Summary of Safety and Effectiveness Data

Daig LIVEWIRE TC™ Steerable Electrophysiology Catheter

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LIVEWIRE TC™ Steerable Electrophysiology Catheter
Daig Corporation

1 General Information

Device Generic Name: ..... Radio Frequency-Powered Cardiac Catheter Ablation Catheter and Cables

Device Trade Name: ..... Livewire TC™ Steerable Electrophysiology Catheter

Includes: ..... Livewire TC™ Steerable Electrophysiology Catheter
Accessory cables

Applicant's Name and Address: ..... Daig Corporation
14901 DeVeau Place
Minnetonka, MN 55345

PMA Application Number: P960016

Date of Notice of Approval to the Applicant: ..... May 4, 1999

2 Indications and Usage

The device is indicated for cardiac electrophysiological mapping and for use with a compatible RF generator for:

- interruption of accessory atrioventricular (AV) conduction pathways associated with tachycardia;
- the treatment of AV nodal re-entrant tachycardia (AVNRT); or
- creation of complete AV nodal block in patients with a difficult to control ventricular response to an atrial arrhythmia.

3 Contraindications

Do not use this device:

- in patients with active systemic infection;
- via the transseptal approach in patients with left atrial thrombus or myxoma, or interatrial baffle or patch; or
- in patients with aortic valve replacement via the retrograde transaortic approach.

4 Warnings and Precautions

See WARNINGS AND PRECAUTIONS in the final draft labeling (Information for Use)

5 Device Description

The Daig Livewire TC™ Steerable Electrophysiology Catheter (Livewire Catheter) is a flexible electrode catheter which provides electrophysiological mapping of the heart and transmits radio frequency (RF) current to the catheter tip electrode for ablation purposes. The catheter is constructed of a radiopaque polyurethane insulation/shaft and platinum electrodes. All electrodes may be used for recording and stimulation, but only the tip electrodes may be used to deliver RF energy. The remote control handle located at the proximal end of the catheter deflects distal tip of the catheter.

Livewire TC™ Steerable Electrophysiology Catheter

The Livewire TC™ Steerable Electrophysiology Catheter comes in six different versions, differing only in the dimensions of the steerable, distal portion of the catheter. The nominal length of the catheter is 115 cm, and the diameter is 7 French. The steering handle and electrical plug connections are the same for all versions. The product designations for these different tips are:

Curl: Small (Sml), Medium (Med), and Large (Lrg)
Sweep: Small (Sml), Medium (Med), and Large (Lrg)

The tip may be deflected by rotating an adjustment collar on the steering handle.

The tip electrode on all versions is 4 mm and is made of platinum. There are 3 ring electrodes, and the spacing between the ring electrodes is 2 mm – 5 mm – 2mm. Only the 4 mm tip electrode is employed to deliver the RF energy used in the ablation procedure. The other ring electrodes are used for electrophysiology mapping studies.

Compatible Generator

The Livewire Catheter must be used with a dispersive pad (reference electrode), and a compatible RF generator with the following specifications:

- A thermocouple (for temperature measurement)
- Maximum temperature limit - 100°C
- Modes - Temperature control and monitoring and power control.
- Maximum output - 50 watts
- RF output frequency - 450–550 KHz
- Impedance range - 40–250

Accessory Cables

Livewire TC™ Catheter Extension Cable is an extension cable designed to connect the Livewire TC™ Steerable EP Catheter to the commercially available RF generator. All of the connections are contained in one cable including the thermocouple which plugs directly into the RF generator.

6 Alternative Practices or Procedures

The principal alternative forms of therapy for the management of supraventricular tachycardia are antiarrhythmic drugs, surgical ablation, or catheter ablation with a different approved catheter. Antiarrhythmic drugs, although they are effective in many patients, may be associated with significant side-effects, and are not curative. Surgical ablation is curative, but may be associated with higher morbidity than catheter ablation.

