The Potential use of 3-D Ultrasound for Arteriovenous Fistula Flow Dynamics Assessment

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The ReDVA Project—Combat the problem of renal dialysis vascular access failure

Goals
- Develop clinical technologies and methodologies that improve long-term performance of VA techniques
- Knowledge exchange

Introduction

Haemodialysis is the most common treatment for end stage renal disease. An arteriovenous fistula (AVF) is considered the preferred vascular access needed for haemodialysis, although, up to 50% fail to mature. One theory as to why AVFs fail to mature is adverse local haemodynamics. To study the local haemodynamics computational fluid dynamics (CFD) is used. 3-D ultrasound could potentially provide a cheap and accessible means to generate the patient-specific geometries needed for this study.

AVF Creation

Fistula surgically created by joining an artery to a vein. One commonly used fistula type is a radiocephalic (radial artery and cephalic vein).

Radiocephalic Fistula [1]

CFD Analysis of AVFs

Biological processes within fistula occur at very small scale and currently unable to get an accurate view of local haemodynamics in vivo. Therefore, CFD software used to model and assess the haemodynamics within patient-specific AVFs. Geometries of patients’ AVFs needed for CFD currently acquired using magnetic resonance imaging (MRI) at five time-points: pre-surgery, and post-surgery at 2-4 weeks, 4-6 weeks, 6-8 weeks and 6 months

Problems

MRI Problems: expensive and time-consuming
Patient Problems: difficult for renal patients to commit to five extra hospital visits (in addition to dialysis sessions) for MRI scanning, some potential patients find MRI claustrophobic, frailty of patients (difficult to lie still for one hour).
Geometry Problems: loss of signal around fistula region; therefore, geometry difficult to acquire in specific region of interest.

Solution—Ultrasound

Ultrasound is already used to assess renal patients pre-surgery, and post-surgery at regular intervals in Ninewells. 3-D ultrasound could offer a viable alternative to MRI for patient AVF geometry acquisition. Advantages: no additional patient visits are needed, assessment is non-invasive, accessible, cheap, good resolution is attainable, flow measurements can be acquired, and 3-D geometries can be attained.

Foreseeable Issues

Ultrasound is operator dependent. Also, specific ultrasound machine needed capable of 3-D image acquisition, and position and orientation of images need to be known.

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