Adaptation of ECG-gated non-contrast enhanced magnetic resonance angiography trigger delay technique for patients with high heart rate

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Introduction

- Cardiovascular diseases are severe medical conditions and one of the main problem is peripheral arterial disease
- Diagnosing peripheral arterial disease accurately in early stage is extremely important
- One of the most widely used method for imaging peripheral arteries with MRI is contrast enhanced MRA
- Contrast enhanced MRA procedure can only be performed for patients with normal renal function
- As an alternative to contrast agent studies, it is possible to perform non-contrast enhanced MRA procedures for patients who are suffering from renal insufficiency
- Existing non-contrast enhanced peripheral arterial imaging method is limited for patients with high heart rate.

Materials and methods

- The aim of this research was to modify the trigger delay technique method so that the ECG-synchronized non-contrast enhanced 3D TSE MRA method could also be applied on patients with an increased heart rate.

- Two groups of volunteers with different selection criteria:
  - First group (control group)
  - The second group (group of volunteers with elevated heart rate)

- The size of the first group was 12 volunteers and the second group was 2 volunteers.

Materials and methods

- This research was carried out at Tartu University Hospital, using a magnetic resonance imaging device Philips Ingenia with magnetic field of 1.5 T

- This study was coordinated with ethics committee of human studies of the University of Tartu (Permit 265/T-17, 19.12.2016).

- Studies were carried out between January 15 and May 1, 2017.

Materials and methods

Control group volunteers underwent two MRA scans of peripheral arteries (thigh region).

The difference between these two scans was the trigger delay value for imaging heart diastolic phase.

Transaxial reconstructions were performed for quantitative evaluation.

Measurements were performed on subtracted images as well as on anatomical images.

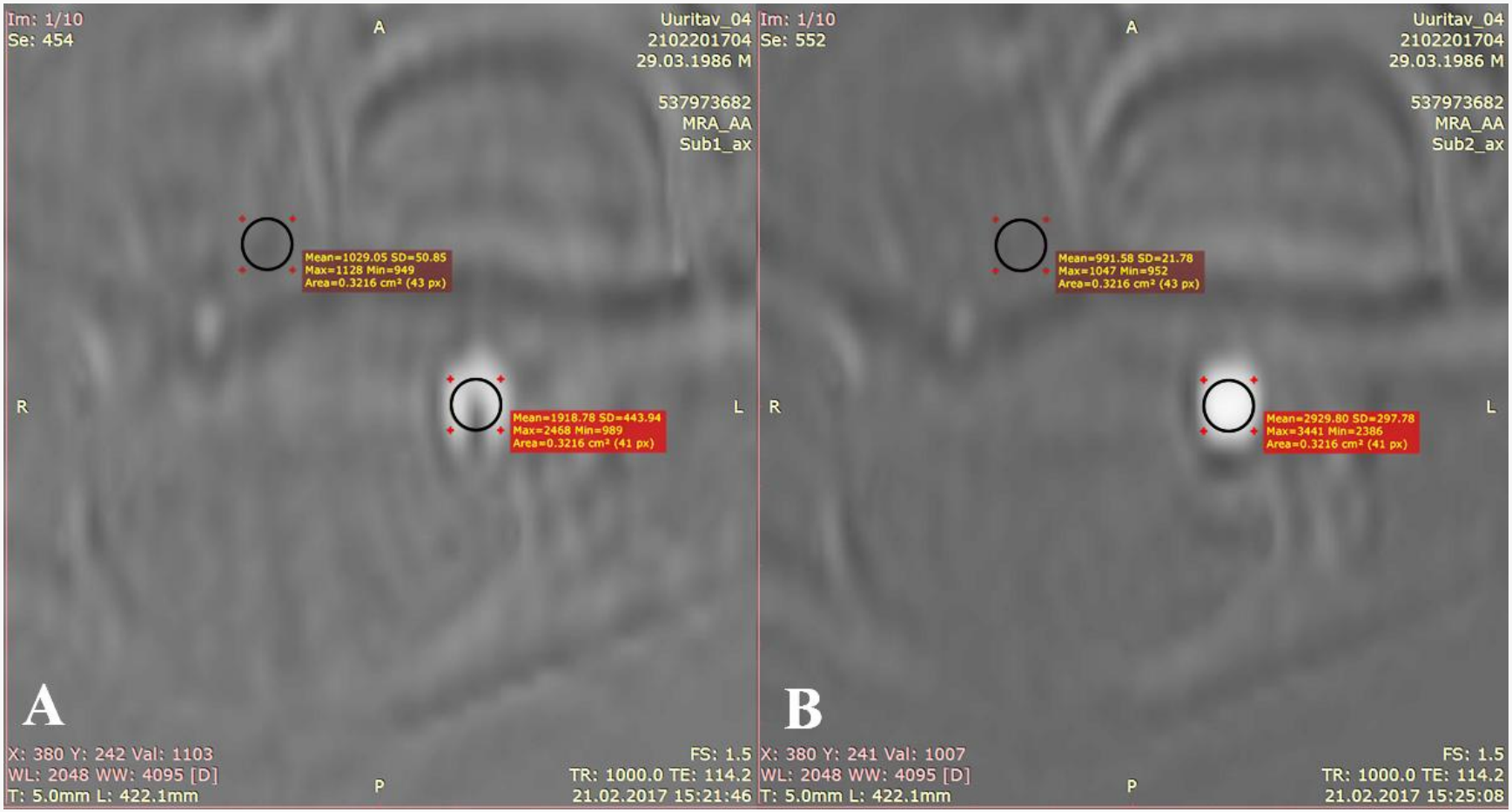
On the subtracted images, the arterial contrast was found compared to background tissue (muscle):

