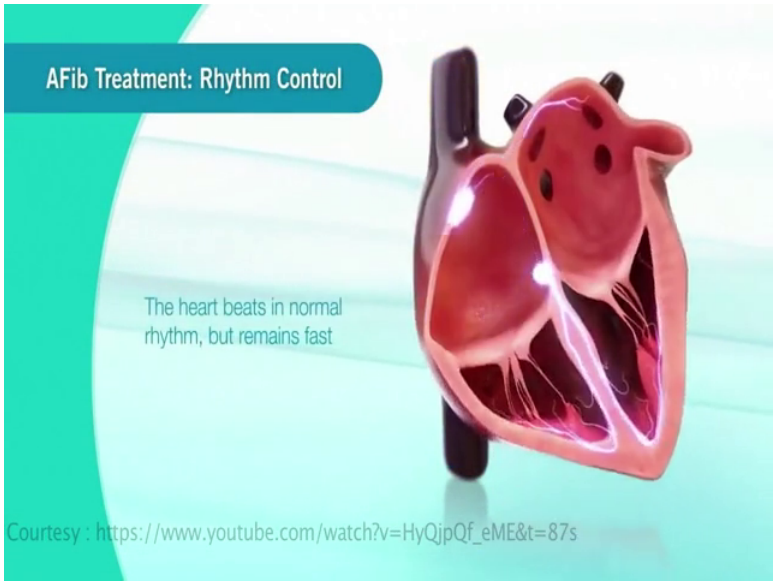
They slow the heart rate down, but do not address the irregular rhythm or pattern of AFib.

(Refer Slide Time: 15:44)



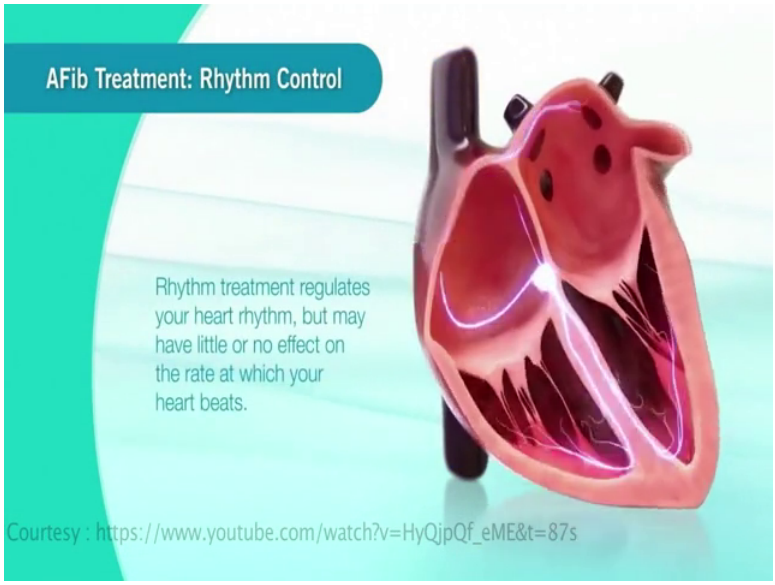
Your doctor may recommend a treatment designed to more specifically address the rhythm of your heart.

(Refer Slide Time: 15:52)



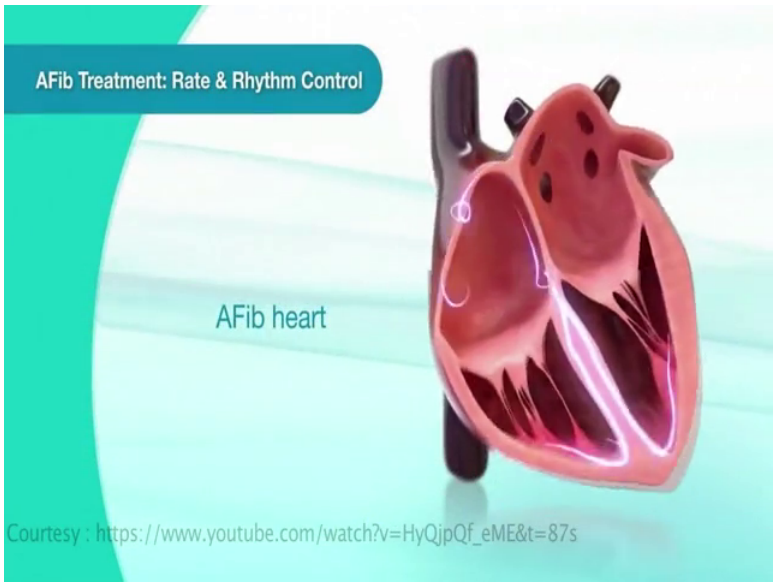
When rhythm control medication is used, the heart beats in normal rhythm, but remains fast.

(Refer Slide Time: 15:56)



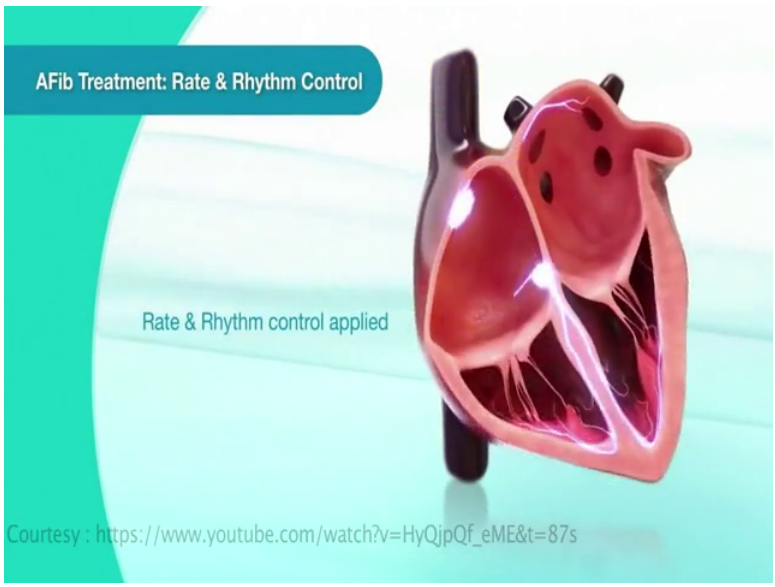
Rhythm treatment regulates your heart rhythm. But, may have little or no effect on the rate at which your heart beats.

