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EFFECTS OF ARTIFICIAL PACING ON VENTRICULAR REPOLARIZATION.
A VECTORCARDIOGRAPHIC STUDY IN PRESENCE OF A NORMAL SEQUENCE OF ACTIVATION OR OF BUNDLE BRANCH BLOCK.

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SUMMARY

Artificial pacing induces on electrocardiogram (ECG) a massive T wave inversion generating a posteriorly directed repolarization vector. In order to better evaluate this problem we studied by vectorcardiogram the effects of artificial pacing on ventricular repolarization in presence of a normal sequence of activation or of bundle branch block. Thus we evaluated 24 patients (pts) with implanted VVI programmable pacemakers. In each case a unipolar catheter was positioned at right ventricular apex and pacing rate was 70 beats/min. The resting ECG and VCG before implantation were normal (N) in 11 pts and showed a right bundle branch block (RBBB) in 7 pts and a left bundle branch block (LBBB) in 6 pts. ECG and VCG were repeated 7 and 40 days after implantation during spontaneous rhythm. AV conduction was 1:1 during all recordings. After pacing the maximal T vector changed its direction in N and RBBB pts and proved to go superiorly, posteriorly and to the right (even if less to the right in RBBB pts). Instead it did not vary evidently in LBBB pts. It is noteworthy that maximal post-

pacing T vector changed its direction in a patient with intermittent RBBB when the normal ventricular activation pattern was restored. Post-pacing T loop maintained its elongated or elliptical shape and showed an inverted direction of inscription in some cases. A post-pacing ST vector directed as the maximal T vector was present. QRS loop did not vary evidently. Pacing induced in N and RBBB pts massive T wave inversion and cospicuous ST depression in both limbs and precordial leads of unpaced ECG. Instead ECG of LBBB pts after pacing showed a more negative T wave only in the two cases in whom on VCG the direction of inscription changed.

In conclusion our data indicates that pacing modulates repolarization process (T wave "memory") according to the preexistent ventricular activation. It is possible that post-pacing repolarization represents the net electrical effect of coexisting ventricular activation patterns.

INTRODUCTION

As it is well known[1,2,3] after the endocardial surface of the right ventricle has been paced, "primary" T waves alterations are recorded in the electrocardiogram (ECG) during spontaneous rhythm. This effect has been attributed to the artificially induced change in the activation sequence that persistently modifies the order of spontaneous ventricular repolarization[2,3]. Moreover it has been reported that post-pacing T waves show a similar direction to that of the QRS complex of paced beats, both in the limbs and precordial leads[2,3]. This observation has been utilized to support a causal

link between the change in the activation sequence and the subsequent T wave abnormalities[2,3]. In order to better describe the effects of artificial pacing on ventricular repolarization we recorded the vectorcardiogram (VCG) in patients with normal QRS or with bundle branch block before and after the implantation of a permanent pacemaker.

METHODS

We evaluated 24 patients (pts) with implanted VVI programmable pacemakers. The resting ECG and VCG (Frank system) before implantation were normal (N) in 11 pts and showed a right bundle branch block (RBBB) pattern in 7 pts and a left bundle branch block (LBBB) pattern in 6 pts. ECG and VCG were repeated 7 and 40 days after implantation. In each case a unipolar catheter was positioned at right ventricular apex and demand pacing rate was maintained constantly at 70 beats/min. Cardiac stimulation was performed using pacing stimuli which were 0.50-0.60 msec in duration and at approximately 5 V. Programmability of pacemakers allowed (reducing pacing rate) to obtain all recordings during sinus rhythm and while AV conduction was 1:1. In each case ECG and VCG of paced beat were also obtained.

