Comparison between scalar and corrected orthogonal electrocardiogram in diagnosis of acute myocardial infarcts

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Twelve-lead electrocardiograms and orthogonal electrocardiograms taken with Frank's corrected orthogonal lead system have been compared in 259 patients with recent myocardial infarction. In the scalar electrocardiograms a diagnostic recognition rate of 62 per cent was recorded. Q/R-ratios >0.21 in X lead, >0.22 in Y lead, and <0.10 or >1.20 in Z lead were used as signs of myocardial infarction in the orthogonal electrocardiograms. Eighty-two per cent showed pathological Q/R ratios according to these criteria. The orthogonal electrocardiogram technique is of value in the diagnosis of recent myocardial infarction because of its simplicity, the strict criteria which can be applied, and the high recognition rate.

Alone or in combination with other tests, the electrocardiogram provides the best diagnostic criteria of recent myocardial infarction. From a theoretical point of view, however, it is not possible to diagnose all cases of recent myocardial infarction from the electrocardiogram. The aim of this study was to compare the diagnostic changes in the 12-lead electrocardiograms according to accepted criteria with orthogonal electrocardiograms hoping to improve accuracy in the diagnosis of myocardial infarction.

Material and methods

The material comprises all patients with the diagnosis of recent myocardial infarction seen during a period of one year provided the case history was less than 48 hours and the patients had lived more than 24 hours after admission to the hospital. The diagnoses were based on case histories, electrocardiograms, and SGOT values. In all patients at least one orthogonal electrocardiogram was also taken. Twelve lead electrocardiograms and SGOT levels were recorded on the first, second, and third days after admission and just before discharge and further electrocardiograms were usually recorded during the stay. Orthogonal electrocardiograms were recorded on the second and third days and just before the patients left hospital, using Frank's corrected orthogonal lead system (Frank, 1956). All the electrocardiograms were taken with a Mingograph ECG analyser. Pathological Q waves in the scalar electrocardiograms were taken as a sign of myocardial infarction

according to accepted criteria (Lipman and Massie, 1965). Electrocardiograms with pathological Q waves were termed 'typical' and those without pathological Q waves 'atypical'. Cases with bundle-branch block were regarded as typical provided there was at least one electrocardiogram with normal conduction showing a typical Q wave pattern of myocardial infarction, as also were cases of right bundle-branch block with signs of anterior or diaphragmatic myocardial infarction. The ST and T wave changes were regarded as primary abnormalities as not according to the ventricular gradient approach of Grant (1957). In all patients at least one transaminase value exceeded 40 Karmen units. All cases with border-line SGOT values showed a definite peak value of the SGOT during one of the first few days, with normalization later. Case histories with pain in the upper abdomen, in the chest, and/or in the front of the neck have been called typical case histories, while case histories without pain have been called atypical. All patients with atypical case histories had typical 12-lead electrocardiograms except 6 patients in whom there were borderline 12-lead electrocardiograms with distinctly pathological orthogonal curves.

Increase of erythrocyte sedimentation rate to at least 10 mm/hour from the first to the fifth day in the hospital has been called positive erythrocyte sedimentation rate reaction. A temperature of 38°C or more during the first four days has been called a positive temperature reaction, while a maximum temperature less than 38°C has been called a negative temperature reaction (despite the fact that many of these patients had a subfebrile reaction, followed by normal temperature in a few days). Earlier angina pectoris has been defined

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as typical chest pain provoked by physical and/or emotional stress for at least one month before the acute infarction. By earlier infarction is meant myocardial infarction diagnosed in hospital at least one month before admission to hospital. No patient has been included more than once. If a patient had more than one myocardial infarction during the trial period, only the first episode has been included.

In all patients the Q/R ratios in X, Y, and Z leads have been recorded in all orthogonal electrocardiograms. The Q and R wave amplitudes, respectively, have been measured by hand, using the PR segment as baseline. In cases where the wave amplitudes were seen to be particularly small, the amplitudes were increased by changing the calibration of the electrocardiogram analyser. A magnifying glass was used in all measurements which were performed on at least two different occasions in all cases. If there was any considerable discrepancy between the two results, they were repeated at least once more. In all cases with borderline ratios at least three measurements were performed. The criteria for pathological Q/R ratios have been adopted from the work of Draper *et al.* (1964), also used by Naval, Cosma, and Pipberger (1967). This means that Q/R ratios more than 0.21 in the X lead, more than 0.22 in the Y lead, and less than 0.10 or more than 1.20 in the Z lead, in the absence of the WPW syndrome or left bundle-branch block, have been recorded as pathological Q/R ratios caused by myocardial necrosis. Q/R ratios more than 1.20 have been discarded in cases with right bundle-branch block or in cases with signs of pure right ventricular hypertrophy. No case had congenital heart disease.

