Total Electrical Alternation in Pericardial Disease

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Simultaneous electrical alternation of atrial and ventricular components can occur in malignant and sometimes tuberculous pericardial disease and is due, apparently, to a rotary pendular movement of the heart at a rate that differs from the pulse. This oscillation occurs only during effusion with tamponade and clears with paracentesis. It is thought to be the result of unusual freedom or release from the normal pulmonary and thoracic restraints.

Several years ago one of us observed a curious coincidence of phenomena in a patient very ill with tuberculous pericarditis. In addition to the findings of pericardial effusion there was an alternating pulse and an alternating friction rub. The electrocardiogram obtained at the same time exhibited extensive electrical alternation of the QRS and T waves, and, though it was not appreciated at the time, alternation of the P waves. Unfortunately, except for the electrocardiogram, none of the other phenomena was graphically recorded and all disappeared not long after the effusion was tapped. Antibiotic therapy was instituted and the pericarditis cleared completely. None of the alternating phenomena ever reappeared.

Not long thereafter another case of electrical alternation was observed in a patient with malignant hemopericardium. Here too, simultaneous P wave alternation, though present, was initially overlooked.

In June 1955, McGregor and Baskind reported 3 cases of simultaneous alternation of atrial and ventricular complexes resulting from pericardial effusion and offered an explanation for the phenomenon. In the 2 years since this review 2 more examples of electrical alternation of atria and ventricles were seen and recognized at the Veterans Administration Hospital in West Roxbury. Both were the result of malignant pericardial disease with tamponade. Both patients were profoundly ill and studies were necessarily limited. However, careful removal of small quantities of pericardial contents, (60 ml. in one patient and 150 ml. in the other) resulted in abolition of the alternating phenomena. These 4 cases are offered as a relatively large addition to a meager literature on the subject.

Material

Case 1. A 30-year-old man was admitted to the hospital complaining of pleuritic pain for 1 week and cough, night sweats, and weight loss for the preceding 3 weeks.

Examination revealed an acutely ill man with a temperature of 100.4°F, a blood pressure of 102/85, and a pulse of 124. There were dullness and altered breath sounds over the right base. The heart was enlarged, the sounds were distant, and a friction rub was heard with every other beat. Pulsus alternans was present. The electrocardiogram disclosed extensive ventricular and limited atrial alternation (fig. 1).

X-rays showed pericardial and right pleural effusions together with areas of pneumonitis. Tubercle bacilli were recovered from the sputum and eventually from the pericardial and pleural effusions.

Paracentesis was performed shortly after admission and 300 ml. of straw-colored fluid were obtained. This served to abolish the manifestations of tamponade and the alternating phenomena. Antibiotic therapy was also instituted. The fever and other constitutional symptoms receded by the sixth day and improvement was continuous thereafter.

Case 2. A 53-year-old truck driver was admitted to the hospital with epigastric pain, weakness, chills, and malaise. There was a history of cough for 5 years and increasing dyspnea for 1 year.

Physical examination disclosed an acutely ill and dyspneic man with a blood pressure of 138/84, a temperature of 97.6°F, and a pulse of 108. The heart sounds were distant and a systolic murmur was noted. A 40-mm. Hg drop in systolic blood pressure occurred during inspiration.

From the Veterans Administration Hospital, West Roxbury, Mass.
Fig. 1. Case 1. Tuberculous pericarditis with tamponade. P alternation is best seen in V₃, T alternation in I and II.

Fig. 2. Case 2. Malignant hemopericardium with tamponade. P alternation is best seen in F(aV₇) and V₅, T alternation in V₇.

X-rays showed an enlarged heart shadow and pulmonary congestion; a subsequent electrocardiogram demonstrated total electrical alternation (fig. 2). On the third hospital day the venous pressure was 370 mm. of water and the circulation time, arm-to-tongue, was 37 seconds. On the following day, because of leg tenderness, heparin was administered. However, he became cyanotic and tachypneic, his blood pressure could not be obtained, and he died on the fifth hospital day.

At autopsy the pericardium contained 1,300 ml. of dark liquid blood. There was granulomatous involvement of the parietal pericardium secondary to adenocarcinoma of the right lung. There were 5 pinhead-sized metastases on the visceral pericardium.

Case 3. A 30-year-old man in the latter stages of Hodgkin's disease was transferred to the West Roxbury Veterans Administration Hospital for terminal care. The major complaints included
dyspnea, chest pain, and cyanosis. The blood pressure was 100/82 and the pulse was 124. A 15-mm. paradoxical variation in blood pressure was noted. The heart sounds were distant and an apical systolic murmur was heard with every other beat. The roentgenogram revealed pericardial and left pleural effusions. The electrocardiogram showed simultaneous atrial and ventricular alternation (fig. 3), which disappeared following paracentesis of 150 ml. of yellow fluid.

