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The effect of recanalization of the occluded coronary artery in acute myocardial infarction on left ventricular function

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In 20 patients with acute myocardial infarction a left ventriculogram was obtained within 6 h after the onset of chest pain and again during a follow-up study, 2–3 weeks later. In 17 patients the infarct-related vessel (IRV) could be recanalized with selective intracoronary infusion of a thrombolytic agent and was still patent during the second study. In three other cases the IRV was already patent during the first angiogram and remained so at the time of the follow-up study. The ejection fraction of these 20 patients increased from 52 to 56% ($P < 0{\cdot}02$*).*

In eight other patients the infarct-related artery could not be recanalized or was reoccluded at the time of the control study. The ejection fraction of these patients with unsuccessful recanalization decreased from 49 to 37% ($P < 0{\cdot}001$*).*

Analysis of regional function in eight patients with anterior infarction and seven patients with inferior infarction, all with a successful recanalization and persistent patency of the infarct-related vessels, suggests that improvement of global ejection fraction is only partially due to improvement of regional pump function in the reperfused 'infarct zone' but may also be caused by enhancement of regional function in other wall regions or by changes in afterload.

Coronary artery thrombosis is found in the majority of patients with an acute myocardial infarction[1–3]. Recently it has been confirmed that acutely occluded coronary arteries can be recanalized by intracoronary infusion of a fibrinolytic agent[4–7]. Such intervention might prevent myocardium, made acutely ischemic by coronary occlusion, to progress to necrosis or alternatively support marginally viable cells[8–11]. Animal experiments have shown that restoration of coronary blood flow may save myocardium[5,12] and improve survival[12] if the reperfusion is instituted within a few hours after coronary occlusion. On the other hand, reperfusion of ischemic myocardium might be harmful because of the occurrence of serious arrhythmias[5,6,8] and/or intramyocardial hemorrhage[13,14]. To answer the question whether this latest approach to the treatment of patients with acute myocardial infarction will be ultimately beneficial to most patients with acute myocardial infarction, a carefully designed randomized trial is needed[15]. Such a study should include detailed analysis of the influence of myocardial reperfusion on left ventricular function before and after the procedure as well as identical studies on those patients assigned to placebo treatment. Up to now, the assessment of global ejection fraction has mainly been employed for this purpose[2,4,6,16]. However, any improvement of global left ventricular function after successful recanalization of a coronary artery might be caused by several factors: salvage of jeopardized myocardium[16], compensatory hyperactivity of other wall segments or changes in pre- and afterload. In an effort to study this problem, the effect of myocardial reperfusion on regional left ventricular function has been quantitated by careful analysis of segmental wall motion in 28 patients, who form part of our current studies.

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Materials and methods

Between September 1980 and March 1982, 83 patients were catheterized within the first 6 h after the onset of symptoms of acute myocardial infarction (AMI)[17]. The diagnosis of AMI was based on a history of typical chest pain, ECG changes and serial CPK values. In all patients the ECG at admission showed changes compatible with acute myocardial ischemia although a Q wave was not always present. After informed consent was obtained coronary arteriography was performed via the retrograde brachial[18] or femoral[19] approach. In 28 patients two sequential left ventriculograms (during the acute event and during the follow-up study, 2–3 weeks later) of sufficient quality were obtained to permit automated analysis[20]. The relatively small number of sequential or initial angiograms was due to any of the following three factors:

(1) refusal of the patient to cooperate with the follow-up study;
(2) a left ventricular end-diastolic pressure of $\geqslant 35$ mm Hg at the time of acute infarction;
(3) the clinical course of events rendering repeat study superfluous or unwarranted.

