Archivos del Instituto de Cardiología de México

Volumen *Volume* 70 Número *Number* 1 Enero-Febrero *January-February* 2000

Artículo:

Cambios espontáneos en la longitud de ciclo de taquicardias ventriculares monomórficas y polimórficas y su relación con el sitio de activación epicárdica temprana en cada latido

INVESTIGACIÓN BÁSICA

SPONTANEOUS CHANGES IN VENTRICULAR TACHYCARDIA CYCLE LENGTH AND THEIR RELATION TO EARLIEST SITES OF EPICARDIAL ACTIVATION IN A CANINE MODEL

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RESUMEN

CAMBIOS ESPONTÁNEOS EN LA LONGITUD DE CICLO DE TAQUICARDIAS VENTRICULARES MONOMÓRFICAS Y POLIMÓRFICAS Y SU RELACIÓN CON EL SITIO DE ACTIVACIÓN EPICÁRDICA TEMPRANA EN CADA LATIDO

Antecedentes: *El propósito de este estudio fue estudiar los cambios espontáneos en la longitud de ciclo de taquicardias ventriculares monomórficas (TVM) y polimórficas (TVP) y su relación con el sitio de activación epicárdica temprana en cada latido.* ***Métodos:*** *A 24 perros mestizos, se les practicó toracotomía, previa anestesia. Se obtuvieron mapas isocrónicos a partir de 127 electrodos unipolares, dispuestos en un saco ventricular. Después de inducir bloqueo auriculoventricular, se ligó la arteria coronaria descendente anterior, bajo condiciones de marcapaso ventricular (140/min), durante 60 minutos, seguido de reperfusión. En 7 perros, se realizó estimulación del ganglio estelar izquierdo 5 minutos después de la reperfusión.* ***Resultados:*** *Se obtuvieron 7 TVM por reperfusión y 4 TVP por estimulación simpática. En ambas taquicardias ventriculares se observaron cambios similares en la longitud del ciclo; aceleración inicial hasta alcanzar un mínimo, para después desacelerarse antes de su terminación espontánea. Los mapas de activación ventricular mostraron una difusión radial de la onda de activación a partir del sitio de activación temprana. Las TVM fueron lentas (481 ± 80 msec) en comparación con las TVP (352 ± 90 msec) (P < 0.01). En las TVM la variación de latido a latido fue de 15 ± 17 msec correspondiendo a pequeños cambios en el sitio de activación temprana a lo largo del borde isquémico. Mientras que en las TVP la variación en la longitud del ciclo fue mayor (62 ± 23 msec), correlacionándose con grandes cambios en el sitio de origen de la activación temprana en el ventrículo derecho e izquierdo. El análisis de regresión lineal mostró una sig-*

SUMMARY

Background: *The purpose of this study was to examine the spontaneous changes in cycle length during episodes of sustained monomorphic (MVT) and polymorphic (PVT) ventricular tachycardias and to relate these changes with the earliest epicardial activation site of the beat.* ***Methods:*** *Isochronal activation maps were obtained from 127 unipolar electrograms recorded from the surface of both ventricles with a sock electrode array in 24 open chest anesthetized dogs. After atrioventricular block, the left anterior descending coronary artery was occluded for 60 min under ventricular pacing (140/min), followed by reperfusion. In 7 dogs the left stellate ganglion was stimulated 5 min after reperfusion.* ***Results:*** *In 7 MVTs (reperfusion) and 4 PVTs (sympathetic stimulation), cycle length changes showed an initial acceleration, reaching a minimum cycle length and then decelerating before termination. Isochronal maps showed radial spread from earliest activation, without conduction block. Cycle length (481 ± 80 msec) in MVT had beat to beat variations of 15 ± 17 msec corresponding to small shifts in sites of the earliest activation, clustered along the border of the ischemic myocardium. In PVTs the cycle length (352 ± 90 msec, p < 0.01) had a variability of 62 ± 23 msec, corresponding to wide changes in the sites of earliest activation in right and left ventricles. Linear regression analysis showed a strong and significant correlation between cycle length variability and the number of electrodes with the earliest activation (r = 0.77, p < 0.0001).* ***Conclusion:*** *In these models of monomorphic and polymorphic ventricular tachycardias, cycle length variability showed a significant correlation with the number of electrodes with the earliest activation. MVTs showed concentrated origins with regular cycle length, whereas PVTs*

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Aceptado: 13 de octubre de 1999.

nificativa correlación entre la variación en la longitud del ciclo y el número de electrodos que registraron la activación epicárdica temprana (r = 0.77, p < 0.0001). ***Conclusiones:*** *La variabilidad de la longitud del ciclo durante taquicardias ventriculares monomórficas y polimórficas mostró una correlación significativa con el número de electrodos que registraron la activación epicárdica temprana. Las TVM mostraron actividad epicárdica agrupadas con variaciones regulares de la longitud del ciclo, mientras que las TVP mostraron actividad epicárdica dispersa con variaciones irregulares de la longitud del ciclo. Estos resultados sugieren que el sitio de activación epicárdica temprana puede ser un factor que influye en las fluctuaciones de la longitud del ciclo en este modelo experimental de arritmias.*

showed dispersed origins with irregular cycle length. These results suggest that the earliest epicardial activation site of the beat could be a factor in determining the dynamics in the cycle length.