[Sub1-Sub1 (muscle)] / Sub1 (muscle)

For anatomical images, the arterial contrast was calculated between systolic and diastolic heart phase: (Diastol1-Systol) / Systol

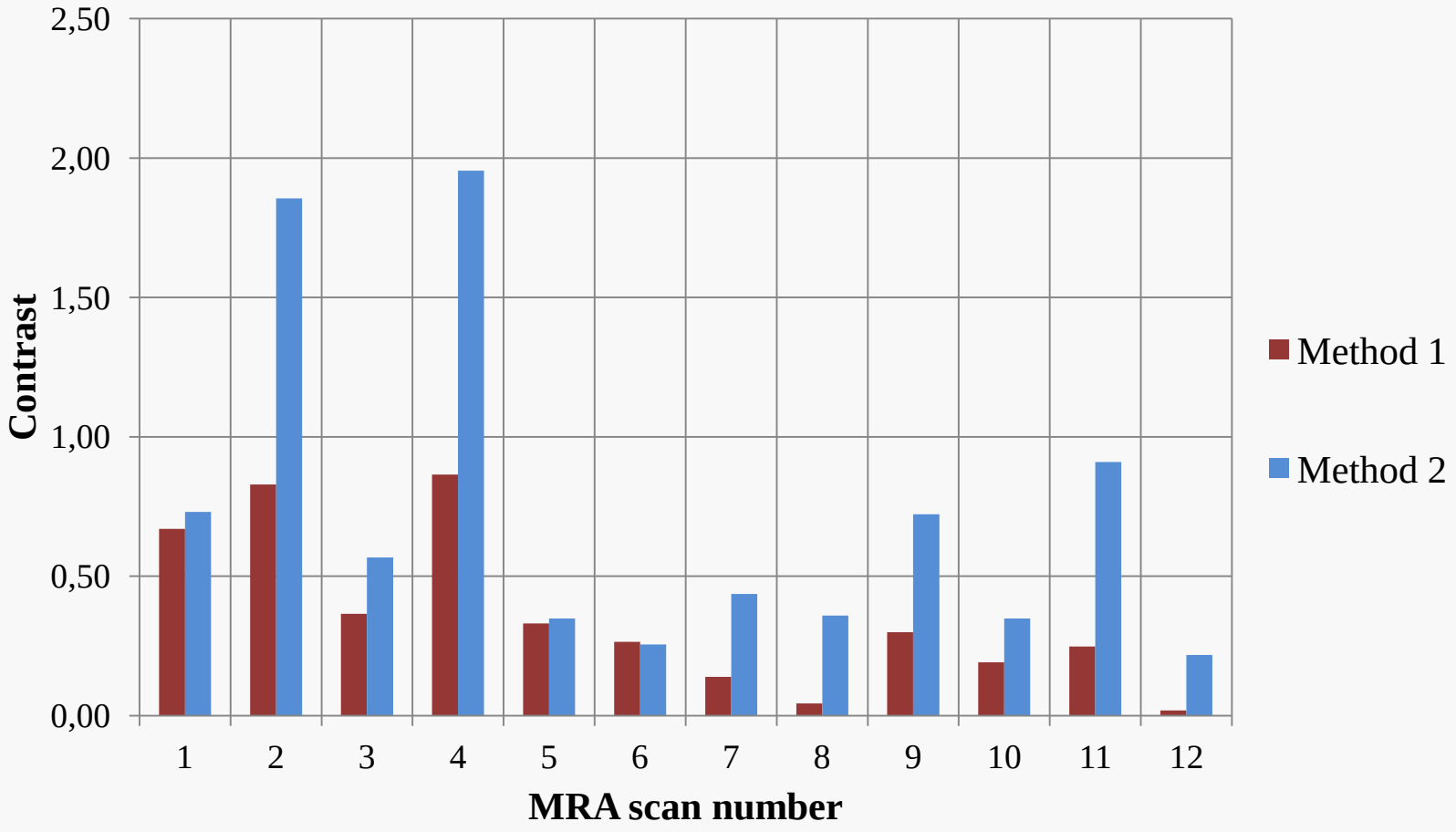
Materials and methods

- TRANCE (TSE sequence) scan parameters:
  - FOV: 420 mm x 352 mm x 120 mm
  - Voxel size: 1,7 mm x 1,7 mm x 2 mm
  - TR: 800 ms (if heart rate is 75 BPM)
  - TE: 114 ms
  - Slice thickness: 2 mm
  - Number of slices: 60
  - Slice orientation: coronal plane
