QT interval in right and left bundle-branch block

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The QT interval of the electrocardiogram is prolonged in right and left bundle-branch block. Since the QT interval is not prolonged outside the normal range due to myocardial disease alone, this lengthening of the QT interval is due to the conduction defect and is probably due to delayed depolarization (and thus repolarization) of the heart. There is, however, a significant difference in the QT interval in left and right bundle-branch block (t = 3·86; P < 0·01), since the QT was shorter in right than in left bundle-branch block. This may be due to the completion of normal repolarization in the left ventricle, so that only in some cases of right bundle-branch block does repolarization end in the right ventricle.

Correction of the actual QTc for the conduction defect of left bundle-branch block can be made by subtracting the prolongation of the QRS due to the block from the actual QTc. This will allow the QTC (corrected for conduction defect and rate) to be directly compared with normal (0·42 sec). Correction for right bundle-branch block can be made by subtracting 0·20 sec less from the actual QTc.

The QT interval is prolonged in hypokalaemia and hypocalcaemia, and shortened in hypercalcaemia. It is used to evaluate such abnormalities (Grant, 1970) and may also reflect cellular levels of these electrolytes.

However, in the presence of bundle-branch block the QT is abnormal, and it is thought such conduction defects invalidate measurements of the QT (Ashman, 1942). The QT interval decreases with increasing heart rate, and to allow for this factor a number of formulae have been proposed to express the relation between the cardiac cycle length and the QT (Bazett, 1918–1920; Ashman, 1942). These cumbersome formulae for the average and maximum normal QT have been superseded by the QTc as proposed by Kissin, Schwarzschild, and Bakst (1948). Though there are differences in men, women, and children for the QT, such differences can be ignored if the maximum figure for the normal QT is used to evaluate any individual QT.

This study was undertaken (while taking these factors into consideration) to determine the effect of bundle-branch block on the QT and to try to see if this effect of bundle-branch block could be corrected for in any measurement of the QT or QTc. This would then allow electrolyte abnormalities to be assessed even in patients with bundle-branch block.

Subjects and method

One hundred and fifty electrocardiograms showing left

bundle-branch block, and 126 electrocardiograms indicating right bundle-branch block were examined during a 9-month period at two busy general hospitals. They were obtained by examination of all electrocardiograms with a QRS > 0·12 sec. The criteria used in selecting cases of bundle-branch block were those of Lipman and Massie (1965). Thus the QRS was at least 0·14 sec; there was delayed onset of intrinsicoid deflection over the affected ventricle (> 0·06 sec) with the initial 0·04 sec shown as a positive deflection in leads over the unaffected ventricle and the terminal 0·04 sec shown as a negative deflection in these leads.

In 55 electrocardiograms with left bundle-branch block and 33 electrocardiograms with right bundle-branch block there were electrocardiographic changes which were not due to bundle-branch block, such as those of myocardial infarction or arrhythmias such as atrial fibrillation; in some, drugs known to affect the QT had been given or the heart rates were in excess of 150/minute or below 40/minute. These cases were excluded because of the possible effect of such factors on the QT and the difficulty of determining the QT at the extremes of heart rate (Lepeschkin, 1955). To eliminate any error due to age or sex these details were recorded for each patient.

The cycle length (C), the QT, the QRS, and the PR interval were measured for each electrocardiogram to an accuracy of ±0·02 sec. All the leads were examined and the mean of the longest and shortest measurements of the QT in these leads and the longest measurement of the QRS in any lead were recorded (Grant, 1970); the PR was measured in the same lead as the QRS. The ST interval (the measurement from the end of the S wave to the end of the T wave) was calculated from the differ-

ence between the width of the QRS and the QT for each electrocardiogram. The significance of the differences in the average measurements of the QT in left and right bundle-branch block was determined using Student's t test.