(Refer Slide Time: 16:03)



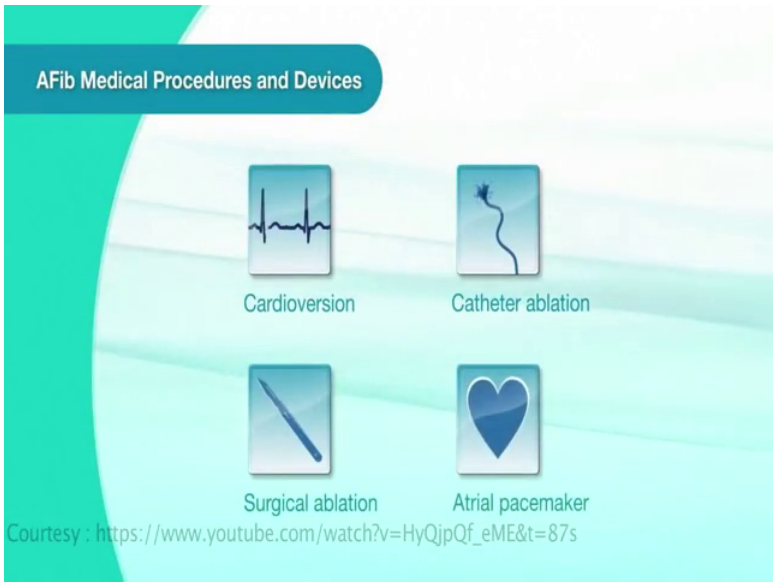
Combination of rate and rhythm control treatments may be recommended to reduce the heart rate and maintain the normal heart rhythm.

(Refer Slide Time: 16:11)



Rate control medication is used to slow the heart rate down. When rhythm control is added, the goal is to have the heart beat at a normal rhythm.

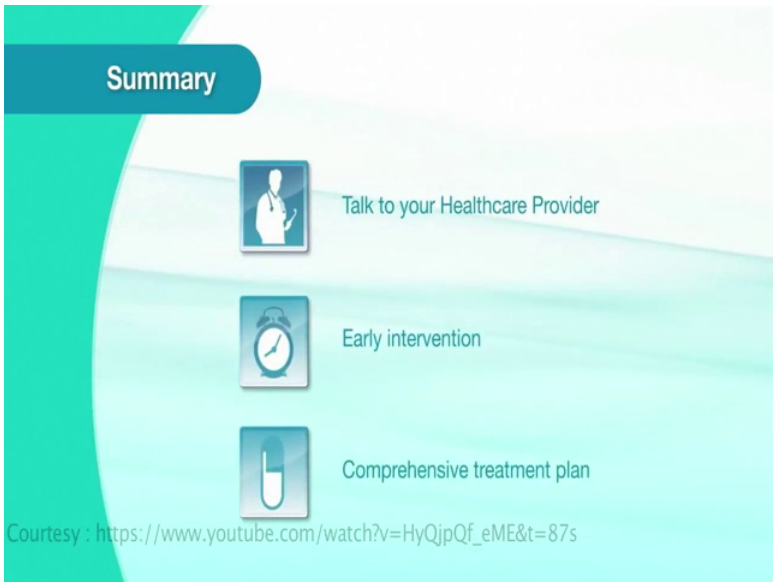
(Refer Slide Time: 16:22)



Other treatments for AFib may include surgical and nonsurgical procedures and implanted devices. If medicine has not been effective your doctor, may perform a procedure called a cardioversion. In which electrical current is used to restore a normal heart rhythm. Radiofrequency ablation sometimes called catheter ablation is a procedure that stops the heart from setting off the faulty electrical signals that cause the chaotic heartbeats of AFib.

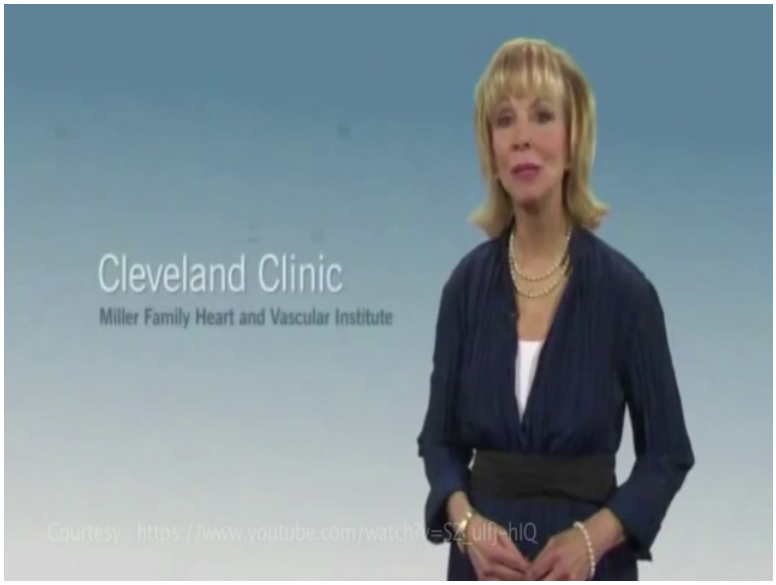
Surgical ablation is a surgical procedure to destroy the cells causing abnormal heart rhythm, it may be used when other treatments have not worked. The surgeon treats the surface of the heart directly rather than relying on catheters and X-rays to reach the heart. For some patients, a small battery power device called an atria pacemaker may be implanted under the skin to generate electrical signals to regulate heartbeat.

(Refer Slide Time: 17:20)



Talk with your health care provider about which treatment options are best for you. Whichever plan you decide on, it is important to remember that AFib is a progressive disease. The longer you wait to restore your normal heartbeat the more difficult it is for your heart to return to a normal rhythm. Finally, keep in mind that a comprehensive approach to treating all the risks of AFib is important.

(Refer Slide Time: 17:49)



Catheter ablation has emerged as an excellent minimally invasive treatment option for atrial fibrillation.

(Refer Slide Time: 17:55)

Our specialists are some of the most experienced in performing this procedure with success rates among the best in the nation. They will work with you to decide if an ablation is right for you. Doctors Patrick Tchou, Bryan Baranowski, and Walid Saliba will tell you more.

For those patients where medications have not been able to control the atrial fibrillation; obviously, their lives have been affected. Some patients can be very symptomatic with atrial fibrillation they can interfere with their ability to do daily activities.

(Refer Slide Time: 18:31)

So, ablation as a means of controlling and settling down this atrial fibrillation can vastly improve those patient's lives.

