The Q Wave in Precordial Electrocardiograms Overlying the Hypertrophied Right Ventricle: Intracavity Leads

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Right ventricular cavity electrocardiograms were obtained in six subjects having qR patterns in V leads made from precordial sites overlying the hypertrophied right ventricle. Four of the six, unlike control subjects, had no initial R wave in the right ventricular cavity; one had only a questionable initial R wave. Simultaneous intracavity and precordial electrocardiograms suggested that the initial Q wave over the hypertrophied right ventricle is due to abnormal depolarization of the interventricular septum, and that the large R wave over the hypertrophied right ventricle is the result of delay in activation of the free wall of that chamber.

SEMIDIRECT unipolar electrocardiographic leads (V leads) from sites on the precordial overlying the normal human right ventricle usually reveal a QRS pattern characterized by a small initial R wave and a large final S wave (rS pattern*). When the right ventricle is hypertrophied, V leads obtained from the right precordium may show one of four types of QRS complex: (1) the normal rS pattern; (2) right bundle branch block; (3) evidence suggesting dilatation but not hypertrophy of the right ventricle; (4) the QRS pattern which is considered diagnostic of right ventricular hypertrophy. This latter pattern, with which we are primarily concerned, is a qR pattern associated with a QRS of normal duration. Occasionally, there may be seen an rSR or qRs pattern. The Q wave in precordial leads overlying the hypertrophied right ventricle may be quite deep in proportion to the succeeding R wave, resulting in Q:R ratios ordinarily associated with myocardial infarction.

Since the origin of the Q wave in electrocardiographic leads from the chest overlying the hypertrophied right ventricle is in consider-

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* In discussing the QRS complex of the electrocardiogram, small letters will be used to designate relatively small deflections; capital letters will be used to designate large deflections.
the five-channel Hathaway pressure recording apparatus. Blood samples, collected under oil and stored in ice over mercury, were analyzed for oxygen and carbon dioxide in the Van Slyke manometric apparatus. Duplicate samples were required to check within 0.2 volume per 100 cc.

Intracavity leads (fig. 2) were taken from the pulmonary conus, midzone of the right ventricle, low in the right ventricle, right ventricular side of the tricuspid valve and low in the right atrium. In the intrinsicoid deflection is delayed, the R is prominent, and the S is small.

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Results

Case Reports

D. H., a 61 year old white man, had pulmonary emphysema confirmed by spirometry, chronic cor pulmonale, and secondary polycythemia. An angiocardiogram revealed right ventricular hypertrophy. Cardiac catheterization performed May 26, 1950 revealed a pulmonary artery pressure of 75/25 mm. Hg. Arterial oxygen saturation was 68.27 percent of capacity. Hemoglobin was 17.45 Gm. per 100 cc. of blood (Van Slyke oxygen capacity method). Arterial carbon dioxide content was 66.84 volumes per 100 cc. of blood. The arterial hypoxemia and hypercapnia were considered characteristic of severe pulmonary emphysema. The pulmonary arterial hypertension was in keeping with the impression of cor pulmonale.

The standard lead electrocardiogram, together with unipolar extremity leads and unipolar precordial leads, is shown in figure 1. The standard leads show right axis deviation. Lead aVR shows a qR complex, consistent with but not diagnostic of right ventricular hypertrophy. Since the QRS pattern of lead V1 was not typical of right ventricular hypertrophy, leads V6R, V5R, V4R and V3R were taken. These V leads all showed the classic qR or qRs pattern of right ventricular hypertrophy. In the leads VTR through V1, the qRs pattern differs from that seen in septal infarction in the fact that here none of these areas was a definite initial R wave seen in the QRS complex.

C. B., a 56 year old white man, had pulmonary emphysema, cor pulmonale, and congestive heart failure. Hematocrit was 59.
On Dec. 22, 1950, cardiac catheterization was performed. Pulmonary artery pressure was 90/45 mm. Hg. Right ventricular pressure was 80/15-7 mm. Hg. Systemic arterial carbon dioxide content was 65.69 volumes per 100 cc. of blood. Hemoglobin was 16.87 (Van Slyke oxygen capacity method).