In 17 of the 28 patients the IRV could be recanalized and was still patent during the control study. Eight patients sustained an anterior myocardial infarction (IRV = left anterior descending coronary artery), seven an inferior infarction (IRV = right coronary artery), two a lateral wall infarction (IRV = left circumflex coronary artery). In three other patients the IRV was already patent at the time of the first coronary angiogram and remained so during follow-up. In eight patients the IRV could not be recanalized or was reoccluded at the time of the control study. The study groups consist therefore of eight patients with unsuccessful recanalization, 17 patients with successful recanalization of the IRV and three in whom the IRV was already open. In the eight patients with anterior infarction and the seven with inferior infarction with successful recanalization of the IRV, detailed analysis of regional left ventricular function was performed. Their data provided the essence of this study. Regional left ventricular function was studied from the 30° right anterior oblique left ventricular cine-angiogram with an automated hardwired endocardial contour detector linked to a minicomputer[20]. In Fig. 1 an example of the end-diastolic (ED) and end-systolic (ES) contours of the left ventriculogram, as displayed by the analysis system, is shown. Systolic regional wall displacement is determined along a system of 20 coordinates based on the pattern of actual endocardial wall motion in normal individuals[21]. From the regional wall displacement values, the regional contribution to global ejection fraction (CREF) was calculated. This is a new regional pump function parameter which expresses the contribution of each segment to global ejection fraction[22]. The cross-hatched zones in Fig. 2 represent the segmental CREF values between the 10th and 90th percentile, as determined in 20 normal individuals. The segmental CREF values in the anterobasal (segments 1–5), anterolateral (segments 5–9), apical (segments 9, 10, 19 and 20), inferior (segments 15–19) and posterobasal (segments 11–15) wall regions, before and 2–3 weeks after intervention with thrombolytic therapy, were compared with the paired t-test of Student.