(Refer Slide Time: 18:47)

We know the initial trigger, the initial spark, initial firing for atrial fibrillation tends to come from the pulmonary veins. And these are the four veins that are draining blood that has just gone through the lung and picked up oxygen, back to the left side of the heart, so that, it can then be pumped to everywhere it needs to go.

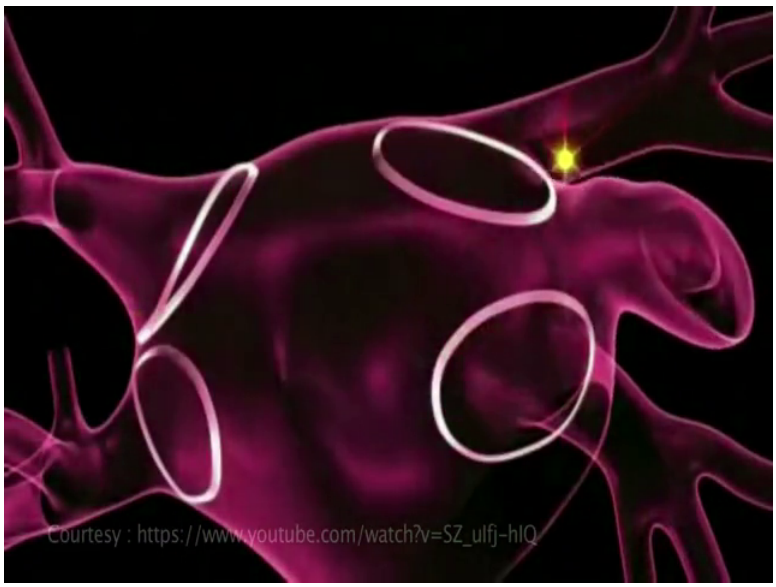
(Refer Slide Time: 18:54)

These are all muscular sleeves that line those veins and those muscle cells for whatever reason, in select individuals can act in a very irritable fashion where they fire very rapidly and that tends to serve as the initial spark that sets people off into atrial fibrillation shorting out the entire chamber.

(Refer Slide Time: 19:12)

Medicines when we use them as an approach to the management of atrial fibrillation try to calm down that irritability. When the medicines are ineffective and more than, take the patient to the next level of our therapeutic approach and go for an ablation procedure.

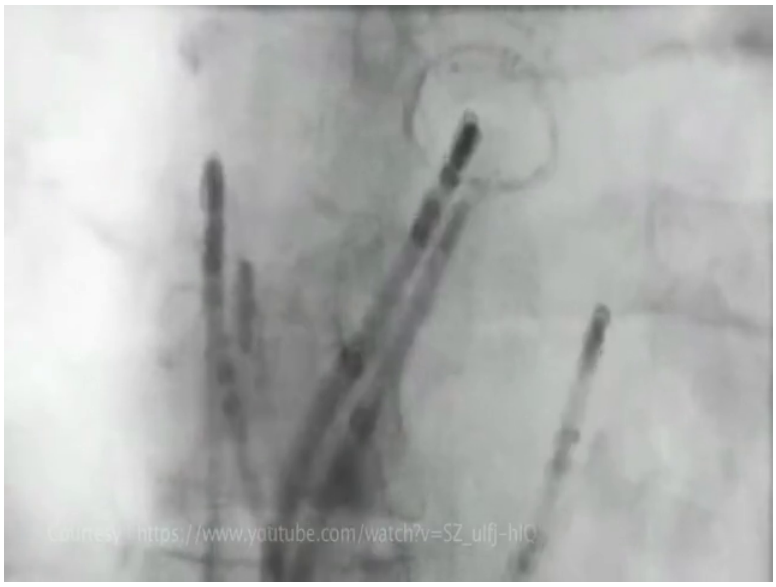
(Refer Slide Time: 19:26)



What we are doing is burning or ablating the tissue around those veins to ultimately turn that tissue over into scar. Scar does not conduct electricity therefore, if there is electrical firing within the vein that electrical firing can exit the vein and short out the entire chamber.

So, essentially a catheter ablation is similar to a heart catheterization which most patients are probably familiar with. Typically, at the clinic here, we use 3 or 4 catheters that have different functions. What we do is we put those catheters through the ground all the way in the heart. One catheter is for example, in intracardiac ultrasounds, that we can see what is going on inside the heart.

(Refer Slide Time: 20:02)

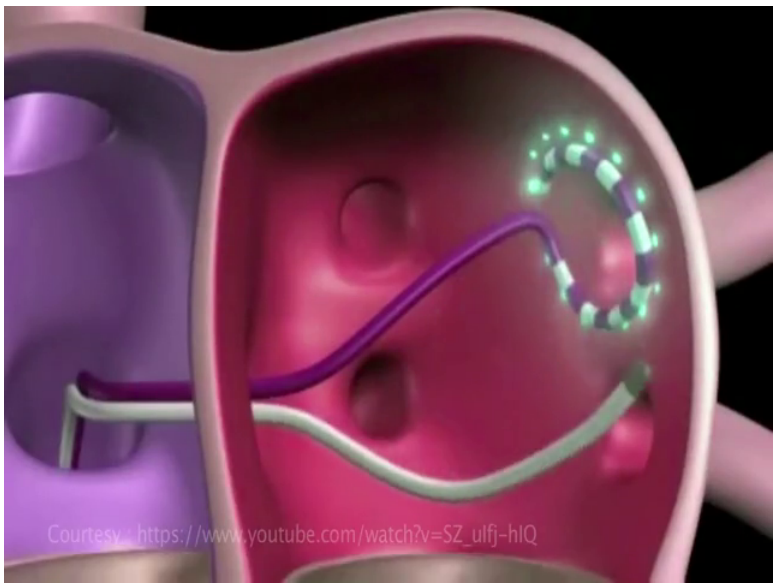


Another catheter is the ablation catheter and then we have a catheter which is the mapping catheters that we can look at the electrical activity inside the left atrium.

(Refer Slide Time: 20:12)

It is because the left side of the heart is the left atrium. This is where actually most of the action of atrial fibrillation happens.

(Refer Slide Time: 20:24)



And we use the mapping catheter to see where the electrical activity is and how much electrical activity is around the pulmonary veins and we use the ablation catheter to go to rides and eliminates this electrical activity. And to confirm the we have isolation of the pulmonary veins, so that, the impulses that come from the pulmonary veins do not make

it to the left atrium and therefore, maximizing the chances of keeping the patient in normal rhythm.