RESULTS

After pacing, the maximal T vector changed its direction in N pts going superiorly, posteriorly and to the right (Fig. 1). The same vector in RBBB pts was directed posteriorly as N pts but less to the right and

sometimes inferiorly (Fig. 2). The difference between RBBB pts and N pts was confirmed by a patient in whom it was possible to record post-pacing VCG while his QRS intermittently showed a normal or a RBBB pattern (Fig. 3). Maximal post-pacing T vector was directed more to the right during normal ventricular activation pattern. LBBB pts showed a behaviour quite different from that of N pts and of RBBB pts (Fig. 4). In fact maximal post-pacing T vector did not vary evidently in these pts. Post-pacing T loop in all pts maintained its elongated or elleptical shape, showed a nearly identical length-width ratio, had the efferent limb inscribed more slowly than the afferent limb. An inverted rotation of T loop was observed after pacing in some cases. A post-pacing ST vector directed as the maximal T vector was frequently present. Post-pacing QRS loop did not vary evidently in all pts. Pacing in N pts and in RBBB pts induced massive T wave inversion and cospicuous ST depression in both limbs and precordial leads of unpaced ECG. Instead ECG of LBBB pts after pacing showed a more negative T wave only in the two pts in whom on VCG the direction of inscription changed.

The direction of post-pacing T loop was nearly identical to that of QRS loop of paced beat in N pts and in RBBB pts, while it was not in LBBB pts. It is noteworthy that in N pts, unlike the other pts, the direction of the post-pacing T loop was completely and precisely opposed to that of the T loop of the paced beat.