RESUME

CHANGEMENTS SPONTANES DE LA DUREE DU CYCLE DE TACHYCARDIE VENTRICULAIRE ET LEUR RELATION AVEC LES SITES D'ACTIVATION PRECOCE A L'EPICARDE

Resume: *Le but de cette étude était d'examiner les changements spontanés de la période des battements pendant les tachycardies ventriculaires monomorphes et polymorphes et de corréler ces changements avec la localisation de sites d'activation précoce sur l'épicarde ventriculaire.* ***Méthodes:*** *Un bloc AV fut induit chez 24 chiens anesthésiés à thorax ouvert, suivi d'une occlusion de l'artère interventriculaire antérieure pendant 60 min en stimulant les ventricules à 140 bat/min, depuis une reperfusion. Pour 7 chiens, 5 min après la reperfusion, le ganglion stellaire gauche fut stimulé pendant 1 à 2 min. Des cartes isochronales furent tracées à partir des temps d'activation déterminés sur 127 électrogrammes unipolaires répartis sur l'épicarde des deux ventricules.* ***Résultats:*** *Dans 7 cas de tachycardi monomorphe (TVM) et 4 de tachycardie polymorphe (TVP), on a observé une accélération initiale de la période, suivie d'une décélération terminale jusqu' à l'arrêt des TV. Les cartes isochronales montraient une propagation radiale à partir du site d'activation la plus précoce sans retard de conduction. Les TVM étaient plus lentes (481 ± 80 ms) que les TVP (352 ± 90 ms) (p < 0.01). Les TVM montraient des fluctuations de la période de battement en battemen de 15 ± 17 ms associées à de petits déplacements du site d'activation précoce en marge de la zone d'ischémie. Pour les TVP, la variabilité de la période était plus grande, 62 ± 23 ms, avec des déplacements importants des sites d'activation précoce sur la surface des deux ventricules. Une analyse de régression linéaire a montré une corrélatiol significative entre la variabilité des périodes et le nombre d'électrodes montrant une activation précoce (r = 0.77, p < 0.001).* ***Conclusion:*** *Dans ces modèles de TVM et de TVP, la variabilité de la période est significativement corrélée avec la dispersion spatiale des sites d'activation précoce. Les TVM montrent des sites d'emergence rapprochés avec des durées de cycles régulières, alors que les TVP montrent des sites d'origine plutôt dispersés ayant des durées de cycles irrégulières. Ces résultats suggerènt que dans ce modèle expérimental, la localisation des sites d'activation précoce sur l'épicarde ventriculaire peut déterminer les fluctuations de la durée de la période de la tachycardie.*

Palabras clave: Taquicardia ventricular. Longitud del ciclo. Reperfusión. Estimulación simpática.
Key words: Ventricular tachycardia. Cycle length. Reperfusion and sympathetic stimulation.

INTRODUCTION

Cycle length variability has been reported in monomorphic and polymorphic ventricular tachycardia.[1-7] This variability appears more often in the first 10 or 20 beats of monomorphic ventricular tachycardia and decreases in time.[6,7] Such Changes have been explained by fluctuations in action poten-

tial duration[8,9] and in reentrant ventricular tachycardia, by different dynamics within the reentry circuit where two pathways with different conduction velocities are present.[2,3] Also it has been suggested that in ventricular tachycardias generated by an automatic focus a variability in exit conduction time (e.g., a Wenckeback-type block) will result in manifest R-R cycles that are variable in spite of a constant ectopic cycle of discharge.[4] Recently it has been reported that spontaneous cycle length variations at the onset of reentrant monomorphic ventricular tachycardia are associated with trends towards acceleration or deceleration in rate of the ventricular tachycardia.[10] Until now the causes of cycle length variability during ventricular tachycardia are unknown and it is not clear whether they occur independently of the mechanisms involved, changes in the activation sequence or in the origin site of the beat.

The present study was performed to examine the spontaneous cycle length variability during episodes of sustained monomorphic and polymorphic ventricular tachycardia and to analyse whether there is any relation between cycle length variability, earliest epicardial activation site, surface ECG morphology and epicardial ventricular activation patterns of the beats.

METHODS

Twenty four dogs with average weight 28 kg, of either sex, were anesthetized with sodium thiopental (30 mg/kg IV) followed by alpha chloralose (60 mg/kg IV). Anesthesia was maintained by administering alpha chloralose (100 mg IV) every hour. The heart was exposed through a bilateral thoracotomy at the fourth intercostal space and a pericardial cradle was constructed. A pair of bipolar electrodes were sutured onto the right atrial appendage for recording of an atrial electrogram. A pair of bipolar electrodes were sutured to epicardial connective tissue of the right ventricle (RV) for pacing, avoiding any damage to the underlying ventricular muscle. The pacing electrodes were connected to a Bionova programmable stimulator (Institut de Génie Biomédical, Ecole Polytechnique, Montréal, Canada). Catheters were inserted in the femoral artery to record blood pressure by means of a Nihon Kohden pressure transducer (Nihon Kohden, Tokyo, Japan). Complete atrioventricular (AV) block was induced by injection of 0.1-1.0 mi of 37% formaldehyde into the region of the AV node[11] and pacing from the right ventricle was started a 140 per minute (min). The left anterior descending (LAD) coronary artery was isolated after the first diagonal, usually 5 mm from the atrial appendage. A cotton suture was introduced under the artery and both ends were threaded through a piece of polyethylene tubing for reversible occlusion. The ligature was released after 60 min of complete occlusion and arterial blood flow was restored distal to the site of occlusion (reperfused infarct). A sock electrode array of 127 unipolar recording contacts, distributed with an interelectrode distance of 5-10 mm, was positioned on the ventricular surfaces for epicardial mapping before inducing AV block. Each unipolar contact was referred to the Wilson terminal. The signals, as weIl as a surface lead ECG (lead II), were amplified and monitored by means of a Nihon Kohden chart paper recorder and stored on a 8 Tracks Sony Digital Tape Recorder #PC-108 M, JAPAN. The left stellar ganglion was exposed in 8 dogs for stimulation with bipolar electrodes using a Grass S8 stimulator and stimulus isolation unit (Grass Instruments, Co., Quincy, MA, USA) (8 volts, 10 Hz, 2 msec) for 45 sec, to achieve 20% or more increase in the aortic blood pressure above control. In six dogs one plunge-needle containing seven bipolar electrodes pairs was placed throughout the heart in the left ventricle between the end branches of the LAD and circumflex, and ventricular pacing was done sucessively from endocardium to epicardium 140/min (8-10 V, 10 Hz, 1.5 msec).