In the scalar electrocardiograms R/S ratios more than 1.0 in V₁ and/or V₂ have been recor-

ded. R waves less than 2 mm in V₁-V₃ have also been especially noted and defined as rudimentary R waves in V₁-V₃ in the absence of left bundle-branch block or pulmonary emphysema.

Results

The material comprises 259 patients, of whom 190 were men and 69 women. The age and sex distribution are shown in Table 1. The average age of the men was 60.0 years and of the women 67.7 years. The electrocardiographic localization of the infarction in the scalar electrocardiograms is summarized in Table 2, and so are the various equivocal changes. A total of 124 (65%) of the men and 38 of the women (55%) had unequivocal signs of myocardial infarction in the scalar electrocardiogram according to accepted criteria (Lipman and Massie, 1965). In 7 of the men and 2 of the women the 12-lead electrocardiograms were within normal limits, despite typical case histories and SGOT rises. More cases,

TABLE 1 Age and sex distribution of 259 patients

Age	Men	Women
< 40 yr	6	0
40-49 yr	27	4
50-59 yr	56	11
60-69 yr	65	22
> 70 "	36	32
Average age	60.0 yr	67.7 yr

TABLE 2 Males and females
Correlation between scalar electrocardiographic findings and clinical data

Typical scalar electrocardiograms			Atypical scalar electrocardiograms		
	Men	Women	Men	Women	
Anterior myocardial infarction	61	15	ST-T changes	46	23
Anterior + diaphragmatic myocardial infarction	12	3	Left ventricular hypertrophy	9	5
Diaphragmatic myocardial infarction	47	16	Left bundle-branch block	1	1
Lateral myocardial infarction	4	3	Right bundle-branch block	3	1
			Normal electrocardiogram	7	2
Total	124	37		66	32
Typical case history	117	37		62	30
Positive temperature reaction	99	34		42	23
Positive erythrocyte sedimentation rate reaction	100	29		33	19
Earlier myocardial infarction	37	14		7	6
Angina pectoris	58	24		28	20
Positive temperature reaction, erythrocyte sedimentation rate reaction, and typical case history	84			29	
SGOT _{max} (mean)	211	152		110	131
	Karmen units	Karmen units		Karmen units	Karmen unit

both male and female, with typical scalar electrocardiograms had positive temperature and erythrocyte sedimentation rate reactions than had those with atypical scalar electrocardiograms. The frequency of earlier myocardial infarction and angina pectoris was the same in both groups of both sexes.

Considering the scalar and orthogonal electrocardiograms together, the cases have been put into 4 subgroups (Table 3). *Group 1*: Cases with typical scalar and typical orthogonal electrocardiograms; *Group 2*: Cases with atypical scalar, but typical orthogonal electrocardiograms; *Group 3*: Cases with atypical scalar and atypical orthogonal electrocardiograms; and *Group 4*: Cases with typical scalar electrocardiograms, but with atypical orthogonal electrocardiograms.

The ages in the different subgroups did not differ from the total material. However, the SGOT values were significantly higher in men with Q wave infarctions (typical scalar) than in men with equivocal electrocardiographic signs, whether or not these cases had typical orthogonal electrocardiographic findings. In the small female group, cases with typical scalar electrocardiograms had mean SGOT maximum values slightly higher than in the other groups.

In Table 4 the different orthogonal electrocardiographic diagnoses are summarized. In the same Table, 39 male and 15 female patients with equivocal scalar electrocardiograms and unequivocal orthogonal electrocardiograms are recorded. It is seen that the increase of diagnostic changes in the orthogonal electrocardiograms compared with the 12-lead electrocardiograms are mostly due to the addition of anterior and strictly posterior myocardial infarctions.

