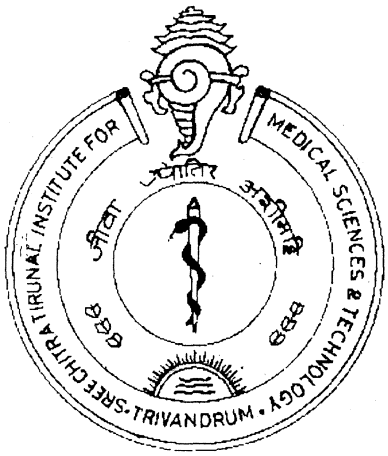


SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES & TECHNOLOGY

TRIVANDRUM-695011

PROJECT REPORT

NAME	:	K.SANTOSH KUMAR DORA
PROGRAMME	:	POST DOCTORAL FELLOWSHIP
STUDY PERIOD	:	FEBRUARY 2002 TO JAN 2003

Dr. Jaganmohan A. Tharakan M.D., D.M.
Professor and Head
Department of Cardiology
SCTIMST
Trivandrum

This is to certify that Dr. K. Santosh Kumar Dora has carried out the project entitled "Electrophysiological study to determine the mechanism of rheumatic atrial flutter" during his post doctoral fellowship period in the department of Cardiology, SCTIMST.

Dr. Jaganmohan A. Tharakan

Acknowledgement

It is a proud privilege for me to express my deep sense of gratitude and respect to my esteemed teacher and guide Dr. V.K. Ajith Kumar, additional professor, Department of cardiology, SCTIMST for his constant supervision and valuable guidance without which the present work would not have been materialized.

With great esteem, I express my sincere thanks to my esteemed teacher Professor J.A. Tharakan, Head of the Department of Cardiology, SCTIMST for guiding and providing every facility to carry out the study.

Dr. K. Santosh Kumar Dora

ELECTROPHYSIOLOGICAL STUDY IN DETERMINING THE MECHANISM OF RHEUMATIC ATRIAL FLUTTER

Introduction:

Atrial flutter, unlike other forms of atrial tachyarrythmia i.e. paroxysmal supraventricular tachycardia, ectopic atrial tachycardia, atrial fibrillation etc, is relatively uncommon. According to western literature the incidence of atrial flutter ranges from 5 per 1,00,000 in less than 50 yr old to 587 per 1,00,000 in subjects older than 80 yr age[1]. Systematic studies on incidence and prevalence of atrial flutter is lacking in Indian subcontinent. Persistent and chronic atrial flutter is usually associated with underlying heart disease i.e.ischemic heart disease, cardiomyopathy, valvular heart disease etc[2].

Initially atrial flutter had been classified into two types: typical and atypical[3]. Typical atrial flutter is recognized by negative F waves in II, III, aVF and atypical flutter is recognized by positive F waves in II, III, and aVF. Presently it is well known that typical and atypical atrial flutter share the same reentrant circuit in counterclockwise or clockwise fashion. Wells and Colleagues described two distinct type of atrial flutter that are widely recognized subsequently: type I and type II[4]. Type I atrial flutter can be interrupted by rapid atrial pacing where as type II atrial flutter cannot[4, 5]. In the absence of drug therapy, type I atrial flutter is characterized by atrial rate ranging from 240-340 beats per minute and type II atrial flutter, atrial rate ranging from 340-433 beats per minute[4, 5]. Type I atrial flutter uses a single right atrial macro reentrant circuit with well-defined anatomic and functional boundaries. The wave front travels up the interatrial septum and down the atrial free wall along the crista terminalis and then through the isthmus bound by the tricuspid valve ring and the region extending from the IVC to the Eustachian valve[6-10]. The conduction velocity at the right atrial isthmus is slow[11, 12]. The

slow conduction has been further substantiated by unipolar intracardiac electrogram recordings[13]. The slow nonuniform anisotropic conduction is attributed to the cris-cross muscular trabecular pattern in the isthmus[14]. The importance of slow conduction at the IVC-tricuspid annulus junction to sustain atrial flutter has been highlighted in many mapping techniques[15-18]. Crista terminalis forms a functional transverse block, which may be related to rate of tachycardia, thus enlarging the reentrant circuit to sustain atrial flutter[19.20]. Atrial flutter can also arise with a circuit around an incisional scar after a surgical procedure[21]. Considering these various etiological and electrophysiological factors atrial flutter is currently classified into five different types as follows[22].

1. Typical atrial flutter
2. Reverse typical atrial flutter
3. Incisional atrial flutter
4. Left atrial flutter
5. Atypical atrial flutter

Typical and reverse typical explains to the right atrial isthmus dependent atrial flutter of counterclockwise or clockwise fashion. Incisional atrial flutter describes to a scar dependent atrial flutter owing to a previous surgical procedure as described earlier. Left atrial flutter circuit is confined to left atrium, which is a now a days increasingly recognized especially when left atrium is diseased. When the atrial flutter does not fit to any of the above types described, it is termed as atypical atrial flutter. Considerable work has been done on different aspects of atrial flutter over last two decades. Atrial flutter is often seen in patients of Rheumatic heart disease also. As Rheumatic heart disease is rare in western countries, there is little data on atrial flutter

in Rheumatic heart disease. Detailed electrophysiological studies on the mechanism of atrial flutter in Rheumatic heart disease are lacking. This study aims to find out the electrophysiological characteristics of atrial flutter in patients of Rheumatic heart disease.