Ventricular electrograms were classified as follows: ventricular premature depolarization (VPDs), non sustained ventricular tachycardia (NSVT) (three or more consecutive ventricular complexes at a rate greater than 100 beats/min that terminate spontaneously within 30 sec), sustained ventricular tachycardia (SVT) (ventricular complexes at a rate greater than 100 beats/min that persist more than 30 seconds) and ventricular fibrillation (VF).[11] On the basis of QRS morphology ventricular tachycardias were classified as monomorphic (MVT) and polymorphic (PVT).

Protocol

Epicardial maps were first obtained during sinus rhythm, idioventricular rhythms (IVR) under basal conditions, in six dogs from pacing in the left ventricle at 5 to 7 different levels from endocardium to

epicardium, and after occlusion of the LDA during 60 min, followed by 30 min of reperfusion. Right ventricular pacing at 140 per min was maintained during occlusion, and maps of IVRs were taken at 5, 15, 30, and 60 min of ischaemia. During reperfusion when ventricular tachycardia was induced, pacing was stopped. In 7 dogs, 5 min after reperfusion, sympathetic left stellate ganglion stimulation was done during 1 or 2 minutes. Epicardial maps were recorded for each beat of ventricular tachycardia and the earliest and total activation time values were determined.

Epicardial Mapping

Unipolar electrograms were simultaneously recorded with a sock electrode array of 127 epicardial contacts connected to a digital data acquisition system, programmed with custom-made software (CARDIOMAP II). The version of the system used in this study is based on a micro-VAX host computer (Digital Equipment Corporation, Maynard, MA, USA) and has the capability to record up to 128 channels simultaneously. Signals are amplified by programmable-gain analog amplifiers with a 0.05-200 hz bandwidth, multiplexed, sampled at 500 Hz, converted to a digital format and stored on digital magnetic tape on-line. Files containing either 1 second or 46 seconds of data were selected and stored on hard disk during the experiment. Data were analyzed in 1-second time window. The activation times were detected automatically on each electrogram as the points of most rapid change in potential with a negative slope in excess of -0.5 mV/msec. All computer-selected activation times were verified on a videoscreen by an operator. Isochronal maps were determined by interpolation and drawn automatically by the computer for selected cycles of ventricular activation with use of the point of earliest activation as the zero reference time. On these maps, the entire ventricular epicardium is represented as a disk. The course of the LAD coronary artery, circumflex coronary artery, the occlusion site, the needle plunge site and the right and left ventricle are indicated in *Figure 1*. Map areas are presented with isochronal lines labeled with their appropriate timing value. On each map, the first area encompasses the earliest 10 msec of epicardial activation (epicardial breakthrough area), as determined by computer interpolation. Slow conduction was considered when we found closer isochronal lines and an increased number of isochronal (time between isochronal lines more than 20 msec). It was possible to identify the ischemic area through the changes in the activation time in IVRs maps during occlusion. At the end of the experiment ventricular fibrillation was induced, and the heart was removed with the sock attached and the stimulating and recording electrodes, the needle plunge site and the LAD were localized. The LAD was cannulated, and methylene blue was injected into the LAD to obtain a gross estimate of the ischemic area. Experimental procedures were carried out in accordance with the guidelines of the Canadian Council for Animal Care and closely monitored by our institutional animal care committee.

Data records

Data records of 46 seconds of sustained ventricular tachycardias were analyzed. Mean cycle lengths during VTs were obtained by an automatic method, from activation times detected on 127 simultaneous electrograms. Data records were also analyzed by segments in order to relate cycle length variability with the number of electrodes with the earliest epicardial activation. Each data record was divided into seven segments 6.144 seconds, that is, 3072 points sampled at 2 msec intervals. The last four seconds of each data record were not considered.

Statistical analysis

Data are presented as means ± standard deviation. Statistical analyses were performed by Student's *t*-test and analysis of variance (ANOVA) when appropriate. A p value < 0.05 was considered statistically significant. Linear regression analysis was employed to compare the relation between cycle length variability during ventricular tachycardia and the number of electrodes with the earliest epicardial activation.