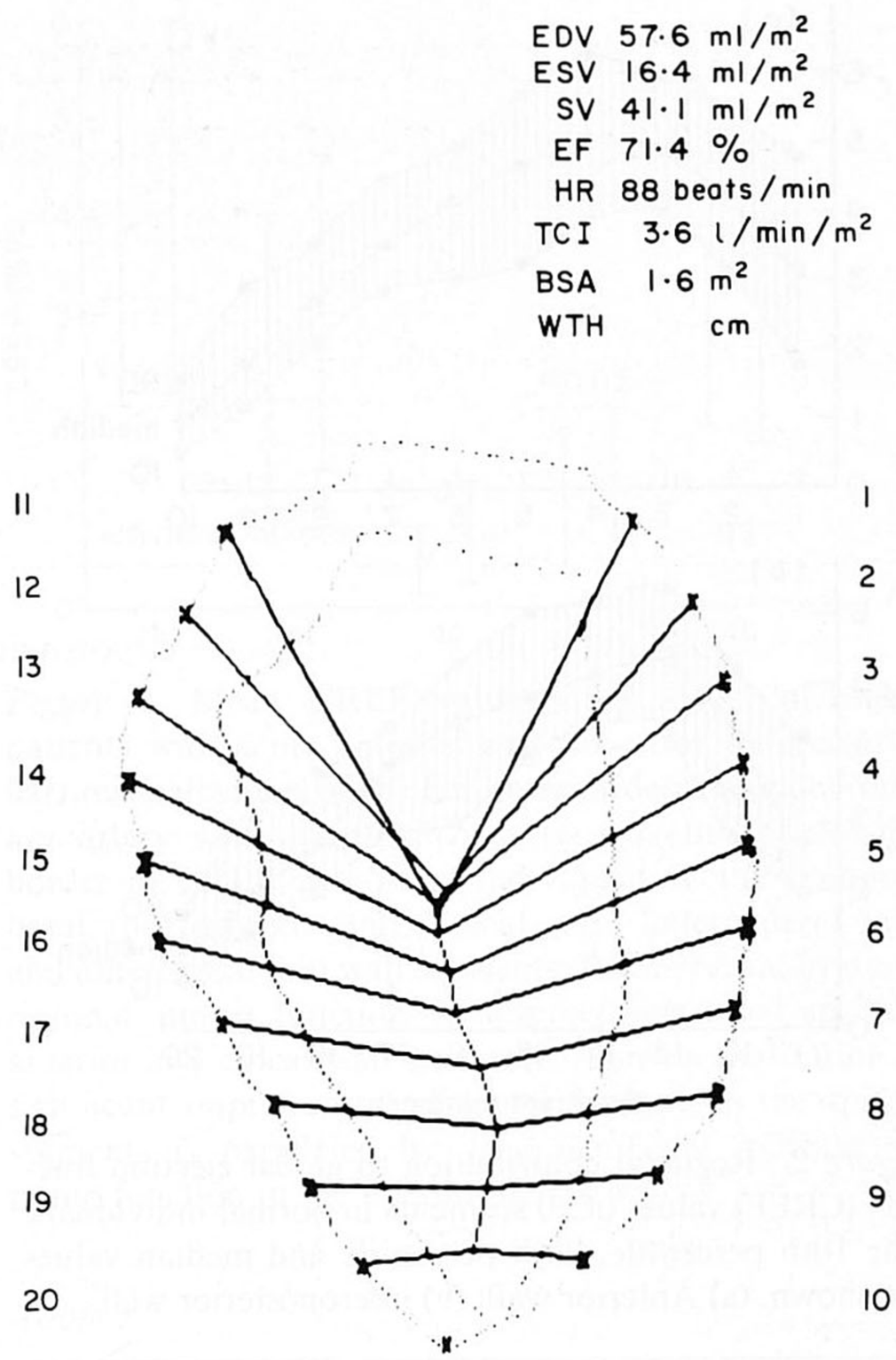

Figure 1 Example of the computer output showing the end-diastolic and end-systolic contours of the 30° RAO left ventriculogram. The corresponding volume data, ejection fraction and others parameters are shown in the right upper corner. Left ventricular wall motion is determined in 20 separate segments, 10 in the anterior (1–10) and 10 in the inferoposterior wall (11–20).

