

Atherosclerotic Plaque Imaging with Ultra Short Echo Time (UTE) MRI

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Introduction

The disruption of atherosclerotic plaques is the most frequent cause of acute thromboembolic vascular events. Plaque tissue constituents are likely to be much more clinically significant than lumen size in order to determine plaque vulnerability. Plaque can be composed of calcified tissue, fibrous tissue, lipid core and intra-plaque hemorrhage. There is a clinical need for a non-invasive, radiation-free high-resolution method to characterize plaque composition in order to determine atherosclerotic plaque burden and identify vulnerable plaque before it leads to a clinical event.

MR angiography methods have been used to determine the degree of lumen stenosis [1]. Lumen size, however, does not reflect plaque vulnerability. Recently MR multi-contrast methods have been used to characterize plaque composition [2]. These methods, however, do not allow for the visualization of calcification because of its short transverse relaxation time (T_2). Presently calcification is observed as a uniformly dark signal intensity area [3], which can also be caused by diverse signal artifacts. Therefore, calcification tends to be overestimated. Ultra-short Echo Time (UTE) MRI allows for the detection of short T_2 components. Calcification of the vessels may therefore be visualized with UTE.

Materials and Methods

Five aortic specimens with calcified atherosclerotic plaque were excised. The samples were imaged using a state-of-the-art dual-source CT (SOMATOM Definition, Siemens AG Medical Solutions, Erlangen, Germany) and calcium content of the specimen was quantified.

The UTE sequence and reconstruction algorithm were implemented on a 1.5 T clinical scanner (MAGNETOM Avanto, Siemens AG Medical Solutions, Erlangen, Germany). The UTE sequence consists of a 60 μ s long non-selective RF pulse followed by a 40 μ s transmit/receive switch time and a 100% asymmetric data acquisition from the centre to the surface of a sphere. In order to achieve the shortest possible TE, data acquisition starts already during ramp-up time of the readout gradient. The online reconstruction program consists of a Kaiser-Bessel Gridding algorithm (window width = 3 and $\beta = 4.2054$) with sampling density compensation modified to correct for undersampling. The following sequence parameters were used: TR = 100 ms, $\alpha = 90^\circ$, BW = 1000 Hz/pixel, 16384 projections, Tacq=27min. No fat saturation was used. To estimate the T_2 of the samples, four data sets with TE=0.1, 0.4, 1.2 and 5 ms were acquired. Using the CT image as reference, regions-of-interest (ROIs) were set on calcified and fatty tissue areas and a T_2 fit was estimated.

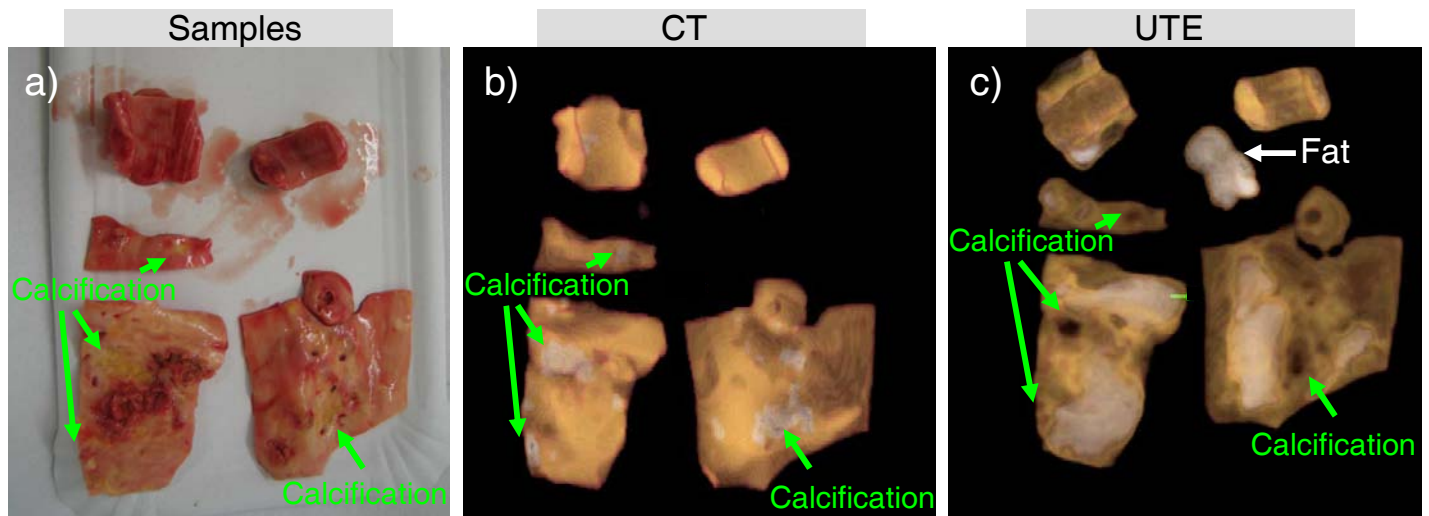


Figure 1. Photograph (a) of the aortic ex-vivo specimen with atherosclerotic calcified plaque and its corresponding CT (b) and UTE (c) images. While the positioning of the sample coincides in (a) and (b), the MR data (c) was acquired with a similar but not identical positioning. The fat sample was only available for the MR measurement.

Results

Figure 1 shows a photograph (a) of the aortic ex-vivo specimen with atherosclerotic calcified plaque and its corresponding CT (b) and UTE (c) images. The calcified areas, which could be determined in the samples as hard yellow tissue, and bright signal areas in the CT image, correlated well with the low signal areas in UTE data set. In the UTE images it was possible to see signal intensity variation inside the calcification regions, which may be related to the calcification density and distribution. The highest signal intensity areas in the UTE image appeared to be related to fatty tissue. The estimated T_2 decay of the sample regions showed a multi-exponential behavior with components shorter than 1ms not only in the calcification area, but also in other regions of the samples, demonstrating the need to measure these samples with ultra-short echo times.

Discussion

Preliminary results of UTE of atherosclerotic plaque have been shown. Calcified regions could be observed as low signal intensity areas in the UTE images, which correlated well with calcified regions in the CT data and the direct observation of the samples. Future work will include a comparison with histology to validate these preliminary observations.

The goal of atherosclerotic plaque imaging is the identification of patients with plaques vulnerable to disruption, which may be possible by means of characterizing its composition. The different constituents of an atherosclerotic plaque have different properties and therefore different T_1 and T_2 relaxation times. A method that could distinguish between these relaxation times may be able to display the heterogeneous structure of the plaque. A UTE multi-echo sequence may allow for the creation of parametric maps showing different T_2 s corresponding to different tissue types. UTE imaging could be combined with fat saturation or saturation of the long T_2 components in tissue in order to acquire signal coming only from short T_2 components, allowing a better visualization of the calcified areas. Its combination with other MR techniques may provide a comprehensive tissue characterization protocol.

References

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