

## **Supplemental Appendix to:**

# **A Lattice-Tip Temperature-Controlled Radiofrequency Ablation Catheter for Wide Thermal Lesions: First-in-Human Experience with Atrial Fibrillation**

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## **Additional Disclosures**

Vivek Reddy's disclosures with medical companies include: Abbott (Consultant), Ablacon (Consultant, Equity), Acutus Medical (Consultant, Equity), Affera (Consultant, Equity), Apama Medical (Consultant, Equity), Aquaheart (Consultant, Equity), Autonomix (Consultant, Equity), Axon (Consultant), Backbeat (Consultant, Equity), BioSig (Consultant, Equity), Biosense-Webster (Consultant), Biotronik (Consultant), Boston Scientific (Consultant), Cardiofocus (Consultant), Cardionomic (Consultant), CardioNXT / AFTx (Consultant), Circa Scientific (Consultant, Equity), Corvia Medical (Consultant, Equity), East End Medical (Consultant, Equity), EBR (Consultant), EPD (Consultant, Equity), Epix Therapeutics (Consultant, Equity), EpiEP (Consultant, Equity), Eximo (Consultant, Equity), Farapulse (Consultant, Equity), Fire1 (Consultant, Equity), Impulse Dynamics (Consultant), Javelin (Consultant, Equity), Keystone Heart (Consultant, Equity), LuxCath (Consultant, Equity), Manual Surgical Sciences (Equity), Medlumics (Consultant, Equity), Medtronic (Consultant), Middlepeak (Consultant, Equity), Newpace (Equity), Nuvera (Consultant, Equity), Philips (Consultant), Stimda (Consultant), Surecor (Equity), Thermedical (Consultant), Valcare (Consultant, Equity), Vizara (Equity) and VytronUS (Consultant, Equity).

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**Online Table 1 Procedural Parameters During Pulmonary Vein Isolation with Various Technologies**

	No. of Pts	Radiofrequency Application Time, min *	Transpired Ablation Time, min *	Left Atrial Dwell Time, min *
<b>Irrigated RFA</b>				
<i>Thermocool AF, 2010</i>	139	--	110.3	
<i>Heartlight-TC Arm, 2015</i>	172	50 ± 24	--	
<b>Force-Sensing RFA</b>				
<i>Toccastar-Tacticath, 2015</i>	152	47 ± 26	--	
<i>SMART-AF, 2014</i>	160	60.6	121.5	
<i>SMART-SF, 2018</i>	159	49.5	104.3	
<b>Temperature-Guided RFA</b>				
<i>TRAC-AF, 2017</i>	35	26.3 ± 5.2	--	
<i>QDOT, 2019</i>	52	8.1	46.0 ± 21.3	(81.7 ± 20.2) †
<b>“One-Shot” Ablation</b>				
<i>FIRC &amp; ICE, 2016 (Cryo)</i>	378			92
<i>Cryo-DOSING, 2017 (Cryo)</i>				
>> Conventional Dosing	400			118 ± 25
>> Time-to-Effect Dosing	355			51 ± 14
<i>RADIANCE, 2019 (RFB)</i>	39			40.5 ± 11.5
<i>AF-FICIENT, 2019 (RFB)</i>	99			45.5
<i>IMPULSE/PEFCAT, 2019 (PFA)</i>	81			33.7 ± 16.6
<b>SUMMARY ‡</b>		<b>40.3</b> (8.1 – 60.6)	<b>95.5</b> (46.0 – 121.5)	<b>63.5</b> (33.7 – 118)
<b>Lattice-Tip Catheter</b>	65	<b>2.7 ± 0.65</b>	<b>21.8 ± 12.1</b>	<b>43.0 ± 18.4</b>

\* Data are expressed as either the mean, or if available, the mean ± standard deviation.

† Since this value does not relate to balloon ablation, it is not included in calculating the Summary value of the left atrial dwell time.

‡ These averages do not factor in the number of patients in each study sample.