The average QT for each bundle-branch block was compared with the average QT for normal men and women and patients with cardiac disease as determined by Ashman (1942). The constant K for Bazett's formula, the average $QT = K\sqrt{C}$, was calculated for all cases of both left and right bundle-branch block and from this the QTc was determined. (Kissin et al. (1948) used the constant from Bazett's formula for the maximum QT to give the maximum QTc and found it was 0·42: figures above this were abnormal.) From these measurements a correction factor was found that, when subtracted from the actual QTc, gave the QTC (corrected for heart rate and conduction defect).

Results

There were 43 women and 52 men with left bundle-branch block and 39 women and 54 men with right bundle-branch block. There was no significant difference in the mean age of both groups. In the Table are the measurements of the QT, the cycle length (C), the PR interval, and the QRS, and the calculated figure for the ST interval for these electrocardiograms.

TABLE *Average measurements of electrocardiograms in cases of right and left bundle-branch block*

	Right bundle-branch block	Left bundle-branch block
Mean QT	0·395 (SD 0·050)	0·422 (SD 0·48)
Mean QRS	0·15 (SD 0·049)	0·158 (SD 0·047)
Mean PR	0·171 (SD 0·045)	0·161 (SD 0·046)
Mean ST	0·245 (SD 0·049)	0·264 (SD 0·046)
Mean C	0·734 (SD 0·161)	0·737 (SD 0·163)
Mean age (yr) of women	70·6 (SD 12·7)	64·8 (SD 12·3)
Mean age (yr) of men	65·2 (SD 12·8)	65·9 (SD 9·1)

The normal QT for such heart rates (average C=0·735) is 0·36 sec (Ashman and Hull, 1941); the upper limit of normal is 0·38 sec. The difference of the mean QT of right bundle-branch block from normal was 0·035 sec (t = 6·54, P < 0·01). There was a difference of 0·062 sec between the QT of left bundle-branch block and the normal QT (t = 12·1, P < 0·01). Since the normal QRS width varies from 0·08 to 0·10 sec, the QRS in cases of left bundle-branch block was approximately 0·07 sec longer than normal, and in cases of right bundle-branch block was approximately 0·06 sec longer than normal. Thus in cases of left bundle-branch block the

prolongation of the QT was compatible with the increase in the width of the QRS, but was 0·03 sec less for cases of right bundle-branch block.

There was a significant difference in the QT between left and right bundle-branch block of 0·027 sec (t = 3·86, P < 0·01). Little of this difference was due to a difference in the width of the QRS since the ST interval was also significantly different between the two groups (t = 2·17, P < 0·02).

Either the logarithmic relation, $QT = K$ log 10 $(C + 0·07)$ as devised by Ashman (1942) or a square root relation adequately expressed the variation in the QT with heart rate. Thus for left bundle-branch block the correlation coefficient for the equation $QT = K$ (log 10 $(C + R)$) was 0·62 and a similar coefficient for right bundle-branch block was 0·66, K being 0·47 and 0·44, respectively (R = 0·07 as in the similar equation of Ashman, 1942).

Using Bazett's formula:

LBBB: $QT = 0·488\sqrt{C}$
The mean QTc = 0·488 (SD 0·50).

RBBB: $QT = 0·46\sqrt{C}$
The mean QTc = 0·46 (SD 0·46).

In 2 cases of left bundle-branch block the QTc was measured before and after the onset of left bundle-branch block. In a man of 60 years the QTc was measured before and after the change from right to left bundle-branch block (QTc = 0·46 and 0·52, respectively). In a woman of 69 years the QTc lengthened from 0·38 to 0·44 after the onset of left bundle-branch block.

No other differences were found and the slightly longer QRS in left bundle-branch block was almost exactly compensated by a decrease of the PR interval when compared to right bundle-branch block. Variation of the QT in different leads was found to be ≤0·04 sec.

