caused a 10 mm Hg decrease in the height of the regurgitant CV waves, a decrease in the pulmonary artery systolic and diastolic pressures. Thus, inspiration reduced the diastolic pressure against the pulmonic valve, perhaps accounting for the preoperative decrease in the intensity of the murmur with inspiration.

Another contributory factor could be a decrease in regurgitant blood volume with inspiration. In patients with acute severe mitral regurgitation, retrograde flow from the pulmonary veins to the pulmonary arteries can occur in systole. This retrograde flow may decrease with inspiration, thereby decreasing the volume in the pulmonary arterial bed and the regurgitant flow across the pulmonic valve.

Mitral valve replacement was followed by normalization of pulmonary artery pressures. Consequently, the usual right-sided inspiratory augmentation of venous return produced the expected increase in the intensity of the murmur of pulmonic regurgitation.

**Exercise-Induced ST Segment Alternans**

Victor S. Wayne, M.B.; B.S.; Richard L. Bishop, M.D.; and David H. Spodick, M.D., F.C.C.P.

We report a rare electrocardiographic finding occurring in previously undescribed circumstances in which a 61-year-old man undergoing exercise testing developed striking ST segment elevation on the ECG characterized by electrical alternans of the ST segments. The significance of electrical alternans is briefly discussed in the light of this event.

Widespread exercise testing has led to recognition of a range of electrocardiographic responses to myocardial ischemia. While ST-segment depression is the most common finding, ST-segment elevation (regarded as representing probable transmural myocardial ischemia) also occurs. We report the unusual finding of alternation of exercise-induced ST-segment elevations.

**Case Report**

A 61-year-old man was referred for exercise testing following a five-year history of intermittent exertional chest pain, with one episode of pain at rest. Physical examination was unremarkable, and the resting ECG revealed sinus rhythm with T wave inversion in lead aVL and partial T wave inversion in leads V1 and V6.

The patient was exercised according to a modified Bruce protocol. After three minutes at 2 mph and 3.5 percent grade, he complained of mild retrosternal chest discomfort. The ECG revealed marked ST segment elevation in the precordial leads whereupon exercise was promptly terminated.

The ST segment elevation peaked at 7 mm with concomitant ST segment depression in the inferior leads. The striking feature of the ST segment elevation was that within 20 seconds of its development, the ST segments displayed electrical alternans (Fig I). There was no

---

**REFERENCES**

blood pressure change, and frequent premature ventricular contractions (PVCs) occurred over this period.

These electrocardiographic changes, together with the chest pain, totally resolved at one minute into the recovery period prior to nitroglycerin being administered. The patient subsequently underwent cardiac catheterization which revealed severe proximal, triple vessel coronary artery disease with preserved left ventricular function (ejection fraction 50 percent).

**Discussion**

Electric alternation has been described in a variety of conditions including pericardial effusion and tamponade. However, alternans of the isolated ST segment has been reported only rarely. This form of alternans was described in a patient with potassium intoxication and in a cyanotic infant with tricuspid atresia. However, ST segment alternans in patients with coronary artery disease has been described only during episodes of Prinzmetal's angina occurring at rest. The occurrence of this phenomenon in our patient during exercise indicates that it is not specific for variant angina, as has previously been suggested, and may in fact be more common than its infrequent documentation would suggest.

The mechanism of ST segment electrical alternans is unknown, and could conceivably involve either the phases of depolarization or repolarization. An area of myocardium may fail to be activated on alternate beats because of an ischemia-induced increase in its refractoriness, resulting in more ST segment elevation of the beats when all the myocardium including the ischemic zone is depolarized, and conversely, a more "normal" ST segment when the ischemic zone is refractory and therefore not depolarized. Alternatively, alternation of transmembrane action potentials due to abnormal electrolyte flux in the ischemic cells could affect any phase of the action potential thereby resulting in alternating depolarization or repolarization abnormalities causing the observed ST segment fluctuations.

The suggestion of a hemodynamic basis for, or consequences of, the phenomenon is not supported by a study of the temporal relation of the PVCs occurring during the period of ST segment alternans.

Irrespective of the occurrence of PVCs, there was strict alternation of the pattern of repolarization throughout the tracing. Thus, neither the increased post-PVC coronary flow nor any post-PVC potentiation had any effect in this situation, making this phenomenon occurring at a cellular level unlikely to be related to fluctuations in blood flow. It also suggests that the fluctuation in electrical activity is unlikely to be mirrored by hemodynamic fluctuations, although in the context of this acute event, to test this hypothesis by specifically looking for the presence or otherwise of pulsus alternans was not logistically feasible.

In summary, a case is presented of ST segment electrical alternans occurring in the hitherto undescribed setting of exercise. This phenomenon may be more common in patients with ischemic heart disease than realized. The question as to why this episode as with other electrical alternans should specifically occur on alternate beats still remains to be answered.

**References**

1. Spodick DH. Electric alternation of the heart: its relation to the kinetics and physiology of the heart during cardiac tamponade. Am J Cardiol 1962; 10:155-65