The intracardiac electrocardiographic leads and standard leads, unipolar extremity leads and unipolar precordial leads obtained at the time of catheterization are reproduced in figures 3 and 4. The standard leads show right axis deviation and deep Q waves in leads II and III. There is a definite Q wave in leads V_{4R}, V_{5R}, and V_{6}; all show the QRS complex characteristic of right ventricular hypertrophy. It was felt that the patient possibly had healed posterior myocardial infarction in addition because of the large Q wave lead in V_{F}; however, the probability that this Q wave was referred from the posterior transitional zone between right and left ventricles could not be excluded. Simultaneous precordial and intracavity electrocardiograms (fig. 4) revealed that the Q wave in lead V_{1R} was simultaneous in onset with the initial downward deflection in tracings made from the right ventricular cavity. In no part of the right ventricular cavity was the normal R's pattern obtained. Since there was no electrocardiographic evidence of massive septal infarction, it was felt that the possible old posterior myocardial infarct played no role in the absence of an R wave in the right ventricular cavity leads.

R. P., a 62 year old Negro man, had bronchietasis, pulmonary emphysema, cor pulmonale, and congestive heart failure.

Cardiac catheterization was performed on Jan. 5, 1951. Brachial artery blood showed oxygen saturation 76.9 per cent of capacity and a carbon dioxide content of 64.22 volumes per 100 cc. of blood. Hemoglobin (Van Slyke) was 14.38 Gm. per 100 cc. Right ventricular pressure was 54/7 mm. Hg.

The standard electrocardiographic leads, unipolar extremity leads, and unipolar precordial leads obtained at the time of cardiac catheterization are reproduced in figures 5 and 6.

The standard leads show right axis deviation. Lead V_{1R} shows a qR pattern with the QRS complex of normal duration. There is a small initial R wave in leads V_{5R} and V_{6}. Lead V_{4} (fig. 6) contains a rather wide S wave in the QRS complex. These findings are considered indicative of right ventricular hypertrophy. Intracavity leads from the apex of the right ventricle revealed a QS pattern.

J. S. was a 54 year old white man suffering from pulmonary emphysema and cor pulmonale without congestive heart failure.

**Fig. 3.** Case C. B. Standard and unipolar electrocardiographic limb leads: unipolar precordial leads. Standard leads show right axis deviation and a deep Q wave in leads II and III. Leads V_{4R}, V_{5R} and V_{6} show the qR or qRs pattern characteristic of right ventricular hypertrophy.

Cardiac catheterization was performed Oct. 27, 1950. Pulmonary artery pressure was 55/32 mm. Hg. Right ventricular pressure was 56/2.5 mm. Hg. The systemic arterial blood was 81.3 per cent saturated with oxygen and contained 52.09 volumes of carbon dioxide per 100 cc. of blood. Hemoglobin (Van Slyke oxygen capacity method) was 14.74 Gm. per 100 cc. of blood.

Standard and unipolar limb leads and unipolar precordial lead electrocardiograms were made. The standard leads revealed right axis deviation. There was a large Q wave in lead III and in lead V_{F}; this was thought to be referred from the Q wave over the right precordium. Leads V_{1R} and V_{5R} revealed the QRS pattern characteristic of right ventricular hypertrophy. Intracavity leads within the right ventricle taken at one-half and one-third normal sensitivity revealed only a questionable R wave and a large S wave.

Patient E. S. was a 54 year old Negro man who had cor pulmonale in congestive failure. Venous
blood carbon dioxide combining power was 64 volumes per 100 cc.

Cardiac catheterization was performed Aug. 18, 1950. The pulmonary artery pressure was found to be 72/30 mm. Hg. Right ventricular pressure was 60/9 mm. Hg.