**Online Table 2: Procedural Outcomes of Linear Atrial Lesions**

	No. of Pts	Successful Linear Lesion, n (%)	Epicardial CS Ablation, n (%)	RF Application Time, min *
<b>Mitral Isthmus Line</b>				
<i>Jais et al, 2004</i>	100	92 (92%)	68 (68%)	25 ± 14
<i>Matsuo et al, 2011</i>	80	70 (87.5%)	34 (42.5%)	14.0 ± 6.7
<i>Yokokawa et al, 2011</i>	55	35 (63.6%)	43 (78.2%)	--
<i>Pak et al, 2011</i>	100	32 (32%)	87 (87%)	18.2 ± 3.7
<i>Scherr et al, 2015</i>	40	29 (72.5%)	34 (85.0%)	24 ± 10
<i>Latcu et al, 2016</i>	53	30 (56.6%)	40 (75.5%)	29 ± 14
<i>Wynn et al, 2016</i>	59	49 (83.1%)	--	--
<i>Maurer et al, 2017</i>	114	106 (93.0%)	46 (40.4%)	33.7
<i>Lee et al, 2018 †</i>	236	154 (65.2%)	201 (85.2%)	25.7
<i>Fujisawa et al, 2019</i>	143	132 (92.3%)	44 (30.8%)	14.1
<i>Chen et al, 2019</i>	177	165 (93.2%)	70 (39.5%)	25.1 ± 15.8
<i>Sato et al, 2019</i>	135	128 (94.8%)	55 (40.7%)	20.7
<b>SUMMARY ‡</b>		<b>77.2%</b> (32% - 94.8%)	<b>61.2%</b> (30.8% - 87%)	<b>23.0</b> (14.0 - 33.7)
<b>Lattice-Tip Catheter</b>	22	22 (100%)	1 (4.5%)	<b>1.0 ± 0.92</b>
<b>Roof Line</b>				
<i>Arbelo et al, 2014</i>	59	48 (81.4%)		--
<i>Wynn et al, 2016</i>	61	55 (90.2%)		--
<i>Mujovic et al, 2018</i>	41	39 (95.1%)		--
<b>SUMMARY ‡</b>		<b>88.9%</b> (81.4% - 95.1%)		--
<b>Lattice-Tip Catheter</b>	23	22 (95.7%)		<b>0.4 ± 0.16</b>
<b>Cavo-Tricuspid Isthmus Line</b>				
<i>Ramoul et al, 2015</i>	60	60 (100%)		11.8
<i>Wynn et al, 2016</i>	68	65 (95.6%)		--
<b>SUMMARY ‡</b>		<b>97.8%</b> (95.6% - 100%)		<b>11.8</b>
<b>Lattice-Tip Catheter</b>	48	48 (100%)		<b>0.5 ± 0.24</b>

