ROBOTICALLY STEERABLE CATHETER FOR THE DIAGNOSIS AND TREATMENT OF CARDIAC DISORDERS


Department of Biomedical Engineering, Noorul Islam University, Kumaracoil, K.K Dist, Tamil Nadu

Corresponding author Email Id : animansoor@gmail.com

ABSTRACT

Now a day's many people have been diagnosed with complex cardiac arrhythmia, resulting in hospitalization. The method for treating certain complex cardiac arrhythmias is known as catheter ablation. In this process, a tiny catheter is used to deliver energy to destroy small areas of heart muscle responsible for causing rapid or irregular heart rhythms. This required a manual technique in which physicians insert one end of the catheter with inadequate assurances that it reaches the desired site in the heart. Here the outcomes are less than optimal. This problem is overcome by the use of robotic catheters, which can be used by the physicians to manipulate the catheters with increased accuracy, precision and are able to accurately target only the desired area that are in need of treatment. A detailed study about the robotic steerable catheter has been discussed in this review journal.

Keywords: Ablation, Arrhythmia, Catheters, Cardiovascular procedures.
INTRODUCTION

Robotic catheter is a medical robot; it is designed to perform complex operations using a slender flexible tube called a catheter. This eliminates the need for large incisions and gives way to minimal invasive surgeries, where the target organ can be accessed through small incisions using specialized surgical tools. It is designed for accurate positioning, manipulation and stable control of catheter during cardiovascular procedures. There are many complications in using manual catheters, the catheter may deviate from its path during the procedure, and such problem can be eliminated by the use of robotic catheter.

Catheter ablation of cardiac arrhythmia is a complex procedure and it is very challenging to locate and access the site of interest. The use of manually operated catheter mostly rely on the operator’s skill, this may sometimes lead to the dislocation of the catheter. It is also very difficult to maintain stability using manual methods. Techniques such as virtual reality, image fusion and robotics have been applied recently to the diagnosis and treatment of human arrhythmias (Saoudi et al., 2007 & Saoudi et al., 2006). A novel electromechanical master slave system that can remotely control the steerable guide catheter has been developed to enable precise positioning and manipulation of any type of electro-physiological catheter within the heart for the purpose of mapping and ablation. The system comprises three linked components: the physician’s workstation, remote catheter manipulator and steerable guide catheter (Interv et al., 2008).

Cardiac disorders

The robotic steerable catheters find a great application in the diagnosis and treatment of cardiac arrhythmia. Arrhythmias, or electrical faults in the heart causing irregular heartbeats or abnormal heart rhythms, affect millions of people each year. These are characterized as occurring either in the atria (upper chambers of the heart), or in the ventricles (lower chambers of the heart).
Common forms of arrhythmia include:

- Atrial fibrillation (AF) is a complex arrhythmia in which the atria or upper chambers of the heart beat rapidly and irregularly. As a result, the ventricles or lower chambers never adequately fill with blood, and blood pools in the atria increasing the risk of stroke.

- Atrial flutter is a rapid, but organized and predictable, pattern of beating of the atria. As with AF, the ventricles cannot respond to all of the atrial beats, so blood pools in the atria, increasing the risk of stroke.

- Atrioventricular nodal reentrant tachycardia (AVNRT) occurs when the abnormal signal begins in the atria, but instead of transferring to the ventricle through the atrioventricular (AV) node, the electrical signal is returned to the atria. This sequence can happen over and over again.

- Wolff-Parkinson-White is an arrhythmia caused by an abnormal bridge of tissue that connects the atria and ventricles of the heart. This extra pathway allows electrical signals to go back and forth between the upper and lower chambers of the heart without passing through the AV node, which controls the heart rate. As a result, very fast heart rates and other life threatening arrhythmias can develop.

- Ventricular tachycardia is an arrhythmia which arises from the lower chambers of the heart. It is characterized by heart rates over 100 beats per minute, but heart rates often approach 200 beats per minute. At this rate, very little blood is pumped out of the heart to the brain and other organs.

