Functional properties of fresh and cryopreserved carotid and femoral arteries, and of venous and synthetic grafts: comparison with arteries from normotensive and hypertensive patients

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Abstract The ideal arterial graft must share identical functional properties with the host artery. Surgical reconstruction of the common carotid artery (CA) is performed in several clinical situations, using expanded polytetrafluoroethylene prosthesis (ePTFE) or saphenous vein (SV) grafts. At date there is interest in obtaining an arterial graft that improves the results of that nowadays available. The use of a fresh or cryopreserved/defrosted artery appears as an interesting alternative. However, if the fresh and cryopreserved/defrosted arteries allow an adequate viscoelastic and functional matching with the host arteries needs to be established. The aims were to compare the viscoelastic and functional performance of: (1) conduits used in CA reconstruction (SV and ePTFE) with those of the fresh and cryopreserved/defrosted CA and femoral arteries (FA), and (2) normotensive and hypertensive patients’ arteries with those of the arterial substitutes in vitro analyzed. Pressure, diameter and wall thickness of the CA were recorded in 15 normotensive and 15 hypertensive patients (in vivo studies), and in SV, fresh and cryopreserved/defrosted CA and FA (obtained from 15 donors), and ePTFE segments (in vitro studies). From stress–strain relationship we calculated elastic and viscous modulus, and the characteristic impedance. The local buffer and conduit functions were quantified as the viscous/elastic quotient and the inverse of the characteristic impedance. Fresh and cryopreserved/defrosted CA and FA were more alike, both in viscoelastic and functional levels, respect to normotensive and hypertensive patients’ arteries, than the ePTFE and SV grafts. CA and FA cryografts could be considered an important alternative for carotid reconstruction.

Keywords Arterial wall · Carotid bypass · Carotid reconstruction · Cryopreservation · ePTFE · Femoral artery · Functional matching · Saphenous vein · Stress–strain · Viscoelasticity
Abbreviations
CA Carotid artery
ePTFE Expanded polytetrafluoroethylene
FA Femoral artery
SV Saphenous vein

Introduction

Surgical reconstruction or bypass of the common carotid artery (CA) may be indicated in several clinical situations (i.e. recurrent stenosis with inability to perform endarterectomy, arterial aneurysm, advanced cancer of the neck with involvement of the CA) (Sise et al. 1992; Snyderman and D’Amico 1992; Law et al. 1995; Wright et al. 1996; Sessa et al. 1998; Nishinari et al. 2002). The re-establishment of the carotid flow can be performed via the interposition of a by-pass between the vessel stumps, by utilizing a synthetic substitute, like expanded polytetrafluoroethylene (ePTFE) or an autologous vein (Sise et al. 1992; Snyderman and D’Amico 1992; Law et al. 1995; Wright et al. 1996; Sessa et al. 1998; Nishinari et al. 2002). The re-establishment of the carotid flow can be performed via the interposition of a by-pass between the vessel stumps, by utilizing a synthetic substitute, like expanded polytetrafluoroethylene (ePTFE) or an autologous vein (Sise et al. 1992; Snyderman and D’Amico 1992; Law et al. 1995; Wright et al. 1996; Sessa et al. 1998; Nishinari et al. 2002). Although, surgical revascularization using the mentioned conduits generally restores blood flow, several questions regarding to their adequacy still remains unanswered. Synthetic prostheses are well tolerated but heal very little, the wall may incorporate bacterial colonies, and additionally, patients appear to be at high risk for a second stenosis (Sise et al. 1992; Sessa et al. 1998). Since the autologous substitutes have a greater biological compatibility, and a lesser risk of infection, some clinicians prefer their use in arterial reconstruction, and the autologous saphenous vein (SV) is among the most utilized (Wright et al. 1996; Nishinari et al. 2002). However, SV is not always available, due to disease or previous use (Sessa et al. 1998). The mechanical strength, and durable resistance to infection and thrombosis, makes the superficial femoral artery (FA) a viable alternative conduit for CA bypass or reconstruction (Wright et al. 1996; Sessa et al. 1998; Nishinari et al. 2002; Fields and Bower 2004). However, the use of autologous FA has limitations, due to at least two important reasons. First, its removal makes necessary to perform a lower limb bypass, with additional risks for the patient and second, its availability is limited, since the walls can be altered, mainly in elderly patients (Nishinari et al. 2002).

Consequently, CA substitutes that have the advantages of those nowadays available, and that overcome their limitations, are necessary. In this context, fresh and/or cryopreserved CA or FA from human donors could be interesting alternatives. However, the mechanical performance of fresh and cryopreserved CA and FA, and hence, their functional matching when they are used as CA substitutes, remains to be established. Related to this, during cryopreservation, several damages on the arterial cellular and extracellular components (the determinants of the arterial function) have been described (Rosset et al. 1996; Rigol et al. 2000; Bia et al. 2005a). So, if cryopreserved arterial segments are to be used as arterial substitutes their post-thaw functional performance needs to be evaluated. What is more, this evaluation would be compulsory, since the anastomotic mechanical and functional matching, is considered an important predictive factor for the long-term patency of vascular reconstruction (Dardik and Greisler 1999).

Two main functions, essentially mechanical, are ascribed to the human CA: to serve as conduits of low impedance (local conduit function) for the cerebral blood flow, and to smooth out the pressure and flow oscillations (pulsatility) determined by the intermittent left ventricular ejection (local buffer function) (Nichols and O’Rourke 1998). The arterial mechanical properties and functional capability are not constant, but change during physiological conditions and can be distorted by cardiovascular diseases (Armentano et al. 1995a, 1998). For instance, it is known that during hypertension arteries get stiffer and this hypertensive condition, particularly frequent in recipients, must be taken into account when selecting an arterial substitute. In this sense, the ideal arterial substitute—in mechanical terms, that with identical mechanical and functional properties respect to the native artery—would vary depending on the recipient’ s conditions.

This works’ purposes were: first, to compare the viscoelastic properties, local buffer and