

# Evaluation of the Spatial Changes of the Coronary Morphology Due to Stent Implantation with Three-Dimensional Angiography

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## Abstract

*3-dimensional (3D) geometry of the coronary artery often changes due to stent implantation.*

*In our investigation we analyzed the effect of stent on the 3D geometry in each heart-cycle phase. At the site of implantation the degree of decrease in the coronary curve were measured, and the correlation between the original curve and the change of the curve were determined. The effect of 17 Coroflex Blue (B. Braun) stents implantation (3.07±0.33 mm in diameter and 17.64±4.42 mm in length) in 17 patients was analyzed. The curve of the segment was characterized by either the 2D images gained from the best optimal projection (BOP) or the 3D reconstruction, measuring the distance between the line superimposed onto the midline of the stented segment (arch) and the distance of the end-points of the stented segment (chord) before and after the intervention.*

*The difference in the ratio of arch/chord after and before the stenting showed significant correlation both at end-diastolic and end-systolic analysis with the start-off arch/chord ratio, but the diastolic correlation was slightly higher ( $r=0.93$ ,  $p=2 \times 10^{-8}$  and  $r=0.89$ ,  $p=6 \times 10^{-7}$ , respectively).*

*We have experienced more than 10% growth in change of the curve at higher than 1.15 start-off arch/chord ratio.*

*In the intervened coronary segment the change of the spatial morphology depending on the start-off curve even after flexible stent implantation.*

## 1. Introduction

Despite the well known patient -and procedural - related predictors, the certain appearance of the restenosis is almost unpredictable after percutaneous coronary interventions [1-5]. Stent implantation frequently results in significant three-dimensional (3D) changes in the

geometry of native coronary arteries during the cardiac cycle. The role of these dynamic geometrical changes of the stented coronary artery segment on the development of restenosis is poorly clarified. [6-8]. Alterations in the native vascular geometry may increase the risk of in-stent restenosis due to changes in vessel wall compliance and subsequent alterations in shear stress provoking mechanical longitudinal stretching of the smooth muscle cells and intimal cells, leading to a series of biochemical processes, such as the secretion of different growth factors, cytokines and mitogens, which are associated with the proliferative response to vascular injury [9-11]. Furthermore, the stent implantation may result in hinge motion or buckling at the ends of stents due to the abrupt changes in vessel wall rigidity [12-13].

These phenomena are also suspected to be a pathomechanical factor in the development of edge stenosis after DES implantation [14-15]. In the analysis of stent-vessel interactions 2D measurement of the pre- and post-stent vessel angulations has been previously used to characterize stent-induced changes [6, 16-17]. The traditional angiography technique is hampered on the inaccuracy of two-dimensional angiographic projections of 3D structures.

Determination of the vessel angulations is dependent on the selected angiographic projection. With the advent of 3D angiography it is possible to calculate the optimal angulations for a certain coronary segment which projection shows orthograde (without foreshortening) the investigated segment [17-18]. This projection appears the most appropriate for characterization of the stent-induced conformational changes and may obviate the need for more complicated mathematical algorithm (like the Frenet-Serret curvature analysis).

## 2. Methods

In our investigation we analyzed the effect of stent on the 3D geometry in each heart-cycle phase (Figure 1.). At the site of implantation the degree of decrease in the

coronary curve were measured, and the correlation between the original curve and the change of the curve were determined.



Figure 1. 3D reconstruction of the end-systolic and end-diastolic frame of the right coronary artery before (upper row) and after (lower row) the stent implantation

The effect of 17 Coroflex Blue (B. Braun) stents implantation ( $3.07 \pm 0.33$  mm in diameter and  $17.64 \pm 4.42$  mm in length) in 17 patients was analyzed. Male/female ratio was 82/18% (14/7) 11 right coronary arteries, 4 left anterior descending arteries and 2 circumflex arteries were stented. During angiography 3D reconstruction of the intervened coronary-segment was performed by IC3D software integrated into Axiom Artis (Siemens) roentgen device. The best optimal projection (BOP) was defined in order to minimize the foreshortening of the target segment. The curve of the segment was characterized by either the 2D images gained from the BOP or the 3D reconstruction installed into the BOP, measuring the distance between the line superimposed onto the midline of the stented segment (arch) and the distance of the end-points of the stented segment (chord) before an after the intervention. The bigger the curve of the stented segment was the bigger this arch/chord ratio became (Figure 2).

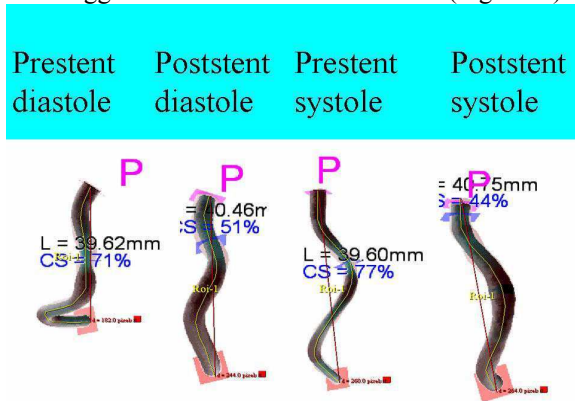


Figure 2.

### 3. Results

The difference in the ratio of arch/chord after and before the stenting showed significant correlation both at end-diastolic and end-systolic analysis with the start-off arch/chord ratio, but the diastolic correlation was slightly higher ( $r=0.93$ ,  $p=2 \times 10^{-8}$  and  $r=0.89$ ,  $p=6 \times 10^{-7}$ , respectively). We have experienced more than 10% growth in change of the curve at higher than 1.15 start-off arch/chord ratio (Figure 3).

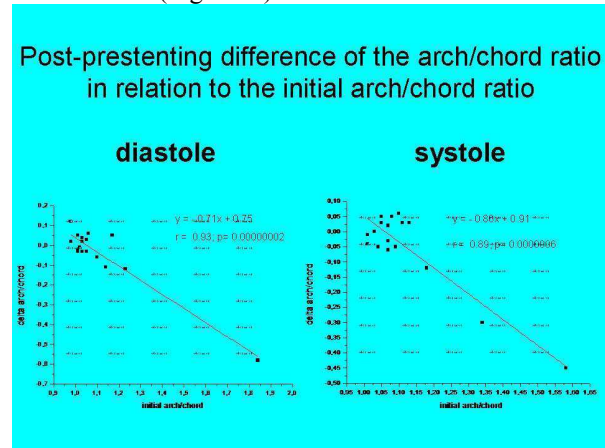


Figure 3.

### 4. Discussion and conclusions

In the intervened coronary segment the change of the spatial morphology depending on the start-off curve even after flexible stent implantation. The degree can be estimated with 3D measurements and can be taken into consideration when defining the appropriate stent parameters [19-20].

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