Comparison Of Minimal Versus Zero Fluoroscopic Catheter Ablations In Gestational Supraventricular Arrhythmias

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Abstract

Introduction: Management of gestational supraventricular tachycardia (SVT) is challenging and requires a multidisciplinary approach for optimal management. Antiarrhythmic pharmacologic therapy has variable efficacy and carries potential risks to both mother and fetus. Catheter ablation during pregnancy has traditionally been considered a last option due to procedural safety and ionizing radiation risks. Recent advances including intracardiac echocardiography and multi-electrode electroanatomic mapping have greatly enhanced the safety and efficacy profile to successfully perform ablations with minimal to no fluoroscopy even during pregnancy; however, most of the literature publications are case reports. Though the use of fluoroscopy-guided catheter ablations for refractory cardiac arrhythmias in pregnancy have been extensively studied, there are still a paucity of data about the efficacy, safety, and aggregate outcomes of purely zero-fluoroscopic ablations in comparison to minimal fluoroscopic approaches. Methods: A literature search was performed for catheter ablations in the past fifteen years for gestational arrhythmias that used minimal or no fluoroscopy. Sixteen cases describing catheter ablations with zero-fluoroscopy were compared to twenty-four cases using minimal fluoroscopy, defined as total documented exposure time of less than 10 minutes. Baseline characteristics, techniques, and outcomes of both groups were compared. Results: Analysis of both groups demonstrated that zero-fluoroscopic approaches for treatment of gestational SVT, though underutilized, have comparable successful outcomes without additional risk compared to minimally fluoroscopic procedures. Utilization of electroanatomic mapping with or without concomitant intracardiac echocardiography in the zero-fluoroscopy group further demonstrated equal efficacy rates of successful ablation when compared to the control group. Furthermore, there were no reported immediate or long term periprocedural complications in either group, including delivery outcomes. Conclusions: Zero-fluoroscopy catheter ablation for SVT in pregnancy appears to be as effective and safe when compared to minimal fluoroscopy ablations while eliminating the theoretical risks of ionizing radiation.

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Abstract

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Methods : A literature search was performed for catheter ablations in the past fifteen years for gestational arrhythmias that used minimal or no fluoroscopy. Sixteen cases describing catheter ablations with zero-fluoroscopy were compared to twenty-four cases using minimal fluoroscopy, defined as total documented exposure time of less than 10 minutes. Baseline characteristics, techniques, and outcomes of both groups were compared.

Results: Analysis of both groups demonstrated that zero-fluoroscopic approaches for treatment of gestational SVT, though underutilized, have comparable successful outcomes without additional risk compared to minimally fluoroscopic procedures. Utilization of electroanatomic mapping with or without concomitant intracardiac echocardiography in the zero-fluoroscopy group further demonstrated equal efficacy rates of successful ablation when compared to the control group. Furthermore, there were no reported immediate or long term periprocedural complications in either group, including delivery outcomes.

Conclusions : Zero-fluoroscopy catheter ablation for SVT in pregnancy appears to be as effective and safe when compared to minimal fluoroscopy ablations while eliminating the theoretical risks of ionizing radiation.

Key Words:

- Catheter ablation
- Fluoroscopy
- Arrhythmias
- Pregnancy / Gestation
- Supraventricular tachycardia

Introduction :

Supraventricular tachycardia poses a clinical challenge during pregnancy and necessitates careful risk-benefit considerations to both mother and fetus. Though non-sustained arrhythmias are common in pregnancy, symptomatic tachyarrhythmias warrant careful investigation. The mechanism of increased arrhythmia burden remains unclear though hormonal and autonomic changes likely play key roles in physiologic changes precipitating to arrhythmias. Furthermore, studies have shown that patients with pre-existing SVT may experience exacerbations during pregnancy due to stretching of atrial and ventricular myocytes, resulting in early after depolarizations, shortened refractoriness, slowed conduction, and spatial dispersion through activation of stretch-activated ion channels[1].