Strictly posterior myocardial infarctions

TABLE 3 Correlation between scalar electrocardiogram, orthogonal electrocardiogram, age, and serum transaminase (mean)

<i>Group 1: Typical scalar and typical orthogonal electrocardiograms</i>		
	<i>Men</i>	<i>Women</i>
No. of cases	121	37
Mean age	59.9 yr	68.4 yr
Age (range)	33-80 yr	48-81 yr
SGOT _{max} (mean)	212 Karmen units	152 Karmen units
<i>Group 2: Atypical scalar but typical orthogonal electrocardiograms</i>		
No. of cases	39	13
Mean age	62.2 yr	66.1 yr
Age (range)	34-90 yr	49-89 yr
SGOT _{max} (mean)	105 Karmen units	129 Karmen units
<i>Group 3: Atypical scalar and atypical orthogonal electrocardiograms</i>		
No. of cases	27	19
Mean age	58.0 yr	68.2 yr
Age (range)	40-85 yr	41-85 yr
SGOT _{max} (mean)	116 Karmen units	132 Karmen units
<i>Group 4: Typical scalar electrocardiogram but atypical orthogonal electrocardiogram</i>		
No. of cases	3	0
Mean age	52 yr	
Age (range)	37-68 yr	
SGOT _{max} (mean)	161 Karmen units	

were seen in 15 cases, i.e. 6 per cent. It is also seen that 3 cases with equivocal changes in the orthogonal electrocardiogram had unequivocal signs of myocardial infarction in the 12-lead electrocardiograms. Two had scalar diagnoses of anterior myocardial infarction and one diaphragmatic myocardial infarction. No woman had equivocal orthogonal electrocardiograms together with unequivocal scalar electrocardiogram.

R/S ratios > 1 in V₁ and/or V₂ and rudimentary R waves in V₁-V₃ in the scalar electrocardiograms are summarized in Table 5.

TABLE 4 Summary of orthogonal electrocardiogram findings

Typical orthogonal electrocardiograms (160) and (52)			Atypical orthogonal electrocardiograms (30) and (17)		
	Men	Women		Men	Women
Anterior myocardial infarction	70	22	Normal scalar and normal orthogonal electrocardiograms	4	2
Anterior + diaphragmatic myocardial infarction	21	7	Normal orthogonal with atypical scalar electrocardiogram	1	0
Diaphragmatic myocardial infarction	30	11	Atypical orthogonal electrocardiogram with typical scalar electrocardiogram	3*	0
Strictly posterior myocardial infarction	10	4			
Lateral myocardial infarction	9	2			
Diaphragmatic + posterior myocardial infarction	8	1			
Diaphragmatic + lateral myocardial infarction	12	5			
Atypical scalar with typical orthogonal electrocardiograms (39) and (15)					
Anterior myocardial infarction	18	9			
Anterior + diaphragmatic myocardial infarction	1				
Diaphragmatic myocardial infarction	8				
Strictly posterior myocardial infarction	10	5			
Lateral myocardial infarction	2	1			

* 2 cases with anterior myocardial infarction and 1 with diaphragmatic myocardial infarction.

Twelve men and 2 women had an R/S ratio > 1 in V_1 and V_2 . Five men and 1 woman in this group had an orthogonal electrocardiographic diagnosis of diaphragmatic posterior or diaphragmatic lateral myocardial infarction. These 6 cases had typical Q wave infarctions in the 12-lead electrocardiogram. Five men and 1 woman with this sign had strictly posterior myocardial infarction according to the orthogonal electrocardiogram, while 2 men had lateral myocardial infarction. No case with this scalar sign had atypical or normal orthogonal electrocardiogram.

Of the 28 cases (22 male and 6 female) with an R/S ratio more than 1 in V_2 (but not in V_1) (Table 5), 9 (8 male and 1 female) had unequivocal scalar signs of diaphragmatic myocardial infarction. In these 9 the orthogonal electrocardiogram pointed to an extension laterally or strictly posterior. In 12 cases (8 male and 4 female) with equivocal scalar electrocardiogram a diagnosis of strictly posterior or lateral myocardial infarction was made in the orthogonal electrocardiogram. Seven cases (6 male and 1 female) showed atypical findings in both 12-lead electrocardiogram and orthogonal electrocardiogram.

Rudimentary R waves in V_1 – V_3 were recorded in 15 cases, of whom 14 had anterior myocardial infarction according to the orthogonal electrocardiogram (i.e. Q/R ratios less than 0.10), while only 1 had equivocal signs of myocardial infarction in both 12-lead electrocardiogram and orthogonal electrocardiogram.