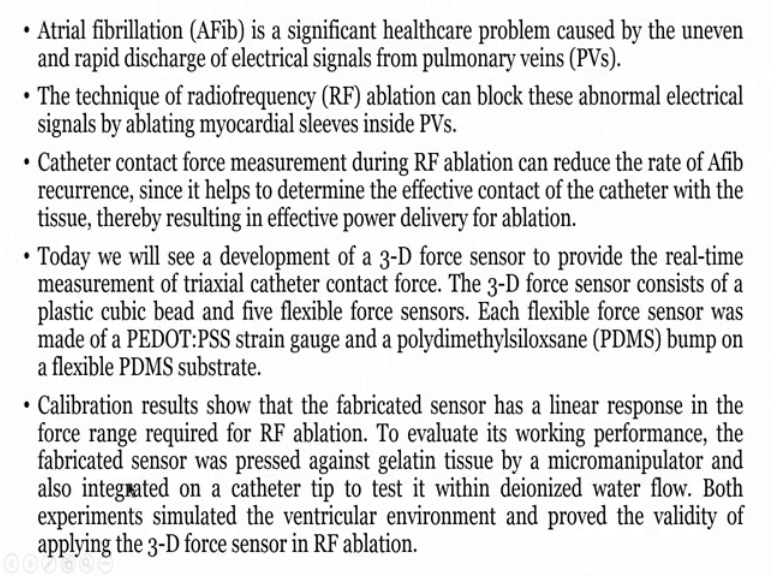
We do not use general anesthesia usually. We use something called conscious sedation and they are comfortably sedated usually sleeping, but readily arousable. The procedure itself from starting from coming into the room and then to leaving the room is probably around 5 to 6 hours. A lot of the time is spent in getting the catheters in, getting into the left upper chamber and then at the end getting everything out. So, I would say about half the time is the ablation time.

A lot of the pioneering work in terms of driving how the ablation procedure evolved was done at our institution. So, we had the experience with which types of procedures, which approach is, which catheters, which mapping systems work best and I think that gives us an advantage that having experience, seeing the evolution of the ablation procedure take off in terms of providing the best possible approach that we need for or for operations when they ultimately decide. And we decide with them that the ablation procedure is the correct procedure for them.

So, you have seen this video, right. And you now know what exactly is atrial fibrillation. So, when you have atrial fibrillation then, the doctor inserts the catheter and first is to understand the electrical mapping of heart. So, from the chamber you have to see where exactly the misfiring of signal happens that you can see when you can understand and when you can map the electrical signals from the heart. Once you know where, where are, what are the electrical signals the or which is the area that is misfiring, or integral signals are abnormal, you have to treat those area. Treating those area we have to ablate those areas, we have to burn those area. This ablation is performed by a tool call catheter.

The electrical mapping is also performed by a tool called catheter right catheter for electrical mapping, catheter for ablation. So, now, let us see this particular video. If you see the screen, you can see this video where we will be looking at the catheter ablation.

(Refer Slide Time: 23:22)



So, now you know what is catheter ablation right. And what we understand that, the for catheter to ablate it can use RF frequency. So, it can be RF ablation. Radiofrequency ablation catheter for radiofrequency ablation for treating atrial fibrillation correct.

So, now atrial fibrillation or in short it is also called AFib, is a significant health care problem caused by the uneven and rapid discharge of electrical signals from pulmonary veins like we have discussed. The technique of radiofrequency ablation can block these abnormal electrical signals by ablating myocardial sleeves inside pulmonary veins. So, we can ablate, we can burn the myocardial sleeve inside the pulmonary veins. So, when you want to burn you have to apply RF frequency so, radiofrequency. Radiofrequency generate heat, this heat will cause burning of the tissue.

Now, if this is the heart and if this is the catheter, we need to understand what is the force that we are applying? Or that the clinician is applying during the treatment right. If the force is more, then the region which are not needed to be ablate also we get ablated. And if the force is less, then the recurrence rate would be higher correct.

So, a force sensing in catheter ablation is extremely important. First thing, right. So, catheter force or catheter contact force measurement during RF ablation can reduce the rate of AFib re-ocurrence right. Because, we know with the help of force sensing how much force a clinician is applying. So, an optimized force can be applied with the help of catheter contact force sensing. So, how it can reduce the rate of AFib recurrence? Since,

it helps to determine the effective contact of the catheter. Effective contact of the catheter with the tissue thereby, resulting in effective power delivery of ablation right. So, very important catheter contact force. Now, for that we will see a development of a 3-D force sensor that we have worked in a laboratory to provide the real time measurement of a triaxial catheter force sensor.

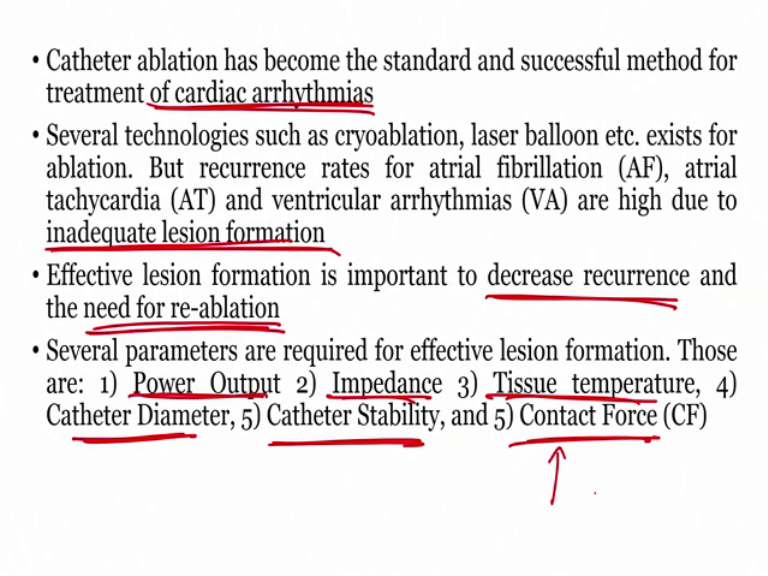
And the 3-D force sensor consists of a plastic cube bead and 5 flexible force sensors. We will discuss about this in detail when we reach to that particular slide. And, how this force sensors are fabricated? This force sensors are fabricated with the help of PEDOT: PSS. That is we have created or we have patterned or we have fabricated strain gauges using PEDOT: PSS.

And there is a PDMS bump on the flexible PDMS substrate. We will see this. How it works? PDMS is nothing, but polydimethylsiloxane. We have calibrated the fabricated sensor and it is showing a linear response in force range required for RF ablation. And to evaluate its working performance, the fabricated sensor we have tested against gelatin. Gelatin is called phantom tissue, not real; phantom tissue. You can create a gelatin in the laboratory and you can test your fabricated force sensor.