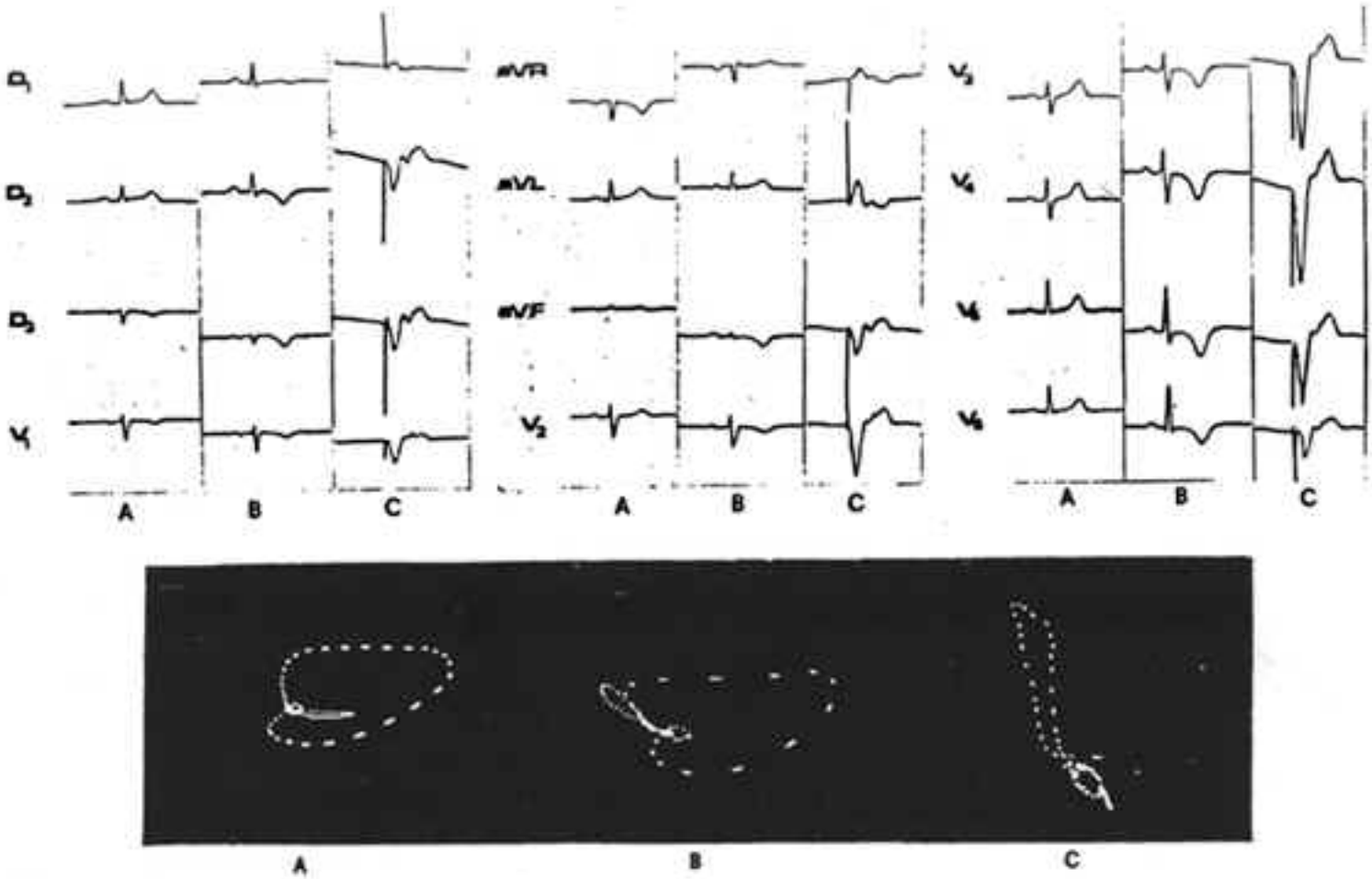

Fig. 1. Effects of right ventricular pacing on the normal (panel A) ECG and VCG (horizontal plane). Pacing from the right ventricular apex (panel C) induced a LBBB pattern with marked left axis deviation. The post-pacing ECG (panel B) shows negative T waves and ST depression in both limbs and precordial leads. The post-pacing maximal T vector (panel B) instead of being aligned with the maximal QRS vector of paced beat, was completely and precisely opposed to the maximal T vector of paced beat. Post-pacing T loop maintained its characteristics if we refer to shape, length-width ratio and velocity of inscription.