Discussion

There is a significant increase in the QT interval in patients with right and left bundle-branch block, but it is greater for left than for right bundle-branch block. In view of the frequency of myocardial diseases such as ischaemic heart disease in patients with left bundle-branch block (Hiss and Lamb, 1962) and to a lesser extent patients with right bundle-branch block (Reusch and Vivas, 1959) it could be suggested that the prolongation of the QT was secondary to this. However, though the average QT is slightly increased in patients with cardiac disease, this is within the limits of normal. Thus Ashman (1942) found that the mean QT for such patients was 0·41 log 10 $(C + 0·07)$. Therefore, the expected QT for the right bundle-branch group would be 0·371 and for the left bundle-branch group

would be 0·372 sec. This was confirmed by examination of 342 electrocardiograms of patients with cardiac disease with a QRS <0·12 sec; the mean QT was 0·364 and the average cycle length was 0·75 sec (personal communication). Ashman (1942) found the upper limit of normal of the QT was 0·42 log 10 (C+0·07) and there is therefore no need to apply a correction factor for the QT or the QTc in patients with cardiac disease when these measurements are used to estimate electrolyte imbalance.

Although the slightly shorter QRS of the right bundle-branch block cases cannot be the cause of the shorter QT in such cases compared with left bundle-branch block, intrinsicoid deflection which represents the time of depolarization of the majority of the ventricle over which the lead is placed, occurs later in the left than the right ventricle. Intrinsicoid deflection occurs 0·015 to 0·035 sec after the onset of the QRS in lead V1 and 0·035 to 0·055 sec after the onset in lead V6 (Lipman and Massie, 1965). This difference of 0·02 sec is not the explanation of the difference in the QT because in 35 patients with left bundle-branch block and 24 patients with right bundle-branch block measurements of the time from intrinsicoid deflection to the end of the T wave in leads V6 and V1, respectively, showed that there was a difference of 0·028 sec between left and right bundle-branch block. The groups were comparable as regards heart rate, age, and sex and these factors could not be the cause of the difference in the QT.

There are rare cardiac diseases with prolongation of the QT (Gale et al., 1970), but it seems that usually conduction must be delayed to a large ventricular area before the QT is prolonged. Since the left ventricle makes the major contribution to the QRS (depolarization) and to repolarization (Goldman, 1970) and the latter includes all the changes up to the end of the T wave, the terminal part of the T wave is of left ventricular origin. (Durrer et al. (1970) found that the conus of the right ventricle and the posterobasal segments of the heart were excited last (after 60–70 msec); they admitted that these areas might not contribute significantly to the QRS. Similar considerations probably apply to repolarization.) Therefore probably the delay in repolarization of the right ventricle in right bundle-branch block in most cases is not of sufficient magnitude to delay the termination of the T wave.

It seems necessary to estimate a correction factor for the QT in bundle-branch block even if the block is not associated with other evidence of cardiac disease. Since it is impossible to exclude myocardial disease in patients with bundle-branch block, or to be certain of the anatomical site of the blocks, these correction factors apply to an electrocardiographic diagnosis.

As would be expected from the previous equation, the prolongation of the QT in patients with bundle-branch block is greater at slower heart rates. However within the limits of heart rate of this study, a simple correction can be made by subtraction of 0·06 sec from the QT of patients with left bundle-branch block and 0·03 sec from the QT of patients with right bundle-branch block. In view of the slight variation in the width of the QRS, this can also be taken into consideration. Thus the correction factor in patients with left bundle-branch block is found by subtraction of 0·10 sec from the width of the QRS and similarly by subtraction of 0·12 sec from the width of the QRS in patients with right bundle-branch block.

The QTc is of greater use in cardiology, and by subtraction of 0·07 sec in cases of left bundle-branch block, and of 0·04 sec in right bundle-branch block from the calculated QTc for each case, comparison with the maximum normal QTc (0·42) can be made. Such calculations will be helpful when the electrocardiogram is being used to assess hypokalaemia or hypocalcaemia since lengthening of the QT (or QTc) is a valuable sign of such conditions (Lipman and Massie, 1965).

However, Lepeschkin (1955) considered that the composite nature of the QT militated against its usefulness. It would be better divided into three parts, the QRS (depolarization), the ST segment (from the S wave to the beginning of the T wave, phase 2 of the action potential), and the T wave (phase 3 of the action potential). Certainly the ST interval as measured here from the end of the QRS to the end of the T wave is more useful than the QT and has a similar relation to the heart rate.

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