Catheter ablation is an alternative to pharmacologic therapy and advancements in electrophysiology techniques have allowed for successful ablations during pregnancy. However, one area of concern is the exposure of ionizing radiation to both mother and fetus. With the more widespread use of electroanatomic mapping and intracardiac echocardiography, fluoroscopy-free ablations are now feasible, though rarely described in the literature. Here, we review the characteristics of supraventricular tachyarrhythmias and outcomes of pregnant women who underwent zero-fluoroscopy ablations in comparison with cases of the more traditional minimal fluoroscopy approach.

Methods :

A Pub-Med, Medline, and Embase search were performed for catheter ablations in the past fifteen years for gestational arrhythmias that used minimal or no fluoroscopy. Sixteen cases describing catheter ablations with zero-fluoroscopy were compared to twenty-four cases using minimal fluoroscopy, defined as total documented exposure time of less than 10 minutes. The following data points were analyzed: maternal and gestational age, prior pharmacological therapy, presenting symptoms, arrhythmia etiology, and location. Cases describing cases of ventricular arrhythmias or arrhythmias secondary to recent surgical complications were not included in the data analysis. EKG findings, ablation procedure techniques, use of anesthesia, and complications were also included in the data.

Means and standard deviations along with the proportions of baseline clinical characteristics are reported with respect to the total number of patients in both the zero-fluoroscopy and minimal fluoroscopy groups. Mean gestational and maternal age at time ablations were analyzed. A comparative analysis of arrhythmias in both groups including subtype and left versus right-sided etiologies were completed. A 2-sample t-test was performed for continuous variables and a Chi-squared test was used for categorical variables when comparing parameters between the minimal fluoroscopy group and the zero-fluoroscopy group. A p-value of less than 0.05 was considered statistically significant.

Ablation Procedures

Supraventricular arrhythmias in both groups were AVNRT, AVRT, WPW, and atrial tachycardia arrhythmias (Table 1). In the zero-fluoroscopy group, 87.5% of procedures utilized electroanatomic mapping with and without intracardiac echocardiography, with 68.75% utilizing Ensite NavX and the remainder CARTO as the electroanatomic mapping tool. The majority of clinical arrhythmias in the zero-fluoroscopy group arose from the right side with six cases reported left-sided etiologies of arrhythmias and 3 requiring transseptal approaches. Similarly, the majority of cases in the minimal fluoroscopy group had culprit arrhythmias originating from right-sided regions (Table 2) Though there was no uniform documentation of the use of local versus general anesthesia in these cases, only two reported the use of generalized anesthesia in the zero-fluoroscopy group.

Results :

The majority of the ablations in the study group were performed in the second and third trimester of pregnancy, regardless of fluoroscopy use. The mean gestational age was 21.1 $\pm$ 7.3 weeks

weeks with a maternal age of 31 $\pm$ 8 years in the zero-fluoroscopy group versus a mean maternal age of 27 $\pm$ 4 years weeks and a gestational age of 25.8 $\pm$ 7.1 weeks in the minimal fluoroscopy group (Table 3). There was no statistical significance between the means for both groups in respect to maternal and gestational ages at time of ablation therapy. On average, patients undergoing zero-fluoroscopy ablations were at younger gestational ages ($p = 0.0591$) in comparison to the minimal fluoroscopy group, though the former had a greater maternal age ($p = 0.0597$). Three were of advanced maternal age, defined here as above 35 years old, in the zero-fluoroscopy group with no reported cases in the minimal fluoroscopy group.

Most patients initially presented with symptoms of palpitations, dizziness, and tachycardia. The majority had previously been on a beta-blocker regimen prior to recurrence. Three cases described the prior use of amiodarone, sotalol, or digoxin for arrhythmias.

