SIMULATION OF LONGITUDINAL ARTERIAL STRETCH IN THE LOWER LIMBS DURING GAIT

Richard J. Beck, Antonie J. van den Bogert, Azita Tajaddini, and Brian L. Davis
Biomedical Engineering Department, Cleveland Clinic Foundation, Cleveland, OH
email: beckr2@ccf.org

INTRODUCTION

Peripheral arterial disease is common in patients with diabetes and is a major risk factor in the etiology of gangrenous lesions that can, in turn, lead to lower extremity amputations. Correction of stenosis using stents can maintain patency in affected vessels; however, these devices are susceptible to mechanical problems. A fractured strut within a stent can initialize new obstructions in the lumen. The incidence of fractures corresponds to the length of the stented segment and the number of implants [1].

The present study was based on the hypothesis that activities of daily living impose longitudinal stretch on arteries traversing the hip and knee regions, and that this elongation may play a role in stent failure. Thus the purpose of the current study was to estimate arterial stretch during gait and to relate this to joint excursions.

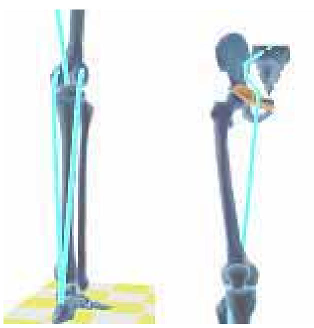

Figure 1: Views of the adapted SIMM graphical model.

METHODS

Using SIMM (Software for Interactive Musculoskeletal Modeling, V.4.0.1, MusculoGraphics, Inc., Motion Analysis Corp., Santa Rosa, CA), a model of the lower extremity was modified to include representatives of the iliac, femoral, and popliteal arteries. This software sets realistic geometrical constraints on muscle objects by conforming the muscle length and orientation to the motion of the bones [2]. An object created as a muscle and placed in the location of an artery will follow the same geometric rules. Using a SIMM leg model of an adult subject with height of about 1.8 meters and weight of about 75 kg, attention was given to the general anatomical route of the vessels. The mechanical anchor that perivascular connective tissue provides was modeled as origin and insertion. The arteries are subjected to the influence of residual strain and constant tension, therefore the resting lengths of the model arteries are assumed to be identical to the resting lengths of the surrounding muscles.

To demonstrate iliofemoral stretch, a new digital muscle was created, with origin in the sacral region and insertion on the proximal tibia (Figure 1). The SIMM default placements of the medial and lateral heads of the gastrocnemius were used to model the popliteal artery (Figure 1). For both iliofemoral and popliteal regions, the relationship of arterial length as a function of the gait cycle was predicted using SIMM.

RESULTS AND DISCUSSION

Plots generated from SIMM indicate the estimated length change for the iliac and femoral arteries together to be about 2.5 cm (Figure 2A). Likewise, the popliteal artery stretches an estimated 4 cm (Figure 2B). These geometrical demands associated with normal gait illustrate the necessity for compliance in vascular tissue. Modern stents and vascular tissue have dissimilar properties, providing undesirable stresses at their interface. Arterial stretch may therefore play an important role in stent failure.

Limitations of the current approach include (i) selecting origin and insertion points that may not replicate normal anatomy, (ii) restricting the analysis to gait, (iii) modeling a single subject, (iv) estimating global rather than local stretch, and (v) including wrapping surfaces that may not replicate the exact course of an artery. Nevertheless, predictions from the model suggest that lower extremity arteries undergo substantial longitudinal stretch, and that stent and vascular graft designers should be cognizant of these biomechanical demands.

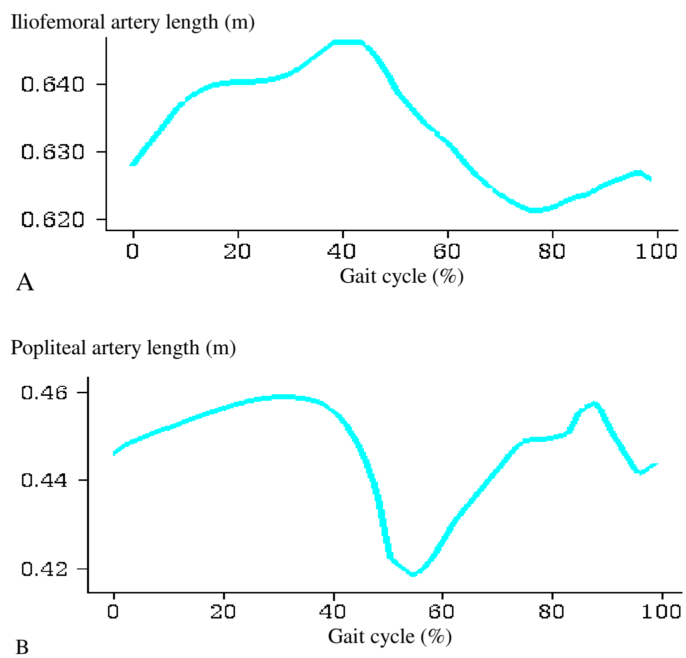

Figure 2: Iliofemoral length (A) and Popliteal length (B) plots from the SIMM model.

REFERENCES

1. Scheinert D, et al. *J. Am Coll Cardiol* **45(2)**, 312-315, 2005.
2. Delp, S. L. and Loan, J. P. *Computing in Science &Engineering,* **2**, 46-55, 2000.