Despite all therapeutic efforts the patient died on the thirty-seventh hospital day. Postmortem examination showed widespread Hodgkin's disease with involvement of the pericardium and with focal myocardial lesions. The pericardium contained 1,000 ml. of clear yellow fluid.

Case 4. A 43-year-old man with a 1 month history of rapidly progressive dyspnea, fatigue, and chest pain was admitted to another hospital where a diagnosis of pericardial effusion was made.
Paracentesis yielded bloody fluid which was shown to contain malignant cells.

The patient arrived at the West Roxbury Veterans Hospital with evidence of pericardial effusion and tamponade, a temperature of 100.6 F, and a heart rate of 120. The area of cardiac dullness was increased, the heart sounds were distant and a paradoxical pulse was noted. The electrocardiogram showed the presence of total alternation (fig. 4). Paracentesis was performed shortly after admission and 350 ml. of bloody fluid were removed. The initial pressure of 280 mm. of water was reduced to 220. At the conclusion of this procedure both the paradoxical pulse and the electrical alternans disappeared.

Within a few hours rapid recurrence of tamponade made another tap necessary and a polyethylene catheter was left in the pericardium. A total of 1,100 ml. of grossly bloody fluid was removed during the next 24 hours. A biopsy of a supraclavicular node disclosed epidermoid carcinoma, probably pulmonary in origin. Eventually pericardial bleeding stopped and following a course of radiotherapy the patient was returned to the original hospital.

**Discussion**

Electrical alternation can, as a matter of definition, involve any component of the electrocardiogram. There may be changing individual wave forms, changing intervals, or combinations of the two. By common agreement, however, the term "electrical alternation" is reserved for records having a constant interval between alternating complexes, a constant site of origin (identity of pacemaker), and demonstrated independence from respiratory activity. The last is important in cases where the heart rate could be just twice the respiratory frequency.

Isolated alternation of the P waves is extraordinarily rare. It has been reported on only 2 occasions; once, apparently, as the result of drug intoxication and in another patient with primary amyloidosis of the heart. Alternation limited to the ventricular complex is also unusual. For example, Hamburger, Katz, and Saphir encountered only 1 instance in 10,000 consecutive records. Feldman found none in 6,000 tracings while Kalter and Schwartz collected 5 cases in 6,059 patients. It is clear, however, that minor degrees of alternation could be obscured by other electrocardiographic variations.

Simultaneous alternation of all electrical components has been reported 10 times. In addition to the 3 cases of their own McGregor and Baskind collected 6 others from the literature of which only 2 had been detected by the reporting investigators. One additional case is noted from an electrocardiogram in Wood's textbook illustrating electrical alternans of the ventricular complexes. It was obtained from a patient with malignant hemopericardium and demonstrates well-marked P wave alternation best shown in lead III.

The first case of total electrical alternation recognized as a consequence of pericardial effusion was reported by McGregor in 1946. However, 4 years earlier, Reisinger, Pekin, and Blumenthal published a similar record from a patient with malignant hemopericardium. Also, in 1945, Fletcher reporting another patient with neoplastic pericardial effusion noted QRS alternation while overlooking similar changes of the P waves.

Electrical alternation of the ventricular components is classically attributed to coronary heart disease or myocarditis. Simultaneous alternation of atrial and ventricular complexes might, therefore, result from myocardial disease of all chambers. However, this has not been demonstrated at postmortem examinations of patients who during life exhibited this phenomenon. It is, apparently, encountered only in the presence of serious pericardial disorders with tamponade.

Careful inspection of the records exhibiting simultaneous atrial and ventricular alternation suggests that the alternating pattern is a manifestation of varying axis and that this in turn is due to an actual change of cardiac position occurring with every other beat. It is commonly best seen in the midprecordial leads, with the complexes resembling first the waves from an adjacent lead to one side, possibly to the right of the selected position, then resembling those to the left, and alternating between the 2 even during suspended respiration. The variation does, in fact, except for
the frequency, simulate that noted as a consequence of deep respiration. Where it is large enough to be well seen in the limb leads, the axis shift of the P waves is in the same direction as the QRS complexes. This alternation of pattern involving all electrocardiographic components obtained during held respiration is entirely consistent with an alternating cardiac position and is not well explained in any other way. The coincidental mechanical alternations (friction rubs, murmurs, pulsus alternans) do not detract from this hypothesis. The gross variations of cardiac position suggested by the electrocardiograms would be of sufficient degree to distort the great vessels and interfere with cardiac filling or emptying. It would also be sufficient to result in changing intensity of coincidental friction rubs or murmurs.