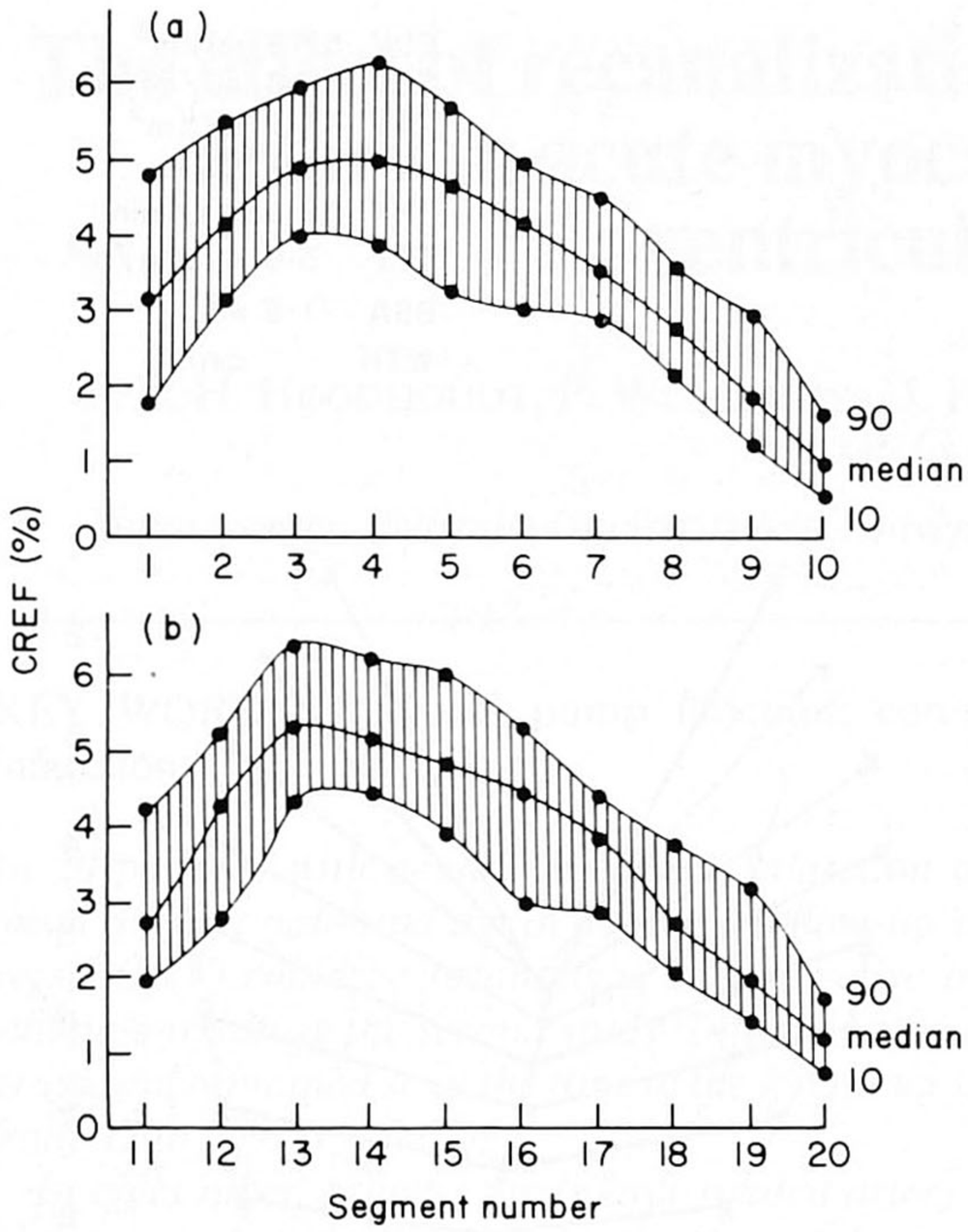

Figure 2 Regional contribution to global ejection fraction (CREF) values of 20 segments in normal individuals. The 10th percentile, 90th percentile and median values are shown. (a) Anterior wall; (b) inferoposterior wall.

Results

In Tables 1 and 2 the hemodynamic data of the patients with acute myocardial infarction (AMI) during the first heart catheterization (acute) and during the follow-up study (chronic) are shown. Most prominent are the decrease in stroke volume (SV), cardiac index (CI) and ejection fraction (EF) in Table 1. In contrast, in Table 2 the results of 17 patients with successful re-opening and three with already patent IRV are shown. Global ejection fraction increased significantly ($P < 0{\cdot}02$) from 52 to 56%. The individual CREF data of a patient with anterior infarction, during the acute event and during the follow-up study, are shown in Fig. 3. A few hours after the onset of infarction, regional pump function was severely depressed in the anterior and apical wall segments (segments 3–10 and 19, 20) but was only slightly affected in the infero-posterior wall (segments 11–18). Three weeks after successful recanalization regional pump function was improved in both the anterior and the infero-posterior wall segments. In Fig. 4 the CREF values (mean ± s.d.) in five wall regions of eight patients with anterior infarction, during the acute event

Table 1 Hemodynamic data of eight patients with 'unsuccessful recanalization' of the occluded coronary artery

	Acute	Chronic	P value
Heart rate (beats/min)	79 ± 18	82 ± 17	NS
Mean AoP (mm Hg)	84 ± 20	90 ± 13	NS
LVEDP (mm Hg)	16 ± 7	21 ± 11	NS
CI (1/m²)	3·7 ± 1·3	3·0 ± 1·4	<0·09
LVEDV (ml/m²)	96 ± 20	100 ± 30	NS
LVESV (ml/m²)	49 ± 14	66 ± 32	NS
SV (ml/m²)	47 ± 15	35 ± 12	<0·02
Ejection fraction (%)	49 ± 11	37 ± 14	<0·001
Akinetic segments (%)	16 ± 16	20 ± 19	NS

Abbreviations: AoP = aortic pressure; LVEDP = end-diastolic pressure; CI = cardiac index; LVEDV = end-diastolic volume; LVESV = end-systolic volume; SV = stroke volume. Values expressed as means ± s.d. P value = Student's t-test (paired data); NS = non significant.

