Pulmonary vein isolation (PVI) has become the gold standard treatment for paroxysmal atrial fibrillation (PAF). Recently, PVI has also been shown to be as effective as and possibly safer than more aggressive strategies such as complex fractionated atrial electrogram ablation and left atrial linear lesion ablation in patients with persistent atrial fibrillation (PSAF).\(^1\) One of the major challenges with PVI has been the inability of physicians to create durable electrical isolation of the pulmonary veins with currently available technologies. The number one reason for post-ablation recurrence of atrial fibrillation (AF) is electrical reconnection of an area that has previously been treated. Even after their second recurrence more than 90% of PAF and PSAF patients had at least one reconducting pulmonary vein (PV).\(^2\)

The endoscopically guided laser ablation system, also known as the HeartLight® system, is the newest addition to the options available for PVI. It offers the unique capability of being able to visualize the tissue at the antrum of the PV through its internal micro-endoscope. This compliant balloon ablation device is also able to adapt to wide variation in vein architecture and is able to deliver titrated energy based on anatomical considerations. The HeartLight system is CE approved, has been in limited commercial distribution in Europe since 2011 and has been used in approximately 3000 cases. More recently, a multi-center, randomized US-FDA trial has been completed comparing laser ablation to radio frequency ablation in PAF patients. Many EU studies have also been completed, first evaluating safety and feasibility and then exploring issues of long term efficacy, durability of isolation, as well as comparisons of the HeartLight technique to existing approaches.

**Technology Description**

The HeartLight system consists of a 12F balloon catheter, a 12F inner diameter steerable sheath, a re-usable endoscope and the HeartLight Console.

The HeartLight catheter is an internally irrigated closed system containing six lumens: two for fluid (inlet and return port); two for the illumination fibers (one on each side of the central lumen); one for the laser fiber to deliver therapeutic energy; and one for the endoscope, which sits at the proximal end of the balloon looking forward at a wide angle. The balloon is made from a compliant polyurethane material. Fluid is pumped continuously through the balloon and changing the pump speed allows the user to dynamically tailor the size of the balloon to fit with the patient’s anatomy.

The HeartLight system uses Deuterium Oxide ($D_2O$) fluid rather than standard saline. This is due to the fact that laser energy is absorbed into $H_2O$ very well, but not into $D_2O$. In this way, there is a very efficient transfer of heat from the laser fiber to the tissue with no energy loss in the fluid of the balloon.

**The HeartLight Procedure**

The procedure is similar to the approach used in other left sided ablation techniques in that a transseptal puncture is made using the tools of choice for the electrophysiologist. Once access to the left atrium has been achieved, the CardioFocus
sheath is exchanged over a guidewire placed in the left superior pulmonary vein.

The HeartLight catheter is prepared by flushing it with D_2O, loading the endoscope and inserting it into the deflectable sheath. The HeartLight system is then advanced through the vasculature and introduced into the left atrium. Once in the left atrium, the balloon is directed to the PV ostium and inflated; the light source illuminates the areas of contact around the balloon and the endoscope allows full color, beat by beat viewing of the tissue where blood has been displaced.

The HeartLight console performs a variety of functions. It brings white light illumination within the heart and generates aiming beams similar to a laser pointer to show exactly where lesions will be placed on the tissue. The aiming beams are both green and red as blood and tissue have different optical properties. Once the area for treatment has been identified, the console can deliver 980nm laser energy when a footswitch is activated; power between 5.5W and 12W can be delivered. The possible energy doses are quite low in comparison to RF systems: 5.5W for 30 seconds; 7W for 30 seconds; 8.5W for 20 seconds; 8.5W for 30 seconds; 10W for 20 seconds; and 12W for 20 seconds. The capacity to titrate energy dependent upon the anatomical location within the heart is a benefit of this approach and insures that only appropriate amounts of energy will be used.

The console’s LightTrack® software feature takes a snapshot at each energy delivery position. The split screen mode allows the user to see the previous location and the next energy delivery position superimposed so that overlapping and contiguous lesion sets can be assured.

All clinically significant veins are treated and then the veins are mapped to confirm electrical isolation using standard circular mapping catheters.

Safety Considerations

To optimize procedural safety, esophageal temperature monitoring is recommended throughout the procedure to minimize the risk of thermal injury to the esophagus. Phrenic Nerve Injury (PNI) has also been associated with balloon based PVI technologies. The HeartLight system has a 2-3% PNI complication rate according to recent data published by Sediva et al. In order to minimize PNI, the phrenic nerve is paced via a multipolar mapping catheter positioned in the superior vena cava until the diaphragm is captured. Diaphragmatic capture is closely monitored and ablation is immediately discontinued if weakening or loss of capture is detected.

Preclinical Studies

Endoscopic balloon based ablation was first described in 2004 by Reddy et al. In-vivo porcine studies were conducted to evaluate the feasibility of the system, manipulation of the catheter within the pericardial space, visualization of the anatomical structures and delivery of laser lesions to the ventricular myocardium. The first generation catheter delivered a full 360° circumferential laser lesion and was the first to utilize and endoscope inside of the balloon to allow for the possibility of visualizing endocardial tissue. Additional in vivo studies led to the prescribed and current dosing strategies as well as the evolution of the catheter to the current compliant balloon and 30° laser arc.

Clinical Studies

Early European experience with the HeartLight catheter has been described in several clinical publications.