Methods:

Between February 2002 to December, 2002 four patients of rheumatic heart disease and atrial flutter were studied. Base line characteristics are noted in table-1. Written informed consent was obtained from all patients after discussing risk and benefits of the procedure. Patients had been under effective oral anticoagulants for more than 1 month before the electrophysiological procedure. Oral anticoagulants were stopped and replaced by I.V. heparin 5 days prior to the procedure. Atrial flutter was defined by an atrial rate ranging from 200 to 350 per minute with identically recurring regular saw tooth flutter waves, and evidence of continual electrical activity, visualized in any ECG leads. Patients having atrial flutter with echocardiographic evidence of a rheumatic heart disease with or with out any anti-arrhythmic drugs were taken up for the study if the valvular lesions were not very significant and the patient was in NYHA functional class I or II. Patients having significant valvular lesion requiring any intervention or surgery were excluded. Patients with atrial flutter but without having any evidence of rheumatic heart disease were excluded.

Electrocardiogram:

A 12 lead electrocardiogram and rhythm strips of inferior and Precordial leads were taken in all the cases prior to the study. The rate and morphology of F waves were noted.

Echocardiogram:

Transthoracic 2-D echocardiogram and Doppler study was performed in all the cases. Dimensions of different cardiac chambers and ventricular functions were determined. LA size was taken in both parasternal long axis and 4 chamber apical view.

RA size was taken in 4 chamber apical view. Mitral valve area was determined by both 2-dimensional and pressure half time method and severity of the mitral stenosis was assessed from a mean of 3 consecutive values. All other lesion severities were determined by Doppler method. A transesophageal echocardiogram was not absolutely necessary and was done as and when required.

Angiogram:

Right atrial angiogram was performed by injecting 25 ml of nonionic contrast (Iopamidol) by a 7F NIH catheter placed at junction of IVC and RA in RAO 45°. The long axis length of right atrium, length of isthmus, length of PR (pouch like recess), vestibule and depth of PR were determined.

Electrophysiological study:

All antiarrythmic drugs were withdrawn at least five half-lives prior to the study except Amiodarone because of its long half-life period. Amiodarone was stopped at the time of admission for electrophysiological study. Venous access were taken at right femoral vein (RFV), left femoral vein (LFV), and right jugular vein (RJV). Three 6F quadripolar catheters (BARD)were put at high right atrium, HIS bundle and right ventricular apex region respectively via RFV or LFV. A 6F Decapolar catheter (BARD) was put at coronary sinus via right internal jugular vein. A 7F twenty polar Halo catheter (BARD) was put at tricuspid annulus via right or left femoral vein. A 7F Quadripolar ablation catheter (BARD STINGER) was put at right atrium via right femoral vein for mapping/stimulation or radiofrequency ablation purpose. Mapping of RA was performed initially to document type and nature of the atrial flutter. Isthmus dependent right atrial flutter was excluded by following electrophysiological findings.

1. The site of earliest right atrial activation at the Bachman bundle region.
2. Right atrial activation as determined by sequential conventional mapping accounting for less than 50% of the arrhythmia cycle length or lesser by at least 100 ms.
3. Post pacing interval in right atrium longer than the flutter cycle length by more than 30 ms at multiple points in RA including cavo-tricuspid isthmus and RA free wall.

Results:

Base line characteristics:

Duration of the study: February 2002-December 2002	
Number of patients:	4 (Male: 2, Female: 2)
Age:	37±8.48 yrs
Rheumatic hear disease:	4
Prior surgical procedures:	
ASD closure:	1
Closed mitral valvotomy:	2
Balloon mitral valvotomy:	1 (Had CMV earlier)
No procedures:	1
Functional class:	
NYHA class I:	2
NYHA class II:	2
Drugs:	
Amiodarone:	3

Digoxin: 1

Atenolol: 1 (same patient taking Digoxin)

Electrocardiographic features:

Atrial rate: 232±26.72 beats per minute

F wave morphology:

Inferior leads –ve: 2

Inferior leads +ve: 2

V1 -ve: 0

V1 +ve: 4

The average atrial flutter rate is 232±26.72 beats per minute. The lower average atrial flutter rate was due to the fact that most of the patients were on Amiodarone prior to the study. Due to the long half-life of Amiodarone the drug effect was possibly present. The electrocardiogram showed –ve F wave in inferior leads in 2 patients and +ve F wave in inferior leads in 2 patients. The F waves were +ve in V1 in all the cases. The pattern of F wave showed a typical atrial flutter in all the cases although +ve F wave in both inferior leads and V1 in the same patient is an uncommon combination. The typical pattern of F wave morphology in inferior leads in all the patients prompted a systematic electrophysiological study and radiofrequeny ablation.

Echocardiogram:

Mitral stenosis:

Mild: 4

Moderate: 0

Severe: 0

2D mitral valve area:	1.735±0.30cm^2
PHT mitral valve area:	1.825±0.32cm^2
Mitral regurgitation:	
Trivial:	1
Mild:	2
Moderate:	1
Severe:	0
Tricuspid stenosis:	
Mild:	2
Moderate:	0
Severe:	0
Tricuspid regurgitation:	
Mild:	0
Moderate:	2
Severe:	0
Aortic valve disease:	
Moderate aortic regurgitation:	1
Long axis atrial chamber dimension:	
Left atrium:	75.75±13.30 mm
Right atrium:	55.5±36.60 mm