  - TSE factor: 34
  - Flip angle: 90°
  - Arrhythmia rejections: yes
  - NSA=1



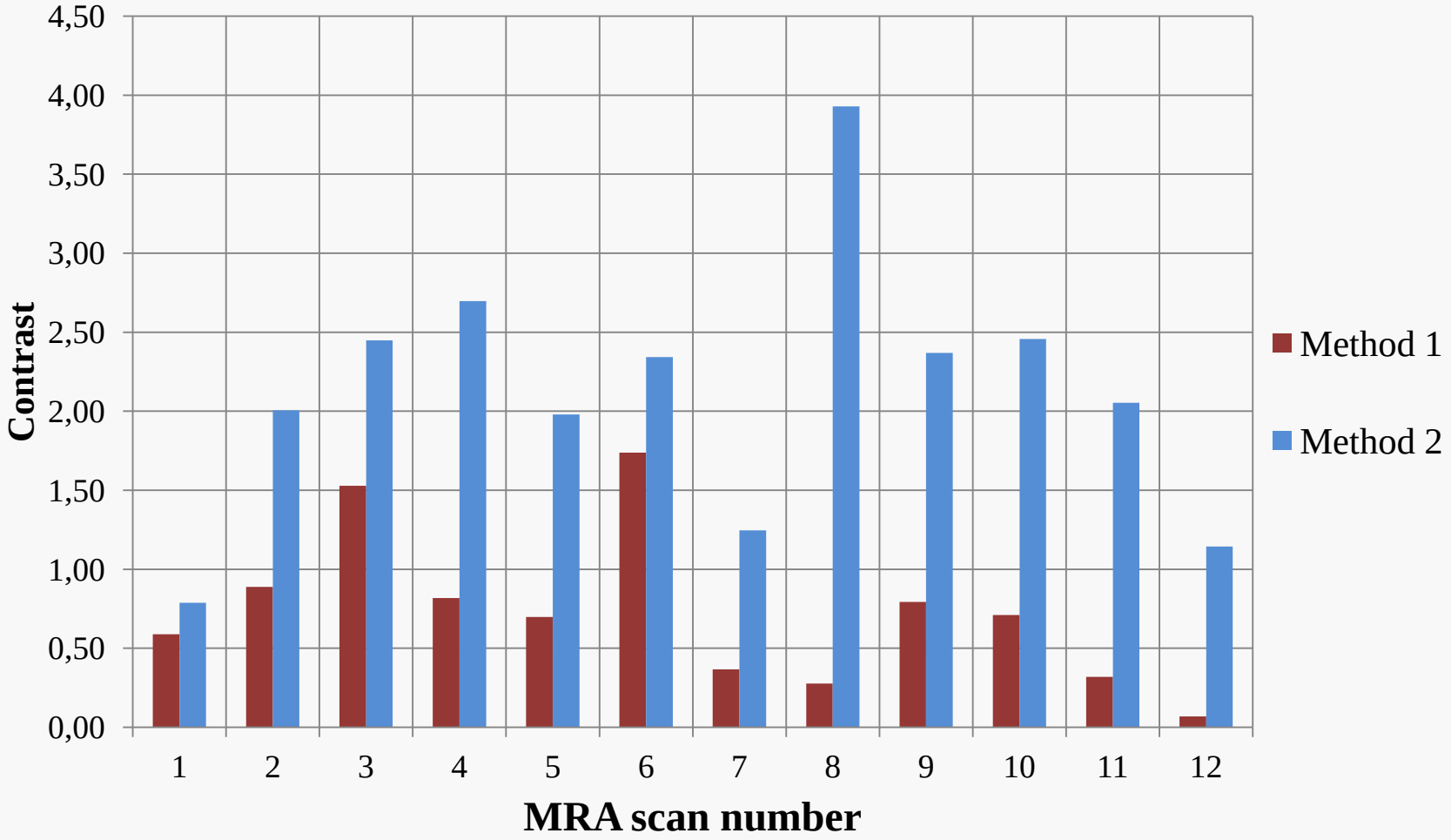
Measurements of transaxial reconstruction images. Part A is image that is generated using trigger delay technique that is in clinical use. Part B image is generated using method that is tested in this research. The measurement of the background tissue is depicted as upper ROI circles and arterial measurements are depicted as lower ROI circles.