7 Marketing History

The Livewire TC™ Cardiac Ablation System has been CE marked for use in Europe since March 21, 1996. In addition, the Livewire TC™ is available for commercial distribution in most of the world including Canada, Japan, and Australia.

8 Adverse Events

8.1 Observed Adverse Events

The Livewire Catheter was studied in 329 patients undergoing electrophysiologic (EP) mapping and ablation in two clinical studies: 236 patients using an investigational RF generator and 93 patients using a commercially available generator. Of the 329, eleven patients were not treated with the Livewire Catheter due to either investigational generator issues (9) or non-availability of catheter accessories (2). There was 1 major (atrial perforation) and no minor adverse events in these 11 patients. These 11 patients were excluded from further adverse event analysis. The 318 patients included 10 patients treated for typical atrial flutter.

The number of patients with adverse events (major or minor) was 9 of 226 (4.0%) in the study using the investigational generator and 2 of 92 (2.2%) in the study using the commercially available generator.

Table 1. Observed Adverse Events
All Patients Treated (N=318), includes 10 patients with atrial flutter

Adverse Event Category Description	Total No. of Pts. Experiencing Adverse Events	% of Pts Experiencing Adverse Events [95% C.I.]
Major; Heart block (requiring a pacemaker)	4	1.3% [0.3%, 3.2%]
Minor (included puncture site bleeding, pericardial effusion, left bundle branch block, transient complete heart block, and first degree atrioventricular block)*	7	2.2% [0.9%, 4.5%]

** Patients with both minor and major adverse events (N=2) were counted only as major adverse events.*

C.I. – Confidence intervals by the exact (binomial) method

8.2 Potential Adverse Events

Adverse events (in alphabetical order) which may be associated with catheterization and ablation include:

Catheterization/catheter procedure related:

- air embolism
- arrhythmias
- AV fistula
- cardiac perforation
- hemothorax
- nerve palsy or weakness
- pneumothorax
- pseudoaneurysm
- tamponade
- thrombi
- thromboembolism
- thrombosis
- valvular damage
- vascular bleeding/local hematomas
- vasovagal reactions
- visual blurring

RF ablation related:

- cardiac perforation/tamponade
- cardiac thromboembolism
- cerebrovascular accident (CVA)
- chest pain/discomfort
- complete heart block
- coronary artery dissection
- coronary artery spasm
- coronary artery thrombosis
- pericarditis
- transient ischemic attack (TIA)
- valvular damage
- ventricular tachyarrhythmia

9 Summary of Preclinical Studies

9.1 Bench Testing

All bench testing for the Livewire was performed on ethylene oxide sterilized catheters and cables. Tests were devised based on product specifications and the various standards or guidance documents including the FDA Electrode Recording Catheter Preliminary Guidance (1995), AAMI HF-18, and IEC 601. Testing consisted of the following areas Product Durability Tests, Mechanical and Reliability Tests, Electrical Integrity Tests, and Thermocouple Accuracy.

Product Durability Tests

The purpose of the product durability test is to qualify the performance and safety of the Livewire ablation catheter as it relates to the product specification. Catheters were sterilized, and then tested, and the entire process was repeated a total of ten times. Each test cycle included the following steps:

1. Catheters were packaged and sterilized
2. Catheters were checked for electrical continuity and shorts
3. Effective tip curve performance of catheters were monitored
4. Catheters were tested for tip curve deflection 50 times
5. Catheters were connected to RF generator and 50 lesions at maximum output for 60 seconds were made
6. Catheters were tested for tip curve deflection 50 times
7. Catheters were submerged in Buell Cleaner for 2 minutes
8. Catheters were visually inspected for damage
9. Catheters were checked for electrical continuity and shorts

The processing steps 1-9 were completed a total of ten times each. The minimum performance requirement for the Livewire catheter is to endure without any mechanical or electrical failure for 200 full tip curve deflections and 100 RF lesions at full output capacity of the RF generator. All samples passed the required acceptance criteria, and the results are below.

