Correlation of Peri-Procedural Cardiac Enzyme Release with Atherosclerotic Plaque Burden using 3-D Fusion of Intravascular Ultrasound and Angiography

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Introduction

- Coronary atherosclerosis, a leading cause of death, is often treated with percutaneous coronary intervention (PCI) of stenotic vessels.
- Controversy exists regarding the mechanism of cardiac enzyme release during PCI, and its prognostic significance:
  - MB isoenzyme of Creatine Kinase (MB-CK)
  - Troponin I or T (TP)
- 3-D Fusion of x-ray coronary angiography and intravascular ultrasound (IVUS) data allows a geometrically correct representation of in-vivo coronary geometry.
- Morphologic 3-D parameters can be correlated with enzyme release to support or disprove the hypothesis of a correlation.

Patients

- 19 coronary vessel segments in 16 patients (6 LAD, 5 LCX, 8 RCA).
- Study was approved by both Institutional Review Boards, and all patients provided informed consent.
- Imaged in-vivo with single-plane angiography and IVUS pre and/or post intervention.
- Total CK, MB-CK, TP levels were recorded.

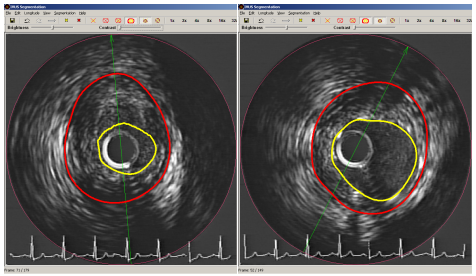

Figure 1. Segmented IVUS images of the same vessel location pre (left) and post (right) angioplasty and stenting; arrow indicates same orientation.

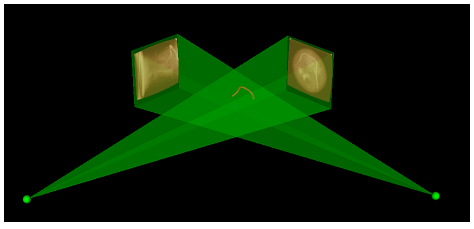

Figure 2. Principle of 3-D fusion: From the know imaging geometry, the IVUS catheter path is reconstructed and the frames mapped into 3-D.

Morphologic Parameter	n	CK-MB R	CK-MB slope	TP R	TP slope
Plaque volume	19	$\Downarrow 0.227, p < 0.4$		$\Downarrow 0.226, p < 0.4$	
%-area stenosis	19	$\Downarrow 0.483, p < 0.05^*$		$\Downarrow 0.022, p \approx 0.9$	
Vessel area	19	$\Downarrow 0.365, p < 0.15$		$\Downarrow 0.050, p \approx 0.8$	
Lumen area	19	$\Uparrow 0.097, p \approx 0.7$		$\Uparrow 0.013, p \approx 0.9$	
Lumen increase	14	$\Downarrow 0.479, p < 0.1$		$\Uparrow 0.195, p \approx 0.5$	

*(*statistically significant; ⇑ = positive, ⇓ = negative correlation)*

Table 1. Correlations and significance of slope over all vessel segments.

Morphologic Parameter	n	CK-MB R	CK-MB slope	TP R	TP slope
Plaque volume	11	$\Downarrow 0.490, p < 0.15$		$\Downarrow 0.422, p < 0.2$	
%-area stenosis	11	$\Downarrow 0.749, p < 0.01^*$		$\Downarrow 0.712, p < 0.02^*$	
Vessel area	11	$\Downarrow 0.431, p < 0.2$		$\Downarrow 0.320, p < 0.5$	
Lumen area	11	$\Uparrow 0.394, p < 0.3$		$\Uparrow 0.404, p < 0.3$	
Lumen increase	7	$\Downarrow 0.593, p < 0.2$		$\Downarrow 0.085, p \approx 0.9$	

(vessel segments with TP release $\geq$0.03 and $<2 ng/mL$ only)

Table 2. Correlations and significance of slope after exclusion of outliers.

3-D Fusion and Analysis

- The stented vessel segments and 5mm reference segments proximal and distal were identified and registered between pre and post interventional IVUS pullbacks (Figure 1).
- Lumen/plaque (yellow) and media/adventitia (red) borders semi-automatically segmented using multi-resolution graph search.
- 3-D Fusion involves segmentation of catheter path and lumen outline from two single-plane angiographic projections of known geometry (epipolar constraint, Figure 2).
- IVUS frames were aligned with the 3-D catheter path and their absolute orientations determined by differential geometry and calculation of the overall best match with the angiographic outline in 3-D space (Figure 3).
- 3-D contours were resampled perpendicularly to actual vessel centerline, several morphologic parameters were calculated (Tables 1 and 2).

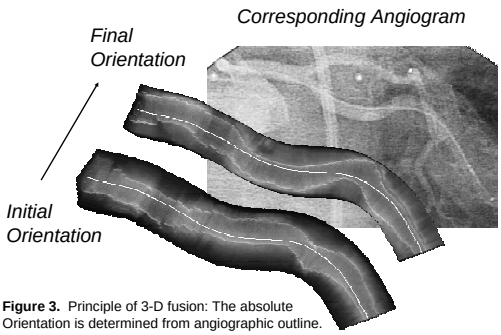

Figure 3. Principle of 3-D fusion: The absolute Orientation is determined from angiographic outline.

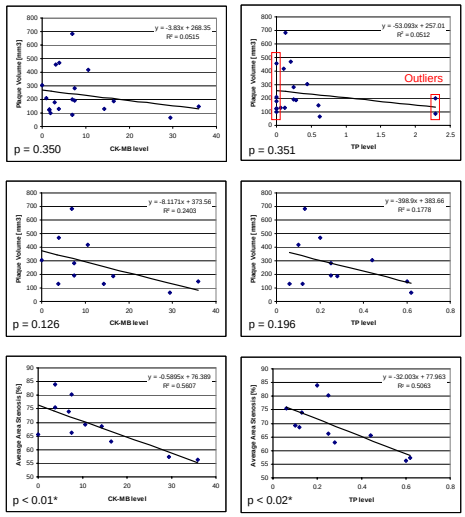

Figure 4. Detailed results for best statistically moderate to borderline correlations of measured morphologic parameters with enzyme release.

Results

- Rather than the expected positive correlation between plaque burden or vessel size with cardiac enzyme release, most correlations were negative and not significant (a p<0.05 slope was considered statistically significant).
- Exclusion of outliers (TP<0.03, TP>2*ng/mL*) improved correlations (Tables 1, 2; Figure 4).
- %-area stenosis and plaque volume showed statistically significant negative correlations with both MB-CK and TP releases.

Conclusions

- No statistically significant positive correlation has been found to indicate that cardiac enzyme release increases with plaque burden.
- The negative correlations are unexpected and contrary to the initial hypothesis, but consistent throughout the study, despite a limited number of patients available.
- Cardiac enzyme release during complex PCI may not be a marker of atherosclerotic burden.
- Our results support previous concepts relating enzyme release to procedure complexity and unstable plaque.

Contact

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