A comparative breakdown of ablations performed based on etiology, location of arrhythmia, and approach for left sided arrhythmias can be seen in Table 4. All ablation procedures led to successful ablation of the culprit supraventricular tachycardia. There was no statistically significant difference in arrhythmia type including AVRT, AVNRT, and AT (p-values of 0.739, 0.601, 0.922, respectively.) In addition, there was no statistically significant difference between the two groups with respect to left sided procedures (p=0.792). Lastly, analysis of transeptal versus retrograde aortic approaches for left-sided ablations in both groups did not demonstrate statistical significance (p-values of 0.375 and 0.856, respectively).

There were no reported immediate perioperative complications and all reported fetal outcomes resulting in the successful delivery of healthy children. In addition to the advantage of zero exposure to ionizing radiation to the fetus and mother, all documented peri-procedural outcomes, both immediate and long-term complications were negligible.

Discussion :

This is the first systematic review comparing minimal to zero-fluoroscopic ablation for gestational supraventricular arrhythmias and demonstrates comparable safety and outcomes. Normal physiologic changes in pregnancy i.e., increased effective circulating volume, cardiac output, and resting heart rate may attribute to arrhythmogenesis. Sustained supraventricular tachycardias (SVTs) may occur in up to 1.3% of all pregnant women without structural heart disease and those with a history of arrhythmias are at significant recurrence risk[2].

Antiarrhythmic drugs, though effective, are not without risk in pregnancy as many cross the placental barrier with equivocal side effects. Most common pharmacologic options for gestational SVT remain a Food and Drug Administration category C, meaning risks could not be ruled out. The current lack of randomized trials and systematic data of the efficacy and safety of anti-arrhythmic drugs in pregnancy have caused a recent shift towards therapeutic catheter ablation procedures[3]. However, theoretical fluoroscopic radiation exposure to the fetus remains a particular concern of ablation therapy, especially in the first trimester during organogenesis[4]. Though the exposure levels for fetal abnormalities varies, a reasonable threshold for concern on fetal exposure is 50 mGy, a dose which has not been associated with fetal anomalies or pregnancy loss[24]. One study demonstrated that with proper abdominal shielding, theoretical fetal exposure during a catheter ablation procedure was $<$1 mGy[25]. Nevertheless, given the risks above, fluoroscopic free ablation is gaining wider acceptance as an alternative to treat pregnant patients with refractory arrhythmias[26].

Our baseline demographic data demonstrated similar findings in both groups including clinical presentations, with most arrhythmias consisting of Wolff-Parkinson-White, AVNRT, and atrial tachycardia. The majority of arrhythmias were right-sided in etiology with initial presentations of symptomatic tachycardia. Utilization of electroanatomic mapping with or without concomitant intracardiac echocardiography in the zero-fluoroscopy group were utilized in 87.5% of the cases. Furthermore, there was a trend towards a statistically significant difference between both maternal and gestational ages at time of ablation therapy. There were more zero-fluoroscopic ablations being performed at earlier gestational times, with minimal fluoroscopic ablations completed later in the third trimester. These findings are reflective of the inherent benefits of utilizing no ionizing radiation with zero-fluoroscopic procedures. Our findings demonstrated equal efficacy rates of successful ablation when compared to the minimal fluoroscopy group. There was no significant difference in the etiology of arrhythmias, whether it was right or left sided. In addition, there was similar rates of transeptal and retrograde aortic approaches for left-sided ablations. Regardless of techniques, there were equal successful outcomes in both groups. There were no documented immediate or long-term perioperative complications in the zero-fluoroscopy group, including delivery outcomes.

In rare cases where the culprit arrhythmia is refractory to both medical and ablative therapy or the patient is a poor candidate for ablations, sustained control of maternal tachyarrhythmias should ultimately be prioritized in the setting of hemodynamic compromise. Strategies may include initiation or escalation of pharmacotherapy with close inpatient monitoring and consideration of a timely cesarean section[5]. Ultimately, it is imperative to have shared decision making and collaboration amongst cardiology, maternal fetal medicine

and obstetric specialists to ensure maximum safety to both mother and fetus.

One major limitation of our review was the lack of uniform documentation as all data points were derived from individual case reports or series, including use of anesthesia, duration of post-procedural follow up, obstetric complications, and prior pharmacologic strategies for rhythm control.