Test	Test Sample	Number of Devices Tested	Acceptance Criteria	Results of Testing
Remote Tip Curve Performance	Entire Livewire Catheters Catheters laid out flat Catheters placed into serpentine tube to simulate cardiac anatomy	6	Tip curves through range in a smooth fluid motion At full curve position the tip electrode should align with the catheter shaft in a single plane At full curve position the tip electrode should be within .25" of the catheter shaft When return to the straight position the tip electrode should be within .25" of straight with reference to the catheter shaft	All Samples Passed
Mechanical and Electrical Integrity through 1000 Curve Cycles and 500 RF Lesion Cycles	Entire Livewire Catheters	6	Minimum catheter requirements are that catheter must be able to maintain its mechanical and electrical integrity after 200 full tip curve deflections and 100 RF lesions at full output.	All Samples Passed
Pull Wire Joint Strength Test	Tip electrode to pull wire	6	Minimum pull force of 10 lbs.	All Samples Passed
Adhesive Joint Reliability Test	Tip electrode to flexible gray shaft	6	Minimum pull force of 5 lbs.	All Samples Passed
RF Joint Strength Test	Flexible tip to braided shaft	6	Minimum pull force of 4 lbs.	All Samples Passed
Catheter Shaft to Remote Handle Integrity Test	Catheter Handle and 6" of Livewire Catheter	6	Catheter to handle connection must withstand torque of 3 (oz.-in.) with no slipping	All Samples Passed
Product Liquid Tightness Test	Handle portion of Livewire Catheter	6	Presence of moisture must not affect mechanical and electrical integrity of the catheters performance.	All samples passed

Mechanical and Reliability Tests

The mechanical and reliability tests performed were conducted based various standards listed above and the FDA Electrode Recording Catheter Preliminary Guidance. All samples were sterilized and preconditioned by thermal cycling before testing. All tested catheters met the established acceptance criteria for mechanical testing.

Test	Test Sample	Number of Devices Tested	Acceptance Criteria	Results of Testing
Tensile Testing	Tip Electrode to Flexible Tip	27	Minimum 2.5 lbs.	All Samples Passed
	Flexible Tip to Catheter Shaft	41	Minimum 4 lbs.	All Samples Passed
	Handle to Handle Extension Cord 4 pin Connector 12 Pin Connector	 10 10	Minimum 10 lbs.	All Samples Passed
	Handle Extension Cord to Connector 4 pin Connector 12 Pin Connector	 10 10	Minimum 10 lbs.	All Samples Passed
Torque Test	Flexible Tip to Catheter Shaft Bond	10	Minimum 1 (oz-in) and 10 revolutions	All Samples Passed
Torque/Twist Test	Entire Livewire Catheter	7	Minimum 1 (oz-in) and 1 revolution	All Samples Passed
Catheter Pressurization Test	Entire Livewire Catheter	6	Must maintain an electrical integrity resistance of > 2 megaohms after exposure to bovine blood at 250 mm of Hg constant pressure	All passed at 45 minutes Five passed and one failed at 60 minutes
Catheter Dielectric Strength Test (IEC 601-2-2)	Entire Livewire Catheter and Extension Cable	6	No electrical breakdown of catheter or flashover after exposure 3000 VRMS for 5 minutes	All Samples Passed
Curve Deflection Durability Test	Entire Livewire Catheter	5	< 4 Ω resistance between like pins and electrodes > 2 Ω resistance @ 3/4 VDC between unlike pins and electrodes Ability to deflect 100 cycles and return to the non-deflected position	All Samples Passed

			by normal use deflection mechanism	
Catheter/Handle Joint Flex Test	Entire Livewire Catheter	4	< 4 Ω resistance between like pins and electrodes > 2 Ω resistance @ 3/4 VDC between unlike pins and electrodes Ability to deflect 100 cycles and return to the non-deflected position by normal use deflection mechanism	All Samples Passed
Catheter Shaft Buckling Test - Testing was completed from the catheter distal end moving back every 2 inches ending at 10inches.	Entire Livewire Catheter	3	Results must be comparable to commercially available catheters.	Results were comparable to commercially available catheters.

