A Video-Assisted Thoracoscopic Technique to Encircle the Four Pulmonary Veins: A New Surgical Intervention for Atrial Fibrillation Ablation


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(#2002-01889 … April 26, 2002)

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ABSTRACT

Background: Atrial fibrillation (AF) is the most common of the so-called benign arrhythmias. It affects not only life expectancy but also quality of life. Until recently, surgeons have most often encountered AF in association with ischemic or valvular disease but rarely as lone atrial fibrillation (LAF). For the subset of LAF patients, a minimally invasive procedure is recommended.

Methods: Using an animal model, we have developed a video-assisted thoracoscopic approach to atrial ablation whereby the ablation is performed encircling the four pulmonary veins as through a median sternotomy.

Results: Fifteen animals were used, and in 5 a complete encircling of the pulmonary veins was accomplished using the thoracoscopic approach.

Discussion: Video-assisted thoracoscopy is a feasible and safe approach for epicardial pulmonary vein ablation. This technique offers the option of surgery to a class of patients who are resistant to medical therapy but for whom the presence of LAF contraindicates the open chest approach.

INTRODUCTION

Chronic atrial fibrillation (CAF) is a widespread arrhythmia that affects survival and quality of life [Kannel 1998]. A large variety of surgical options and different sources of energy for ablation have been proposed for treating AF, all with the common goal of extinguishing AF and restoring effective atrial contraction supported by regular sinus rhythm [Raanani 2001, Williams 2001]. We have used microwave energy clinically to treat AF since January 2001 and have applied it either epicardially or endocardially, depending on patient presentation. We have treated more than 35 patients with encouraging results (Abstract No. 66, Jan. 25, 2002, Miami, VIII CTT). Until recently, we have routinely treated CAF only when it is associated with organic heart disease. However, the majority of AF patients suffer from LAF. Usually these patients are treated with drugs or repeated electrical cardioversions and may ultimately undergo an electrophysiological procedure. Surgery with equivalent results may be conceivable only if surgical incision is avoided. Hence, we have developed a new surgical technique that uses a closed-chest approach, avoids thoracotomy, and is expected to mimic the results of routine sternotomy intervention.

MATERIAL AND METHODS

From June 2001 to February 2002, 15 sheep were operated on. Sheep were chosen as the animal model because the anatomy of the sheep venae cavae and thoracic cavity size is similar to that of humans. All the animal experiments were performed according to the animal experiment ethical directions approved by the Council of the Università degli Studi di Milano pursuant to Article 4 and 5 DL 116/92.

Surgical Technique

Sheep weighing approximately 90 kg (200 lbs) were anesthetized with xilazine, ketamine, diazepam, and atropine. A double-lumen endotracheal tube was placed through a tracheotomy and general anesthesia was maintained with halothane gas. Warm crystalloid solutions and intravenous drugs were infused through the ear veins according to body temperature, blood pressure, and heart rate. The animal was placed in a dorsal decubitus position and tilted 45 degrees toward the left, while anti- and Trendelenburg positions were adopted as necessary to expose different heart structures. The anterior right leg was stretched anteriorly toward the head and secured to free as much chest surface as possible, thus mimicking human operating conditions (Figure ◎). After the first 10 mm port was placed in the fourth intercostal space as close as possible to the root of the anterior right leg and right lung deflation was obtained, a 25 degree Storzl camera shaft was inserted. The pleural cavity was inspected and the phrenic nerve was identified and followed with localization of the

Submitted April 15, 2002; accepted April 26, 2002.