RESULTS

Only 14 dogs were included in the study, because nine dogs presented VF during occlusion of the LAD, and one dog after reperfusion. Reperfusion led to the development of seven sustained MVT spontaneously within 1 to 3 minutes in seven animals, and non sustained VT in another two. In the other five animals only VPDs were observed. In these dogs, it was possible to induce four sustained PVT with left stellate ganglion stimulation 5 min after reperfusion.

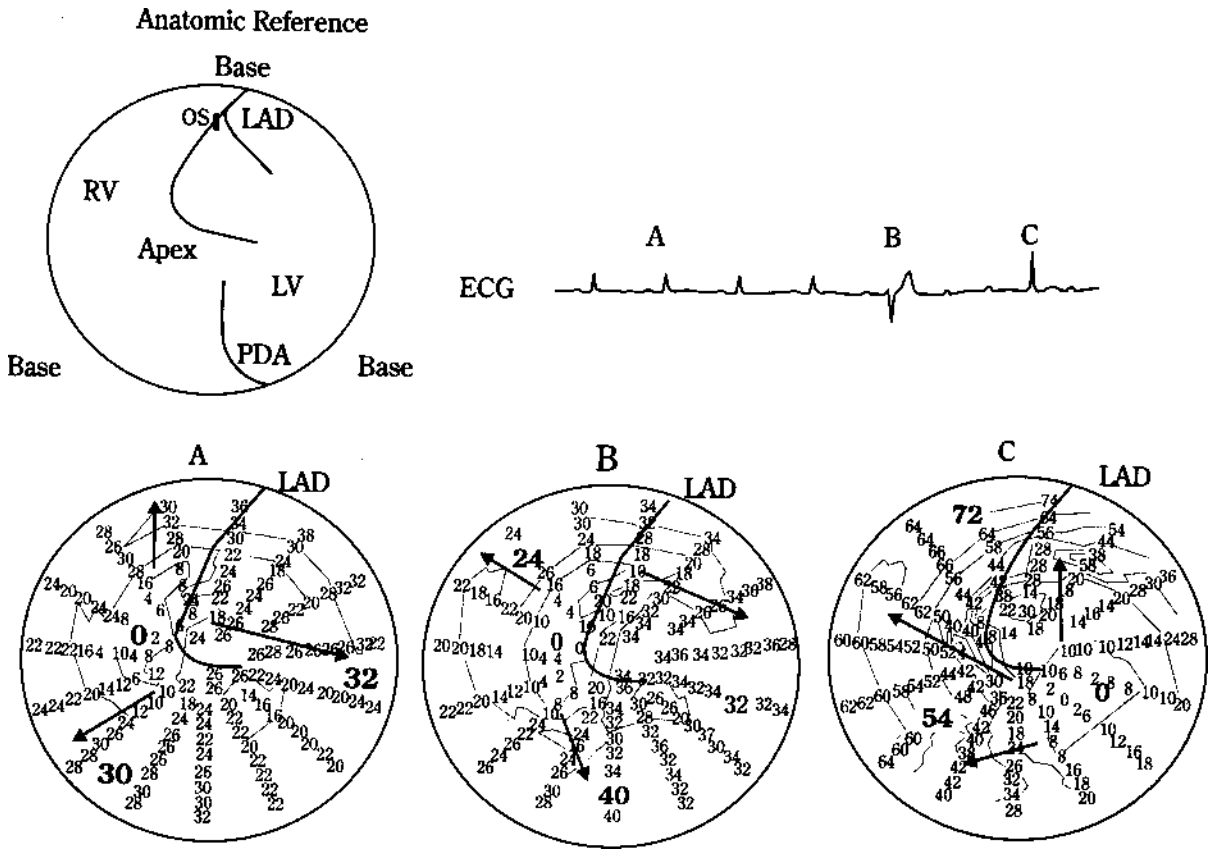

FIG. 1: On the top, planar representation of epicardial sock electrodes with anatomic references. LAD = left anterior descending coronary artery; OS = Occlusion site of LAD; PDA = Posterior descending coronary artery; RV = Right ventricle; LV = Left ventricle. The upper trace is a schematic representation of a continuous ECG record, showing the change from sinus to idioventricular rhythm after injection of formaldehyde into the atrioventricular node. Activation maps during sinus rhythm (A) and idioventricular rhythms arising from the right (B) and left (C) bundle branches are shown at the bottom. Isochronal lines are drawn at 10 msec intervals.

Mapping characteristics during sinus, idioventricular rhythms and ventricular pacing

Epicardial maps during sinus rhythm showed that the epicardial breakthrough area (EBa) was localized in the anterior paraseptal region of the right ventricle. The total epicardial activation time (TEAT) was 33 ± 14 msec *(Figure 1)*. Isochronal maps during idioventricular rhythms (IDVRs, cycle length > 1000 msec) showed that the EBa were localized in the anterior paraseptal region of RV, and the antero-apical or postero-apical regions of the left ventricle (LV) respectively; the EBa was characteristically wide, with radial spread and TEAT averaged 64 ± 9 msec. Left ventricular activation across the paraseptal epicardium was slow, as evidenced by closely spaced isochrone lines over both the anterior and posterior junction of the septum with the free wall. Although the EBa from pacing in the LV close to the endocardium was wide, the TEAT was significantly increased to 79 ± 12 msec compared to the EBa from IDVRs ($p < 0.001$). When pacing was close to the epicardium the EBa was small with prolongation in the TEAT to 110 ± 17 msec *(Figure 2)*.