Electrical Integrity Tests

The electrical tests performed were conducted on entire Livewire catheters and cables based upon meeting Daig product specifications and various standards listed above. All samples were sterilized and preconditioned by thermal cycling before testing. The Livewire test catheters met the test requirements for all tests. The circuit continuity, short circuits, and electrical insulation tests were conducted with the catheter and cables being exposed to least 1.5 amps and 125 volts for one hour.

Test	**Test Sample**	**Number of Devices Tested**	**Acceptance Criteria**	**Results of Testing**
Circuit Continuity Test	Entire Livewire Catheters Straight Tip Curved Tip	 3 3	< 4 Ω resistance between like pins and electrodes > 2 Ω resistance between unlike pins and electrodes	All Samples Passed
Short Circuits Test	Entire Livewire Catheters Straight Tip Curved Tip	 3 3	No short or open circuits	All Samples Passed
Electrical Insulation – High Pot Test	Entire Livewire Catheters	3	Resistance ≥ 1 megohm @ 1000 VDC	All Samples Passed

Electrical Insulation – Maximum Current Test	Entire Livewire Catheters	3	3.5 amps for 1 hour resistance ≥ 1 megohm @ 1000 VDC No electrical breakdown	All Samples Passed
Conductor to Conductor Coupling Test	Entire Livewire Catheters	3	Conductor to Conductor dielectric strength to withstand 1000vp-p for 5 minutes	All Samples Passed
High Frequency Leakage Current (IEC 601-2-2)	Entire Catheter and Extension Cables	6	Leakage current must be < 150 milliamps	All Samples Passed

Thermocouple Accuracy Tests

The thermocouple accuracy tests were conducted using entire Livewire catheters and Extension cables for meeting Daig product specifications. All samples were sterilized and before testing. Worst case conditions were used, consisting of RF generator output at 50 Watts in a 37°C environment using a calibrated independent thermocouple as the control device. The Livewire test catheters and cables met the test requirements for all tests.

Test Sample	Number of Devices Tested	Acceptance Criteria	Acceptance Criteria
Entire Catheter and Extension Cables	6	Catheter Thermocouple Temperature reading must be within ± 1°C of the control thermocouple	All Samples Passed

9.2 Animal Studies

There were two animal studies conducted using the Livewire TC™. The primary study in canines examined safety and performance of the Livewire TC for performing ablation. The second study examined the capability of the Livewire TC™ to pace and sense electrical activity in a canine model.

Primary Animal Study

The study objectives were to:

- demonstrate the capability of the Daig Livewire TC™ Steerable Electrophysiology Catheter to safely deliver RF energy for the purpose of creating lesions in healthy canine myocardium, and
- show that the lesions created destroy the ability of the specialized conduction systems to conduct electrical signals.

A total of 67 applications of RF energy were delivered at up to 7 different anatomical locations in each of 10 mongrel dogs. A total of 55 lesions were observed post-mortem. In 9 of the 10 dogs, the applied energy disrupted normal AV conduction by creating lesions at the site of the AV node or bundle branch location.

It was concluded that the canine study provided evidence showing that the ablation procedure with the Livewire could be safely attempted in human subjects by a trained physician who was familiar with the procedure and the equipment employed.

Second Animal Study

This animal study involved one canine to demonstrate the ability of the Livewire to pace and sense. The study demonstrated that the Livewire was capable of pacing and sensing in both the right atria and ventricle of the canine heart.

9.3 Biocompatibility Testing

All blood and tissue contact materials were tested in accordance with relevant sections of the US Pharmacopoeia and Tripartite Biocompatibility Guidance for Medical Devices. The biocompatibility testing included testing individual blood and tissue contacting materials and final assembled devices. The biocompatibility of the catheter materials was established for the intended use. The following is a summary of the biocompatibility tests by processed material and device.