Our study shows that zero-fluoroscopy catheter ablation for supraventricular tachycardia ablation in pregnancy using current electroanatomic mapping systems with or without ICE have equivalent safety and efficacy compared to minimal fluoroscopy ablations, while eliminating the risk of ionizing radiation exposure to both the mother and fetus.

References

1. Franz MR, Cima R, Wang D, Profitt D, Kurz R. Electrophysiological effects of myocardial stretch and mechanical determinants of stretch-activated arrhythmias. Circulation. 1992; 86:968–978.
2. Hong RA, Bandari AK: Cardiac arrhythmias and pregnancy. In: Elka-yam U, Gleicher N, eds. Cardiac Problems in Pregnancy: Diagnosis and Management of Maternal and Fetal Disease, 2nd ed. New York:Alan R. Liss, Inc, 1990, pp. 167-180
3. Omaygenc MO, Karaca IO, Guler E, Kizilirmak F, Cakal B, Gunes HM, Kilicaslan F. Radiofrequency catheter ablation of supraventricular tachycardia in pregnancy: Ablation without fluoroscopic exposure. Heart Rhythm. 2015 May;12(5):1057-61. doi: 10.1016/j.hrthm.2015.01.037. Epub 2015 Jan 27. PMID: 25637564.
4. Chen G, Sun G, Xu R, Chen X, Yang L, Bai Y, Yang S, Guo P, Zhang Y, Zhao C, Wang DW, Wang Y. Zero-fluoroscopy catheter ablation of severe drug-resistant arrhythmia guided by Ensite NavX system during pregnancy: Two case reports and literature review. Medicine (Baltimore). 2016 Aug;95(32):e4487. doi: 10.1097/MD.0000000000004487. PMID: 27512864; PMCID: PMC4985319.
5. Bongiorni MG, Di Cori A, Soldati E, Zucchelli G, Segreti L, Solarino G, De Lucia R, Marzilli M. Radiofrequency catheter ablation of atrioventricular nodal reciprocating tachycardia using intracardiac echocardiography in pregnancy. Europace. 2008 Aug;10(8):1018-21. doi: 10.1093/europace/eun120. Epub 2008 May 6. PMID: 18460548.
6. Bigelow AM, Crane SS, Khoury FR, Clark JM. Catheter ablation of supraventricular tachycardia without fluoroscopy during pregnancy. Obstet Gynecol. 2015 Jun;125(6):1338-1341. doi: 10.1097/AOG.0000000000000601. PMID: 25774933.
7. Ferguson JD, Helms A, Mangrum JM, DiMarco JP. Ablation of incessant left atrial tachycardia without fluoroscopy in a pregnant woman. J Cardiovasc Electrophysiol. 2011 Mar;22(3):346-9. doi: 10.1111/j.1540-8167.2010.01847.x. PMID: 20662991.
8. Barros CBS, Chokr MO, Pisani C, Leite TSB, Avila WS, Scanavacca MI. Catheter ablation of atrial tachycardia on the non-coronary aortic cusp during pregnancy without fluoroscopy. HeartRhythm Case Rep. 2018 Aug 29;4(12):566-569. doi: 10.1016/j.hrcr.2018.08.010. PMID: 30581733; PMCID: PMC6301911.
9. Greyling A, Vlachou C, Ailoaei S, Buchholz T, Toth B, Ernst S. Catheter mapping and ablation during pregnancy. Herzschrittmacherther Elektrophysiol. 2021 Jun;32(2):164-173. English. doi: 10.1007/s00399-021-00756-5. Epub 2021 Mar 29. PMID: 33782753.
10. Prolic Kalinšek T, Jan M, Rupar K, Ražen L, Antolic B, Žižek D. Zero-fluoroscopy catheter ablation of concealed left accessory pathway in a pregnant woman. Europace. 2017 Aug 1;19(8):1384. doi: 10.1093/europace/euw257. PMID: 28339666.
11. Zuberi Z, Silberbauer J, Murgatroyd F. Successful Non-fluoroscopic Radiofrequency Ablation of Incessant Atrial Tachycardia in a High Risk Twin Pregnancy. Indian Pacing Electrophysiol J. 2014 Jan 1;14(1):26-31. doi: 10.1016/s0972-6292(16)30712-4. PMID: 24493913; PMCID: PMC3878584.
12. Mohd Said MR, Gian Singh SS, Lee KT, Khor LM, Chea CY, Silveraju AR, Mohd Firdaus MA, Karthikesan D, Muthuppalaniappan AM, Abdullah AS, Ismail O, Narasamuloo KR, Krishinan S. From darkness, a light shall spring: Zero-fluoroscopic ablation of supraventricular tachycardia in a pregnant lady. J Arrhythm. 2020 Dec 26;37(1):251-253. doi: 10.1002/joa3.12485. PMID: 33664912;