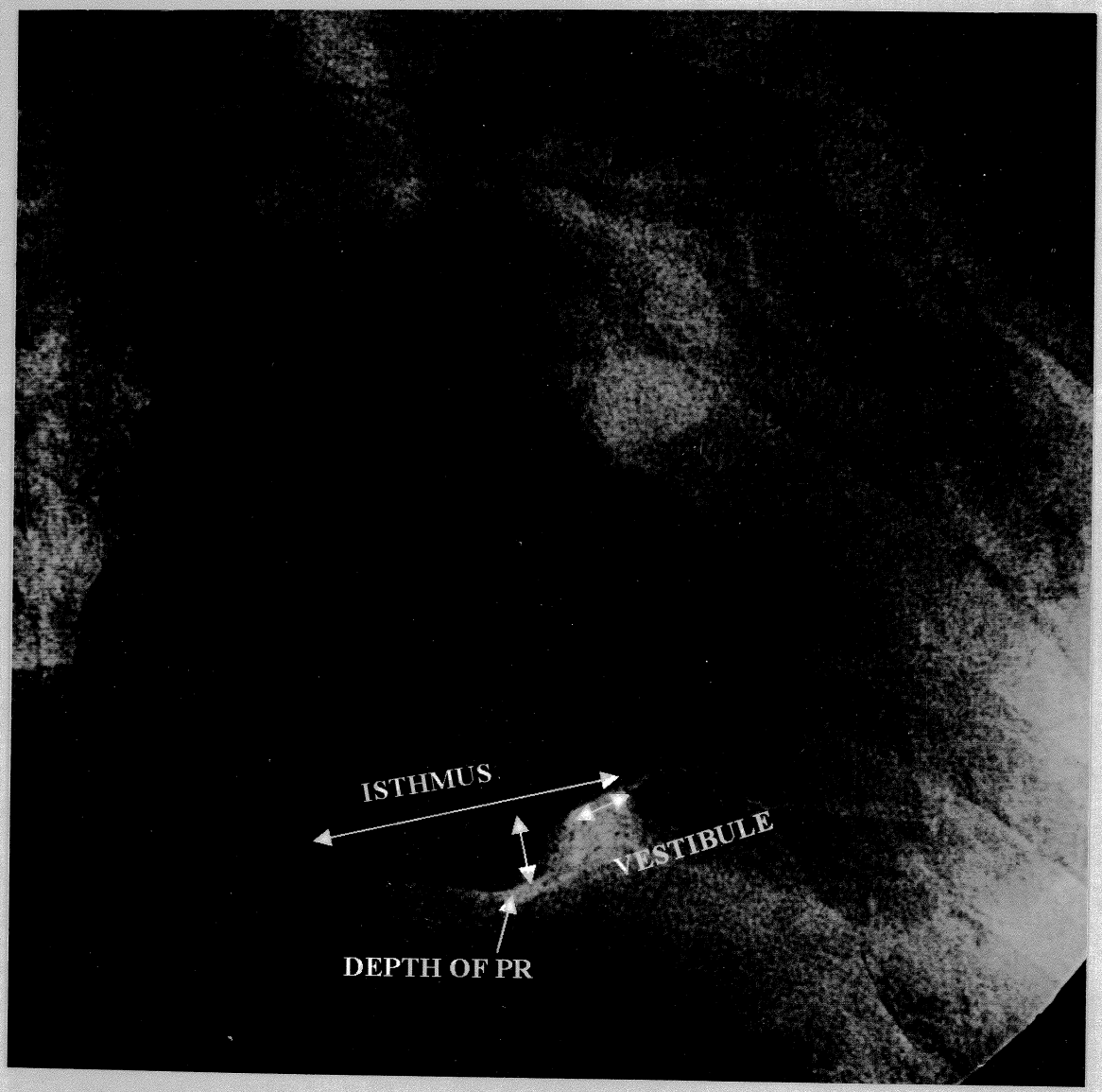
Echocardiogram revealed features of Rheumatic Heart Disease in all the patients. None of the patients had significant valvular lesion prior to the study. Mitral stenosis was present in all the patients but was mild in severity. Moderate mitral regurgitation was

present in only one patient. One patient was having aortic valve disease in the form of moderate aortic regurgitation. Organic tricuspid valve disease was present in two patients with mild tricuspid stenosis and moderate tricuspid regurgitation in both the patients. The long axis length of left atrium and right atrium were measured in all the patients in four chamber apical view. It showed left atrial dimension of 75.75±13.30 mm and right atrial dimension of 55.5±36.60 mm. In the patients having organic tricuspid valve lesion the mean right atrial length was 70±25.44 mm. These measurements showed significant enlargement of both atrial dimensions, especially left atrium in these cases of rheumatic heart disease with atrial flutter.

Angiographic study:

Right atrial length:	74.3±7.89 mm
Isthmus length:	43±9.16 mm
Pouch like recess length:	32.53±10.07 mm
Vestibule length:	12.13±1.80 mm
Pouch like recess depth:	7.88±0.81 mm

Routine RA angiogram had been planned and performed to have knowledge regarding the isthmus to decide regarding choice of appropriate size radiofrequeny ablation catheter to facilitate ablation process. Right atrial angiogram showed increased length of right atrial dimension and isthmus length. The mean right atrial length was 74.3±7.89mm. The mean isthmus length was 43±9.16mm. The organic tricuspid valve disease contributed the increased length of right atrium and isthmus. Chronic atrial flutter and chronic rheumatic process in the absence of rheumatic prophylaxis also contributes to the increased right atrial and isthmus dimensions.