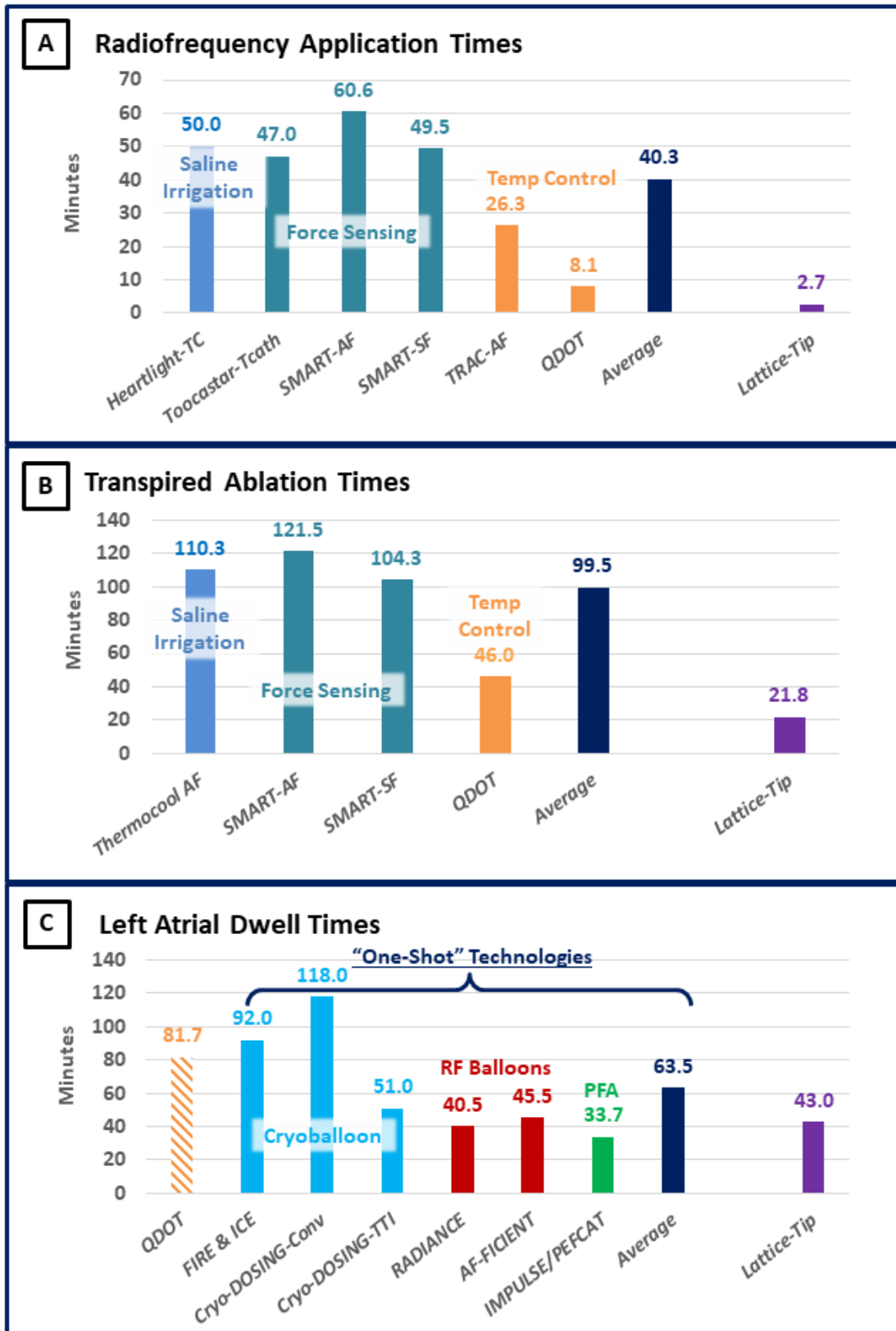
\* Data are expressed as either the mean, or if available, the mean ± standard deviation.

† Also includes an anterior line in a subset (n=23) of the patient cohort.

‡ These averages do not factor in the number of patients in each study sample. In addition, the range (minimum – maximum) is also shown.

References are listed in the **Supplement**.

Online Figure 1



## FIGURE LEGEND

### **Online Figure 1: Pulmonary Vein Isolation Times: Lattice-Tip vs Other Ablation Catheters. (A)**

The PVI radiofrequency application time of the lattice-tip (purple) was substantially lower than the times reported in major trials using other point-by-point RFA technologies including any force-sensing (green) and the recent temperature-guided (orange) saline-irrigated catheters, or the average of these various standard catheters (dark blue). **(B)** Similar results are seen for the PVI transpired ablation times – defined as time transpiring from the first to last PVI lesion – with the lattice-tip again less than the average of the various standard catheters (dark blue). **(C)** The LA dwell times, defined as the time transpiring from catheter entry to exit from the LA, have recently been reported for one-shot ablation technologies, but rarely for point RF catheters (the only time for the latter is shown in the hatched orange bar). The lattice-tip LA dwell time is in line with that observed for both balloon catheters, cryo (blue) and RF (red), and the recently reported one-shot pulsed field ablation basket catheter (green). Not all values are shown for all prior studies because they had not been reported. The specific references for these various trials are noted below.