So, to press the force sensor against gelatin, see that we have used micromanipulator right. We will see the use of micro manipulator and also integrated on a catheter tip, to test it with deionized water flow. So, we have tested the catheter in the water. Why in the water? Because, actually when you insert the catheter in the heart, then the blood will blood is continuously flowing, right.

So, what is the effect of blood on the catheter contact force. That effect of blood, we have to separate from the actual force data that we are observing or measuring right. So, when you talk about performing this kind of experiment, we have performed a catheter with contact force and we have measured in water to understand the effect. Both experiments simulated the ventricular environment and proved the validity applying this ready for contact force for force sensor in ablation, which is your RF ablation.

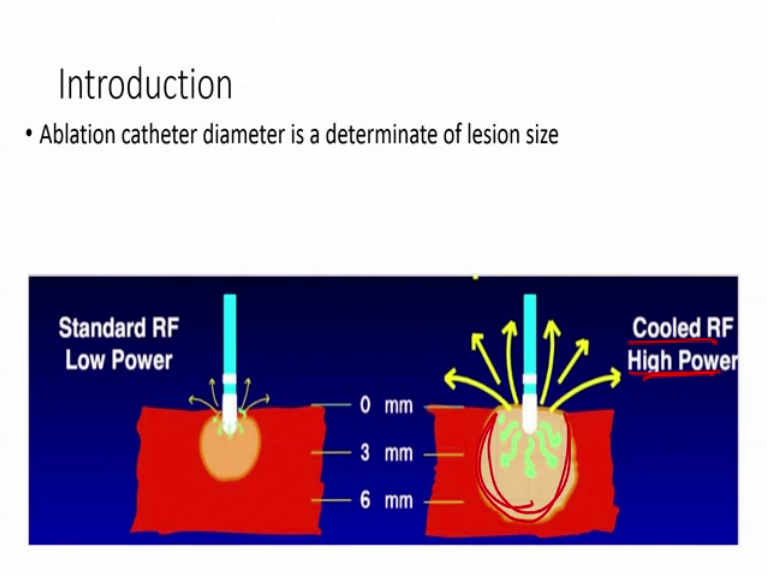
(Refer Slide Time: 29:28)



Now, catheter ablation has become the standard and successful method for treatment of cardiac arrhythmias. It is already utilized or used in treating cardiac arrhythmias several technologies such as cryoablation, laser balloon etcetera exist for ablation. But, the recurrence rates for atrial fibrillation, atrial tachycardia and ventricular arrhythmias are high due to inadequate lesion formation. The lesion is not formatted properly. Then, the burning of that particular region is not done correctly. Then, the recurrence would be higher. So, effective lesion formation is important to decrease recurrence and need for re-ablation.

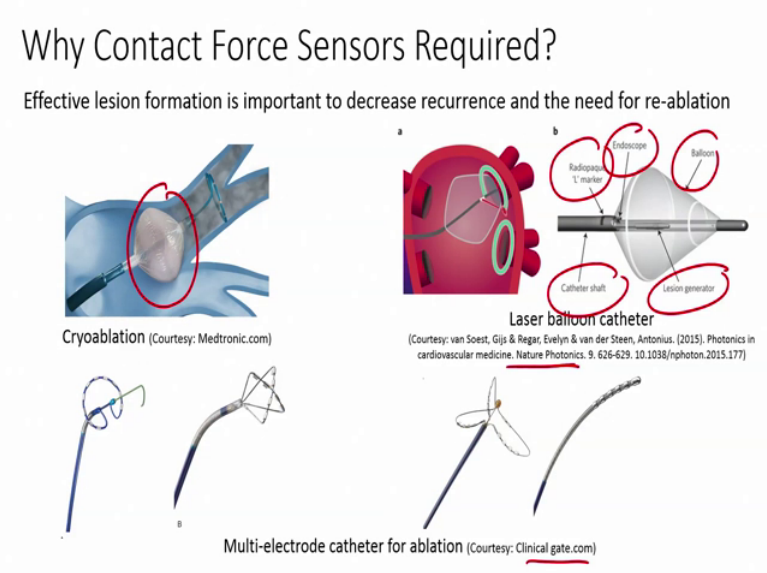
Several parameters are required for effective lesion formation, some are listed here. One is power output how much power we are applying? Impedance, tissue temperature, catheter diameter, catheter stability and contact force. You see, so many things are required to get a perfect lesion formation. And one of the very important thing is your contact force. And thus, force sensing becomes very important when you talk about the catheter, right in atrial fibrillation and in general also.

(Refer Slide Time: 31:20)



So, the ablation catheter diameter is also dependent on or is a determinant of lesion size catheter diameter depends on the lesion sizes. You see, standard RF low power catheter, the lesion size you see. And cooled RF high power catheter, you can see the lesion size right. So, it depends on the catheter diameter.

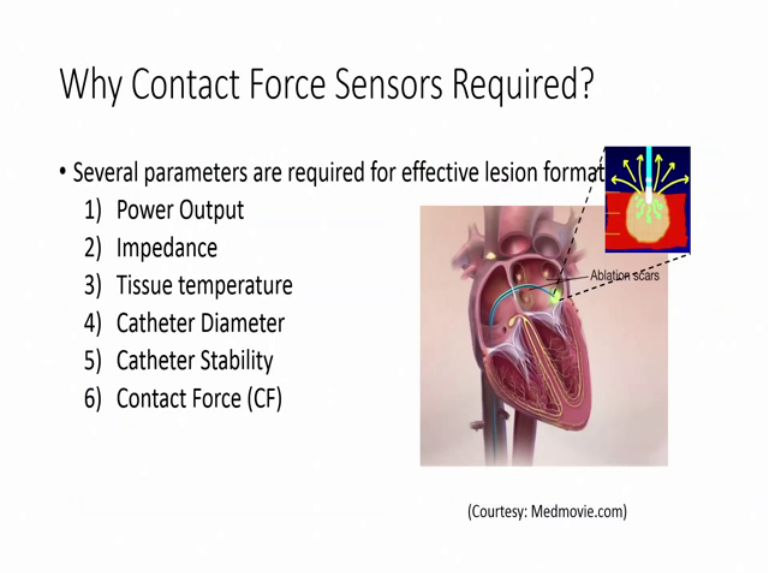
(Refer Slide Time: 31:48)



Now, you can see here cryoablation, this is a balloon catheter right, laser balloon catheter. Here, there are different types of catheters shown here. We have taken from clinical gate dot com and also a paper published in nature photonics. So, you can see