Intracavity electrocardiograms were taken along with the standard leads, unipolar extremity leads, and unipolar precordial leads. The standard leads showed right axis deviation. Leads $V_{3R}$, $V_{6R}$, and $V_{5R}$ demonstrated the characteristic QRS pattern of right ventricular hypertrophy. Intracavity leads taken at approximately one-half normal sensitivity revealed no initial R wave in the region of the pulmonary conus or tricuspid valve of the right ventricle. Unfortunately the onset of the QRS complex was partially obscured by an artefact in leads obtained from the middle of the right ventricle and from near the apex of the right ventricle. However, it was believed that the initial deflection in the leads from the mid-right ventricle and apex of the right ventricle is a Q wave; that in the pulmonary conus was definitely a Q wave. An apparent minute initial R wave in the right atrial and tricuspid lead may have come from the left ventricular cavity via the mitral orifice and left atrium. An initial R wave in the pulmonary artery lead probably came from the left ventricular cavity via the aorta.

R. T., a 22 year old white man, had uncomplicated pulmonic stenosis. Cardiac catheterization was performed Dec. 19, 1950. As the catheter was advanced through the superior vena cava, right atrium, right ventricle, and pulmonary artery, in no instance was there a rise of even 0.1 volume per 100 cc. in oxygen content, thus excluding a left to right intracardiac shunt. Systemic arterial oxygen saturation was 96.15 per cent of capacity, thus militating against a right to left intracardiac shunt. Pressure in the pulmonary artery was 18/10 mm. Hg. and in the right ventricle 165/7 mm. Hg.

Standard electrocardiographic leads, unipolar
Fig. 5. Case R. P. Standard and unipolar electrocardiographic limb leads: unipolar precordial leads. The standard leads show right axis deviation. Lead V_{4R} shows the qR pattern diagnostic of right ventricular hypertrophy.

Fig. 6. Case R. P. Simultaneous precordial and intracavity electrocardiogram. Shows the absence of an initial R wave in the right ventricular cavity lead.
Q WAVE IN PRECORDIAL ELECTROCARDIOGRAMS

limb and precordial leads and simultaneous intracavity 
and precordial leads were made. The standard leads showed marked right axis deviation. Leads 
V2, V3R, V5R, and V6R each revealed the characteristic 
QRS pattern of right ventricular hypertrophy. Intracavity leads obtained from the midportion of 
the right ventricle at one-fifth normal sensitivity demonstrated a small initial R wave occurring simultaneously with Q wave in leads V3R and V4R.

Control Studies

In each of three control subjects intracavity leads from the right ventricle revealed an rS pattern. All controls had rS patterns in semidirect unipolar leads from the precordium over 
the right ventricle. Two control subjects had emphysema; the other had no evidence of heart disease.

DISCUSSION

Following the investigations of Hecht and others, Levine found an rS pattern in 24 of 27 
normal subjects in electrocardiograms taken 
from the right ventricular cavity. This normal 
initial positivity, found also in our control subjects, is interpreted as indicating earlier activation of the left side of the interventricular septum in the normal course of ventricular depolarization.

The cause of the initial Q wave in V leads over 
the hypertrophied right ventricle is in dispute. 
One group of investigators has stated that the 
qR complex in right precordial leads in right 
ventricular enlargement is due to extreme 
clockwise rotation of the heart so that the electrode in the V1 position is facing the posterobasal portion of the left ventricle. Kert and Hoobler have suggested that the initial Q wave over the right precordium in the aforementioned condition may be due to activation of some part of the left ventricle prior to septal depolarization. Sodi-Pallares believes that the 
initial Q wave in right ventricular hypertrophy is the result of transmission of negative potentials in the right auricle to the right side of the 
precordium. Myers believes that the initial Q wave over the right ventricle in right ventricular hypertrophy may be due to one of two factors: the interventricular septum may 
be activated normally from left to right, but the resulting initial R wave of the right ventricular cavity may be so small that it is not transmitted to the right precordium, 
where an initial Q wave may appear as the result.

Schlesinger and co-workers studied five cases of right ventricular hypertrophy by means 
of right ventricular cavity leads; one of their cases had a qR complex in lead V1. This case also had an initial Q wave in the right ventricular cavity electrocardiogram. Kert and Hoobler also found an initial Q wave in the 
right ventricular cavity lead of a case of right ventricular hypertrophy having a qR complex 
in lead V1.