PMCID: PMC7896443.

13. Jeong HK, Yoon N, Park HW, Cho JG. Radiofrequency catheter ablation without radiation exposure in a 13th week pregnant woman with Wolff-Parkinson-White syndrome. Rev Cardiovasc Med. 2020 Jun 30;21(2):303-307. doi: 10.31083/j.rcm.2020.02.46. PMID: 32706218.
14. Kaspar G, Sanam K, Gundlapalli S, Shah D. Successful fluoroless radiofrequency catheter ablation of supraventricular tachycardia during pregnancy. Clin Case Rep. 2018 May 29;6(7):1334-1337. doi: 10.1002/ccr3.1623. PMID: 29988698; PMCID: PMC6028421.
15. Berruezo A, Díez GR, Berne P, Esteban M, Mont L, Brugada J. Low exposure radiation with conventional guided radiofrequency catheter ablation in pregnant women. Pacing Clin Electrophysiol. 2007 Oct;30(10):1299-302. doi: 10.1111/j.1540-8159.2007.00858.x. PMID: 17897139.
16. Bombelli F, Lagona F, Salvati A, Catalfamo L, Ferrari AG, Pappone C. Radiofrequency catheter ablation in drug refractory maternal supraventricular tachycardias in advanced pregnancy. Obstet Gynecol. 2003 Nov;102(5 Pt 2):1171-3. doi: 10.1016/s0029-7844(03)00119-4. PMID: 14607046.
17. Szumowski L, Szufladowicz E, Orczykowski M, Bodalski R, Derejko P, Przybylski A, Urbanek P, Kuśmierczyk M, Koźluk E, Sacher F, Sanders P, Dangel J, Haissaguerre M, Walczak F. Ablation of severe drug-resistant tachyarrhythmia during pregnancy. J Cardiovasc Electrophysiol. 2010 Aug 1;21(8):877-82. doi: 10.1111/j.1540-8167.2010.01727.x. Epub 2010 Feb 11. PMID: 20158563.
18. Kanjwal Y, Kosinski D, Kanj M, Thomas W, Grubb B. Successful radiofrequency catheter ablation of left lateral accessory pathway using transseptal approach during pregnancy. J Interv Card Electrophysiol. 2005 Sep;13(3):239-42. doi: 10.1007/s10840-005-2493-1. PMID: 16177852.
19. Wu H, Ling LH, Lee G, Kistler PM. Successful catheter ablation of incessant atrial tachycardia in pregnancy using three-dimensional electroanatomical mapping with minimal radiation. Intern Med J. 2012 Jun;42(6):709-12. doi: 10.1111/j.1445-5994.2012.02812.x. PMID: 22697153.
20. Raman AS, Sharma S, Hariharan R. Minimal use of fluoroscopy to reduce fetal radiation exposure during radiofrequency catheter ablation of maternal supraventricular tachycardia. Tex Heart Inst J. 2015 Apr 1;42(2):152-4. doi: 10.14503/THIJ-14-4173. PMID: 25873828; PMCID: PMC4382883.
21. Yang PS, Park J, Pak HN. Radiofrequency catheter ablation of incessant atrial tachycardia in pregnant women with minimal radiation exposure: Lessons from two case studies. J Cardiol Cases. 2014 Feb 28;9(6):213-216. doi: 10.1016/j.jccase.2014.02.001. PMID: 30534329; PMCID: PMC6278677.
22. Hung PN, Dan NV, Tuan NX, Tung PV, Tuan NQ (2020) Catheter Ablation of Cardiac Arrhythmias in Pregnancy with Limited Fluoroscopy. Interv Cardiol J Vol.6 No.1:89
23. Leiria TLL, Pires LM, Kruse ML, de Lima GG: Supraventricular tachycardia and syncope during pregnancy: A case for catheter ablation without fluoroscopy. Portuguese J Cardiol 2014;33:805.e1-5.
24. Best PJ, Skelding KA, Mehran R, Chieffo A, Kunadian V, Madan M, Mikhail GW, Mauri F, Takahashi S, Honye J, Hernández-Antolín R, Weiner BH; Society for Cardiovascular Angiography & Interventions' Women in Innovations (WIN) Group. SCAI consensus document on occupational radiation exposure to the pregnant cardiologist and technical personnel.Catheter Cardiovasc Interv. 2011; 77:232–241.
25. Damilakis J, Theocharopoulos N, Perisinakis K, Manios E, Dimitriou P, Vardas P, Gourtsoyiannis N. Conceptus radiation dose and risk from cardiac catheter ablation procedures.Circulation. 2001; 104:893–897.
26. Tamirisa K, Elkayam U, Briller J, et al. Arrhythmias in Pregnancy. J Am Coll Cardiol EP. 2022 Jan, 8 (1) 120–135.