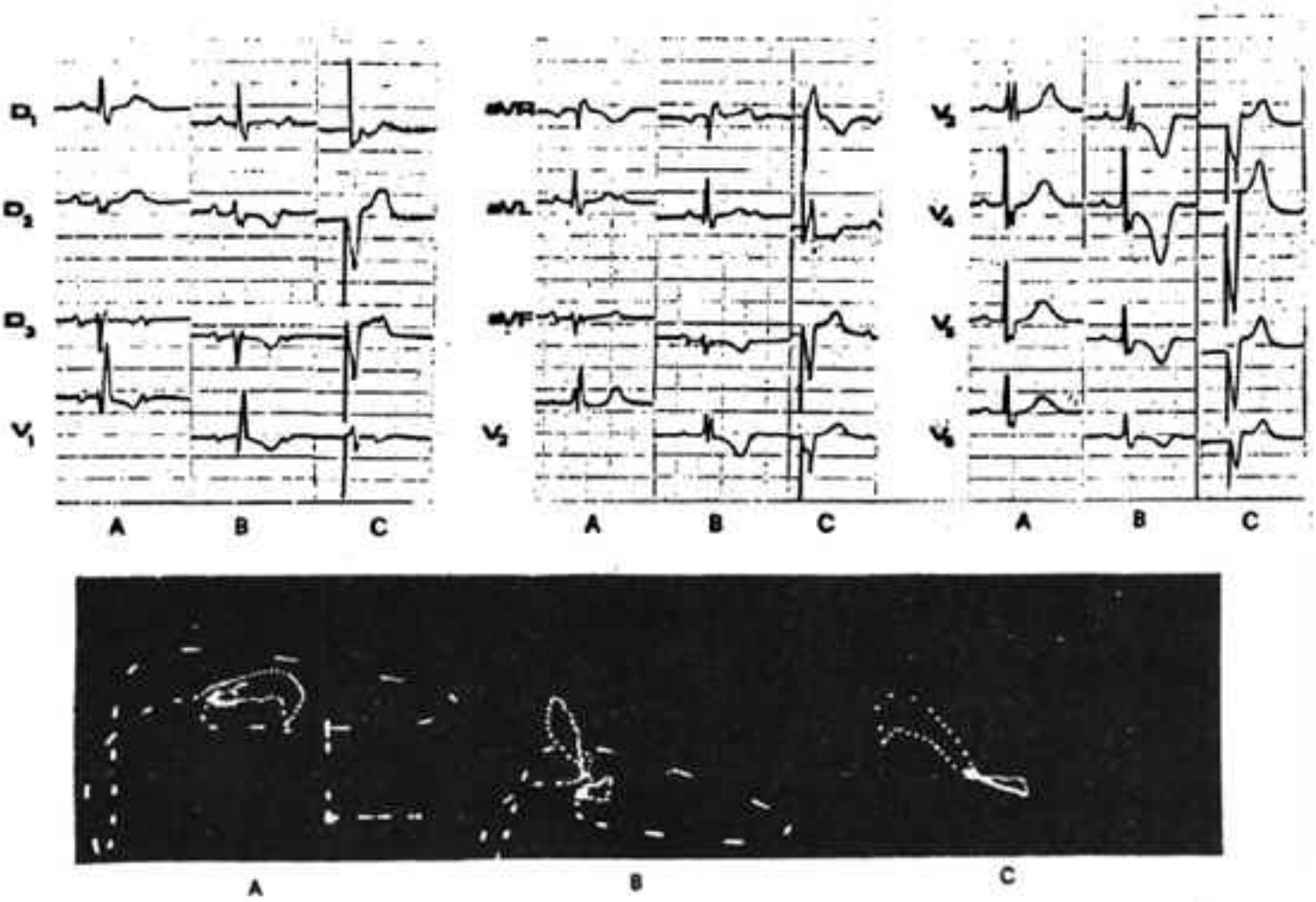

Fig. 2. Effects of right ventricular pacing on the ECG and VCG (horizontal plane) of a patient with RBBB (panel A). Pacing from the right ventricular apex (panel C) induced a left bundle branch block pattern with marked left axis deviation. The post-pacing ECG (panel B) shows negative T waves and ST depression in both limbs and precordial leads. The post-pacing maximal T vector (panel B) was directed less to the right than that of normal patients. Moreover the same vector was not concordant both with the maximal QRS vector of paced beat nor with the maximal T vector of paced beat.