Discussion

Recent discussion of some simple electrocardiographic principles shows that one can never expect to diagnose all myocardial infarctions in the electrocardiograms (Erikssen, Müller, and Anderssen, 1970). Small sub-endocardial infarctions especially fail to produce QRS changes. Changes in the ST and T waves alone are not diagnostic because they may be caused by other diseases, both non-coronary heart disease and extracardiac disorders. Moreover, infarction may be disguised by left bundle-branch block, though some authors think that myocardial infarction may be diagnosed as well in the presence of left bundle-branch block (Sodi-Pallares *et al.*, 1963). Right bundle-branch block does not change the excitation process in the earlier part of the QRS, and therefore an anterior or diaphragmatic myocardial infarction should be diagnosable in its presence. The period from the 3rd to the 10th day after infarction

TABLE 5 Correlation between R/S ratio > 1 in V_1 and/or V_2 and rudimentary R-waves in V_1 – V_3 with orthogonal electrocardiogram diagnosis

	Men	Women	Orthogonal electrocardiogram diagnosis
R/S-ratio > 1 in V_1 and V_2	5 2 0 }	1 1 0 }	Diaphragmatic posterior or diaphragmatic lateral myocardial infarction Strictly posterior myocardial infarction Lateral myocardial infarction Atypical (or normal) orthogonal electrocardiogram
R/S-ratio > 1 in V_2 , but not in V_1	8 5 3 6 }	1 4 0 1 }	Diaphragmatic posterior or diaphragmatic lateral myocardial infarction Strictly posterior myocardial infarction Lateral myocardial infarction Atypical (or normal) electrocardiogram
Rudimentary R in V_1 – V_3	8 0 }	6 1 }	Anterior myocardial infarction Atypical (or normal) electrocardiogram

* Cases with equivocal 12-lead electrocardiograms.

poses a special problem to the electrocardiogram reader (Solomon and Shapiro, 1966).

Transmural loss of myocardium produces pathological Q waves in ordinary leads, giving rise to the common diagnostic changes of infarction, but infarctions that are not transmural may also create QS patterns. Mathur and Kumar (1965), in experimental work on dogs, stress that rudimentary R waves in the praecordial leads V_1 – V_3 were uniformly related to anterior myocardial infarction, the changes in the excitation process being too small to give anything more than an obvious reduction in the R wave instead of a fully developed Q wave (or to insignificant Q waves judged by the usual criteria?).

Depending on the spread of the excitation wave in the myocardium (Scher and Young, 1957), one might also assume that infarctions with special locations may change only the middle and/or the later part of the QRS complex. This is in agreement with, for instance, Abildskov and Boyle (1965) in their experimental work on dogs. In similar human cases one would especially expect changes in the R and S waves. As myocardial infarction therefore probably may give rise to changes only in the R wave and/or S wave without simultaneous pathological Q waves, it should be rational to use the R/S or Q/R ratios as signs of myocardial infarction instead of using Q waves solely. (Whipple (1957) considers that pathological Q waves have their pathological 'mirror image' R waves on the opposite side of the body and vice versa). In this way it should be possible to recognize both the usual changes in the early part of the QRS (Q wave

pattern in ordinary scalar reading) and the more subtle changes which mainly affect the height of the R waves.

The importance of using Q/R ratios in the diagnosis of myocardial infarction is stressed by Naval *et al.* (1967), and their conclusions form the basis for this work. They state that Diagnostic recognition rates of Q/R ratios exceeded those of Q-wave duration and Q-wave amplitude by a wide margin. Sixty-two cases or twenty-nine per cent would have been missed without measuring the Q/R-ratio. The Q-wave duration was found to be the only abnormality in five cases, or two per cent of the cases . . .

Naval *et al.* used a digital computer for all measurements and evaluations. In this work all waves were measured by hand, using the PR segment as baseline to determine the amplitudes, and a relatively large statistical error may of course be introduced. In all cases, therefore, measurements were performed on at least two different occasions and repeated if there was any considerable discrepancy between the two results. It is thought, therefore, that they are valid from a statistical point of view despite the common observer variation in the interpretation of electrocardiograms.

As electrocardiographic patterns of myocardial infarction may be caused by other diseases, only cases with recent myocardial infarctions have been included. The diagnostic score of the 12-lead electrocardiogram in this work is low, 65 per cent in male and 55 per cent in female patients using accepted scalar criteria.