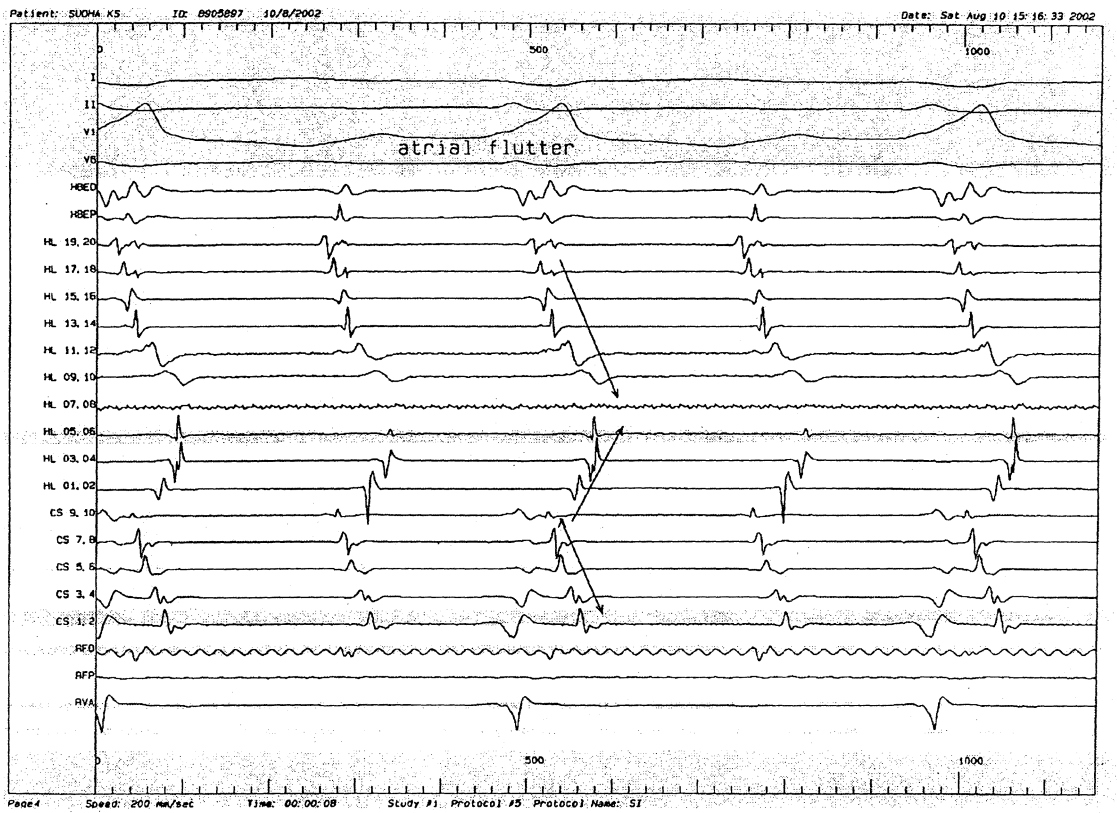

ISTHMUS
VESTIBULE
DEPTH OF PR

Right atrial angiogram:

Right atrial angiogram has been done by injecting contrast at IVC-RA junction by a 7-french NIH catheter. It shows the right atrial isthmus, the vestibule and the pouch like recess. The isthmus extends from IVC-RA junction to tricuspid valve annulus. The vestibule extends from the tricuspid annulus to the beginning of pouch like recess and consists of the smooth part of the isthmus. The pouch likes recess begins from the end of vestibule to the IVC-RA junction and consists of the rough part of the isthmus.

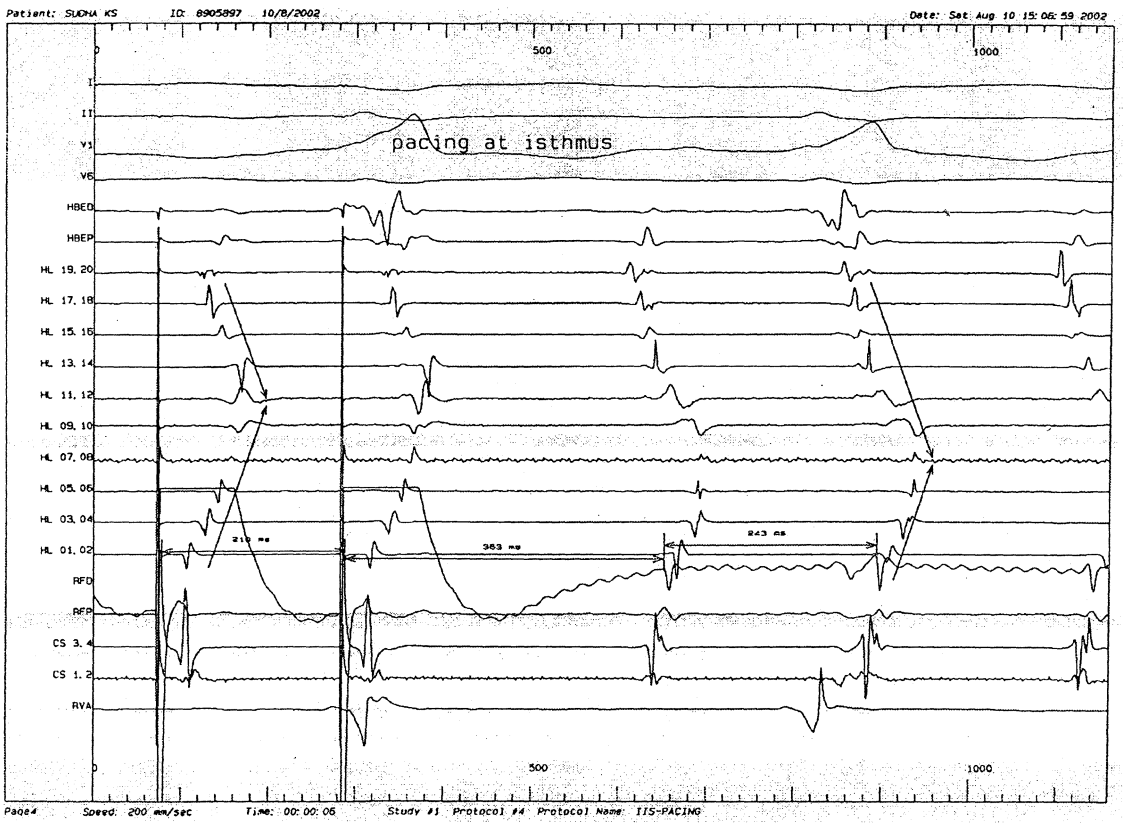
Electrophysiological study:

