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Calculation of parameters of end-systolic pressure–volume relation in the ventricles

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ABSTRACT

The slope and intercept of a non-linear model of the end-systolic pressure–volume relation (ESPVR) are calculated by using a previously derived mathematical formalism describing the pressure–volume relation (PVR) in the left ventricle. An important feature of this mathematical approach is the inclusion of the peak isovolumic pressure P_{isom} in the formalism describing the PVR in the left ventricle. The mathematical procedure used in this study is simple and can be easily implemented in a non-invasive way for clinical applications; only the ventricular pressure P_m near end-systole needs to be estimated.

1. Introduction

The relation between pressure and volume in the ventricles near end-systole (ESPVR), when the cardiac muscle reaches its maximum state of activation, has been the object of extensive studies in the literature (for reviews see [1–4]). Both linear and non-linear approximations of the ESPVR have been presented in the literature [5–8]. The calculation of the slope and intercept V_{om} of the ESPVR has received particular attention for possible clinical applications [9–12]. New approaches have been presented more recently in order to determine the parameters of the ESPVR from single loop measurement for instance by estimating the peak isovolumic pressure P_{isom} or otherwise [13–15]; a critical review is given in [15]. This study presents a new approach in which only the ventricular pressure near end-systole P_m needs to be estimated or measured in an invasive way, all other quantities needed in the calculation can be measured in a non-invasive way by using echocardiography or MRI.

The isovolumic pressure P_{iso} developed in a non-ejecting contraction by the myocardium is considered a good approximation to the active pressure generated by the myocardium on its inner surface (endocardium) in an ejecting contraction (inertia forces and viscous forces neglected), consequently its calculation is important as a way to assess the contractile state of the myocardium. In a series of studies [6,16–22] the author has stressed the importance of introducing the isovolumic pressure P_{iso} and P_{isom} in the formalism describing PVR and ESPVR. This has resulted in a better understanding of the mechanics of ventricular contraction, new relations that show the interrelation between different areas under the ESPVR and a new mathematical expression for the elastance (slope) of the ESPVR that is precisely used in this study (see Eq. (4) in what follows). The clinical implications of these results were also discussed.

This study is based on a non-linear model of the ESPVR and presents a simple procedure to calculate the peak isovolumic pressure P_{isom}, the horizontal intercept V_{om} with the volume axis of the ESPVR and different slopes related to the non-linear ESPVR (see Figs. 1 and 2). For the calculation of V_{om} one needs only to know the end-diastolic volume V_{ed}, the volume of the myocardium V_{ω}, and the cavity volume V_m near end-systole. In order to calculate P_{isom} and other parameters of the ESPVR

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