## Additional References

- 1) Arbelo E, Guiu E, Bisbal F et al, Benefit of Left Atrial Roof Linear Ablation in Paroxysmal Atrial Fibrillation: A Prospective, Randomized Study. *J Am Heart Assoc*. 2014; 3:e000877 doi:10.1161/JAHA.114.000877).
- 2) Aryana A, Kenigsberg DN, Kowalski M, et al, Verification of a novel atrial fibrillation cryoablation dosing algorithm guided by time-to-pulmonary vein isolation: Results from the Cryo-DOSING Study (Cryoballoon-ablation DOSING Based on the Assessment of Time-to-Effect and Pulmonary Vein Isolation Guidance). *Heart Rhythm*. 2017; 14(9):1319-1325.
- 3) Chen S, Zhou G, Lu X et al, The importance of identifying conduction breakthrough sites across the mitral isthmus by elaborate mapping for mitral isthmus linear ablation. *Europace*. 2019; 21, 950–960.
- 4) Chinitz LA, Melby DP, Marchlinski FE, et al, Safety and efficiency of porous-tip contact-force catheter for drug-refractory symptomatic paroxysmal atrial fibrillation ablation: results from the SMART SF trial. *Europace*. 2018; 20, f392–f400.
- 5) Dukkipati SR, Cuoco F, Kutinsky I, et al, HeartLight Study Investigators. Pulmonary Vein Isolation Using the Visually Guided Laser Balloon: A Prospective, Multicenter, and Randomized Comparison to Standard Radiofrequency Ablation. *J Am Coll Cardiol*. 2015; 66(12):1350-60.
- 6) Fujisawa T, Kimura T, Nakajima K, et al, Importance of the vein of Marshall involvement in mitral isthmus ablation. *Pacing Clin Electrophysiol*. 2019; 42:617–624.
- 7) Iwasawa J, Koruth JS, Petru J, et al, Temperature-Controlled Radiofrequency Ablation for Pulmonary Vein Isolation in Patients With Atrial Fibrillation. *J Am Coll Cardiol*, 2017; 70(5):542-553.
- 8) Jaïs P, Hocini M, Hsu L-F, et al, Technique and Results of Linear Ablation at the Mitral Isthmus. *Circulation*. 2004; 110:2996-3002.
- 9) Kuck K-H, Brugada J, Fürnkranz A, et al, Cryoballoon or Radiofrequency Ablation for Paroxysmal Atrial Fibrillation. *N Engl J Med*. 2016; 374(23):2235-45.
- 10) Latcu DG, Squara F, Massaad Y, Bun S-S, Saoudi N and Marchlinski FE, Electroanatomic characteristics of the mitral isthmus associated with successful mitral isthmus ablation. *Europace*. 2016; 18, 274–280.
- 11) Lee JH, Nam G-B, Go T-H, et al, Alternative strategies to improve success rate of mitral isthmus block. *Medicine*. 2018; 97:48.
- 12) Matsuo S, Yamane T, Date T, et al, Completion of Mitral Isthmus Ablation Using a Steerable Sheath: Prospective Randomized Comparison with a Nonsteerable Sheath. *J Cardiovasc Electrophysiol*. 2011; 22:1331-1338.
- 13) Maurer T, Metzner A, Ho SY, et al, Catheter Ablation of the Superolateral Mitral Isthmus Line A Novel Approach to Reduce the Need for Epicardial Ablation. *Circ Arrhythm Electrophysiol*. 2017;10:e005191. DOI:10.1161/CIRCEP.117.005191.
- 14) Mujović N, Marinković M, Marković N, et al, The relationship of early recurrence of atrial fibrillation and the 3-month integrity of the ablation lesion set. *Sci Rep*. 2018; 8:9875, DOI:10.1038/s41598-018-28072-y.
- 15) Natale A, Reddy VY, Monir G, et al, Paroxysmal Atrial Fibrillation Catheter Ablation with a Contact Force Sensing Catheter –Results of the Prospective Multicenter SMART-AF Trial. *J Am Coll Cardiol*. 2014; 64(7):647-56.