Name	Age	Sex	Lesion	F Cl	Atrial CL	RA AT	Act pattern	Entrain(RAFW)	PPI	T CL	Entrain(IST)	PPI	TCL
JK	31	M	RHD, CMV 81,89 BMV 94, Mild MS,MR Mild TS,Mod TR	I	270ms	160ms	Clockwise	+	326ms	270ms	+	290ms	260ms
MJ	47	F	RHD,Mild MS,Mod MR Mild TS, Mod TR Mod AR	II	222ms	140ms	Bidirectional	–	–	–	–	–	–
SD	40	F	RHD, CMV 94,BMV 02 Mild MS, Mod MR	I	245ms	90ms	Bidirectional	+	355ms	243ms	+	363ms	243ms
TD	37	M	RHD, Post OP ASD CL Mild MS, MR	II	263ms	163ms	Counterclockwise	+	296ms	256ms	+	296ms	256ms



Atrial flutter:

Halo catheter shows the pattern of activation wave front in the right atrium. Halo 1,2 represents isthmus, halo 7,8 represents right atrial freewall, halo 13,14 represents right atrial roof and halo 19,20 represents low atrial septal region. The activation wave front shows beginning of the activation simultaneously at isthmus and low atrial septal region and proceeding away from CSOS and meeting at right atrial freewall. This type of bi-directional wave front in the right atrium effectively rules out isthmus dependent classic right atrial flutter.



Pacing at isthmus to entrain atrial flutter:

Atrial pacing cycle length: 210ms, Post Pacing interval: 363ms,Atrial flutter cycle length: 243ms. A difference of 80 ms between the post pacing interval and the atrial flutter cycle length indicates that the isthmus is not a part of the flutter circuit.

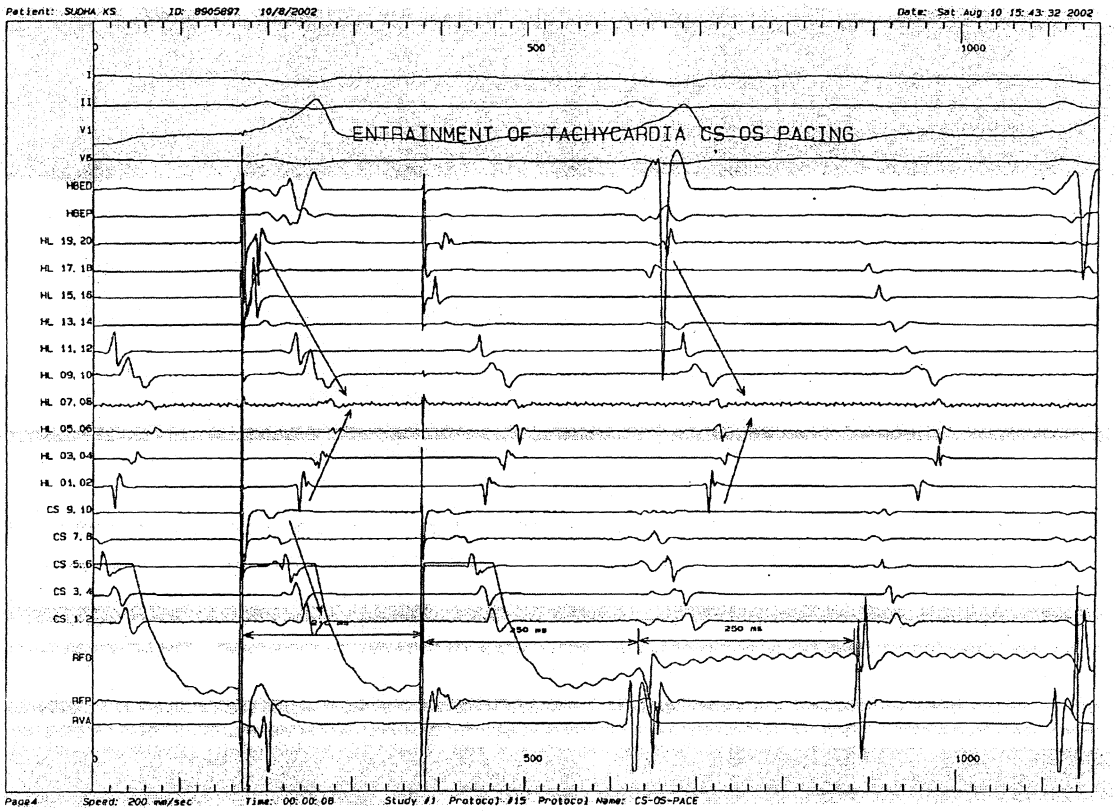


Fig 3: Pacing at CSOS to entrain the atrial flutter:

Pacing cycle length: 210ms, Post pacing cycle length: 250ms, atrial flutter cycle length: 250ms. Post pacing cycle length equal to flutter cycle length indicates that CSOS is a part of the flutter circuit.