Mapping characteristics during idioventricular rhythms and ischemia

The maps were similar to those of control IDVRs, but a slow conduction into the ischemic area was apparent (time between isochronal lines more than 20 msec with closer spacing and increased number of isochronal lines), and a TEAT of 72 ± 10 msec (not shown).

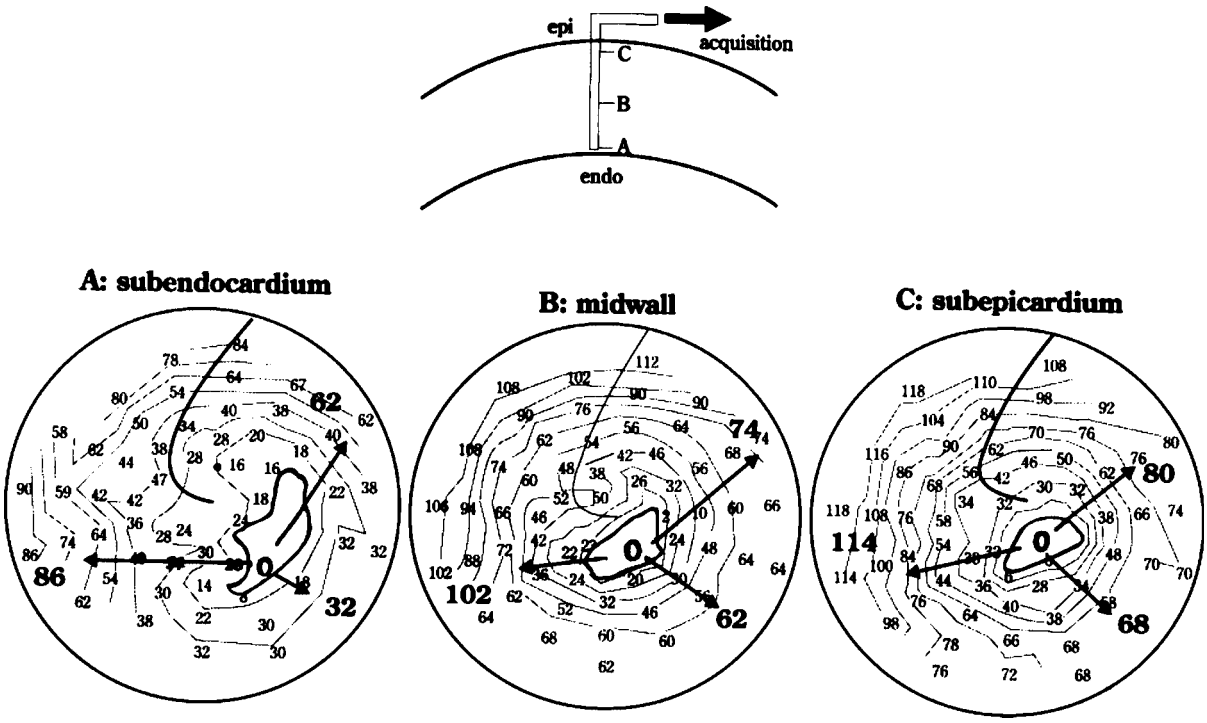

FIG. 2: Activation maps during ventricular pacing from endocardium to epicardium in the left ventricle. Map from subendocardium (A) show radial spread, a wide epicardial breakthrough area, and a total epicardial activation time of 79 ± 12 msec. B pacing from midwall myocardium show a decrease in the size of EBa and an increase in the TEAT and C, pacing from the subepicardium, the size of EBa is reduced, and the TEAT is significantly longer than A and B.

Mapping characteristics during ventricular tachycardias

During sustained MVTs all occurring during coronary reperfusion, isochronal maps showed radial spread from EBa localized at the ischemic border zone. The EBa were wide and the TEAT averaged 60 ± 8 msec, values similar to those measured during IDVRs *(Figure 3)*. During PVTs induced by left stellate ganglion stimulation, dispersed origins were observed with large fluctuations in the EBa and in the TEAT values (between 67 ± 24 to 88 ± 11 msec). The maps were characterized by EBa with radial spread, usually localized in the basal portion of the anterior right ventricle and in the postero-apical regions of the left ventricle *(Figure 4)*.

Dynamics of the cycle length

We evaluated the spontaneous changes in cycle length during episodes of sustained MVT and PVT and their relation to the sites of earliest activation, to ventricular activation patterns as well as to surface ECG QRS morphology. In MVT the coupling interval of the first tachycardia beat to the preceding idioventricular beat was 475 ± 43 msec. There were changes in the cycle length, with acceleration at the beginning, reaching a minimum cycle length and then decelerating before spontaneous termination of the ventricular tachycardia *(Figure 5)*. Cycle length in MVT showed regular beat to beat variability, the mean cycle length was 431 ± 80 msec. Changes in cycle length usually were less than 50 msec, being in four of them less than 20 msec. These small changes corresponded to small shifts in the site of earliest activation, but without changes in ventricular activation pattern or surface ECG QRS morphology *(Figure 3)*. During PVTs the coupling interval of the first tachycardia beat to the preceding idioventricular beat was not significantly different from MVT (572 ± 52 msec). Cycle length dynamics were similar to MVT with acceleration at the induction time, reaching a minimum cycle length and then decelerating before spontaneous termination. Polymorphic ventricular tachycardias showed a constant and large variability in the cycle length