The SGOT values in the men with Q wave patterns were significantly higher than in men with atypical scalar findings, which may, perhaps, be taken as indicating more extensive Q wave myocardial infarctions'. In the smaller female group, however, no such statistical difference in the SGOT values was found. In both the male and female groups a higher percentage of cases with 'Q wave infarctions' had positive erythrocyte sedimentation rate and/or temperature reactions than cases with atypical scalar electrocardiograms. One assumes that the largest myocardial infarctions on an average give rise to the earliest reactions in the body this may also be taken as a sign of larger infarctions with Q wave patterns than with atypical electrocardiograms. The advantage of using Q/R ratios is in the possibility of diagnosing infarctions which fail to create detectable changes in ordinary scalar readings. Our results seem to confirm such a view. Nevertheless, scalar signs not commonly used may be of import-

ance in the diagnosis of myocardial infarctions. Thirty-nine of the men and 15 of the women had diagnostic orthogonal electrocardiographic changes (Table 3) in the presence of equivocal scalar findings in the 12-lead electrocardiograms. If the criteria of Perloff (1964) had been used (R/S ratio > 1 in V₁ and/or V₂) 20 cases would have been transferred from the atypical to the typical group, including all cases with strictly posterior myocardial infarctions and 5 cases with lateral myocardial infarctions. However, using R/S ratio > 1 in V₂ alone as the sign of lateral or strictly posterior myocardial infarction would have included 7 cases (Table 5), in whom both the orthogonal and the scalar electrocardiograms were atypical. In 25 per cent of these cases (Table 5), therefore, this sign was of doubtful value.

In 14 of 15 cases with rudimentary R waves in V₁-V₃ the orthogonal electrocardiograms pointed to anterior myocardial infarction. This is in agreement with Mathur and Kumar's statement above.

Including these 34 (20 + 14) cases among the cases with typical 12 lead electrocardiograms would increase the overall recognition rate from 161/259 (62%) to 195/259 (75%). As 54 cases (39 men and 15 women: Table 3) had typical orthogonal electrocardiograms in the presence of atypical 12-lead electrocardiograms we see that a further 20 cases still had orthogonal criteria of myocardial infarction.

Using the orthogonal criteria solely would give a recognition rate of 212/259 (82%). This means that 20 per cent (82 less 62%) would have been missed using ordinary scalar reading instead of this particular orthogonal reading. Only 7 per cent, however, would have been missed if the 12-lead reading had included the criteria of R/S ratio in V₁ and V₂ and rudimentary R waves in V₁-V₃.

These findings, of course, do not mean that orthogonal electrocardiograms are devoid of errors. The same theoretical obstacles occur as in the 12 lead scalar electrocardiograms. The main advantages of the technique are the strict diagnostic criteria, and the fact that an electrocardiogram with only 3 leads is much easier to interpret.

The Q/R ratios used may be questioned, but the evidence for them seems convincing (Draper *et al.*, 1964) despite possible racial differences.

It might be presumed that the 12-lead electrocardiogram should give more information than an electrocardiogram using but 3 leads. If so, diagnostic changes seen in the 12-lead electrocardiogram would be missed in the orthogonal electrocardiogram. However,

this was seen in only 3 cases: 2 cases with anterior and 1 with diaphragmatic myocardial infarction. Moreover, it has been shown that all the information obtained in the ordinary 12-lead electrocardiogram may be found in the orthogonal electrocardiogram (Pipberger *et al.*, 1967; Rübesamen and Giegler, 1969), by projecting the X, Y, and Z complexes onto the conventional electrocardiogram axes, I, II, III, aVF, and so forth. This applies to all but local apical potential variations, according to Grant (1957), and is consistent with current electrocardiographic theory.

This material is biased both as regards case histories and electrocardiograms because all patients who died during the first 24 hours were included. This was done in order to obtain at least one orthogonal and one 12-lead electrocardiogram taken by an experienced electrocardiogram technician and to secure the diagnosis with pathological SGOT values. A large proportion of cases dying within the first 24 hours had diagnostic 12-lead electrocardiograms. This, however, does not alter the conclusion that orthogonal electrocardiograms are of value in the diagnosis of recent myocardial infarction. The Q/R ratios obtained from the orthogonal electrocardiogram may be of particular value, in conformity with the findings of Naval and his co-workers (1967).

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