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Communication

Determination of the pressure required to cause mitral valve failure

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Abstract

A method has been developed for applying water pressure to a closed mitral valve on the side corresponding to the heart's left ventricle. The pressure is increased until fluid flows through the valve, i.e. until it fails. A specific dissection technique has been developed to produce a specimen with two annular rings, mitral annulus and papillary muscle annulus. Since the valve is maintained intact, with its leaflets attached to papillary muscles by the chordae tendineae, this method allows the effects of ruptured chordae and their surgical repair or replacement to be assessed in vitro. The chamber that holds the valve supports both the mitral annulus and papillary muscle annulus of the specimen. The mitral annulus is sutured onto rubber sheeting held in the chamber. The papillary muscle annulus is held in place by a Perspex support. The main part of the apparatus consists of a water pump connected through flexible tubing to the chamber that holds the valve in place. The pressure at failure is measured using a pressure transducer. Preliminary experiments demonstrate that anterior leaflet marginal chordae, but not strut chordae, are vital to valve function. Posterior leaflet chordae have been found to be important for valve competence.

Keywords: Chordae tendineae; Heart; In vitro testing; Mitral valve; Regurgitation

1. Introduction

A method has been developed to investigate failure of the mitral valve of the heart which involves applying water pressure to a closed mitral valve, from the side corresponding to the left ventricle. The pressure is increased until the valve fails, i.e. until fluid flows through the valve. Mitral valve failure is life threatening but can be corrected by surgery [1,2]. Fig. 1 shows that the valve is composed of two leaflets (anterior and posterior) and chordae tendineae (abbreviated to chordae) connecting the leaflets to papillary muscles; the papillary muscles in turn are attached to the left ventricle of the heart. Further details can be found elsewhere [3,4]. A distinction is often made between marginal chordae, that insert into the edge of the leaflets and basal chordae, that insert away from the free edge of the leaflet [5,6]. There are two thick basal chordae that inserts into the anterior leaflet, these are known as strut chordae [7]. Further details on the nomenclature of chordae can be found in Lam et al. [8].

Previous investigations into the role of chordae on valve function concluded that the marginal chordae of the anterior leaflet are vital to valve function; however, strut chordae have not been found to affect mitral valve competence [6,7,9]. One group found that cutting the strut chordae reduced aortic flow in an isolated working pig heart model [9]. Therefore, they suggested that strut chordae have a role in left ventricular function [9]. Strut chordae may also be important for maintaining continuity between the mitral annulus and papillary muscles [6] and may have a role in controlling leaflet motion [10]. Experimental techniques, including test apparatus, have been developed to study the function of the mitral

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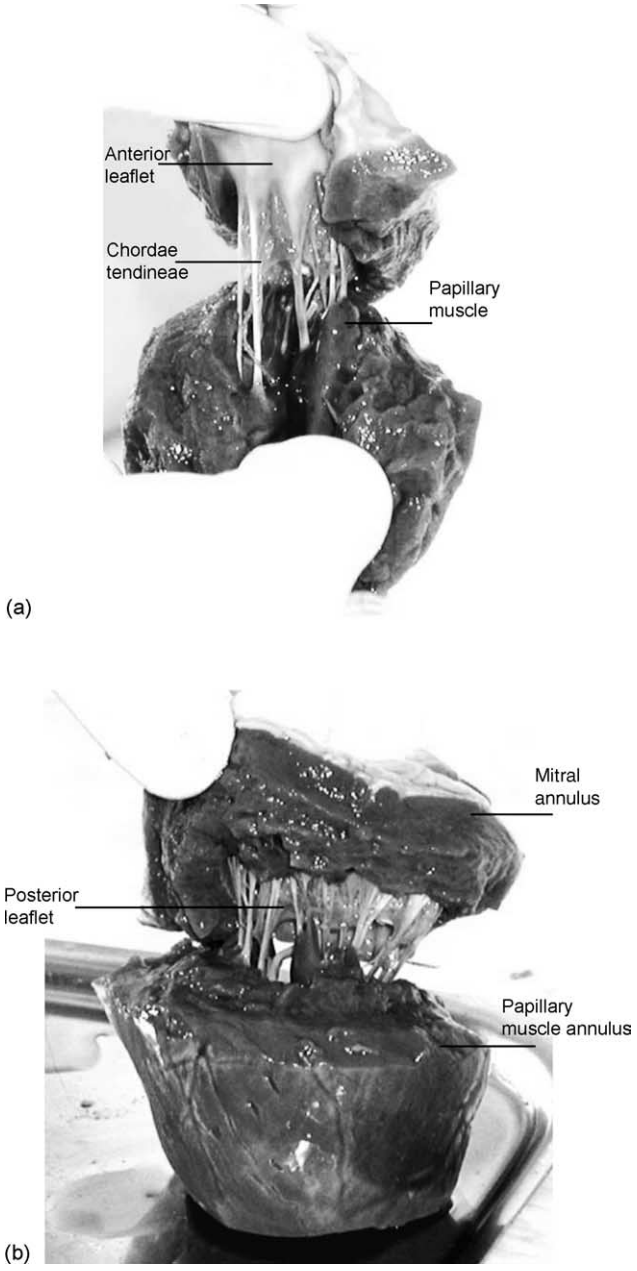