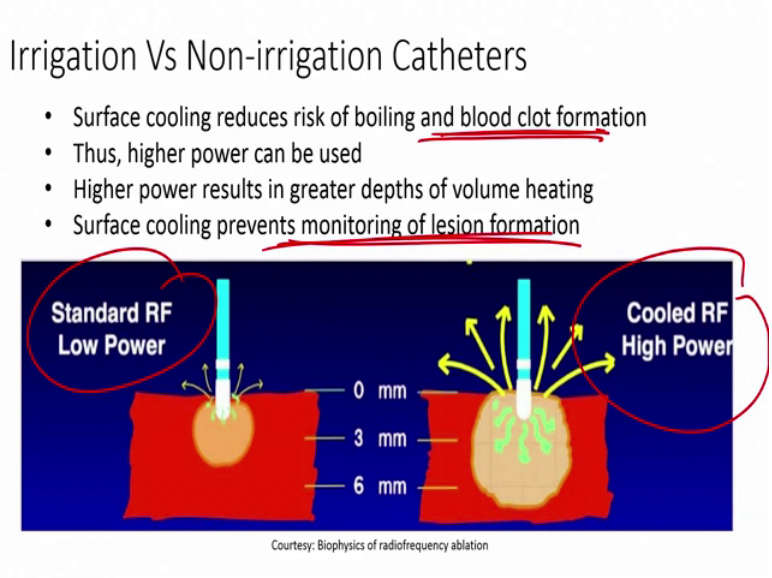
there are multi electrode catheter for ablation, there are laser balloon catheter for ablation. There are catheters for cryoablation. In this particular case, there is an endoscope, balloon, radiopaque, right; catheter shaft and lesion generator. So, multi parameter catheters have been published and is used however, still we require force sensor onto the catheter.

(Refer Slide Time: 32:37)



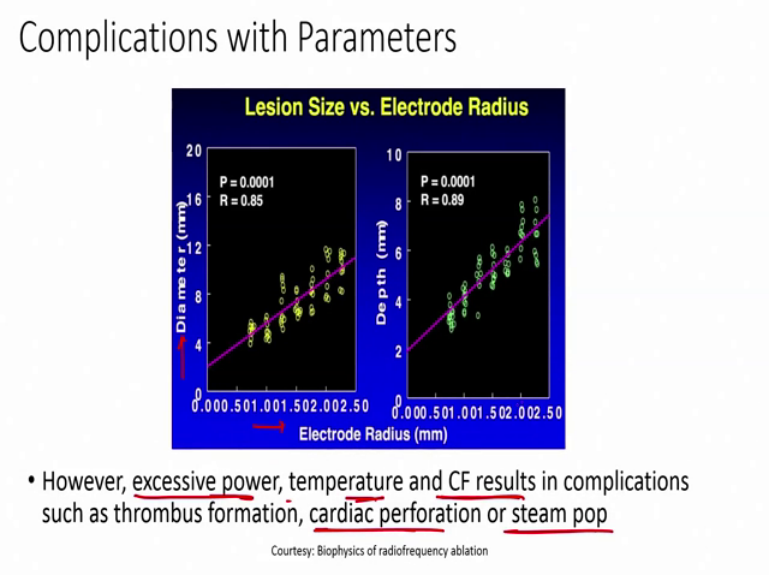
Now, why it is required? Because, to get effective lesion formation and to get idea what is the amount of force that we are applying, right. Where we are applying during the surgery; so, you see here Right this is the ablation scars, right? And this ablation scar depends on several parameters like we discussed earlier. It depends on how much power output is there, how much impedance is there? What is the temperature of the tissue? What is the catheter diameter? What is its stability and what is contact force? So, many parameters are required to understand and to get effective lesion formation right.

(Refer Slide Time: 33:27)



Now, irrigation versus non-irrigation catheters. So, surface cooling reduces, you see here. Surface cooling reduces risk of boiling and blood clot formation, right. Because, when you burn the burn the tissue there can be formation of boils and can, there can be blood clotting. So, if surface cooling is there, we can apply higher power and higher power is proportionate to a better lesion. So, higher power results in greater depths of volume heating surface cooling prevents monitoring of lesion formation right. So, standard RF low power versus cooled RF high power, we will go for cool higher cooled RF high power catheters.

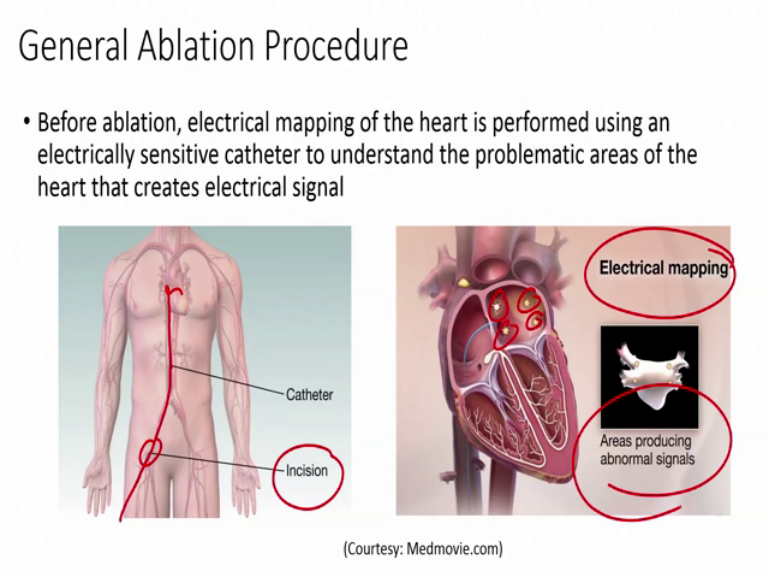
(Refer Slide Time: 34:23)



Now, you can see here excessive power temperature and CF circuits, CF results in, contact force results in complications such as thrombus formation cardiac perforation or steam pop, you see.

So, it's very important that excessive power is not ok. Temperature excessive is not ok. Optimum contact force results are important. Otherwise, there will be a formation of steam popping or cardiac perforation or thrombus formation right. That is why if you see here, there is a lesion size versus electrode radius you can see the diameter here, right and electrode radius here. Same way, the depth versus electrode radius; depth versus electrode radius.