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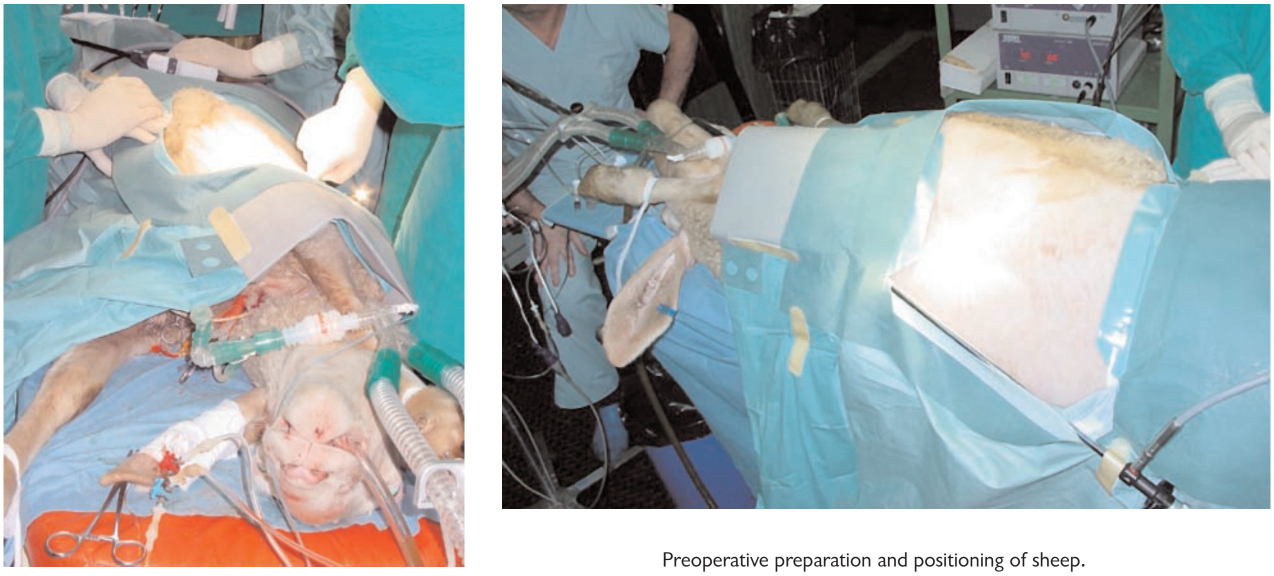

Preoperative preparation and positioning of sheep.

superior and inferior venae cavae. The second and third ports were placed more ventrally toward the sternum in either the second or third space and fifth or sixth space, respectively, according to the size of the animal and conformation of its chest (Figure ◎). The two ports were placed over the superior and inferior venae cavae, while allowing for acceptable maneuverability of the surgical instruments.

With the aid of two blood cherry dissectors, the deflated lung was displaced as posteriorly as possible so as not to hide the pericardial sac. The pericardial sac was then grasped and incised. With scissors, the pericardial sac was opened widely along the course of the phrenic nerve, about 3 cm above it, well beyond the two cavo-atrial junctions. The diaphragmatic pericardial surface was also opened widely toward the apex of the heart to facilitate the dissection of the intrapericardial tract of the inferior vena cava, which in the sheep is rather short and adherent to a thick fat pad on its medial aspect. Traction sutures were passed, in some cases to keep the dorsal flap of the pericardial sac open wide enough to facilitate vision of the lateral aspect of the venae cavae. The superior and inferior venae cavae were dissected free by blunt and sharp dissection maneuvers using blood cherry dissectors and crochet and large right-angle clamps.

Once the venae cavae were freed, a rubber loop was used for taping. An endo-loop cappio was tied around the upper extremity of the right appendage (which in the sheep partly covers the aortic root) and was used for traction by passing the thread with a hook through the skin. In this way, the aditus of the transverse sinus was easily seen. A blunt catheter with a slightly angled tip was inserted in the transverse sinus and advanced until it was reflected back by the intact portion of the pericardium on the left side. At this point, the tip of the catheter was grasped and passed beneath the inferior vena cava with the aid of the right-angle clamp. The catheter end was tied to the tip of the FLEX 10 (AFx Inc., Fremont, CA) microwave energy ablating probe, a 2 cm sliding ablating device contained in a 10 cm malleable sheath. The catheter end was gently pulled out of the thorax, with the probe following, to encircle the pulmonary veins following the same route. Once the ablating probe reached the lateral side of the inferior vena cava, the knot was cut and passed posteriorly to the superior vena cava, to complete the loop around the pulmonary veins. A final lesion on the posterior wall of the left atrium was not part of the procedure protocol because the validation of its efficacy is already on course in the human at our center. When necessary, animals were killed during the procedure using an intravenous bolus of potassium chloride. The chest was opened and the lung and the intrapericardial structures were examined for any damage caused during the procedure. The positions of the catheter and ablating probe were directly assessed, particularly in regard to the left auricle.

RESULTS

In the last 5 animals it was possible to complete the new surgical technique in less than 3 hours without any major complication. In all of these cases, the ablating probe was successfully positioned around the pulmonary veins. The loop always presented laterally to the left appendage without any additional maneuver. All of these animals were killed at the end of the procedure in accordance with the scientific protocol.

