Characteristics of episodes of ST elevation or ST depression during ambulatory monitoring in patients subsequently undergoing coronary angiography

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SUMMARY Transient ischaemic ST segment changes were studied in 296 consecutive patients with coronary heart disease attending hospital for coronary arteriography. They underwent two channel, frequency modulated ambulatory monitoring for 24 hours. During this time 221 episodes of transient ST elevation ($n=56$) or ST depression ($n=165$) with a horizontal deviation of at least 1 mm lasting at least 1 min were found in 70 patients (23.6%). Only 34% of episodes were associated with pain. The duration of the episode, the heart rate at the beginning of the episode, or the extent of ST deviation were not related to the occurrence of pain. Episodes of ST elevation were of significantly shorter duration, occurred significantly more often during the early morning, and at significantly lower heart rates than episodes of ST depression.

The considerable overlap between the characteristics of episodes of ST elevation and ST depression suggests that in many instances a combination of factors is responsible for transient ischaemic ST segment changes.

The objective assessment of angina pectoris during daily life is based on the detection of ischaemic ST segment changes during continuous ambulatory electrocardiographic monitoring. The frequency of spontaneous ischaemic episodes has been investigated only in highly selected subgroups of patients¹⁻⁶ by means of amplitude modulated recording which is not reliable in the low frequency range.^{7,8} Frequency modulation overcomes these recording errors and fulfils the American Heart Association criteria for electrocardiographic recording.⁹ We used frequency modulated recording of ST segments to determine the frequency of symptomatic and asymptomatic ischaemic episodes, and differences in time course, heart rates, and time of appearance of different types of ischaemic episode in patients with confirmed or suspected coronary heart disease.

Patients and methods

We studied 296 consecutive patients who underwent cardiac catheterisation and coronary angiography at this hospital between January and July 1982. Patients with atrial fibrillation, left or right bundle branch block (which interfere with Holter analysis of ST segments), valvar heart disease, and cardiomyopathy were excluded. There were 241 male patients (81%, mean age 52.9 years, range 21-73) and 55 female patients (19%, mean age 54.9 years, range 33-69).

Of the 296 patients, 67 (22.6%) had no major coronary artery stenosed by more than 50%, 55 (18.6%) had single vessel disease, 61 (20.6%) had double vessel disease, and 113 (38.2%) had triple vessel disease. Hypokinesia or akinesia was shown in the left ventriculogram in 132 patients (44.6%).

ST SEGMENT MONITORING

Electrocardiographic monitoring was carried out for 24 hours on the day before coronary angiography when patients were in hospital and walking about. Calcium channel blockers and long acting nitrate medications were stopped the day before the record-

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Fig. 1 Number of episodes of ST depression and extent of ST depression. The proportion of painful episodes is not significantly greater with deeper ST depression (≥ 0.2 mV).

ing. Short acting nitrates were used to alleviate angina, and beta blockers were continued at the patient's usual dose.

The frequency modulated, calibrated recording system Medilog II (Oxford Electronics) was used with CC5 and CM5 leads as described by Balasubramanian *et al.*⁸ With the Oxford Medilog analysis system in the Holter mode we identified episodes of ST segment deviation visually and obtained analogue recordings at 25 mm/s. Recordings were taken of the beginning of an episode, 1 minute before the episode, when ST segment deviation was at a maximum, and at the end of the episode. Episodes were counted if there was ST segment deviation of at least 1 mm (0.1 mV) for at least one minute. An increase in heart rate preceding the episode was defined as an increase of 10% or more from one minute before to the start of the episode. Patients were asked to register painful events either by pressing the event button of the electrocardiographic recorder or by writing a note in a purpose made diary. All data from the electrocardiographic analysis were collected on a special sheet for further evaluation by computer. We noted the time lost from a full 24 hour recording because of artefacts, loose electrodes, or early removal of electrodes. No time was lost in recordings from 49% of the patients, and in recordings from another 24% there were losses of less than two hours. Losses of more than six hours led to exclusion, and a repeat recording was made where possible. The mean recording period for all patients was 22.6 hours.

DATA AND STATISTICAL ANALYSIS

All results were analysed by computer, by means of a data bank system developed at the Institut für Informationsverarbeitung, Statistik und Biomathe-

matik in our institution.¹⁰ We used the χ^2 test to evaluate differences between groups.

Results

FREQUENCY OF DIFFERENT EPISODES AND PAIN AND DEGREE OF ST DEPRESSION

Seventy of the 296 patients studied had episodes of transient ST segment changes. We recorded 221 episodes in 50 (71.4%) male and 20 (28.6%) female patients. One hundred and sixty five (74.7%) episodes were ST depression and 56 (25.3%) were ST

Fig. 2 Number of episodes of ST elevation (a) and ST depression (b) by duration of the episode (<10 minutes or ≥ 10 minutes). There were more short episodes with ST elevation ($p < 0.001$). The proportion of painful episodes is not significantly greater with longer episodes (> 10 minutes).

Fig. 3 The time of day at which episodes of ST elevation (a) and ST depression (b) occurred. ST elevation was most common during the early morning and there was a broad daytime peak for ST depression. The occurrence of pain was not related to the time of day.

elevation. Pain was reported during 77 (34.8%) episodes. Similar percentages of painful episodes occurred during ST elevation ($n = 19$, 33.9%) and ST depression ($n = 58$, 35.2%).

The degree of ST depression did not correlate with the occurrence of pain (Fig. 1). Of 118 episodes of 0.1 or 0.15 mV ST depression, 39 (33.1%) were painful and (19 (40.4%) of 47 episodes with ST depression of ≥ 0.2 mV were painful (χ^2 , NS).