Predetermined criterias were used to determine the nature of the atrial flutter. The average atrial cycle length was low (250±21.43ms). This lower atrial flutter rate can be explained because of use of amiodarone in all but one of the patients. The right atrial activation time remained significantly low compared to the flutter cycle length with a difference of $\geq$ 100 ms in all but one of the cases. In the patient having the difference in atrial cycle length to right atrial activation time of less than 100 ms (80 ms) the right atrial activation pattern remained bi-directional with starting point at Bachman's bundle region. The flutter wave front propagation in right atrium was bi-directional in two patients including the case described earlier. Bi-directional wave front propagation with convergence at right atrial freewall clearly excludes isthmus dependent atrial flutter. The wave front propagation remained counterclockwise or clockwise in right atrium around Tricuspid annulus in twp other cases, which supports the possibility of isthmus dependent right atrial flutter. But in both the cases the right atrial activation time was significantly low compared to the atrial flutter cycle length (difference $\geq$100 ms), thus again excluding isthmus dependent atrial flutter. Entrainment study also showed the unlikliness of isthmus dependent right atrial flutter in all these cases. Entrainment was not possible in one case of atrial flutter with bi-directional wave front propagation in right atrium. In the other case the post-pacing interval remained significantly high compared to the tachycardia cycle length. This clearly indicated that the right atrium is not responsible in maintaining the atrial flutter. In the other two cases of unidirectional wave front propagation entrainment was possible by pacing at right atrial freewall and isthmus but the difference between post pacing interval and tachycardia cycle length remained high (> 30 ms) indicating that the circuit is far from the pacing site, thus excluding isthmus dependent

atrial flutter. Interestingly, in these two patients while pacing at proximal coronary sinus region the post pacing interval remained close to tachycardia cycle length (<30 ms). This indicates that proximal coronary sinus rather than the isthmus and right atrial free wall is a part of the macro reentrant circuit. All these evidences indicate that the macro reentrant circuit is far from right atrial freewall and isthmus and close to coronary sinus, thus possibly originating in left atrium.

Discussion:

Unlike atrial fibrillation, atrial flutter is not as common a rhythm problem in Rheumatic Heart Disease and a detailed electrophysiological study is scant in literature. Doubts has been raised that atrial flutter may be a forerunner of atrial fibrillation. Nair et al[23] have shown that after DC cardioversion of rheumatic atrial fibrillation to sinus rhythm, when programmed atrial stimulation was performed an organized flutter like rhythm was seen before it degenerated into atrial fibrillation. Ablation at proximal coronary sinus region led to noninducibility of atrial fibrillation and sinus rhythm was maintained at a short-term follow up. This interesting observation raises the possibility that atrial flutter may be a occurring for a varied time period prior to atrial fibrillation and cure of it may prevent atrial fibrillation at follow up. This study has tried to show different aspects of atrial flutter in rheumatic heart disease.

<u>Surface ECG in rheumatic heart disease with atrial flutter:</u>

This study shows that even though the surface ECG in the patients of atrial flutter showed a typical saw tooth type F waves in inferior leads, the intracardiac mapping and entrainment study showed that the atrial flutter is not isthmus dependent, rather possibly is originating in left atrium. Oshikawa N et al have shown that the conduction over the

left atrial freewall rather than over the septum and right atrial freewall determinates the morphology of F wave in surface ECG[24]. If the wave front travels caudo-cranially over the left atrium freewall, F wave is negative in inferior leads and positive in V1 and if the wave front travels cranio-caudally over left atrial freewall, the F wave is positive in inferior leads and negative in V1. Similar findings with typical flutter wave in surface ECG and electrophysiological evidences consistent with left atrial flutter have been noted by others[25]. Thus morphology of the F wave in surface ECG fails to indicate the propagation pattern of wave front in right atrium.

Electrophysiological study:

Presence of mitral annulus and multiple openings of pulmonary veins into left atrium and anatomical barriers makes mapping of the left atrium difficult by conventional mapping technique. Thus a detailed left atrial mapping requires advanced mapping techniques like biosense technology[25, 26]. In the absence of direct left atrial mapping to map the atrial flutter, mapping of right atrium also gives indirect suggestion of the left atrium mediated atrial flutter. Site of earliest right atrial activation at Bachman bundle region with bi-directional wave front propagation from that point and right atrial activation time less than 50% of atrial flutter cycle length has been considered as indicative of atrial flutter of left atrial origin[25, 26]. More over during entrainment study if post-pacing interval is significantly high than the tachycardia cycle length, when multiple points in right atrium are paced including right atrial freewall and isthmus, then it is considered to be originated in left atrium[25, 26]. In this study bi-directional wave front in right atrium was seen in two patients and all the patients had right atrial activation time significantly shorter than atrial flutter cycle length. These findings indicate that right

atrium is passively activated rather than actively participates in maintaining the atrial flutter, thus indirectly suggesting that atrial flutter is of left atrial origin. Entrainment study also gives important information regarding site of origin of atrial flutter. If entrainment is not possible from any point of right atrium, then atrial flutter of right atrial origin is highly unlikely. Even if entrainment is possible, the post-pacing interval should remain close to the tachycardia cycle length to suggest that the circuit is near by. In the present study in 3 cases where entrainment was possible, the post-pacing interval remained significantly high (>40 ms) in two cases when paced from any of the sites in right atrium and was 30 ms in one case when paced from right atrial isthmus region. In the same patient, in whom the PPI-Tachy cycle length was 30 ms, pacing at PCS region showed PPI almost equal to the tachycardia cycle length. More over in the same patient right atrial activation time was much shorter than the tachycardia cycle length. All these evidences suggest that the atrial flutter to be originating from left atrium.

Although all the cases of rheumatic heart disease with atrial flutter were thought to be originating from left atrium, as indicated during electrophysiological study, a detailed left atrial mapping could not be performed because of absence of advanced mapping systems.

The acute success rate in radiofrequency ablation of both typical and atypical form of atrial flutter is 90-97%[27-29]. There can be recurrence of atrial flutter in up to 9% cases[29, 30]. Atrial fibrillation may appear at long-term follow up after atrial flutter ablation in 8-86% cases[27-30]. The incidence of atrial fibrillation at follow up is higher in the patients having prior history of atrial fibrillation, presence of structural heart disease and inducible atrial fibrillation after a successful atrial flutter ablation[27-32].