Control study group results (first group)



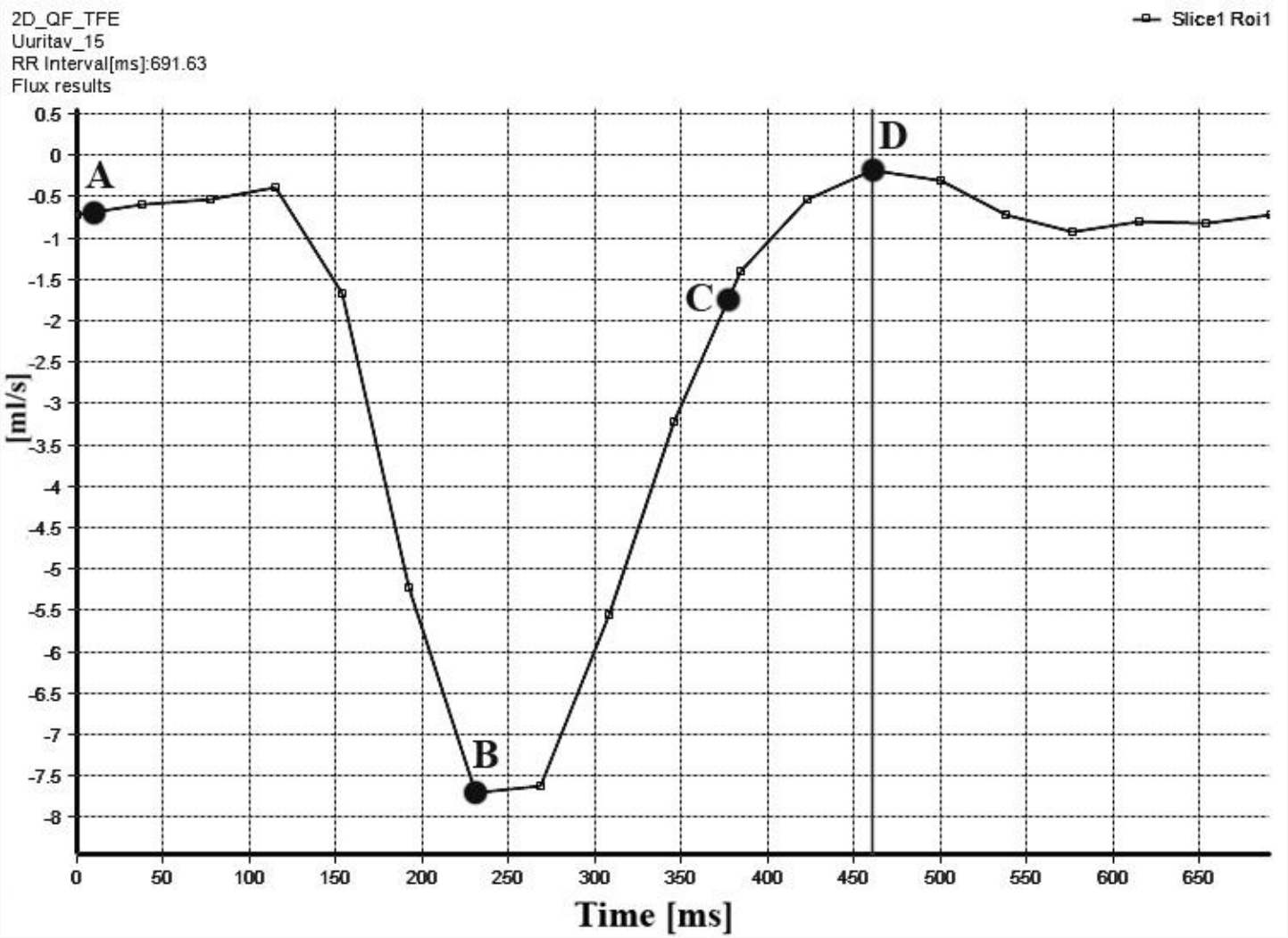
Contrast between arteries and background tissue measured from subtraction images. Method 1 is method that is currently in clinical use and method 2 is the test method for this research.