Fig. 1. Specimen dissected for testing mitral valve failure: (a) anterior view and (b) posterior view.

valve [11,12]. The method developed by Katoh et al. [12] applied a static pressure for a given period of time and regurgitation was then measured. The apparatus used by Fontaine et al. [11] and He et al. [6,13] was used to investigate flow through the valve. It consisted of an atrial inflow tract and an aortic outflow tract; regurgitation and flow patterns were investigated. However, no apparatus has been described for investigating the pressure at which valve failure occurs and how valve complications and corrections affect this pressure. Therefore, apparatus was designed and commissioned to test mitral valve failure. In order to use this apparatus, a dissection technique was developed to isolate a mitral valve attached to an intact papillary muscle annulus.

2. Methods

2.1. Specimens

The dissection used for several in vitro studies of the mitral valve [12,13] produces specimens that have papillary muscles that are independent of each other. For this investigation, a dissection technique and specimen were developed to produce specimens consisting of an intact mitral valve annulus within a circular section of the ventricular wall and another circular section of the ventricular wall that includes the origins of the papillary muscles. In this paper, these will be referred to as the mitral valve annulus and the papillary muscle annulus, respectively (Fig. 1). The chordae of the mitral valve were exposed to allow easy access to chordae for identification and severing of selected chordae around the valve. The main advantage of a specimen dissected in this way is that, despite the chordae being exposed, the mitral valve, chordae and papillary muscles can be maintained in their correct anatomical position.

Measurements of distance from the top of the mitral annulus to the base of the papillary muscle annulus, annular diameters and the length of the papillary muscle annulus in the direction of the major axis of the left ventricle (i.e. the height of the papillary muscle annulus in Fig. 1b) were made from two hearts. These measurements were used to guide the design of the test apparatus.

For testing, the valve annulus was sewed to a 1 mm thick sheet of rubber (Rubberatkins Ltd., Units 1-3 Hareness Road, Altens, Aberdeen, UK) using 2-0 and 3-0 braided polyester suture. The mitral valve diameter can be varied at this stage. A hole in the centre of the disc, cut using an annuloplasty ring (26 mm Duran ring, Medtronic Ltd., Suite One, Sherbourne House, Goxley Business Centre, Watford, UK) as a template, allows fluid to pass through the valve.

All experiments were performed on pig hearts which are an established geometrical model for human hearts [14]. Hearts were delivered by a supplier (Fresh Tissue Supplies Ltd., 81 Rushams Road Horsham, West Sussex, UK). On arrival, hearts were wrapped in tissue paper soaked with physiological saline and placed in heat sealed bags. Hearts were then kept at −40 °C. Hearts were defrosted and dissected to produce the required specimen. Specimens were either used or bagged and refrozen (as described above, ready for use at a later date).

2.2. Overview of apparatus

The main components of the test apparatus are the pump that pressurises the fluid and the test chamber that holds the valve. The two components are linked by silicone tubes (30 and 35 mm outer diameter and 5 mm wall thickness). Bleed holes enable the pump, tube and part of the test chamber to be filled with water, provided a specimen is in place (see Section 2.4). Sections 2.3 and 2.4 will describe each component. Pre-