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Biomechanical property and modelling of venous wall

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A R T I C L E I N F O

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A B S T R A C T

Human saphenous vein has long been used as coronary artery bypass grafts to survive a heart arrested by blocked coronary arteries. Biomechanical properties of the saphenous vein can be critical because mismatch in the biomechanical property between a coronary artery and a graft will reduce graft patency and speed up disease development in the graft. In this paper hence the active and passive biomechanical behaviours of the human saphenous vein and other venous walls were reviewed extensively and comprehensively. The existing *in vitro* uniaxial, bulge, planar and tubular biaxial tensile testing methods, *in vivo* testing cases, property variables, various tested results, constitutive models and their mathematical modelling methods, viscoelasticity, and residual strain/stress are highlighted and summarized. It is demonstrated that the biomechanical properties of the human saphenous vein and other venous walls are not well documented, and their modelling approaches are limited and subjected to be updated in a great deal. Additionally, a few important research issues are proposed. The paper has provided a piece of useful information to investigation into coronary artery bypass grafts.

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1. Introduction

Coronary artery disease (CAD) is an important cause of mortality all over the world. Human great saphenous vein (GSV) frequently serves as coronary artery bypass graft (CABG) to treat CAD because it easily is harvested and handled and without allograft rejection. Even though this idea can be traced back to 1930's (Diodato and Chedrawy), the direct coronary artery surgery by using CABG technique began actually in 1968 in the USA (Miller and Dodge, 1977). Currently, nearly 20,000 CABGs are carried out every year by NHS mainly to treat old people with age of at least 60years in England (http://www.nhs.uk/conditions/Coronary-artery-bypass/Pages/Introduction.aspx).

The GSV is a large, subcutaneous, superficial vein of the human leg. The vein runs along the length of the lower limb, as shown in Fig. 1(a). A segment of GSV can be cut off and used to bridge the blocked coronary artery and the aorta and form a bypass duct, see Fig. (b), eventually the blood can flow into the coronary artery to make the heart working properly.

Unfortunately, saphenous vein CABG has to experience an arterialization process after surgery. In the process saphenous vein CABG can be failure and subsequent remodelling as well as develop various diseases such as aneurysms, thrombosis, atherosclerosis and fibro-intimal hyperplasia (Hassantash et al., 2008; Vlodaver and Edwards, 1971; Walts et al., 1982; Cooper et al., 1996; Ramirez et al., 2012) which are associated with smooth muscle cells and extracellular matrix. In the first post-surgery month, 13–14% of grafts occlude because of thrombosis. By the end of the first year of the surgery, intimal hyperplasia develops to reduce graft diameter by 25–30%. In the following years, grafts occlude at a rate of 2% per year as intimal hyperplasia develops. Beyond 5years, vein grafts are in atherosclerosis due to necrosis, haemorrhage, calcification and thrombosis (Ramirez et al., 2012).

The failure and disease are closely linked to CABG physiological hemodynamic conditions (de Vries et al., 2016) and GSV itself mechanical property such as compliance (Zachrisson et al., 2011a). Up to now, a significant amount of review papers have appeared to clarify the problems in pathology, surgery and hemodynamic factors associated with saphenous vein CABGs, such as (Hassantash et al., 2008; Vlodaver and Edwards, 1971; Walts et al., 1982; Cooper et al., 1996; Ramirez et al., 2012; de Vries et al., 2016), just to name a few.

Additionally, there are a few review papers on artificial vascular grafts. The textile structures used in the construction of artificial vascular grafts were reviewed in detail and the structural factors relating to the failure of vascular grafts were identified (Pourdeyhimi and Text, 1987). The material properties and methods for determining the attributes of these factors to the failure are emphasized for further research. The mechanical mismatch of the artificial small-diameter vascular graft to the host vessel was

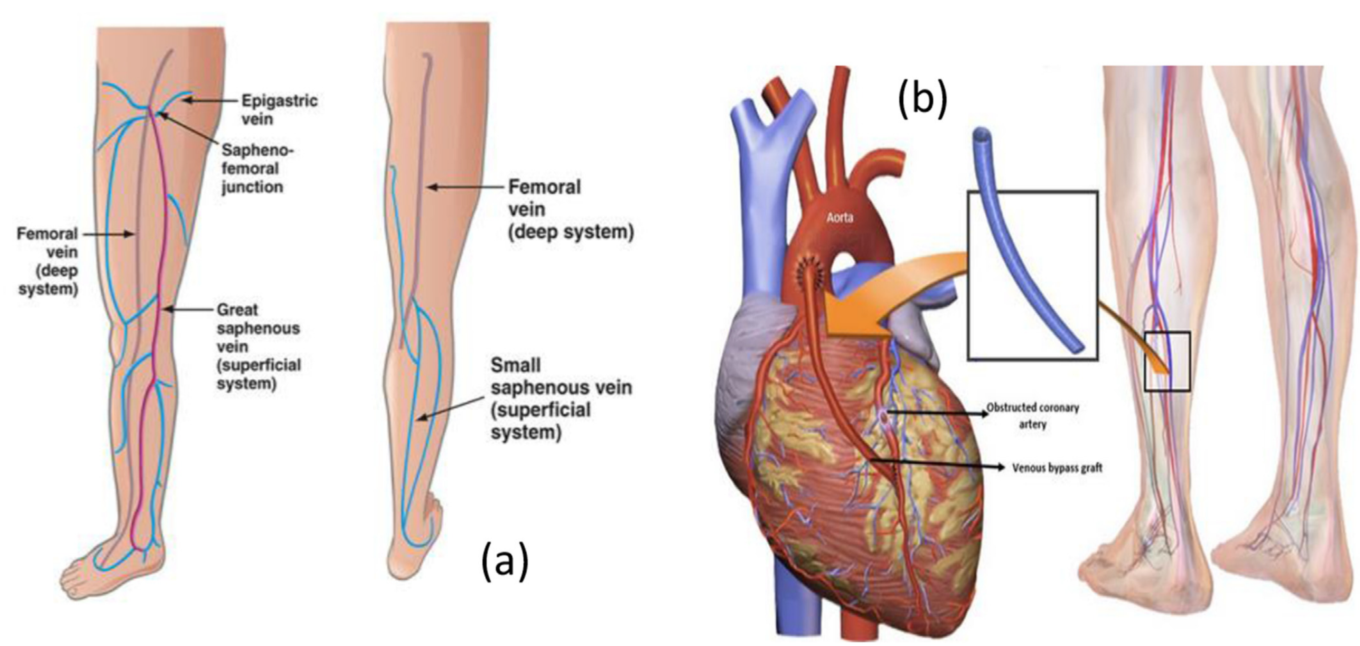

Fig. 1. Greater saphenous vein in human leg (a) and its bypass graft (b), the picture (a) was from (http://www.surgery.usc.edu/vascular/varicoseveinsandvenousdisease.html), the picture (b) was on (https://atlasofscience.org/a-novel-treatment-for-saphenous-venous-graft-thrombosis/).

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