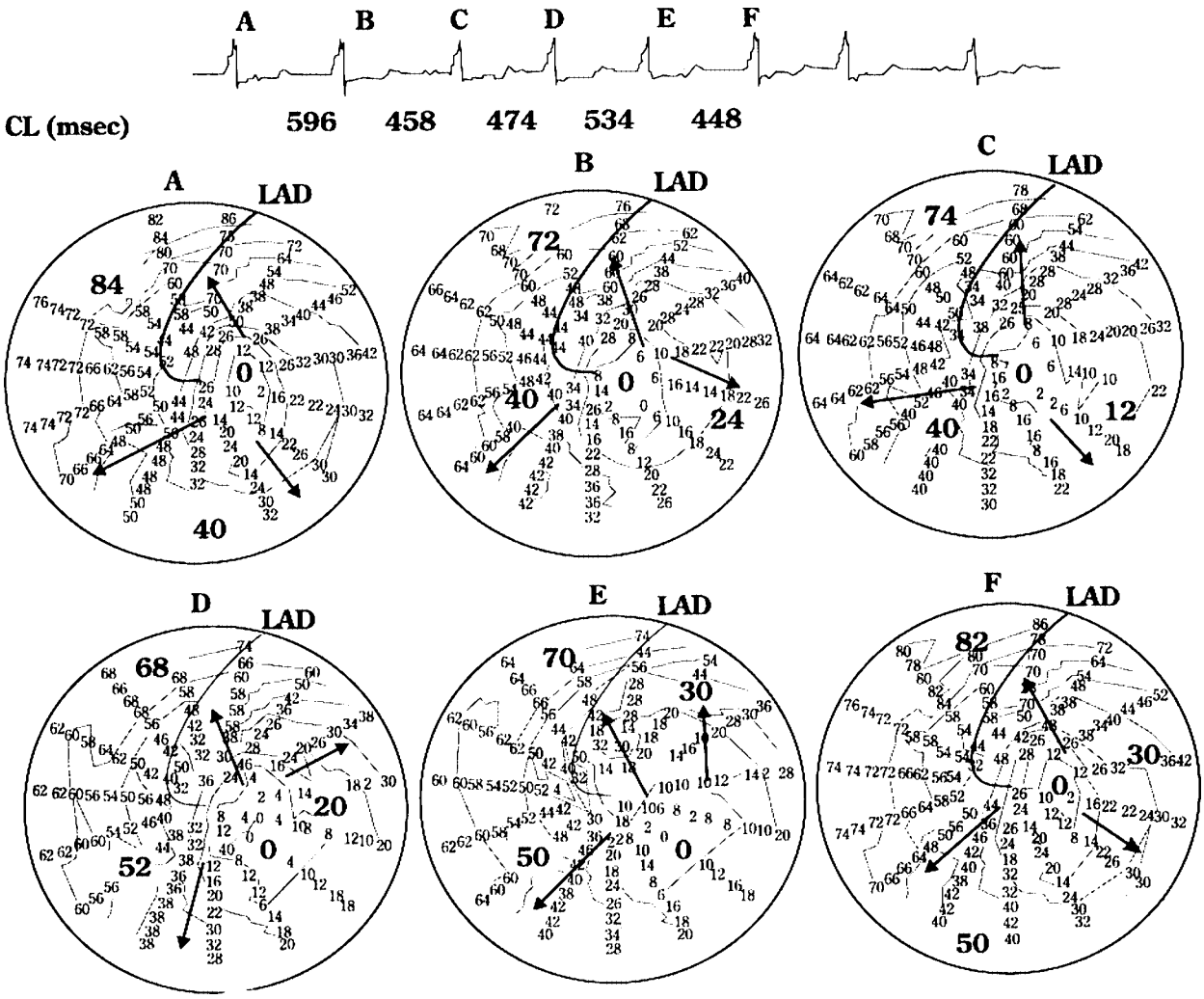

FIG. 3: Monomorphic ventricular tachycardia occurring during coronary reperfusion. The upper panel shows a lead II ECG record and the numbers represent the cycle length measured beat to beat. Isochronal maps of six consecutive beats are shown. The beats arose from loci on the ischemic border zone in the left ventricle. Note that the total epicardial activation times and the sizes of the breakthrough area change little beat: to beat corresponding to small variations in the cycle length.

beat to beat, usually more than 50 msec. The large variability in the R-R intervals corresponded to marked shifts in the site of epicardial breakthrough on the right and the left ventricles, and was associated with changes in surface ECG QRS morphology *(Figure 4)*. The radial spread from the EBa were remained. The mean cycle lengths in PVTs were 352 $\pm$ 90 msec, being significantly different in comparison with the mean cycle length of MVT ($p < 0.001$).

Cycle length and number of electrodes with the earliest epicardial activation

Cycle length analysis was also performed on individual segments of MVTs and PVTs. Linear regression analysis showed a strong and significant correlation between cycle length variability and the number of electrodes with the earliest activation ($r = 0.77$, $p < 0.0001$). Higher cycle length variability corresponded to a higher spatial dispersion of electrodes detecting the earliest epicardial activation.