Control study group results (first group)



The contrast of artery measured from the heart systolic and diastolic phase images. Method 1 is method that is currently in clinical use and method 2 is the test method for this research.

Scan timepoints for second group volunteer in systolic and diastolic phase



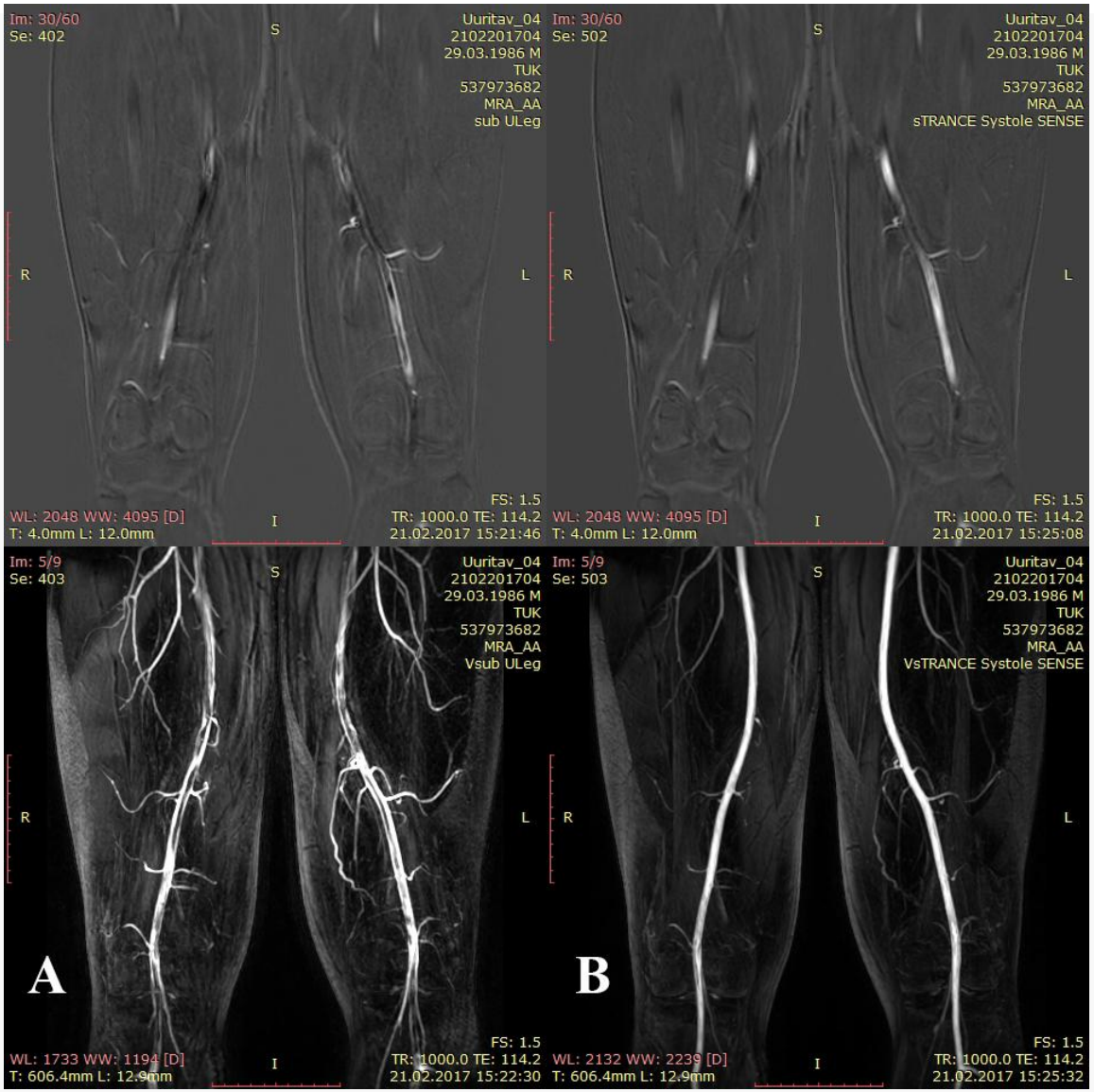
Arterial blood flow velocity graph as an example for one heart cycle of the second group volunteer (heart rate 90 BPM)

Results and discussion

- Research findings suggest that images which were generated using modified trigger delay technique had higher arterial contrast than currently used trigger delay technique.
- In comparison of arterial contrast from the subtracted background tissue measured from transaxial reconstructions of the subtracted images, then the mean arterial contrast in currently (in clinical use) used method was 0.36 (Method 1) and in new modified method it was 0.73 (Method 2)
- When comparing the arterial contrast between systolic and diastolic heart phase images measured from transaxial reconstructions of anatomical images, the average arterial contrast (compared to systolic phase images) in currently (in clinical use) used method was 0.73 (Method 1) and in new modified method it was 2.12 (Method 2)

Results and discussion

- The second test group volunteers (heart rate 80 BPM or higher) underwent also both scans using two different trigger delay values. Authors fixed error message (cardiac cycle too short) values and possible delay values that did not give error message.
- At 90 beats per minute for pulse rate, the maximum possible trigger delay value was 85 ms lower than the value what manufacturer's recommended.



One randomly chosen volunteer subtracion images and MIP images of peripheral arteries. The upper part of the images depicts subtraction images and in the lower part there are MIP images. Left (A) is method, what is currently in use and right (B) is method which is tested in this research.

Conclusions

- Contrast-enhanced MRA scans are expensive, and they can only be performed on patients whose renal function is normal
- Research findings suggest that images which were generated using modified trigger delay technique had higher contrast of arteries (compared to subtracted background) than currently used trigger delay technique
- The result for second test group was that existing trigger delay technique was not usable for patients with high heart rate, because of technical limitations of MRI pulse-sequences.
- This study showed that selecting the diastolic trigger delay value from the beginning of the pulse-sequence (modified method) is a solution for performing ECG-synchronized non-contrast enhanced 3D TSE technique on patients with elevated heart rate.
- The tested method showed less artifacts in large blood vessels, collateral vessels had better image quality using existing method.
- The positive results of this research provides the basis for the implementation of this method in clinical work.
- This study will provide the basis for further researches to explain the peculiarities of collateral and large blood vessels visualization.