Electrophysiological evidence of lower loop reentry, upper loop reentry and multiple early breaks along tricuspid annulus has more propensity for developing atrial fibrillation and it has been noted that isthmus ablation with bi-directional cavo-tricuspid conduction block is associated with cure or control of atrial fibrillation in approximately 50% patients with atrial flutter[33]. Flutter of left atrial origin is known to have multiple loop reentry mechanism and multiple lines of conduction block[26]. Therefore it has more propensities for development of atrial fibrillation. Thus with successful ablation of atrial flutter, the recurrence of atrial flutter and or development of atrial fibrillation at long term in patients with rheumatic heart disease with minimal valve lesion will be possibly low. In present cases, radiofrequency ablation was attempted at right atrial isthmus region in all the cases, but even after application of multiple lines atrial flutter remained uninterrupted. This again suggested that right atrial isthmus possibly not a part of atrial flutter in rheumatic heart disease.

Echocardiogram and angiographic study:

Echocardiogram helps in identifying the structural disorder in the heart. In rheumatic heart disease, echocardiogram and Doppler study help in knowing the severity of valve lesion and estimating the size and function of different chambers. It is well known that right atrium can sustain an atrial flutter because of anatomical and functional barrier and slow conduction at the isthmus region, which helps in creating a macro reentrant circuit. Similar macro reentrant circuit is lacking in left atrium. Openings of multiple pulmonary vein ostia into left atrium makes the critical length of possible reentrant circuit small for atrial flutter. Also area of slow conduction is absent in normal left atrium. But in the presence of rheumatic heart disease, the left atrium can enlarge to a

size to be big enough to provide macroreentrant circuit to maintain an atrial flutter. More ever the diseased left atrium with fibrosis in patchy distribution can give rise to slow conduction at places. In the present study echocardiogram showed invariably a large left atrium and a large right atrium in the presence of organic tricuspid valve disease. The presence of large left atrium and a diseased left atrium can very well explain the genesis of left atrium mediated atrial flutter in these cases. Angiographic studies have been performed to define the cavo-tricuspid isthmus anatomically and to see various morphological features of it[34, 35]. Isthmus is significantly large in patients of atria flutter with structural heart disease. The isthmus is divided into two parts: (1) a vestibule, which is smooth, adjacent to tricuspid annulus and (2) a pouch like recess, which lies in between Eustachian valve and vestibule. The pouch like recess is trabeculated and the depth may be variable making application of radiofrequency lesions difficult. In the present study, a routine right atrial angiogram was done to define cavotricuspid isthmus and its morphology prior to radiofrequency ablation to select the optimal catheter size. It showed a large isthmus in all the case and the pouch like recess was present in all. However the electrophysiological study showed that the atrial flutter is probably originating in left atrium. Never the less right atrial angiogram remains an important part in defining the isthmus in isthmus dependent atrial flutter.

Limitations:

Different parts of left atrium except coronary sinus were not mapped. Lack of evidence of macro reentrant circuit for atrial flutter in right atrium rather than direct mapping in left atrium was taken as an evidence of left atrium mediated atrial flutter. A multipolar catheter in esophagus could have facilitated left atrial freewall mapping, but

the signals obtained would have been poor in these adult patients. Left atrium could have been mapped by transseptal route after septal puncture. Number of patients in this study is only four. A large number of patients need to be studied before reaching at a conclusion. The present study continues to get more information on this by studying more number of cases.

Conclusion:

This study establishes poor contribution of surface electrocardiogram F wave morphology in predicting type and site of atrial flutter especially in the presence of structural heart disease like rheumatic heart disease. Electrophysiological study showed in presence of rheumatic heart disease, atrial flutter may be dependent on left atrium and a radiofrequency ablation line at cavo-tricuspid isthmus may not be useful.

References:

1. Granada J, Uribe W, Chyou PH et al : Incidence and predictors of atrial flutter in the general population. J Am Coll Cardiol 2000; 36:2242-46
2. Olgin JE, Zipes DP: Specific arrythmias, Diagnosis and treatment in Heart Disease, A Text book of cardiovascular medicine 6th edition,2001
3. Peuch P, Latour H, Grolleau R: Le fluuter et ses limites. Arch Mal Loeur, 1970; 63: 116-144.
4. Wells JL Jr., MacLean WAH, James TW, et al: Characterisations of atrial flutter: Studies in man after open heart surgery using fixed atrial electrodes. Circulation 1979, 60: 665-673.
5. Waldo AL, MacLean WAH: Diagnosis and treatment of arrythmias following open heart surgery- Emphasis on the use of epicardial wire electrodes. New York, Futura, 1980
6. Olgin JE, Kalman JM, Lesh MD: Conduction barriers in human atrial flutter: Correlation of electrophysiology and anatomy. J. Cardiovasc Eletrophysiol 1996; 7: 1112-1126.
7. Olshanky B, Okumara K, Hess PG et al: Demonstration of an area of slow conduction inhuman atrial flutter. J Am Coll Cardiol 1990; 16: 1639-1648.
8. Kalman JM, Olgin JE, Saxon LA et al: Activation and entrainment mapping defines the tricuspid annulus as the anterior boundary in atrial flutter. Circulation 1996; 94: 398-406

9. Nakagawa H, Lazzara R, Khastgir T et al: Role of the tricuspid annulus and the Eustachian valve ridge on atrial flutter. Relevance to catheter ablation of the septal isthmus and a new technique for rapid identification of ablation success. Circulation 1996; 94: 407-424.