Of all the arrhythmias, AF is the most common. AF is a growing problem worldwide, affecting over 4.5 million people in Europe alone. One of the results of AF is
inadequate blood flow to the body, concomitant with an increased potential for stroke, as the blood left in the atria pools and forms clots that can dislodge and travel to the brain. One method of treating arrhythmias is to destroy the cells that are causing the heart to beat irregularly using a catheter placed in specific locations inside the heart. This is called catheter ablation.

ROBOTIC CATHETERIZATION

Catheterization was initially done manually. It underwent a lot of advancements until the evolution of robotically steerable catheters. The robotic system consists of a physician workstation that includes the instinctive motion controller, a remote catheter manipulator and a setup joint that is mounted on a table at the patient’s side. The remote catheter manipulator directly controls a robotic hollow catheter consisting of an internal steerable guide sheath system (Saliba et al., 2008). The operator will be in a separate work area, isolated from the patient table. The workstation consists of a hand operated joystick for controlling the catheter. It allows the operator to perform the procedure from a remote work area away from the radiation exposure. The robotic catheter itself is comprised of a multidirectional inner guide with full rotational ability (Riga et al., 2009). This allows the catheter to rotate 270° in any direction. The minimum bend radius is 10mm. The catheter can be inserted into the patient through the femoral vein and positioned in the right atrium. The sheath can be controlled from the workstation. Patients were brought to the electrophysiology laboratory in the post absorptive state. A multipolar catheter was placed into the coronary sinus. CARTO electroanatomic mapping system was used in the reconstruction of corresponding atrial chamber anatomy (Saliba et al., 2008). Robotic catheterization of target vessels during fenestrated stent grafting in a pulsatile flow model is easily possible with negotiable amount of radiation exposure to the operator. Vessel cannulation times are comparatively reduced with significant reduction in the number of movements.
compared with conventional cannulation techniques (Riga et al., 2010).

**Figure:** 1 Robotic Catheter System

In 2006, a medical device company named Catheter Robotics Inc. was founded. They developed AMIGO™, a Remote catheter system that incorporates the most modern technologies while they remain easy to learn and use. The first application with Amigo will be in Electrophysiology, in future it is expected cardiac application may include use of it, in the treatment procedure of Abdominal Aortic Aneurysm, heart valve replacement or repair, Patent Foramen Ovale (PFO) repair and vascular applications. Another well known company Hansen Medical INC introduced a robotic catheter system for enabling intravascular system called Mangellan™ Robotic System.

Recently in April, 2013 Hansen Medical, Inc. has announced that it will present its Sensei® X Robotic Catheter System with the new Artisan Extend® Catheter at the Heart Rhythm Society's (HRS) 34th Annual Scientific Sessions from May 8-11, 2013 in Denver, CO. Hansen Medical’s Artisan Extend Catheter includes a simplified and advanced flush design which can improve the physician’s performance during complex electrophysiology procedure. This includes a robotic platform comprising of advanced levels of 3D catheter control and 3D visualization. The manufacturing cost is also comparably lower than the previous versions.

For expanding the treatment options of a trial fibrillation, and to work with SENSEI® X Robotic Catheter System to deliver catheter stability, reach-ability and contact force sensing for the treatment of complex cardiac arrhythmia, such as a trial fibrillation, Hansen Medical Inc, introduced Lynx® Robotic Ablation Catheter. It integrates a 7-hole irrigated ablation catheter
into a smaller profile robotic navigation catheter.

Figure: 2 The Lynx® Robotic Ablation Catheter, Source: Hansen Medical Inc. (www.hansenmedical.com) DOA: 14-05-2013

Another product of Hansen Medical Inc, IntelliSense® is a system-based force sensing technology that comes with every Sensei® X Robotic Catheter System. The technology enables contact force sensing on ablation catheters guided with the Artisan® family of robotic catheters. IntelliSense force sensing allows constant estimation of the contact forces by gently pulsing the catheter a short distance in and out of the steerable inner sheath and measuring forces at the proximal end of the catheter (Ryan, 2012). The Niobe (Steriotaxis, 2009) is a remote magnetic navigation system, in which a magnetic field is used to guide the catheter tip (Ernst et al., 2004).