UV Adhesive

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	6 cm^2	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Failed when undiluted Passed when at a 1:5 dilution
Hemolysis (Saline)	2 grams	Must be non-hemolytic	Passed
Acute Systemic Toxicity (Extracts)	4 grams	No mortality or evidence of significant systemic toxicity from the extracts.	Passed
Intracutaneous Reactivity (Extracts)	4 grams	No evidence of significant irritation or toxicity from the extracts.	Passed
Sensitization Maximazation (Saline)	4 grams	No dermal inflammatory response greater than that seen in any control.	Passed
Implantation	1mm x 1 cm	Macroscopic reaction must no be significant	Passed
Ames Mutagenicity (Saline)	4 grams	No mutagenic changes	Passed

Estane (polyurethane)

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	3 cm^2	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Passed
Hemolysis (Saline)	30 cm^2	Must be non-hemolytic	Passed
Acute Systemic Toxicity (Extracts)	60 cm^2	No mortality or evidence of significant systemic toxicity from the extracts.	Passed
Intracutaneous Reactivity (Extracts)	60 cm^2	No evidence of significant irritation or toxicity from the extracts.	Passed
Sensitization Maximazation (Saline)	60 cm^2	No dermal inflammatory response greater than that seen in any control.	Passed
Implantation	1mm x 1 cm	Macroscopic reaction must no be significant	Passed
Ames Mutagenicity (Saline)	60 cm^2	No mutagenic changes	Passed

Pellethane (polyurethane)

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	3 cm^2	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Passed
Hemolysis (Saline)	30 cm^2	Must be non-hemolytic	Passed
Acute Systemic Toxicity (Extracts)	60 cm^2	No mortality or evidence of significant systemic toxicity from the extracts.	Passed
Intracutaneous Reactivity (Extracts)	60 cm^2	No evidence of significant irritation or toxicity from the extracts.	Passed
Sensitization Maximazation (Saline)	60 cm^2	No dermal inflammatory response greater than that seen in any control.	Passed
Implantation	1mm x 1 cm	Macroscopic reaction must no	Passed

		be significant	
Ames Mutagenicity (Saline)	60 cm^2	No mutagenic changes	Passed

Entire Livewire Catheters

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	1 Catheter	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Passed
Hemolysis (Saline)	1 Catheter	Must be non-hemolytic	Passed

Platinum/Iridium Rod (Tip electrode)

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	3 cm^2	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Passed
Hemolysis (Saline)	19.3 grams	Must be non-hemolytic	Passed

2mm Ring Platinum Electrodes

Name of Test	Number of Devices or Amount Tested	Acceptance Criteria	Results of Testing
Cytotoxicity (MEM Elution)	6 cm^2	Neither of the monolayers exposed to the test medium may be greater than a grade 2 (mild).	Passed
Hemolysis (Saline)	1 gram	Must be non-hemolytic	Passed

10 Summary of Clinical Studies

10.1 Objectives

A prospective, multicenter (10 centers, 7 in the United States and 3 in Canada) study of radio frequency (RF) ablation was conducted of the following supraventricular tachycardias (SVT): atrioventricular (AV) accessory pathways (AP) associated with tachycardia, AV nodal re-entrant tachycardia (AVNRT), or creation of complete AV nodal block in patients with difficult to control ventricular response to an atrial arrhythmia.

10.2 Study Design

The Livewire Catheter was studied in 329 patients undergoing electrophysiologic (EP) mapping and ablation in two clinical studies: 236 patients using an investigational RF generator and 93 patients using a commercially available generator. Of the 329, eleven patients were not treated with the Livewire Catheter due to either investigational generator issues (9) or non-availability of catheter accessories (2). There was 1 major (atrial perforation) and no minor adverse events in these 11 patients. These 11 patients were excluded from further analysis. Of these 318 patients, 10 were treated for typical atrial flutter. These 10 were excluded from the effectiveness analysis, which was based on the remaining 308 patients.