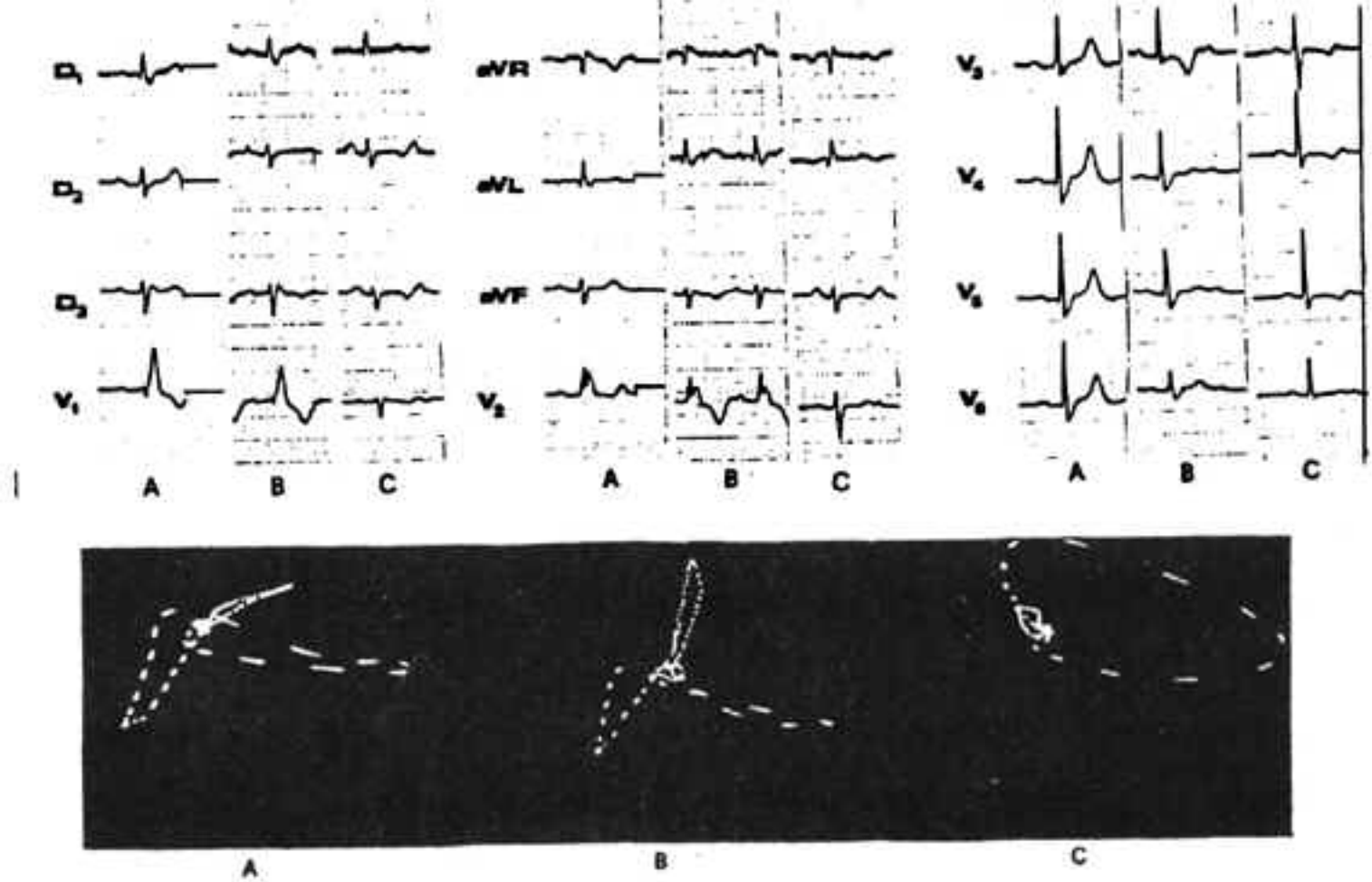

Fig. 3. Effects of right ventricular pacing in a patient with intermittent RBBB. Panel A: pre-pacing ECG and VCG (horizontal plane) showing a RBBB pattern. Panel B: post-pacing ECG and VCG while the QRS showed a RBBB pattern. Panel C: post-pacing ECG and VCG while the QRS showed a normal ventricular ectivation pattern. The maximal post-pacing T vector in presence of RBBB was directed less to the right than that in presence of normal ventricular activation pattern.