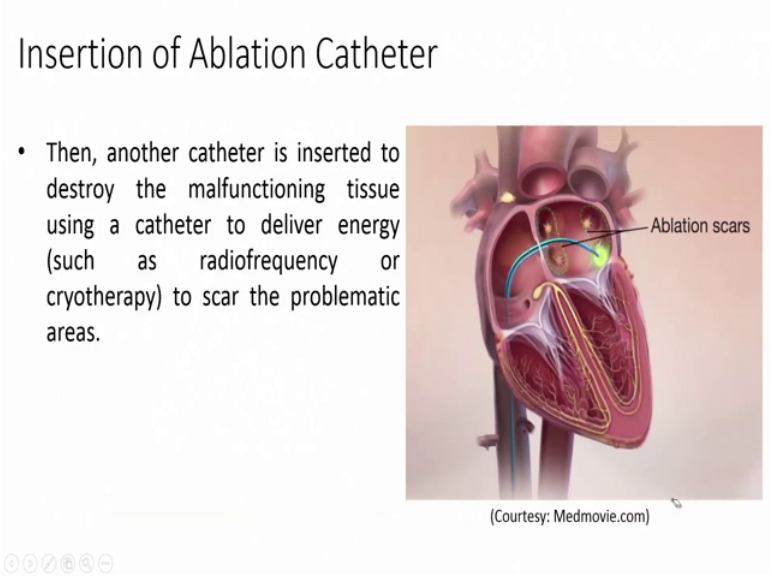
(Refer Slide Time: 35:23)



Now, before ablation as we have seen in the video electrical mapping of the heart is performed using an electrical sensitive catheter to understand the problematic areas of the heart that creates electrical signal right. So, like, do you see there is a small incision that is created here and the catheter is inserted as you can see it is moving towards here right And then, it goes here inside which is here, which is right over here. And the electrical mapping is carried out to understand, which area is causing the misfiring of the signal. It can be in the art, it can also be in the ventricle right; it can be in auricle, it can be in ventricle. So, it is not just limited to auricle it can be ventricle. But, the PVI right single PVI is measured to understand the areas producing abnormal signals.

Once we know the abnormal signals then, we can treat it by the ablating that particular area of the heart or any particular tissue.

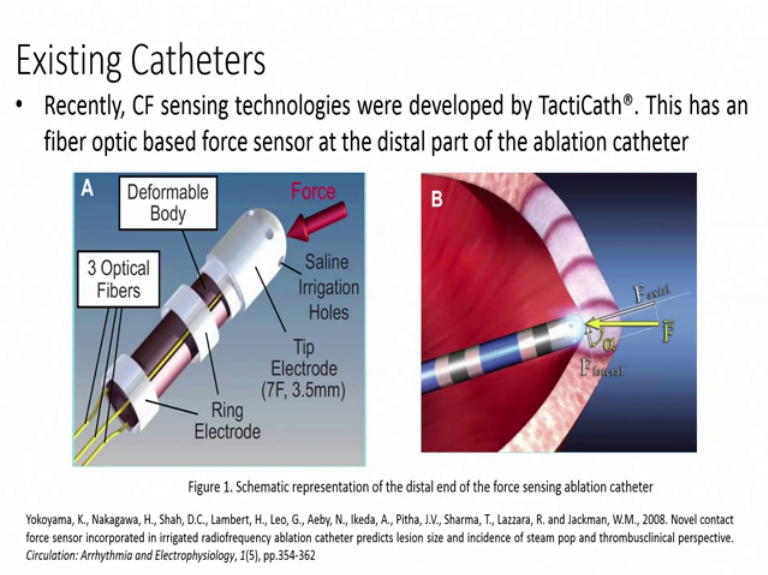
(Refer Slide Time: 36:35)



So, once electrical mapping is done then, another catheter is inserted to destroy the malfunctioning tissue using a catheter to deliver energy such as radio frequency or cryotherapy to scar the problematic areas. So, one is of course, you can heat it and destroy the tissue. Heating, RF frequency will cause burning of the tissue, this burning of the tissue will cause the ablation and the electrical signal cannot pass through this ablated tissue. Second way of doing is cryotherapy, which you can see here is by freezing the tissue.

So, when you use a very cold temperature then, the tissue will start burning again and that will also cause stopping of electrical signal or passing of electrical signal to the tissue because that tissue is burned. So, the ablation of the tissue can be done with the help of help of the catheter. So, first catheter for electrical mapping, second catheter for ablating the tissue correct.

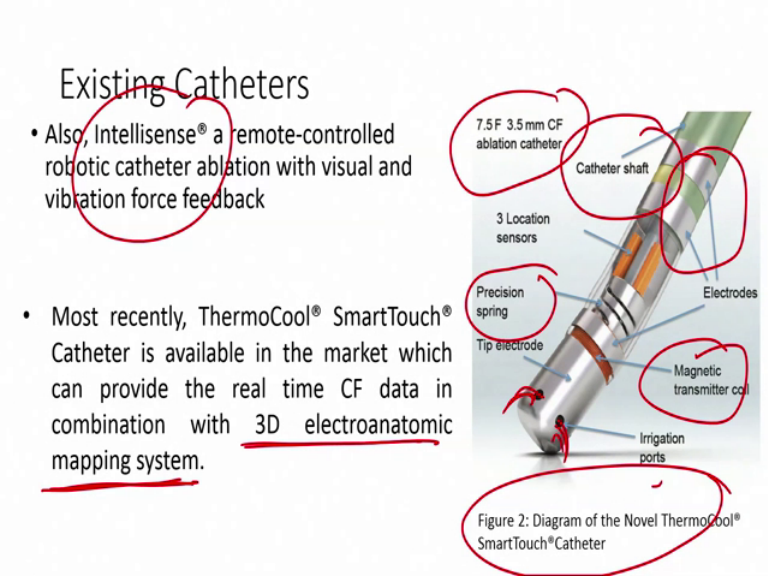
(Refer Slide Time: 37:41)



Now, if that is the case are there any existing catheter that can measure the force right. There should be some existing catheters. So, there are 2 companies. There can be many um. What I am showing today is 2 companies the catheter which are used currently in treating atrial fibrillation. First catheter is, a catheter force sensing technologies that was developed by TactiCath. Where there is a force sensor, there is a saline irrigation holes, there is a tip electrode which about 3.5 millimeter, there are ring electrodes and there are optical fibers.

So, if a body deforms then correspondingly the optical, using optical fibers the force is measured right. You can see here normal force, excel force, lateral force you can see here right. So, force sensing with the help of optical measurements and using optical fibers has been done and it was published in 2008 and right now it is used in surgery, right in operating patients that are undergoing through RF ablation procedure.