Table 2 Hemodynamic data of 20 patients with 'successful recanalization' of the occluded coronary artery

	Acute	Chronic	P value
Heart rate (beats/min)	79 ± 13	72 ± 14	<0·03
Mean AoP (mm Hg)	91 ± 14	96 ± 13	NS
LVEDP (mm Hg)	22 ± 8	20 ± 10	NS
CI (1/m²)	3·1 ± 0·7	3·2 ± 0·6	NS
LVEDV (ml/m²)	80 ± 27	82 ± 13	NS
LVESV (ml/m²)	40 ± 21	36 ± 11	NS
SV (ml/m²)	40 ± 10	45 ± 9	<0·04
Ejection fraction (%)	52 ± 10	56 ± 10	<0·02
Akinetic segments (%)	18 ± 16	13 ± 13	NS

Abbreviations and values as in Table 1.

(first bar) and after an interval of 2–3 weeks (second bar) are demonstrated. The interrupted lines represent the 10th percentile (lower) border of regional pump function in normal individuals. Subnormal CREF values are observed in particular in the anterolateral and apical wall regions, as would be expected in anterior infarction. Analysis with the paired t-test shows a significant improvement of regional pump function in the anterolateral and apical segments, which is accompanied by significant increase of CREF values in the inferior ($P < 0{\cdot}001$) and postero-basal ($P < 0{\cdot}05$) wall regions (Table 3). In Fig. 5 the changes in regional pump function after recanalization of the right artery are shown. At the time of the acute inferior infarction