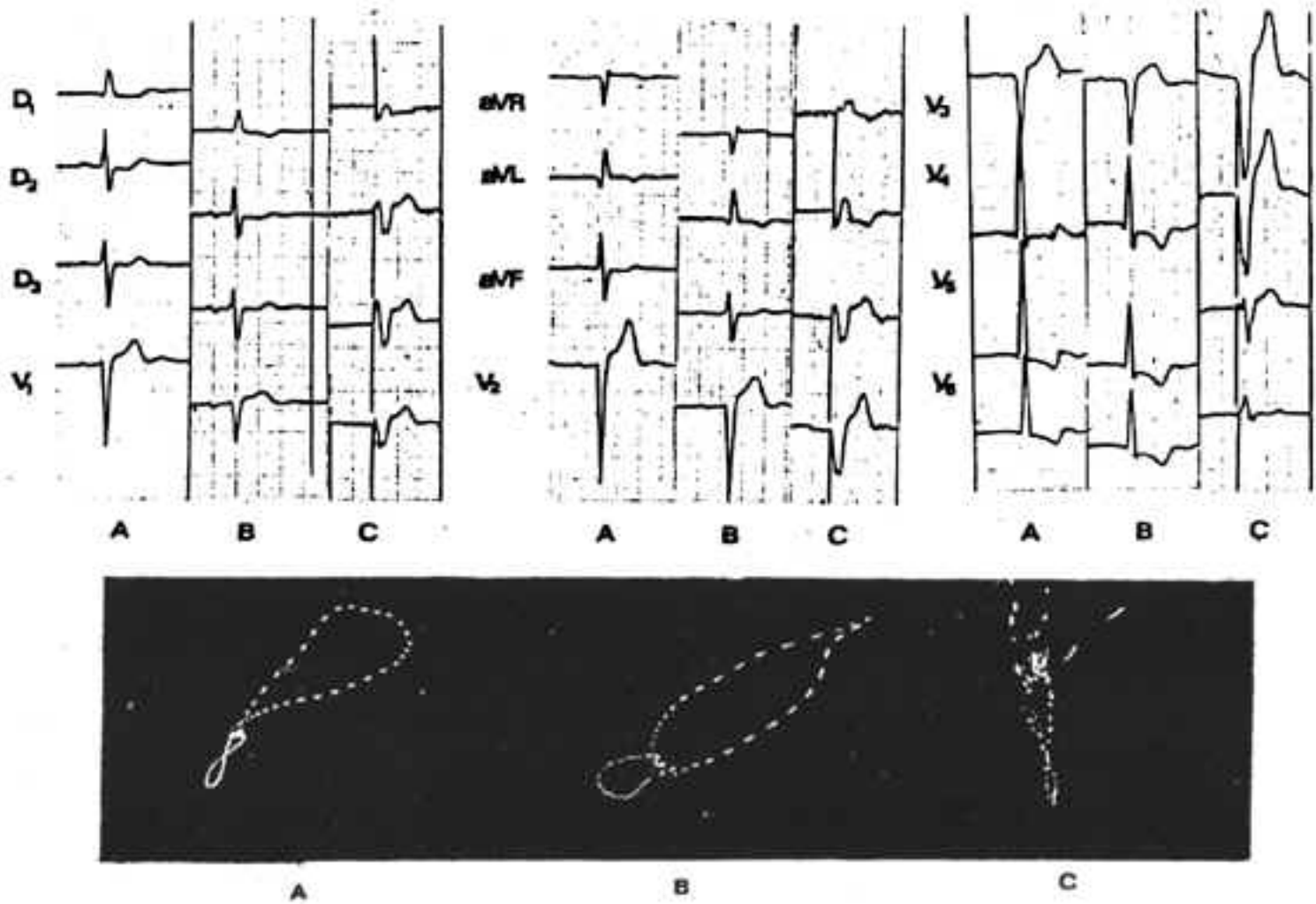

Fig. 4. Effect of right ventricular pacing on the ECG and VCG (horizontal plane) of a patient with LBBB (panel A). Pacing from the right ventricular apex (panel C) induced a LBBB pattern with marked left axis deviation. The post-pacing ECG (panel B) shows negative T waves and ST depression in left precordial leads. The post-pacing maximal T vector was nearly unchanged while the direction of inscription of the T loop was inverted (from counterclockwise to clockwise).

DISCUSSION

T wave abnormalities after right ventricular pacing have been attributed to the "memory" of the artificial ventricular repolarization sequence[2,3,4]. Pacing, causing changes of myocardial action potentials, modulates spontaneous ventricular repolarization and produces T wave changes[3]. Our study however was able to exstablish that pacing produces a different pattern of ventricular repolarization not only between N pts and bundle branch block pts but also between RBBB pts and LBBB pts. In particular the post-pacing T loop of RBBB pts is directed less to the right than that of N pts and somewhat down and, that of LBBB pts does not vary evidently. On this basis we can understand that the electrical effects of a new transient ventricular activation sequence depend in some way on the preexistent depolarization pattern, otherwise the maximal post-pacing T vector would have had the same direction in each patient. It is possible that pacing acting on different substrates shows (on ECG and VCG) diverse final evidences of its influence probably because it is conditioned by preexisting vectors of different magnitudes. Post-pacing repolarization could be the net electrical result of coexisting modulating effects, but also the net sum of electrical gradients because of localized disturbances of ventricular actions potentials.

Previous studies[2,3] indicate that the abnormal T wave is concordant with the abnormal QRS of the preceding ventricular pacing. We observed that the maximal post-pacing T vector, instead of being aligned to the maximal QRS vector of paced beat, was completely and