

## Cardiac electromechanical time intervals of the fetus: physiology and animal studies

C.B. Martin Jr.

Department of Obstetrics and Gynaecology,  
St. Radboud Hospital, Catholic University,  
6500 HB Nijmegen, The Netherlands

### Definitions

The cardiac electromechanical time intervals measure the coupling of electrical and mechanical ventricular systole and the events of mechanical systole. The pre-ejection period (PEP) is the interval from the onset of ventricular depolarization (Q-wave) until beginning of ejection of blood from the ventricles. It can be subdivided into electromechanical delay, from the initiation of depolarization until the start of the rise in intraventricular pressure, and a period of isovolumetric contraction up to the instant when intraventricular pressure equals that in the aorta. The ventricular ejection time (VET) is the period during which blood is being expelled from the ventricles. Diastole can be divided into an isovolumetric relaxation time, from the closure of the semilunar to the opening of the atrioventricular valves, and ventricular filling time to the beginning of the following cycle.

### Physiology

In normal hearts the duration of the PEP varies inversely with preload (degree of ventricular filling) and directly with afterload (diastolic blood pressure). The PEP is shortened by substances with positive inotropic activity (e.g., adrenergic  $\beta$ -receptor stimulants) and prolonged by substances with negative inotropic effects (e.g., halothane) and in heart failure (9). VET is correlated positively with stroke volume and ejection fraction, and at constant stroke volume is shortened by elevating mean aortic pressure and by positive inotropic agents (8). The ratio PEP/VET can be used clinically as a noninvasive measure of ventricular performance (9).

### Studies in Fetal Laboratory Animals

The systolic time intervals have been studied in acute experiments in fetal lambs (3,7) and in chronically instrumented fetal lambs (1,2,6) and monkeys (4,5). PEP/VET is elevated after fetal surgery and reaches stable levels only after 2 to 3 days of recovery (1). The duration of the PEP increases with increasing fetal age (4,6). An inverse relationship between PEP and heart rate has been found in some (7,3) but not all (4) studies; this discrepancy may be related to differences in measuring technique and in the extent to which heart rate decelerations and accelerations were included. PEP is affected by changes in ventricular pre- and afterload in the same direction in the fetus as in the adult (4). In chronically instrumented fetal monkeys, adrenaline shortened PEP, the changes after atropine were inconsistent, and variations in plasma glucose had no effect on PEP (4). An inverse relationship has been observed between PEP and coronary blood flow (6).

both components of the PEP were found to be prolonged during fetal acidemia (4). The most frequently observed effect of hypoxemia with or without acidemia on PEP has been shortening (2,3,7), attributed to increased adrenergic activity. The shortening could be prevented by pre-treatment with propranolol (2). In fetal monkeys, however, a slight prolongation of PEP was observed in mild hypoxemia (4); and in another study PEP was found to increase slightly in 4 of 5 trials of induced hypoxemia in fetal lambs (6). The discrepancy between the results cited is probably due to differences in experimental conditions (acute or chronic), the degree of hypoxemia induced, and the method used to induce it - reduction of maternal FIO<sub>2</sub> (4,6) or of uterine blood flow (2). During umbilical cord occlusions the PEP increased in parallel with increasing blood pressure (afterload) (3).

VET varies inversely with heart rate over the normal range and during tachycardia in both fetal monkeys (5) and lambs (3). Below about 150 beats/min in monkeys and 115 beats/min in sheep, no further prolongation of VET was observed, suggesting that no further increase in ventricular filling and stroke volume occurs below these levels. No relation was found between VET and gestational age (5). VET, corrected for heart rate, was shortened by adrenaline and in the presence of combined hypoxemia and acidemia, but not when either of these latter factors was present alone (5).

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