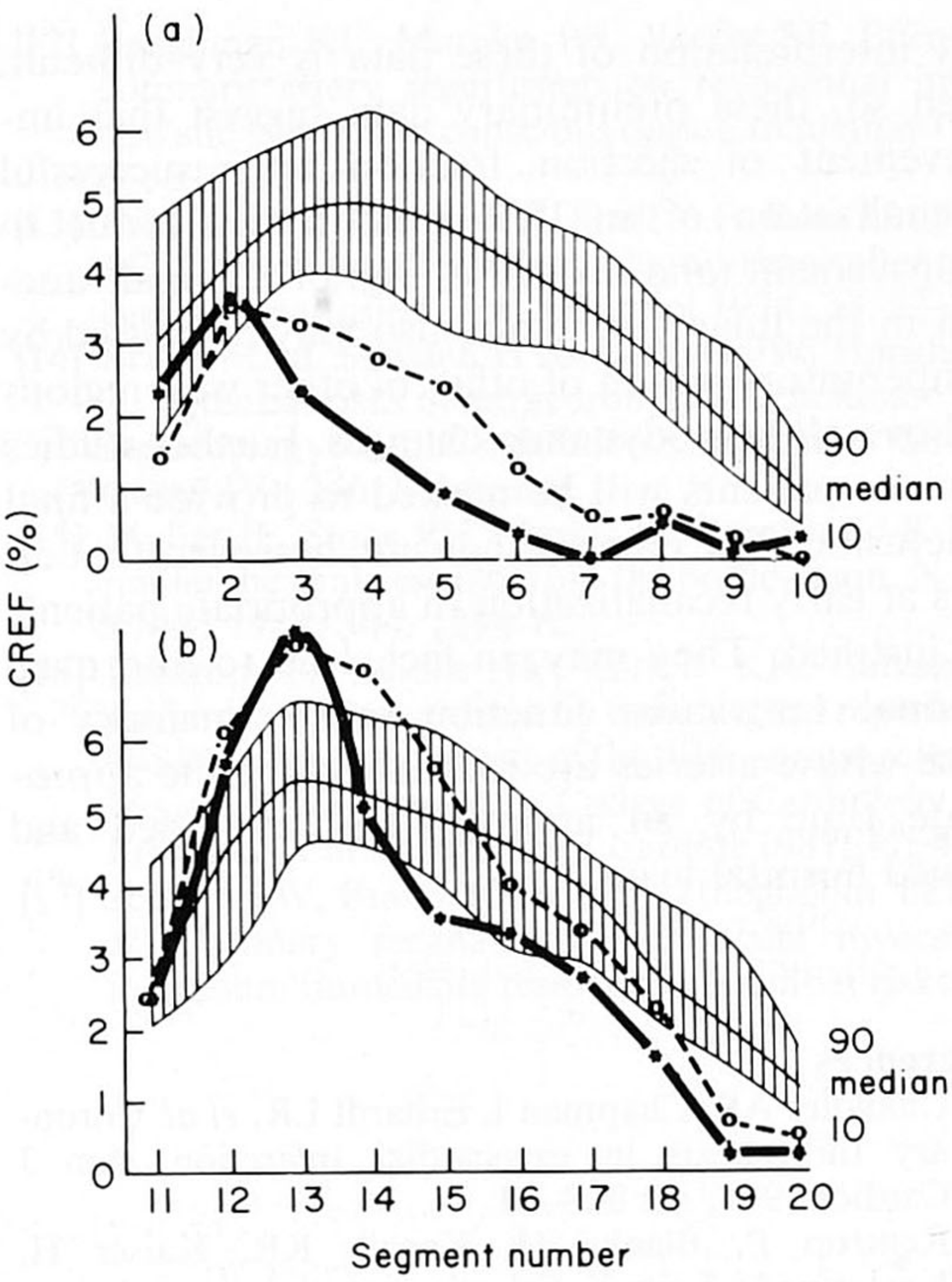

Figure 3 Regional contribution to global ejection fraction (CREF) in 20 segments of the 30° RAO left ventriculogram, before (——) and three weeks after (– – – –) recanalization of an occluded left anterior descending coronary artery in a patient with acute anterior myocardial infarction. CREF values are severely depressed in the anterior and apical wall segments (3–10 and 19,20) and approximately normal in the inferior and postero-basal segments (11–18). After coronary recanalization regional pump function improves not only in the anterior, but also in the inferior wall. Shaded areas represent CREF values in normal individuals. (The 10th percentile, 90th percentile and median values are shown.) (a) Anterior wall; (b) inferoposterior wall.

a severe depression in pump function was observed in the infero-posterior wall, while CREF values in the anterior wall remained within normal limits. After successful recanalization of the IRV, a significant ($P<0{\cdot}01$) increase of CREF was observed in the inferior wall segments.

Discussion

As shown in Tables 1 and 2, unsuccessful recanalization of an occluded coronary artery appears to be associated with depressed global left ventricular function, while successful recanalization or spontaneous patency of the IRV improves ejection fraction. This finding is in agreement with the results