Tables

Source	Maternal Age	Gestational age (weeks)	Arrhythmia	Pharmacologic Therapy
Omaygenc[3]	27	21	AVRT-WPW	Metoprolol
	21	30	AVNRT	Metoprolol
	25	12	WPW	Metoprolol
Guangzhi, Chen[4]	33	31	PVC	Beta blocker
	22	25	AVRT-WPW	Beta blocker
Bongiomi[5]	32	10	AVNRT	None

Bigelow[6]	27	22	AVNRT	Propranolol, flecainide
Ferguson[7]	20	27	AT	Beta blocker, calcium channel blocker,
Barros[8]	32	12	AT	Propafenone and sotalol
Greyling[9]	26	17	AT	Beta blocker
Kalinsek[10]	32	22	AVRT; orthodromic	None
Zuberi[11]	48	30	AT	Labetalol, digoxin
Said[12]	49	28	AVNRT	Labetalol
Jeong[13]	36	13	WPW, a-fib	None
Kaspar[14]	34	11	SVT	Sotalol, amiodarone
Leiria [23]	33	26	ORT, LL AP	Sotalol

Table 1: Zero fluoroscopy ablation procedure techniques, outcomes, and location of clinical arrhythmia

AT: atrial tachycardia ; AVNRT: AV nodal re-entry tachycardia ; WPW: Wolf-Parkinson White ; PVC: premature ventricular contraction ; ORT: orthodromic reciprocating tachycardia ; SVT: supraventricular tachycardia; ICE: intracardiac echocardiography

Source	Maternal Age (yrs)	Gestational Age (weeks)	Arrhythmia (Ablation Site If Defined)	Fluoroscopy Time	Clinical Presentation	Right vs Left-Sided Etiology
Berruezo[15]	30	30	AT / right atrial appendage	8 min 1 s	Palpitations	Right
	22	12	ORT, left atrial appendage	1 min 49s	Palpitations / Chest Pain	Left
Bombelli[16]	27	29	WPW	6 min 48s	Tachycardia	Left ; retrograde
	28	30	AVNRT	8 min 36s	Tachycardia	Right
Szumowski[17]	29	37	AT / tricuspid annulus	1 min 10 s	Syncope	Right
	34	38	AVRT	28s	Tachycardia	Right
	24	35	AVNRT	53s	Tachycardia	Right
	31	31	ORT , left atrial appendage	1 min 46s	Syncope	Left ; retrograde
	27	22	ORT, left atrial appendage	57s	Palpitations and Syncope	Left ; retrograde
	27	12	ORT, left atrial appendage	60s	Palpitations and Syncope	Left; retrograde
Kanjwal[18]	32	22	WPW-AVRT / lateral mitral isthmus	7 min 37s	Palpitations/Chest Pain	Left ; transeptal
Wu[19]	32	14	AT / right atrial appendage	55s	Palpitations / Dyspnea	Right