DURATION AND TIME OF APPEARANCE

There were significantly more episodes of ST elevation of short duration (< 10 minutes) and significantly more episodes of ST depression of long duration (≥ 10 minutes) (χ^2 , $p < 0.001$). The occurrence of pain during an episode did not correlate

with the duration of the episode. Many short episodes were associated with pain and many long episodes were not associated with pain (χ^2 , NS). The depth of ST depression was not correlated to the duration of an episode. An increase in heart rate was significantly more common when episodes lasted more than 10 minutes ($p < 0.05$).

We also compared the duration of anginal attacks as perceived by the patients with the duration of their transient ischaemic episodes. Of the patients, 71.6% reported that angina lasted from one to five minutes, yet most ischaemic episodes lasted for seven minutes or longer (92 of 140 episodes, 65.7%). Thus not only do many transient ST changes pass unnoticed by the patient, but also the duration of the ischaemic episode is usually symptomatically underestimated.

ST elevation was most frequent late at night and early in the morning (Fig. 3). This diurnal difference was significant when frequencies from 8 am to 8 pm and from 8 pm to 8 am were compared ($p < 0.001$). Also there were significantly more short episodes

Fig. 4 Number of episodes of ST elevation (a) and ST depression (b) by heart rate at which ischaemia became apparent. Most episodes with ST elevation occurred at heart rates below 90 beats/min.

($p < 0.05$) and episodes without tachycardia ($p < 0.025$) during the night. The time of day did not correlate with the occurrence of pain. The diurnal distribution of ST depression without increased heart rate resembled the distribution of ST elevation.

ST ELEVATION OR ST DEPRESSION AND HEART RATE CHANGES

ST elevation started at significantly lower heart rates (90 beats/minute or less) than did ST depression ($p < 0.001$) (Fig. 4). Pain during episodes of ST elevation and ST depression did not correlate with heart rate. Heart rate increased by 10 beats or more one minute before the start of ST changes in 110 of 165 episodes with ST depression (66.7%) and in only six of 56 episodes with ST elevation (10.7%, $p < 0.001$).

Discussion

TRANSIENT ST CHANGES, ANGINAL PAIN, AND MYOCARDIAL ISCHAEMIA

We studied patients who are typical of those encountered in clinical practice. We consecutively investigated all patients undergoing coronary arteriography in our institution. This approach differs from the more selective procedures of other studies³⁻⁵ and provides information about the incidence of transient electrocardiographic changes in an "unselected" group of patients with confirmed or suspected coronary artery disease. Recordings were done while the patients were in hospital but able to walk about. The results may differ from those in patients at home or work. Just under a quarter of our patients showed transient ST segment changes during one day of ambulatory recording.

Anginal attacks accompanied by ST elevation are said to define Prinzmetal's variant angina.¹¹ Yet invasive studies showing impaired coronary flow and ventricular function together with electrocardiographic changes and pain have shown that pain is a late and sometimes insensitive indicator of ischaemia.¹² Nor is pain a consistent finding during episodes of ST depression caused by ischaemia.^{4,13,14} In patients with silent ischaemia there may be a disturbance of pain perception,^{15,16} and painless myocardial infarctions are common and have a poor prognosis.¹⁷ The clinical importance of painless ST changes is controversial because such changes can occur in normal healthy volunteers.¹⁸⁻²⁰ Until the cause of such ST changes in otherwise normal people is known, false positive results will be found when normal populations are screened. These changes are rare, however, in the age group in which most patients with coronary dis-

ease occur.²⁰ Painful and painless episodes associated with similar ST deviations occurred in the same individual. Thus the ST segment changes are unlikely to be artefacts or normal findings.

DIFFERENCES BETWEEN EPISODES OF ST ELEVATION AND ST DEPRESSION IN DURATION, DIURNAL DISTRIBUTION, AND HEART RATES

In our patients episodes of ST elevation were shorter than episodes of ST depression. This suggests that the pathophysiological mechanisms underlying ST elevation and ST depression follow different time courses. There were no differences in pain frequency with shorter or longer episodes and ST depression was not deeper with longer episodes. The duration of an episode does not therefore seem to reflect severity of ischaemic changes.

ST elevations were most frequent in the early morning. This finding has also been described by others^{21,22} and may relate to the circadian variation of disease activity in variant angina.²³ Parallels have been drawn with phases of rapid eye movement sleep in patients with variant angina²⁴ but the interrelations of disease activity and circadian rhythm are still speculative and need further study. In patients with very severe fixed coronary disease, nocturnal ST depression may still be brought about by increased oxygen demand.²⁵ The typical diurnal distribution of episodes of ST elevation was found in our patients, although they had not given a clear cut history of such a pattern for their angina.

ST elevation occurred at lower heart rates than ST depression. This accords with the suggested explanation of a reduction in myocardial blood supply for episodes of ST elevation, while in ST depression with tachycardia increased oxygen demand is a more likely trigger. Continuous intra-arterial pressure monitoring in ambulatory patients^{26,27} showed that in spontaneous ischaemic episodes the rate-pressure product was consistently lower than in exercise induced ischaemia in the same patients. Therefore factors other than increased oxygen demand must be instrumental in precipitating ischaemic episodes.

In our study we found considerable overlap of duration, diurnal distribution, and heart rates in episodes of ST elevation and ST depression. This makes a combination of factors the most likely explanation for the induction of transient ischaemic ST segment changes in many instances.

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