Dukkipati et al. published a multi-center study assessing the durability of PV isolation as demonstrated through a remapping protocol after a mean of 105 days post index procedure. The effectiveness of PV isolation was tested in addition
to performing evaluations of safety and effectiveness in the long term follow-up. Durable electrical PV isolation was confirmed in 162/189 of PVs (86%). High rates of acute PV isolation were found (98.6-98.8%) and the one year single procedure success rate (71.2%) was determined to be comparable to use of other known conventional ablation technologies.

Schmidt et al. assessed the feasibility of PV isolation when solely guided by endoscopic visualization of the PVs without reference to electrical signals. In 137 veins identified and treated, 96 (70%) were acutely isolated by visual guidance alone. An additional 38 veins were isolated subsequently using the balloon via gap mapping with a circular mapping catheter placed distal to the balloon in the pulmonary vein. Ultimately, 134 of 137 (98%) of PVs were acutely isolated with the use of the HeartLight system. After a mean follow up of 266 days, 27 of 35 (77%) patients remained AF free off of all anti-arrhythmic drugs.

Recent publications by Bordignon et al. and Metzner et al. report on the safety and efficacy of various dosing strategies to optimize energy delivery to potentially increase acute and long term success rates while maintaining procedural safety. The higher dose used by Metzner et al. (8.5-10W) resulted in a 90% isolation rate after the first circumferential ablation attempt. Bordignon et al. reported an 89% success rate of first time isolation using higher energy levels (8.5-12W) without any difference in procedural safety. Additionally, the long term success rate (median follow up 311 days) of the patients treated with the high dose protocol resulted in 83% freedom of AF vs. 60% in the lower dose group.

Sediva et al. published 4 year data including 194 patients (63 females, mean age 61 years). Acute procedural results demonstrated 99.2% of all veins targeted were acutely isolated and 95.3% of these veins were isolated on the first attempt. Mean procedure time was 226 min while mean fluoroscopy time was 20.4 min. At one year follow up, 130 of 158 PAF patients (82.3%) and 9 of 12 of PSAF patients (75%) were AF free. At 4 years, 24 of 32 (75%) of PAF patients have remained free of AF. The acute procedural complications included phrenic nerve injury in four patients (2.06%), tamponade or pericardial effusion in one patient (0.51%), stroke or transient ischemic attack in one patient (0.514%), and vascular injury in six patients (3.09%). There were no reports of PV stenosis or esophageal fistula, consistent with worldwide experience.

The Pivotal Clinical Study of the CardioFocus Endoscopic Ablation System – Adaptive Contact (EAS-AC) or HEARTLIGHT® for the Treatment of Symptomatic Atrial Fibrillation was recently presented during the 2015 Heart Rhythm Late Breaking Clinical Trial Session in Boston, MA, USA. Dr. Vivek Reddy, Principal Investigator, New York, NY, revealed that the trial, which randomized CardioFocus’ HeartLight® Endoscopic Ablation System one-to-one versus the Biosense Webster Thermocool® catheter, met both primary efficacy and safety endpoints and demonstrated a low learning curve for physicians using the HeartLight® System.

Trial results show that when performing a single ablation procedure using the HeartLight® System, the majority of patients experienced freedom from paroxysmal AF at 12 months. Moreover, the primary safety endpoint and the primary efficacy endpoint of freedom from AF at 12 months were satisfied for the pre-specified non-inferiority test as per the study design. The study protocol permitted investigators to perform only a single pulmonary vein isolation (PVI) procedure using HeartLight. Investigators were able to use the control arm device for both PVI and other left atrial targets, with up to two control arm procedures allowed.

The FDA has not had the opportunity to fully review the study data, evaluate the adjudication of the safety and effectiveness assessments or conduct an independent confirmation of the analyses and endpoint calculations and so the results are to be considered preliminary.

A multi-center clinical trial comparing irrigated radio-frequency (RF) ablation to HeartLight completed enrollment in August, 2015 in a persistent AF population. One hundred and fifty (150) persistent AF patients were enrolled in six European centers with one year follow up expected to be complete by August 2016.

Worldwide Registry

PVI with the HeartLight System has been performed in over 3000 cases worldwide. Registry data from 406 procedures and 19 centers was presented in 2012 at the Heart Rhythm Society meeting. Acute procedural metrics included a mean procedure time of 180±58 min with an ablation time of 61±17 min. The average fluoroscopy time was 29±19 min. Acute PV isolation rate without the use of an additional catheter was 98.1%. Subsequently, the worldwide registry has been reviewed to include over 1700 patients with an average procedure time of 133 min and an average fluoroscopy time of 25 min.
Procedural Ease and Economics

Perrotta et al. published results of 150 consecutive patients who were divided into tertiles (T) in order to assess the acute and long term efficacy as well as procedural dynamics with respect to the learning curve. Using visual guidance only, 497 of 583 PVs (85%) were acutely isolated on the first attempt. Visually guided PVI rates increased from 73% to 91% with more experience; total procedure and fluoroscopy time significantly declined with experience. All major acute procedural complications occurred in the first T.

The experience from CCB in Frankfurt and from the USA pivotal trial have shown that there is a short learning curve and that during the learning phase, clinical results are at least as good as an RF approach. It can be seen, therefore, that with experience, results become even better with above 80% single procedure success expected. It is also shown that both procedure time and fluoroscopy time will also decrease with experience.

References

2. Lin, D. et. al. Electrophysiologic Findings and Long-Term Outcomes in Patients Undergoing Third or More Catheter


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