Source	Maternal Age (yrs)	Gestational Age (weeks)	Arrhythmia (Ablation Site If Defined)	Fluoroscopy Time	Clinical Presentation	Right vs Left-Sided Etiology
Raman[20]	18	33	AT / mitral annulus	1 min 18s	Palpitations/Dyspnea	Left ; transeptal
Yang[21]	30	17	AT / sinus venosus	6 min	Chest flutters/Dyspnea	Right
	32	21	AT / right atrial free wall	1 min	Tachycardia / Dyspnea	Right
Hung[22]	27	31	AT / right atrial appendage	2 min 24s	Tachycardia	Right
	19	28	AT / coronary sinus ostium	2 min 55s	Tachycardia	Right
	32	28	SVT / right ventricular outflow tract	1 min 44s	Tachycardia	Right
	21	24	WPW / LFW accessory pathway	2 min 5s	Tachycardia	Left
	25	21	AVRT / LFW accessory pathway	3 min 24s	Tachycardia	Left
	24	27	WPW / left septal accessory	3 min 13s	Tachycardia	Left
	27	25	WPW / right posterior free wall accessory	2 min 12s	Tachycardia	Right
	28	26	AVNRT / slow pathway	49 s	Tachycardia	Right
	26	28	AVNRT / slow pathway	27 s	Tachycardia	Right

Table 2: Clinical arrhythmias, ablation sites, total duration time and presenting symptoms in minimal fluoroscopy (<10 min) ablation cases. AT: atrial tachycardia ; AVNRT: AV nodal re-entry tachycardia ; WPW: Wolf-Parkinson White ; AVRT: atrioventricular reentrant tachycardia; PVC: premature ventricular contraction ; ORT: orthodromic reciprocating tachycardia ; SVT: supraventricular tachycardia ; LFW: left free wall

	Zero-Fluoroscopy	**Minimal Fluoroscopy**	**P-Value (< .05)**
Total Number of Cases (n)	16	24	

	Zero-Fluoroscopy	**Minimal Fluoroscopy**	**P-Value ($<$ .05)**
Mean Fluoroscopy Time (x)	N/A	173.79 ± 159.01 seconds	
Mean Gestation Week at Time of Ablation (x)	21.1 ± 7.3 weeks	25.8 ± 7.1 weeks	0.0591
Mean Maternal Age at Time of Ablation (x)	31 ± 8 years	27 ± 4 years	0.0597

Table 3: Comparison of zero-fluoroscopy vs minimal fluoroscopy demographics

Arrhythmias	**Zero-Fluoroscopy**	**Minimal Fluoroscopy**	**P-Value ($<$ .05)**
Total Left-Sided Arrhythmias (n)	6	10	0.792
Total AVRT Arrhythmias	6	11	0.739
Left-sided AVRT Arrhythmias	3	9	0.169
Total AVNRT Arrhythmias	4	4	0.601
Total AT Arrhythmias	5	8	0.922
Left-sided AT Arrhythmias	3	1	0.2
Transeptal Approach (Left-Sided)	3	2	0.375
Aortic Retrograde Approach (Left-Sided)	2	4	0.856
Unspecified Approach	1	4	

Table 4: Zero-fluoroscopy vs minimal Fluoroscopy by arrhythmia type and left atrial location (values listed are represented as numbers for categorical variables)