10.3 Description of Patients and Gender Bias

The 318 treated patients enrolled in the study ranged in age from 11 to 84 years (mean 44 years) and included 182/318 females (57%). Inclusion criteria, exclusion criteria and study enrollment procedures were designed to avoid gender bias. Of the 318 patients studied, 163 , or 51%, were treated for AVNRT. Of this subset, 71% (116/318) were females which is typical for this indication.

[Zhu DWX and Maloney JD. Radiofrequeny catheter ablative therapy for atrioventricular reentrant tachycardia. In: Singer I, ed. Interventional Electrophysiology. Williams and Wilkins, Baltimore, MD, 1997: 275-316.]

10.4 Effectiveness Results

Acute success was defined as ablation of the target site and elimination of the arrhythmia with no recurrence before patient discharge. The acute success rate for all arrhythmias was 201 of 216 (93%) in the study using the investigational generator and 86 of 92 (93%) in the study using the commercially available generator. The difference between the results for the two generators is 0 % with a 95% confidence interval of [-9%, 8%], so the results for the two generators have been combined. Table 2 shows patient age, enrollment and acute success by indication.

Table 1. Patient Age and Acute Success by Indication
All Patients Treated for SVT (N=308)

Arrhythmia	Age, mean (range)	Success (%) [95% CI]
AVNRT	46 (11, 78)	156/163 (96%) [91%, 98%]
AP	36 (12, 66)	99/112 (88%) [82%, 94%]
AV nodal	57 (22, 84)	31/33 (94%) [80%, 99%]
All arrhythmias	44 (11, 84)	286/308 (93%) [89%, 95%]

C.I. – Confidence intervals by the exact (binomial) method

Of the 201 patients successfully treated with the investigational generator, follow-up data was available in 195. Of these 195 patients, recurrence was reported in 41 (21%), and 16 (8%) were lost to follow-up by 12 months. Table 3 shows the recurrence free survival to 12 months.

Table 2. Recurrence-free survival (Kaplan-Meier Estimates)
Patients Successfully Treated with follow-up (N=195*)

Follow-up Time	Cumulative Survival [95% CI]	Number Remaining
One Month	92% [88%, 96%]	179
Three Months	87% [82%, 91%]	164
Six Months	82% [77%, 88%]	150
Twelve Months	77% [70%, 83%]	98

C.I. – Confidence intervals from the Kaplan Meier estimates

11 Conclusions Drawn from the Studies

The preclinical testing demonstrates that the catheter should maintain its mechanical and electrical integrity and that the patient-contacting materials should be biocompatible, under the proposed conditions of use. The clinical data provide reasonable assurance that the Daig Livewire TC™ Cardiac Ablation System is reasonably safe and effective for the treatment of SVT under the proposed conditions of use.

12 Panel Recommendation

In accordance with the provisions of section 515(c)(2) of the act as amended by the Safe Medical Devices Act of 1990, this PMA was not referred to the Circulatory System Devices Panel, an FDA advisory committee, for review and recommendation because the information in the PMA substantially duplicates information previously reviewed by this panel.

13 FDA Decision

FDA performed an inspection and found the applicant in compliance with the Quality System Regulation (21 CFR Part 820).

14 Approval Specifications

Directions for Use: See Final Draft Labeling (Information for Use)

Hazards to Health from Use of the Device: See INDICATIONS, CONTRAINDICATIONS, WARNINGS AND PRECAUTIONS, and ADVERSE EVENTS in the Final Draft Labeling (Information for Use).

Post-approval Requirements and Restrictions: See Approval Order

DAIG
a St. Jude Medical Company

INSTRUCTIONS FOR USE

LIVEWIRE TC™

STEERABLE ELECTROPHYSIOLOGY CATHETER

Read Instructions for Use prior to use of this device.

See individual sterile package label for contents.

SINGLE–USE DISPOSABLE MEDICAL DEVICE. CONTENTS ARE STERILE IF PACKAGE IS UNOPENED AND UNDAMAGED. DO NOT RESTERILIZE.

CAUTION: FEDERAL LAW RESTRICTS THIS DEVICE TO USE BY OR ON THE ORDER OF A PHYSICIAN.