10. Cosio FG, Arribas F, Lopez-Gil M et al: Atrial flutter mapping and ablation. Studying atrial flutter mechanisms by mapping and entrainment. PACE, 1996; 19: 841-853

11. Feld GK, Mollerue M, Birgersdotter-Green U et al: Conduction velocity in the tricuspid valve-inferior venacava isthmus is slower in patients with type I atrial flutter compared to those with out a history of atrial flutter. J.Cardiovasc electrophysiol 1997;8:1338-1348.

12. Poty H, Anselme F, Saoudi N: Inferior venacava-tricuspid annulus isthmus is a critical site of unidirectional block during the induction of common atrial flutter. J. Interv Card Electrophysiol 1998;2:57-69

13. Felen G, Brugada P: Unipolar waveforms and monopolar action potentials in the characterization of slow conduction in human atrial flutter. PACE,1998;21:2580-87.

14. Waki K, Saito T, Becker AE: Right atrial flutter isthmus revisited: Normal anatomy favors nonuniform anisotropic conduction. J Cardiovasc Electrophysiol 2000;11:90-94

15. Olgin J, KalmanJM, Fitzpatrick AP et al: Role of right atrial Endocardial structures as barrier to conduction during human type I atrial flutter: Activation

and entrainment mapping guided by intracardiac echocardiography. Circulation, 1997; 96: 3904-12.

16. Shah DC, Jais P, Haissaguerre M et al: Three dimensional mapping of the common atrial flutter circuit in the right atrium. Circulation,1997;96:3904-3912.
17. Ndrepepa G, Zrenner B, Dersenhofer I et al: Relatioship between surface electrocardiogram characteristics and Endocardial activation sequence in patients with typical atrial flutter. Z Kardiol 2000; 89:527-537.
18. Schmitt H, Weber S, Tillmans H et al: Diagnosis and ablation of atrial flutter using a high resolution non contact mapping system. PACE, 2000;35:1276-1287.
19. Mizumaki K, Fujiki A, Nagasawa H et al: Relation between transverse conduction capability and the anatomy of the crista terminalis in patients with atrial flutter and atrial fibrillartion. Circ J 2002 Dec; 66(12):1113-1118.
20. Yamabe H, Misumi I, Fukushima H et al: Conduction properties of the crista terminalis and its influence on the right atrial activationsequence in patients with typical atrial flutter. PACE 2002;25:132-141.
21. Kalman JM, VanHare GF, Olgin GE et al: Ablation of 'incisional' reentrant atrial tachycardia complicating surgery for congenital heart disease. Use of entrainment to define a critical isthmus of conduction. Circulation 1996;93:502-512.
22. Waldo AL: Treatment of atrial flutter. Heart,2000;84:227-232.
23. Nair M, Shah P, Batra R et al: Chronic atrial fibrillation in patients with rheumatic heart disease. Circulation, 2001; 104: 802-809.
24. Oshikawa N, Watanabe I, Masaki R et al: Relationship between polarity of the flutter waves in the surface ECG and Endocardial atrial activation sequence in

patients with typical counterclockwise and clockwise atrial flutter. J. Interv Card Electrophysiol,2002 Dec; 7(3): 215-223.

25. Jais S, Shah DP, Haissaguerre MH et al: Mapping and ablation of left atrial flutters. Circulation 2000; 101: 2928-2934.
26. Ouyang F, Ernst S, Vogtmann T et al: Characterization of reentrant circuits in left atrial macro reentrant tachycardia. Circulation, 2002; 105:1934-1942
27. Nabar A, Rodriguez LM, Timmermans C et al: Effect of right atrial isthmus ablation on the occurance of atrial fibrillation: observations in four patient groups having type I atrial flutter with or without associated atrial fibrillation. Circulation 1999 mar,23; 99(11) 1441-1445.
28. Fiala M, Heinc P, Luckl J et al: Determination of the end point of the radiofrequency linear lesion in the subeustachian isthmus and its relation to treatment of atrial flutter and fibrillation. Acute and long term results in 90 patients.Vintr Lek 2002 Mar; 48(3): 202-209.
29. Heish MH, Tai CT, Chiang CE et al: Reccurent atrial flutter and atrial fibrillation after catheter ablation of the cavo-tricuspid isthmus: A very long term follow up of 333 patients. J. Interv Card Electrophysiol 2002 Dec; 7(3) 225-231.
30. Tai CT, Chen SA, Chiang CE et al: Long term outcome of radiofrequency catheter ablation for typical atrial flutter: risk prediction of recurrent arrythmias. J. Cardiovasc Electrophysiol 1998 Feb; 9(2): 115-121.
31. Philippon F, Plumb VJ, Epstein AE et al: The risk of atrial fibrillation following radiofrequency atheter ablation of atrial flutter. Circulation 1995 Aug 1; 92(3) 430-435.

32. De sisti A, Leclercq JF, Fierello P et al: The effect of the ablation of atrial flutter in patients with and with out clinical history of paroxysmal atrial fibrillation. G Ital Cardiol 1998 Nov; 28(11); 1253-1260.

33. Yang Y, Mangat I, Glatter KA et al: Mechanism of conversion of atypical right atrial flutter to atrial fibrillation. Am J Cardiol 2003 Jan 1; 91(1); 46-52.

34. Cabrera JA, Sanchev-Quintana D, Yen Ho S et al: Angiographic anatomy of the inferior right atrial isthmus in patients with and with out history of common atrial flutter. Circulation 1999; 99: 3017-3023.

35. Heidbichel H, Willens R, VanRensburg H et al: Right atrial angiographic evaluation of the posterior isthmus: Relevance for ablation of typical atrial flutter. Circulation, 2000; 101: 2178-2184.