DISCUSSION

The results of this study show that there is a relevant relation between cycle length variability and dispersion of sites of earliest activation in MVT and PVT. Both monomorphic and polymorphic ventricular tachycardias showed a “warm up” and “cool off” at start up and termination, respectively. Both types

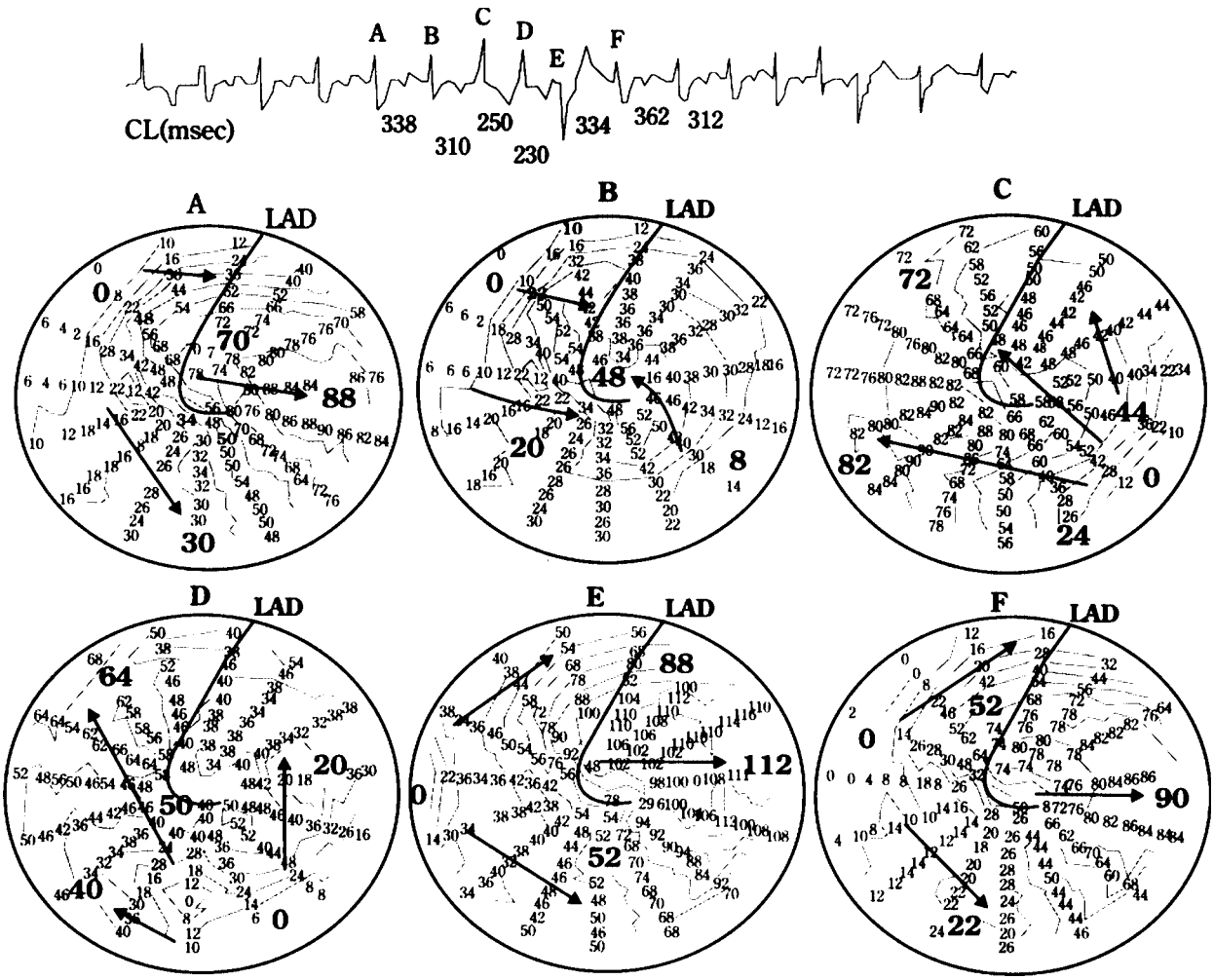

FIG. 4: Polymorphic ventricular tachycardia induced by left stellate ganglion stimulation. The upper panel shows a lead II ECG record and the numbers represent the cycle length measured beat to beat. Isochronal maps of six consecutive beats are shown. The beats arose from different loci in the right (RV) and left ventricle (LV). The second epicardial map corresponds to a fusion beat, where two simultaneous activations in the RV and LV are seen. Note that the total epicardial activation times, size and site of the breakthrough area change from beat to beat corresponding to wide variation in the cycle length.

of tachycardia are probably dependent in our model upon noradrenergic enhancement of automaticity as supported by previous work.[12-15]

Through the epicardial maps, it is possible to determine the cardiac activation sequence, the site of origin and abnormal conduction during ventricular arrhythmias.[16,17] We recorded epicardial maps during pacing at different levels in the heart. When pacing was close to the endocardium the EBa was wide and the TEAT was short, and when it was close to the epicardium, the early EBa was short and the TEAT prolonged. With complete AV block there is normally appearance of idioventricular rhythms whose origins are at various levels within the RBB or LBB. Epicardial maps from IDVRs generated spontaneously after AV block were characterized by (1) localization of the early epicardial breakthrough on the anterior paraseptal region of the right ventricle or anterior paraseptal, anteroapical or posteroapical regions of the left ventricle, (2) large areas of early breakthrough and (3) short total epicardial activation times. These results are consistent with localization of the origin of IDVRs at various levels within the RBB or LBB, as has been reported previously.[18,19]

Epicardial maps obtained during MVT at reperfusion showed wide EBa, radial spread, with