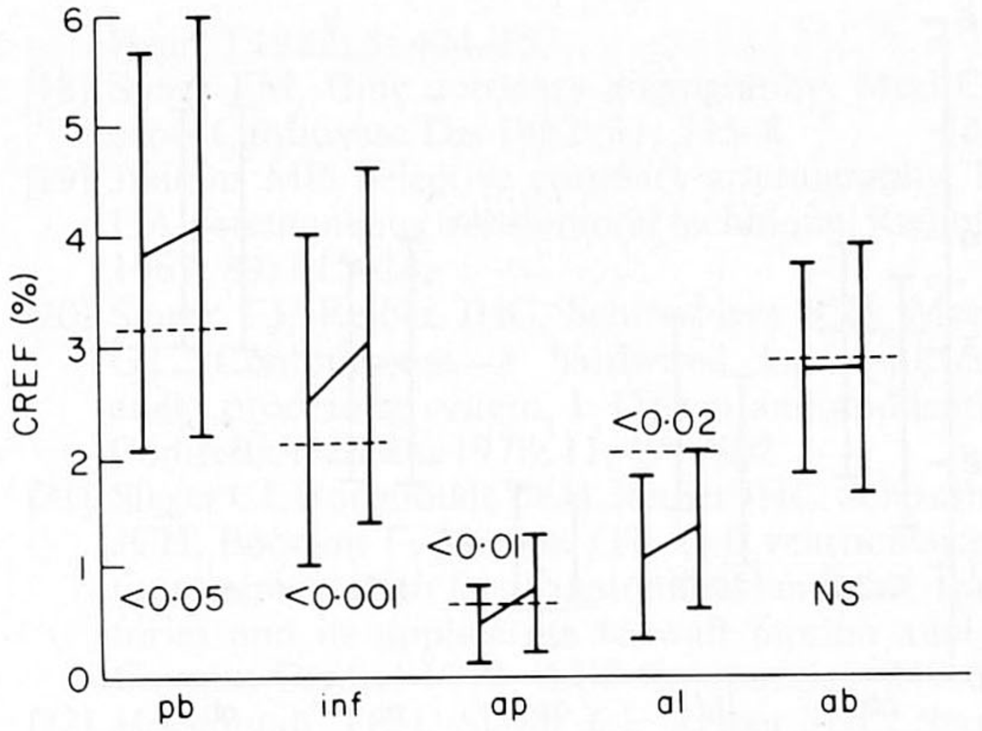

Figure 4 Mean CREF values ± s.d. (bars) of eight patients with acute anterior wall infarction before (first bar) recanalization of the left anterior descending coronary artery with streptokinase. (– – – –) 10th percentile border of CREF in normal individuals in the postero-basal (pb) inferior (inf), apical (ap), anterolateral (al) and anterobasal (ab) wall segments. Before recanalization regional pump function is severely depressed in the anterior and apical wall segments. After recanalization a significant improvement of pump function in the apical segments is paralleled by very significant increase of pump function in the inferoposterior wall.

Table 3

	Acute phase	Chronic phase	
Changes in CREF following successful recanalization of LAD			
Anterobasal	2·70 ± 0·94	2·69 ± 1·14	NS
Anterolateral	1·03 ± 0·73	1·29 ± 0·72	<0·02
Apical	0·43 ± 0·35	0·69 ± 0·52	<0·01
Inferior	2·44 ± 1·49	2·97 ± 1·60	<0·0001
Postero-basal	3·81 ± 1·80	4·01 ± 1·89	<0·05
Changes in CREF following successful recanalization of RCA			
Anterobasal	4·11 ± 1·12	4·12 ± 1·08	NS
Anterolateral	2·87 ± 1·12	2·80 ± 0·99	NS
Apical	1·15 ± 0·45	1·24 ± 0·50	NS
Inferior	1·88 ± 0·86	2·42 ± 0·86	<0·01
Postero-basal	2·47 ± 1·13	2·86 ± 1·04	0·05

of similar studies by Rentrop *et al.*[4], Ganz *et al.*[5], and Mathey[7]. However, such improvement might be due not only to enhancement of regional function in the reperfused 'infarct zone' but also by compensatory action of other wall segments. The results of this study suggest that, although significant improvement of regional function in the infarct zone is observed, at least part of the increase