The reason for anatomic alternation of cardiac position was first proposed by McGregor and Baskind,1 who suggested that "The heart suspended in a large sac of fluid should move more than the normal organ." The helical arrangement of the great vessels together with the spiral musculature of the heart cause a normal systolic rotation of the heart about its long axis. The lungs and mediastinal structures, however, exert a gentle restraining influence that helps to return the heart to its diastolic position. In the presence of a sufficiently large effusion, these restoring forces are separated and insulated from the heart, and the normal cardiac rotation is not completely halted and reversed at the end of systole. The succeeding beat can then add its movement to a still partially rotated heart. In this manner, by the summation of rhythmic pushes, a periodic rotary oscillation can be established somewhat like the rotating pendulums of some clocks. The natural frequency of this cardiac oscillation varies somewhat with the heart size, position, and build of the patient. It would probably be different, however, from the cardiac rate so that the normal cardiac movement would be expected at some times to enhance the degree of pendular rotation and at other times to oppose it. This can result in a variety of rhythmic positional changes.1,11 The one most easily recognized, however, and the least likely to be confused with respiratory variations is the change of position that occurs with every other beat and that causes electrical alternation of both atria and ventricles. It is of some interest that this phenomenon occurs almost invariably in the presence of tachycardia. Three of the 4 cases presented here had pulse rates of 120 to 125 while the fourth had a rate of 100 per minute. The cases reported elsewhere had similar frequencies. It would appear, therefore, that the natural oscillatory rate of the heart would fall between 50 and 65 per minute.

The largest and most clearly inscribed wave forms are contained within the QRS complex and it is here that electrical alternation is most obvious. The T waves are always secondarily involved but, because they are lower and more diffuse, T-wave alternation is less well seen. The P waves are normally the smallest deflections, and alternating changes in these complexes are slight and easily overlooked unless they are especially searched for or are unusually prominent.

One important observation regarding total electrical alternation remains unexplained by the relatively simple hypothesis of varying cardiac position. It is seen, apparently, only in serious pericardial involvement, either tuberculous pericarditis or malignant disease.10 It is present only during tamponade and clears with paracentesis. This implies an added factor of interference with cardiac filling, a detail that may play a critical but presently unknown part. One element that may contribute to this phenomenon is the relatively greater thickness and stiffness of the parietal pericardium in tuberculous infection and in malignant disease than in benign pericarditis. It appears likely that despite the presence of effusion considerable restraint upon abnormally free cardiac movement is still exerted by the lungs and other thoracic structures through a relatively normal and yielding parietal pericardium. However, this would be less effective or even nonexistent through a taut, thick, or stiff covering. This is the situation that permits exaggerated free-
dom of movement and the resultant electrical alternation. A reduction in pericardial contents leads to a lessening in tenseness and stiffness of the parietal membrane and once more permits transmission of the limiting and restoring forces. We have not, in recent years, seen severe tamponade in relatively benign pericardial disease. It is considered likely, however, that alternation could occur with large effusions of any type when accompanied by high intrapericardial pressures.

Curiously, electrical alternation may wane and disappear despite continuing tamponade. Possibly concomitant changes in fluid viscosity, the development of adhesions, or increasing feebleness of cardiac pulsation may interfere with the maintenance of rotational moment.

Summary

Simultaneous electrical alternation of atrial and ventricular components is uniquely related to serious pericardial disease with effusion and tamponade.

Present theories for the genesis of this phenomenon are reviewed and amplified. In the presence of a suitable effusion it is hypothesized that a rotary pendular movement of the heart can occur as the result of an unusual degree of freedom from the normal mediastinal and pulmonary restraints. When this oscillation bears a 1:2 relationship to the heart rate, an alternating difference in cardiac position becomes manifest in total electrical alternation.

Four patients who exhibited synchronous electrical alternation of atria and ventricles are presented and discussed.

SUMMARIO IN INTERLINGUA

Le simultane alternation electric de componentes atrial e ventricular es unicamente relationate a serie morbo pericardial con effusion e temponage.

Le theorias currente relative al genese de iste phenomeno es passate in revista e amplificata. In le presentia de un appropriate effusion, le hypothese es postulate que un movimento pendular rotatori del corde pote occurrer como resultato de un grado inusual de libertate ab le normal restrictiones mediastinal e pulmonar. Quando iste oscillation es relationate al frequentia cardiac in un relation de 1:2, un differentia alternante in le position cardiac se manifesta in total alternation electric.

Es presentate e discutite le casos de 4 pacientes qui exhibiva un synchronme alternation electric del atrios e ventriculos.

REFERENCES

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