- 16) Pak H-N, Oh YS, Lim He, Kim Y-H, and Hwang C, Comparison of voltage map-guided left atrial anterior wall ablation versus left lateral mitral isthmus ablation in patients with persistent atrial fibrillation. *Heart Rhythm*. 2011; 8:199–206.
- 17) Ramoul K, Wright M, Sohal M, et al, Does diffuse irrigation result in improved radiofrequency catheter ablation? A prospective randomized study of right atrial typical flutter ablation. *Europace*. 2015; 17, 295–299.
- 18) Reddy VY, Daly MG, Al-Ahmad A, et al, Feasibility Study of a Multi-electrode Radiofrequency Ablation Balloon Catheter System in Patients with Symptomatic Paroxysmal Atrial Fibrillation. *Heart Rhythm*. 2017; 14(5):S32-S33.
- 19) Reddy VY, Dukkipati SR, Neuzil P, et al, Randomized, Controlled Trial of the Safety and Effectiveness of a Contact Force-Sensing Irrigated Catheter for Ablation of Paroxysmal Atrial Fibrillation: Results of the TactiCath Contact Force Ablation Catheter Study for Atrial Fibrillation (TOCCASTAR) Study. *Circulation*, 2015; 132(10):907-15.
- 20) Reddy VY, Grimaldi M, De Potter T, et al, Pulmonary Vein Isolation With Very High Power, Short Duration, Temperature-Controlled Lesions: The QDOT-FAST Trial. *JACC Clin Electrophysiol*. 2019; 5(7):778-786.
- 21) Reddy VY, Neuzil P, Koruth JS, et al, Pulsed Field Ablation for Pulmonary Vein Isolation in Atrial Fibrillation. *J Am Coll Cardiol*. 2019; 74(3):315-326.
- 22) Reddy VY, Schilling R, Grimaldi M, et al, PV Isolation with a Novel Multielectrode Radiofrequency Balloon Catheter that Allows Directionally-Tailored Energy Delivery: Short-Term Outcomes from a Multicenter First-in-Human Study (RADIANCE). *Circ Arrhythm Electrophysiol*. 2019 (accepted)
- 23) Sato D, Mani H, Makihara Y, et al, Electrogram characteristics of the coronary sinus in cases requiring epicardial ablation within the coronary sinus for creating a conduction block at the left lateral mitral isthmus. *Journal of Interventional Cardiac Electrophysiology*. 2018; 53:53–61.
- 24) Scherr D, Derval N, Sohal M, et al, Length of the Mitral Isthmus But Not Anatomical Location of Ablation Line Predicts Bidirectional Mitral Isthmus Block in Patients Undergoing Catheter Ablation of Persistent Atrial Fibrillation: A Randomized Controlled Trial. *Cardiovasc Electrophysiol*. 2015; 26:629-634.
- 25) Wilber D, Pappone C, Neuzil P, et al, Comparison of Antiarrhythmic Drug Therapy and Radiofrequency Catheter Ablation in Patients with Paroxysmal Atrial Fibrillation: A Randomized Controlled Trial. *JAMA*, 2010; 303(4):333-40.
- 26) Wynn GJ, Panikker S, Morgan M, et al, Batrial linear ablation in sustained nonpermanent AF: Results of the substrate modification with ablation and antiarrhythmic drugs in nonpermanent atrial fibrillation (SMAN-PAF) trial. *Heart Rhythm*. 2016; 13:399–406.
- 27) Yokokawa M, Sundaram B, Garg A, et al, Impact of mitral isthmus anatomy on the likelihood of achieving linear block in patients undergoing catheter ablation of persistent atrial fibrillation. *Heart Rhythm*. 2011; 8:1404–1410.



## **Movie Legends**

***Online Video 1: The Self-Expanding Lattice Tip.*** The lattice electrode assumes its spherical shape upon exiting an 8.5Fr sheath.

***Online Video 2: Cavo-tricuspid Isthmus Line.*** Shown is creation of the entire CTI line with the lattice-tip catheter on the EAM system.

***Online Video 3: ICE Imaging During Cavo-tricuspid Isthmus Ablation.*** An intracardiac video of the lattice-tip on the cavo-tricuspid-isthmus demonstrates the wide thermal footprint, explaining the limited number of applications required for block.

***Online Video 4: Pulmonary Vein Isolation.*** Shown is creation of the entire left PVs isolating lesion with the lattice-tip catheter on the EAM system.

***Online Video 5: ICE Imaging During Pulmonary Vein Isolation.*** Shown is an intracardiac video of the lattice-tip situated at the ridge between the left PVs and LA appendage.

***Online Video 6: Posterior Mitral Isthmus Ablation.*** Shown is creation of the entire mitral isthmus ablation line with the lattice-tip catheter on the EAM system.

***Online Video 7: Lattice Tip Compressibility.*** On a slab of meat, the compressibility of the lattice electrode is shown.

***Online Video 8: Lattice Tip - Tissue Interaction.*** The interaction of the surface topography of the lattice electrode with tissue attenuates its tendency to slide across tissue during application of lateral force.