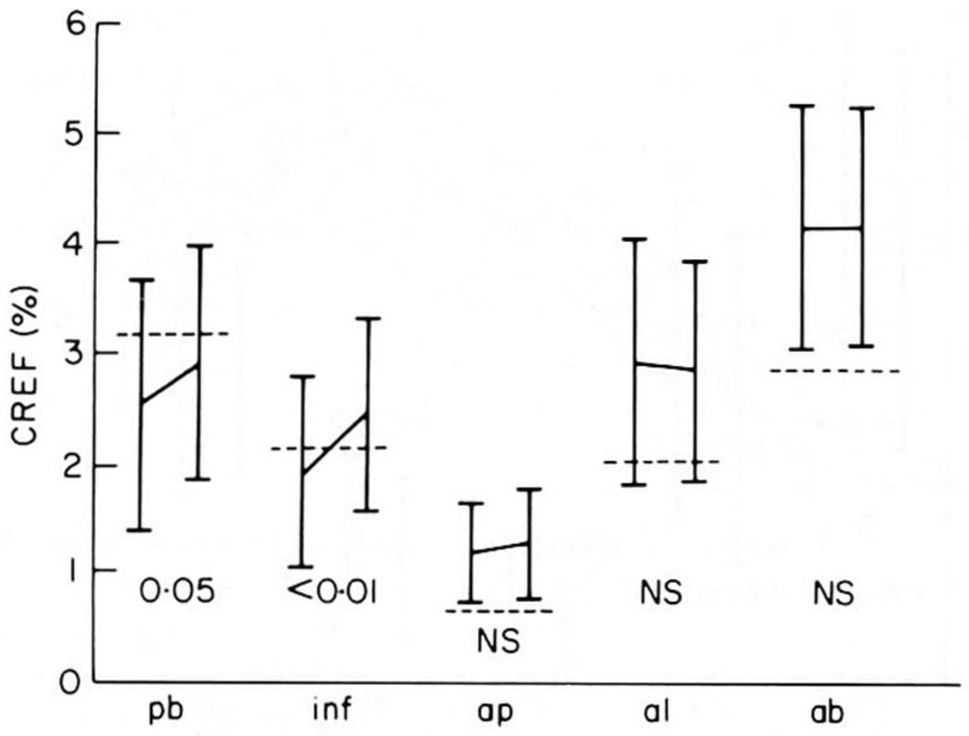

Figure 5 Mean CREF values ± s.d. (bars) of seven patients with acute inferior wall infarction, before (first bar) and 2–3 weeks after thrombolytic recanalization of the right coronary artery. Before recanalization regional pump function is depressed in the inferior and postero-basal wall and well above normal in the antero-apical wall segments. After recanalization a significant improvement of regional pump function is observed in the inferior wall.

in ejection fraction is caused by hyperactivity of other wall regions. However, these results must be interpreted with care, firstly because the number of patients studied is small and secondly because angiograms made during the first hours of myocardial infarction provide only one 'snapshot' of what might be a rapidly changing situation, affecting many aspects of ventricular function, such as ventricular compliance and afterload. Also, analysis of ejection fraction with conventional methods has proven to be subject to substantial variation which makes any interpretation of small changes of ejection fraction in sequential angiograms dubious.

Computer assisted analysis of the angiograms reduces this variability significantly. In fact, in the systems used in this study, intra- and observer variability of repeated assessment of ejection fraction was reduced to only 1·6–2·3%. Even so, variation of ejection fraction in sequential left ventriculograms may be due to changes in pre- and afterload and in heart rate. While in this study no significant changes in left ventricular end-diastolic pressure (EDP), volume or mean aortic pressure (mean AoP) were observed, heart rate decreased slightly in the successfully recanalized group. It would have been interesting to perform a similar analysis of the angiograms of patients with unsuccessful recanalization, but this would have exceeded the boundaries of ethical considerations.

Given the heterogeneity of this small group, with respect to location of infarction and IRVs, the correct interpretation of these data is very difficult. Even so, these preliminary data suggest that improvement of ejection fraction after successful recanalization of an IRV is most likely due to improvement (and no worsening) of regional function in the infarct zone but also may be caused by compensatory action of other of other wall regions and overall hemodynamic changes. Further studies in more patients will be needed to provide a final conclusion. The data do indicate, however, that efforts at early recanalization in appropriate patients are justified. They may, in fact, lead to improved regional ventricular function in the majority of those whose arteries are recanalized at the appropriate time by an appropriately equipped and trained hospital team.

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