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Experimental determination of circumferential properties of fresh carotid artery plaques

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ABSTRACT

Carotid endarterectomy (CEA) is currently accepted as the gold standard for interventional revascularisation of diseased arteries belonging to the carotid bifurcation. Despite the proven efficacy of CEA, great interest has been generated in carotid angioplasty and stenting (CAS) as an alternative to open surgical therapy. CAS is less invasive compared with CEA, and has the potential to successfully treat lesions close to the aortic arch or distal internal carotid artery (ICA). Following promising results from two recent trials (CREST; Carotid revascularisation endarterectomy versus stenting trial, and ICSS; International carotid stenting study) it is envisaged that there will be a greater uptake in carotid stenting, especially amongst the group who do not qualify for open surgical repair, thus creating pressure to develop computational models that describe a multitude of plaque models in the carotid arteries and their reaction to the deployment of such interventional devices. Pertinent analyses will require fresh human atherosclerotic plaque material characteristics for different disease types. This study analysed atherosclerotic plaque characteristics from 18 patients tested on site, post-surgical revascularisation through endarterectomy, with 4 tissue samples being excluded from tensile testing based on large width–length ratios. According to their mechanical behaviour, atherosclerotic plaques were separated into 3 grades of stiffness. Individual and group material coefficients were then generated analytically using the Yeoh strain energy function. The ultimate tensile strength (UTS) of each sample was also recorded, showing large variation across the 14 atherosclerotic samples tested. Experimental Green strains at rupture varied from 0.299 to 0.588 and the Cauchy stress observed in the experiments was between 0.131 and 0.779 MPa. It is expected that this data may be used in future design optimisation of next generation interventional medical devices for the treatment and revascularisation of diseased arteries of the carotid bifurcation.

1. Introduction

Stroke is the third leading cause of mortality leading to severe neurological disability with associated costs of $58bn in the US in 2006 (Bates et al., 2007). Carotid endarterectomy (CEA) is the gold standard for interventional treatment of carotid bifurcation stenoses. Two randomised trials have shown the superiority of CEA over medical therapy alone for symptomatic patients; The North American Symptomatic Carotid Endarterectomy Trial (NASCET) (Ferguson et al., 1999), and the European Carotid Surgical Trial (ECST) (Rothwell et al., 2003), with more than 3500 patients involved in both trials and the results considered to be the highest level of evidence of CEA treatment. Despite the proven efficacy of CEA, great interest has been generated in carotid angioplasty and stenting (CAS) as an alternative to open surgical therapy. CAS is less invasive and has decreased risk of cranial nerve damage (Sajid et al., 2007; Jeyabalan et al., 2009).

Two recent trials, set up to address equivalence and efficacy of CAS over CEA, Carotid revascularistion endarterectomy vs. stenting trial (CREST) and (International carotid stenting study) (ICSS), have recently published their findings (Brott et al., 2010; Ederle et al., 2010). Both trials were large, randomised, multicentre, controlled trials; CREST studied 2502 patients and ICSS studied 1713 patients. CREST reported similar net outcomes with CAS and CEA. For the composite primary endpoint of any stroke, myocardial infarction (MI) or death during the periprocedural period, or ipsilateral stroke on follow-up, stenting was associated with 7.2% rate of these events vs. 6.8% with surgery, a non-significant difference. However, individual risks varied within the CREST trial. When considering death and stroke alone, CEA is safer than stenting (2.6% vs. 4.8%). For the ICSS trial, the 120 day risk of stroke, death or MI in those patients allocated to CAS was significantly higher than CEA (8.5% vs. 5.1%; HR 1.69, 1.16–2.45, $p=0.006$) (Forbes, 2010; Ederle et al., 2010; Gray, 2010). Results from the CREST and ICSS trials seem to contradict each other.

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