Background Information
Autologous arteriovenous fistula (AVF) creation involves surgically anastomosing a peripheral artery to a superficial vein to provide adequate long-term access for haemodialysis purposes1. Repeated cannulation and vessel remodelling often results in a fluxing functional state that requires surveillance and management1. Duplex ultrasound (DU) is the standard imaging modality in AVF surveillance because there is no ionising radiation and no requirement for nephrotoxic contrast1. Further to this, DU provides an array of information that is used to determine function including peak flow velocities, blood volume flows, vessel diameters and residual lumen diameters2-4. However, the extra-anatomical course, complex flow geometries and vessel remodelling makes both image acquisition and interpretation particularly challenging. One significant limitation of DU is the two-dimensional nature of the captured images, which underappreciates the impact of morphological factors that may either contribute to AVF dysfunction or produce abnormal data that is in fact not related to dysfunction. Three-dimensional (3D) imaging and modelling gives us additional information that may reduce or eliminate many challenges faced during haemodialysis AVF surveillance. 3D ultrasound imaging is well established in various areas of sonography such as cardiac and obstetric fields, but it is underutilised for vascular specific applications.

Aim
Create a prototype 3-dimensional (3D) model of an arteriovenous fistula (AVF) using frehand ultrasound (fUS).

Methods
A fUS volume acquisition was performed on one patient with a left brachiocephalic AVF at their usual ultrasound examination (Philips ATL HDI 5000, 117-5MHz transducer). Written consent was obtained from the patient. The ultrasound volume was exported into freeware software Slicer3D, which was underappreciated for vascular specific applications. The ultrasound volume data and planar reconstructions are displayed in figure 1. Distortion can be seen in the coronal plane (figure 1D). Successful segmentation of the brachial artery and cephalic vein with ultrasound image overlay is demonstrated in figure 2. The stenosis overlay was added with a transparent effect to appreciate the residual lumen of the vein. The final result is presented in figure 3 showing the ability to rotate and view the model across three dimensions.

Results
The ultrasound volume data and planar reconstructions are displayed in figure 1. Distortion can be seen in the coronal plane (figure 1D). Successful segmentation of the brachial artery and cephalic vein with ultrasound image overlay is demonstrated in figure 2. The stenosis overlay was added with a transparent effect to appreciate the residual lumen of the vein. The final result is presented in figure 3 showing the ability to rotate and view the model across three dimensions.

Discussion
Modelling tissue from diagnostic imaging has become standard clinical practice for many medical imaging modalities1. Ultrasound is not generally known to produce adequate 3D reconstructions, which is disappointing considering the resolution for superficial structures is exceptional. The result of this prototype creation highlights the potential of fUS in 3D modelling AVFs. The radial artery, AVF anastomosis and cephalic vein are clearly identifiable, including a stenotic site of the cephalic vein. The structure and course of the vasculature can be appreciated, which we believe may provide key insight into the functional state of an AVF when combined with standard DU data. Such a model may also be compared over time, which we anticipate would lead to a better understanding of AVF remodelling and factors leading to dysfunction. There are some clear limitations that will need to be rectified before implementation into clinical practice. The main limitation we encountered was distortion, which is a result of the sweeping motion required to capture the volume of data. The ultrasound machine stitches the image slices together as the sweeping motion is performed by the sonographer4. This means that deviations related to the sweep are translated into the volume of data, which undermines the accuracy of both the volume dataset and resulting model. We’ve since found that this can be reduced by attaching a spatial tracking device to the transducer, which would also allow for longer segment volume acquisitions that could potentially encompass the entire AVF circuit4. Additionally, the manual segmentation was tedious and likely involves a considerable amount of user variability. Automated segmentation software specific to ultrasound generated volumes would be of significant benefit. Upon procuring the appropriate equipment and refining the scanning protocol, we plan to validate the accuracy and reproducibility of this novel technique.

References