APPLICATIONS OF ROBOTIC CATHETERS

Robotic catheters are widely used in many medical procedures. The robotically steerable catheters find a greater application in treatment for cardiac arrhythmia (Latcu et al., 2009), Atrial fibrillation ablation (Saliba et al., 2008) and Endovascular aneurism repair (Riga et al., 2009). With the development in endovascular technologies, endovascular aneurism repair overcome the open surgery for a range of aortic pathologies, with comparatively reduced mortality and effective long term outcomes. In recent studies it is found that robotic catheter operating systems were used in endovascular neurosurgeries (Shuxiang et al., 2012). It is said that the force control of flexible catheter robots were employed in beating heart surgery (Samuel et al., 2011). Robotic catheter is the only non-invasive methods used in the diagnosis and treatment of beating heart. Another application of the remotely steerable robotic endovascular catheters is, it can be enhanced in the
procedure of fenestrated stent grafting. A remote robotic catheter system may help overcome some of the technical difficulties associated with endovascular stent-grafting. A steerable multidirectional catheter with a tight bend radius allows precise and controlled stable movements in multiple planes. It may be useful when dealing with difficult contralateral gates in infrarenal stents or anatomically challenging target vessel cannulation in fenestrated stent-grafting (Riga et al., 2010). Complex thoraco-abdominal aneurysm disease can be treated through a totally endovascular approach, but the procedure is complicated and time consuming which is overcome by the robotic endovascular catheter.

DISCUSSION

The robotic steerable catheter itself has a lot of advantages over the manual catheterization methods. The complex procedure of Ablation can be much simplified and précised with the application of steerable catheters. The robotic catheter system includes a separate work station for the physician to perform the procedure while staying away from the radiation exposure. This creates a problem since it occupies a large area. Due to the big size of the robotic steerable catheter setup, it requires lot of space to accommodate them. This could be overcome by reducing the size in future developments. Also, the procedure takes much time which leads to the maximum radiation exposure. Even if radiation shields are used, it’s hard to protect hands and face from exposure.

Advantages of Robotic Catheter over manual catheter

It has overcome many problems of a manual catheter. The manual catheterization required very skilful and experienced doctors whereas; it is relatively easy for the physician to perform the surgery with steerable catheters. There is a risk of radiation exposure to the physician, since x-rays are employed to locate the position of the catheter inside the patient’s body. In recent methods, the physicians stay in a separate workstation during the procedure. This avoids the risk of radiation exposure. In intravascular neurosurgeries, the catheter
inserted into the blood vessel may damage the sensitive, fragile blood vessels in the brain. Such problem is avoided by using steerable catheters which has a high level of stability (Shuxiang et al., 2012). Robotically steerable catheter system allows precise manipulation and stable positioning of a multidirectional guide catheter minimizing instrumentation of the vessel wall (Riga et al., 2009). The doctors will become tired; lose their concentration and ability to focus while performing a complex surgery for several hours. New improved robotic catheters avoid this problem since it effectively reduces the time of procedure. Robotic catheter will allow greater degree of precision and accuracy than manual methods. It enables a higher stability of the catheter.

Limitations

As with most invasive procedures, use of these robotic steerable catheters is not without risk. Serious adverse events, some of which can be fatal, may occur. Some of the adverse effect of using Magellan Robotic System includes vascular damage, embolization and stroke. Cost-effectiveness is another major limitation of using these robotic catheters. Both the capital cost and the running cost are higher. At the early stage in technology, these methods are more expensive. It is believed that with future advancements, the cost may be reduced, but since these improvements in technology are much complicated, there is a chance of the cost to rise. Another limitation of these advanced steerable catheters is its bulkiness. A lot of space is required to accommodate the whole system (Gomez et al., 2004). Performance of robotic procedures requires specialized training.

CONCLUSION

Robotic catheters are expected to play an increasingly important role in future. A detailed study of the robotically steerable catheter and its various applications in the treatment of cardiac arrhythmia, fenestrated stent grafting, Atrial fibrillation ablation, Endovascular aneurism repair etc was presented in this review journal. The complex treatments can be done by the physician with accurate precision and this procedure does not require deep anesthesia. However it has some limitations as discussed above, some of these limitations
regarding this steerable catheter have to be overcome to develop an advanced robotic catheter in future.

REFERENCE


10. Walid Saliba, Vivek Y. Reddy, Oussama Wazni, Jennifer E. Cummings, J. David Burkhardt, Michel, Johannes Brachmann,