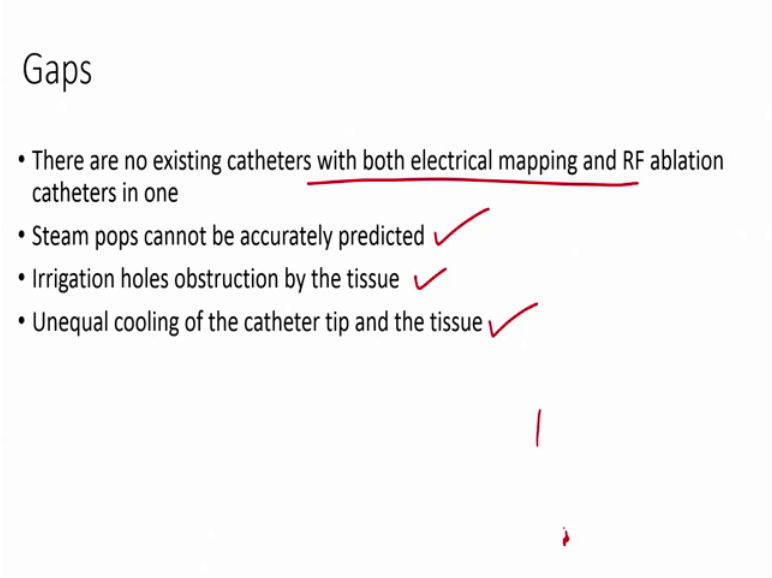
(Refer Slide Time: 39:31)



Another catheter is from Novel Thermocool SmartTouch catheter. A remote-control robotic catheter ablation with visual and vibration force feedback there is a Intellisense. But, we are talking about Thermocool SmartTouch. So, most recently this particular catheter is available in the market, which can provide the real time contact force feedback in combination with 3D electroanatomic mapping system. So, this can not only perform the ablation, but it can also map electrical signals 2 in 1. There are of course, irrigation pots for saline to come out, right for saline. There are tip electrodes for applying the RF frequency. There, there are sensors inside the catheter. There is a catheter shaft, right. There are electrodes over here also magnetic transmitter coil is there. Then, precision spring is there and it can not only measure the force sensing it can also do electrical mapping and also apply RF ablation. Again, the catheter contact force, contact force ablation catheter is about 3.5 millimeter in diameter right.

So, this is what we have talked about the existing catheters and about atrial fibrillation.

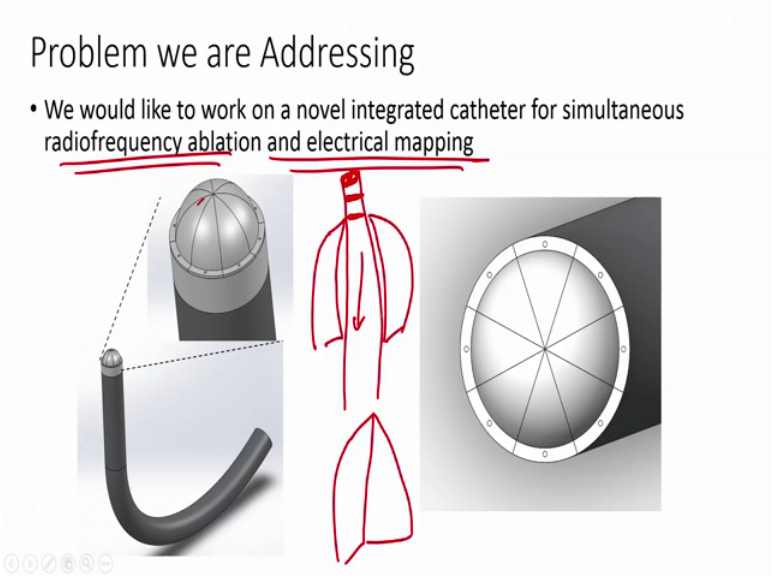
(Refer Slide Time: 41:13)



So, what are the gaps? Very important; what are the gaps in the current technology? And how can we fill those gaps? So, one of the thing is there are no existing catheter with both electrical mapping and RF ablation catheter in one; however, we have just seen that recently electrical mapping and RF ablation can be done using single catheter.

So, now this is not anymore, a gap. So then, second thing is steam pops cannot be accurately predicted. This is a gap irrigation hole obstruction by the tissue, another gap, unequal cooling of catheter tip and tissue, another gap. So, how can we use, how can we reduce this gaps or how can we fill this gaps to make the catheter smarter right.

(Refer Slide Time: 42:07)



First is, our catheter should be working as not only as a electrical mapping catheter and also as a ablation catheter. That is a first choice. So that means that, if I have a catheter, that can perform radiofrequency ablation and electrical mapping both together then it is a uniqueness.

So, what kind of design I can do, so that I have both in one right? So, if I have this catheter and if the dome shape opens up, if the dome shape opens up and another catheter comes out, which can perform the electrical mapping. Then, it can do both electrical. And this external this one, can apply RF frequency so, it can perform RF ablation. So, understand that this dome opens up right it opens up. So, you can see something like this and the catheter within it will come out and perform electrical mapping right.

Catheter within this dome safe structure will come out and perform electrical mapping. When we do not require this electrical mapping or we are done with electrical mapping we can close this dome shape structure again and the catheter will move down right. That is our interest. Of course, the schematic is not so cool what I have drawn but, that is what we want to show.

So, point is this is what we are addressing can we design a catheter that can perform RF ablation as well as electrical mapping both in one. And what kind of force sensor we can insert on this particular catheter? So, in the next module we will be looking at what kind of force sensor we can design, what kind of force sensor we can implement on the

catheter and how this force sensor can be used to get a contact force measurement? Also what kind of force sensor we will be using and we will talk about few results that can that we have obtained.

And you will be learning this as a part of this course that how to design or how to design a force sensor right. Because, force sensor we have designed using micro technology. And in as an application, you can see now that a force sensor or you will be able to see that the force sensor can be indicated on to a catheter to measure the catheter contact force during the ablation.

So, just go through the video once again. Learn these things in detail and once you understand what is arrhythmia, what is atrial fibrillation, what are irrigation catheters, what are the what is how the electrical mapping is done, how the contact force is taken. Then, you will may be able to understand what kind of gaps are there in a particular technology and how can I fill the gap by using my existing knowledge of micro technology. So, I will see you in the next class to tell you more about what kind of force sensor you can think of and how you can indicate that force sensor on to this particular catheter. Till then, you take care. I will see you in the next class. Bye.