DISCUSSION

Chronic atrial fibrillation represents a major challenge. Although it is classified as a benign arrhythmia, it may impair the quality of life of patients and it is responsible for a significant increase in mortality and morbidity [Kannel 1998]. Even in the absence of palpitations, cardiac output is reduced and work capacity is decreased. AF and atrial enlargement influence each other in a vicious cycle, resulting in blood pooling and cardiac heart failure in a large percentage of patients [Alboni 1995]. Anticoagulation treatment is essential and morbidity related to incorrect therapy is responsible for major cardiovascular accidents, with the rate of such events increasing with age. Side effects related to medical therapy are already well established, and the course of treatment followed by the CAF patient often requires hospitalization to perform either pharmacological or electrical cardioversion [Copland 2001]. Finally, it should be noted that 1% of the general population in Western countries is affected by AF. Hence, this benign arrhythmia represents a major social cost that ought to be addressed in a definitive way.

Medical or electrophysiological treatment may restore sinus rhythm in about 40% to 60% of cases, but it commonly requires more than a single procedure, and oral medications can be withdrawn only in a minority of patients [Alpert 2000]. In recent years, surgical treatment has provided a wide offering of ablative patterns and sources of energy that are capable of producing lesions comparable to those of the classical "cut and sew" approach. Until recently, the sternotomy has been the classical approach for carrying out surgical cardiac ablation, principally because AF has been treated concomitantly with procedures that, until recently, required endocardial intervention. Only with the advent of microwave technology has an epicardial approach become conceivable. Microwave energy can be delivered using long, narrow, and malleable probes, and ongoing histological studies at our center have demonstrated lesion transmurality with microwave ablation. Since we began using microwave energy, 20 patients have been treated using a left atrial epicardial ablation approach and we have obtained encouraging results.

A large number of patients suffering from lone AF could benefit from this surgical technique if a minimally invasive approach can be developed. Our objective was to develop a technique that does not require a thoracotomy and is still capable of producing clinical results equivalent to those achieved using the sternotomy approach. A major concern was proper positioning of the ablating probe with respect to the left coronary system, principally in the region medial to the left appendage, where inadvertent damage could have serious consequences. For this reason, in the beginning of our studies we used a 5 mm Fiberscope to assess probe position. In one animal we also performed a 3-port access on the left side to staple the left appendage and directly view the position of the probe. The catheter device (designed by E.M.), which appears at this time to be an integral aspect of this minimally invasive procedure, allows introduction of the ablating probe into the transverse sinus and facilitates guidance beneath the posterior aspect of the heart in the oblique sinus. The catheter allows overpass of the pericardial reflection located laterally to the left auricle and prevents rotation of the probe on its longitudinal axis and dislodgement over the left ventricle apex. It also facilitates capture beneath the inferior vena cava. The catheter has sufficient rigidity to be pushed from outside, but is malleable enough to curve around the lateral heart wall. The catheter is also smooth enough to prevent any organic lesion and long enough to complete the loop from the thoracoport around the 4 pulmonary veins and back to the entry port. Other designs and modifications to the probe itself are under development.

The geometry of the sheep thorax makes maneuverability of the available thoracoscopic instrumentation very difficult in comparison to human anatomy, and in many cases, the procedure was lengthy. Furthermore, the inferior vena cava in its intrapericardial tract is surrounded by abundant and sticky fat, making dissection of the inferior vena cava and its taping very difficult.

CONCLUSION

Despite the noted difficulties, we conclude that this new surgical procedure is feasible, safe, and reproducible once adequate skill manipulating the thoracoscopic devices is gained. We can speculate that in humans the procedure will be much easier and faster because of thoracic conformation, the fat-free intrapericardial sac, and the fact that thoracoscopic instruments have been developed for human use. Most important, the development of new optical devices such as Vista (Jomed-Vista Medical Technologies, Westborough, MA), which offers a 3-dimensional view of the operating field, will facilitate the conversion from routine sternotomy to a thoracoscopic approach. Nonetheless, proper patient selection will be vital to ensure clinical success of the procedure.

ACKNOWLEDGEMENTS

This experimental study was sponsored by AFx, Inc., 47929 Fremont Blvd. Fremont, CA 94538, USA; Ethicon Endo-Surgery, a Johnson & Johnson Company, Via del Mare 56, 00040 Pratica di Mare Rome, Italy; Jomed International AB, Sehlstedtsgatan 1 S-25439 Helsingborg, Sweden; and Karl storz gmbh & Co. Kg, Mittelstrasse 8d- 78532 Tuttlingen, Germany.

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