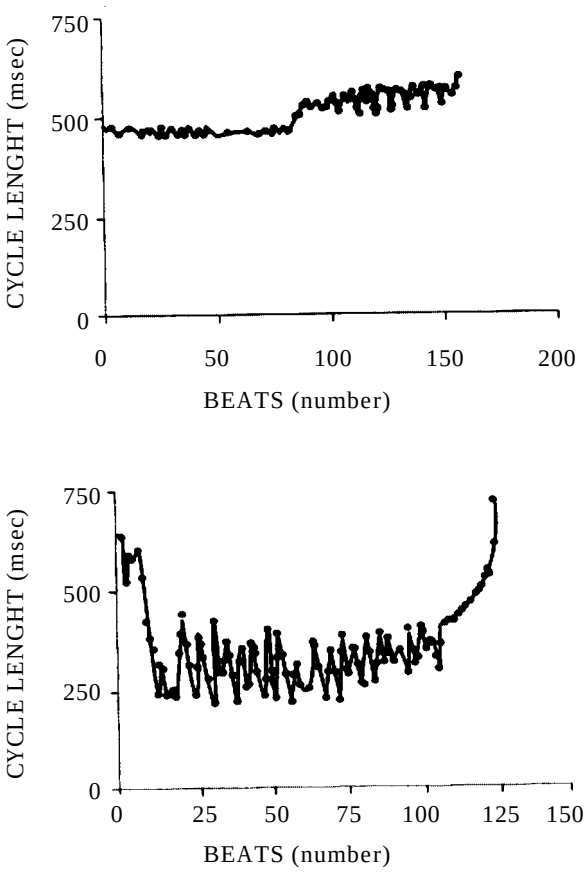

FIG. 5: Graph showing cycle length changes derived from beat to beat intervals during one sustained monomorphic and one sustained polymorphic ventricular tachycardia. Note that both of them show an initial acceleration with a progressively slower rate at the end. On the top graph monomorphic ventricular tachycardia at coronary reperfusion, note that fluctuations in cycle length are less than 50 msec, whereas in the polymorphic ventricular tachycardia induced by left stellate ganglion stimulation (at the bottom) the oscillations are constant and more than 50 msec. Linear regression analysis between mean cycle length and the number of electrodes with the earliest activation show a close correlation ($r = -0.74$, $p < 0.0001$).

short total epicardial activation times (72 ± 11 msec), similar to those in IDVRs, suggesting that Purkinje fibers could be involved in their generation. The EBa, were concentrated along the ischemic border zone in the left ventricle in agreement with Pogwitz and Corr[20,21] and there were no changes in ventricular activation patterns or in surface ECG QRS morphology. Activation maps during PVTs were characterized by a radial spread from the EBa, which were usually localized in the basal portion of the anterior right ventricle and in the posteroapical and anteroapical regions of the left ventricle with marked fluctuations in the size of the EBa and localization, associated with changes in surface ECG QRS morphology. Total epicardial activation times also showed changes: beats with wide breakthroughs had shorter activation times and beats with narrow breakthroughs had longer total epicardial activation times, suggesting endocardial and epicardial origins in right and left ventricles, as suggested by the epicardial maps we obtained during pacing. Similar results were found in previous studies in sympathetically induced ventricular tachycardia in dogs with normal hearts and with atrioventricular block.[22-24] During analysis of VT maps we could not find signs of exit block or of a reentry mechanism, such as continuous depolarization lasting from one beat to the next site of initiation of a beat adjacent to the site of termination of the preceding beat.[25] However we cannot rule out intramural or subendocardial reentry, because we did not use intramural recordings.

Spontaneous changes in cycle length of monomorphic and polymorphic ventricular tachycardias by reentry in humans have been reported.[3-7] The mechanisms for cycle length variability is not fully understood. Cycle length variability in ventricular tachycardias by reentry has been explained by two pathways present in the reentry circuit with different conduction velocities and refractory periods that results in fast and slow circuits. Thus, when the impulse runs through the fast pathway the R-R cycle is short, whereas when a block occurs in the fast pathway, the impulse traverses the slow pathway resulting in a long R-R cycle. In our study cycle length variability of less than 50 msec was seen in MVT. There were no changes in QRS morphology and the sites of epicardial breakthrough were closely clustered around the ischemic area in the left ventricle. In PVT, a constant variability in the cycle length was observed with changes in the R-R interval greater than 50 msec. Cycle length variability was associated with different sites of epicardial breakthrough on the right and left ventricles and changes in surface ECG QRS morphology. MVTs were slower in comparison with PVT, the mean cycle lengths were 431 ± 80 msec and 352 ± 90 msec ($p < 0.001$), respectively. Linear regression analyses showed a strong and significant correlation between cycle length variability and

the number of electrodes with the earliest epicardial activation time.

It is probable that different mechanisms are involved in the dynamics of cycle length during ventricular tachycardias by reentry or by abnormal automaticity. The results show that in our models of MVT and of PVT, where abnormal automaticity is assumed to be the mechanism, variations in the site of the earliest epicardial activation site of the beat could be an important factor in determining the cycle length variability.

CONCLUSION

In these models of monomorphic and polymorphic ventricular tachycardias where abnormal automaticity is involved there is an important quantitative relation between cycle length variability and the spatial distribution of electrodes with the earliest epicardial activation time. MVTs showed concentrated sites of epicardial breakthrough with regular cycle length, whereas PVTs shown dispersed sites of epicardial breakthrough with irregular cycle length.

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