In our series we have studied six cases of 
right ventricular hypertrophy having a qR complex in V leads over the right precordium. 
Only one of these had a definite initial R wave in the right ventricular cavity. One other had a questionable initial R wave in the right ventricular cavity, certainly indicating weakness of septal forces. In four cases there was a definite QS pattern in the right ventricular cavity; in 
two of these, simultaneous records were obtained demonstrating the onset of the QS pattern in the right ventricular cavity to be simultaneous with the beginning of the Q wave in semidirect leads over the right ventricle.

The evidence in the cases we have studied is 
in accordance with the theories of Myers. In 
the cases having a QS pattern in the right 
ventricular cavity leads, one would assume 
that the interventricular septum is being activated either from right to left, or simultaneously on the two sides. Unfortunately, we do not have intracavity leads from the left ventricle, which would serve to show conclusively whether the septum were activated from right to left initially. Wilson has stated that the initial Q waves in ventricular hypertrophy may be due to a decreased density of the junctions between Purkinje fibers and ordinary heart muscle in certain areas as a result of dilatation of the chamber chiefly affected. In the one and possibly two cases in our group showing a small 
initial R wave in the right ventricular cavity 
leads, we believe that left to right septal de-polarization has been interfered with, but to a
lesser degree, resulting in a small initial R wave in the right ventricular cavity which is lost in transmission to the V leads over the right precordium.

The mechanism producing the large R wave of the qR complex in right ventricular hypertrophy is also of interest. Kossmann has concluded that this R wave is produced by activation of the free wall of the left ventricle from his finding that the nadir of Q and the peak of R occurred simultaneously in V leads over the posterior left chest and in lead V₃ in subjects with right ventricular hypertrophy. McGregor supported Kossmann's concept by demonstrating R/S patterns in direct right ventricular epicardial leads taken at operation in 10 cases of tetralogy of Fallot.

In this connection, it is of interest to examine the electrocardiogram of subject R. R. (fig. 6), showing leads V₄₅, lead V₆, and the right ventricular cavity lead recorded simultaneously. In comparing the right ventricular cavity lead with lead V₆, one notes that the nadir of the S wave in the former occurs simultaneously with the peak of R in the latter, indicating that both are produced by the arrival of the force of excitation at the epicardial surface of the left ventricle. The nadir of S in V₆ occurs simultaneously with the peak of R in V₄₅, suggesting that both are produced by activation of the free wall of the right ventricle. In comparing the time of onset of the peak of R in V₄₅ with the time of occurrence of the nadir of S in the right ventricular cavity lead in figure 6, one notes that the peak of R in V₄₅ occurs 0.03 second later than the nadir of S in the cavity lead. In figure 4, the record of subject C. B. shows the peak of R in lead V₂₃ to occur 0.04 second later than the nadir of S in the lead taken from the right ventricular cavity near the apex. The occurrence of the peak of R in leads over the right ventricle later than the arrival of the force of excitation at the free wall of the left ventricle would seem to indicate that the R wave in leads over the right ventricle is produced by the activation of the right ventricular wall, since there is no R wave of comparable magnitude in the leads obtained from the right ventricular cavity.

Summary and Conclusions

Intracavity electrocardiograms were obtained from the right ventricle in six cases of right ventricular hypertrophy having qR complexes in the V leads made from sites over the right precordium, and in three subjects without right ventricular hypertrophy having R/S complexes in the V leads obtained from sites over the right ventricle. In four of the subjects with right ventricular hypertrophy, the right ventricular cavity electrocardiogram showed no initial R wave; in one the R wave was questionable; in one there was a definite initial R wave in the right ventricular cavity leads. The control subjects each showed a definite initial R wave in the right ventricular cavity leads.

It is concluded that the normal early left to right depolarization of the interventricular septum is often interfered with in right ventricular hypertrophy to the extent that the normal initial R wave of the intraventricular QRS electrocardiogram is not produced or is diminished in amplitude. The absence or diminution of this R wave may be responsible for the initial Q wave in V leads obtained from precordial sites over the right ventricle in hypertrophy of that chamber.

It is also concluded that the delayed R wave of the qR electrocardiographic pattern in the V leads obtained from precordial sites over the hypertrophied right ventricle is probably produced by activation of the free wall of the right ventricle.

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