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QUALITY OF THE IMAGE REPRESENTATION OF STENT STRUCTURE, STENT ENHANCEMENT ALGORITHM, IN ASSESSING THE OPTIMAL PREVALENCE OF STENT IN LONG CHRONIC LESIONS

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ABSTRACT

During percutaneous coronary intervention, proper stent implantation is often challenging. Stent enhancement (SE) may be used to visualize implanted stents. SE is an angiographic technique that digitally enhances the visibility of stent metal struts, in order to better assess whether it has been adequately implanted. It is a faster and cheaper alternative to intravascular methods (IVUS, OCT), but it is still less detailed. We perform SE after stent implantation using balloon markers; and it can help us to verify some complications or abnormalities after stent implantation such as stent malposition (stent not pressed against vessel wall), insufficient stent expansion (the stent not being sufficiently expanded), stent deformation (mechanical change of stent shape), edge dissection at stent edge, or stent fracture (stent-structure break). Any of these complications significantly increase the risk of in-stent occlusion or stenosis.

Hypothesis: The change in electrical conditions of diascopy and image acquisition significantly affects the quality of the SE representation of the stent structure

Patients: The study was conducted at the Department of Invasive Cardiology, University Clinical Center of Sarajevo (KCUS), from January 1, 2022, to December 31, 2022. The study included patients of both sexes and different age structures. Hemodynamically stable patients were included in the study, who underwent stenting of chronic lesion on coronary vessels with stents longer than 18 mm of different diameter.

Methods: The procedures were performed in the cardiac catheterization laboratory using a TOSHIBA INFINIX fluoroscopic system. The stent is imaged natively, without contrast application, for 4 seconds to acquire a minimum of 34 images. After deflation, the stent balloon must not be moved until the native imaging is completed, as the reconstruction software performs image stacking by marking the balloon markers.

Results: In the control group of 287 participants, selected based on the study inclusion criteria, the image quality was evaluated. There were 196 (68.6%) males and 91 (31.4%) females. By applying the chi-squared test, a statistically significant difference was found in the gender distribution of participants, with males being more prevalent, $\chi^2 = 7.078$; $p = 0.008$. According to the subjective assessment of image quality with implanted stents, the evaluators rated the images on a scale from 1 to 5. The quality scores of two groups of images (Table 3) were compared: with (90 kV and 900 mA) and (150 kV and 600 mA), where a statistically significant difference was found in the image quality score of the two groups depending on the electrical potential ($p<0.05$).

Conclusion: The stent strut visualization using the SE algorithm can be useful in assessing proper stent implantation and determining the potential need for post-dilatation. The use of the SE algorithm is limited due to artifacts caused by pacemaker electrodes or patient obesity, as well as cardiac motion artifacts that prevent SE reconstruction in certain positions. According to the study results, stent strut visualization is of better quality at higher mA values and lower kv values.

1. INTRODUCTION

During conventional angiography, implanted stents may be difficult to identify. To improve the visualization of metallic struts, algorithms for stent structure enhancement, known as stent enhancement (SE), have been developed.

SE is performed after stent implantation using balloon markers; this quick and inexpensive angiographic maneuver can often reveal complications or abnormalities that might otherwise remain undetected on standard angiographic images.

1.2.Definition and prevalence of the problem

Any complication following stent implantation significantly increases the risk of in-stent occlusion or stenosis.

IVUS (intravascular ultrasound) and OCT (optical coherence tomography) are considered the gold standard for detailed analysis of complications; however, the cost and limited availability of these procedures pose constraints to their routine use.

The SE algorithm for stent strut visualization represents a quick and inexpensive method for assessing whether a stent has been properly implanted.

However, the SE algorithm has certain limitations, primarily related to image quality and artifacts.

2. HYPOTHESIS

The change in electrical conditions of diascopy and image acquisition significantly affects the quality of the SE representation of the stent structure

3. OBJECTIVES OF THE WORK

- Display the operating methods of the SE algorithm
- To compare the image quality of SE reconstruction with the change in the image acquisition parameters
- Show which factors affect image quality

4. PATIENTS AND WORKING METHODS

4.1. Patients

The study was conducted at the Department of Invasive Cardiology, University Clinical Center of Sarajevo (KCUS), from January 1, 2022, to December 31, 2022.

4.1.1. Inclusion criterion

The study included patients of both sexes and different age structures. Hemodynamically stable patients were included in the study, which underwent stenting of chronic lesion on coronary vessels with stents longer than 18 mm of different diameter.

4.1.2. Exclusion criterion

The study did not include hemodynamically unstable patients, minors, unconscious patients, patients with acute myocardial infarction, or those in whom the implanted stent was shorter than 18 mm.

4.2. Methods of operation

The procedures were performed in the cardiac catheterization room using a TOSHIBA INFINIX fluoroscopic system.

The stent is imaged natively, without contrast application, for 4 seconds to acquire a minimum of 34 images.

After deflation, the stent balloon must not be moved until the native imaging is completed, as the reconstruction software performs image stacking by marking the balloon markers.

The Toshiba Infinix system allows manual adjustment of all fluoroscopy parameters (kV, mA, matrix, pulse width, frame rate), which are automatically restored to system-defined default values after the procedure. It is precisely this technical capability that enabled this type of research and the testing of our hypothesis—namely, whether stent structures in the SE algorithm are better visualized through adjustments of fluoroscopy parameters.

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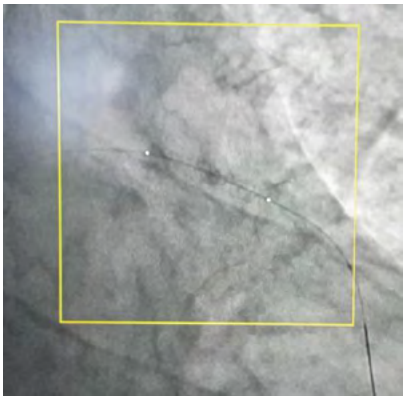

Figure 1. Positioning the SE reconstruction field and aligning the markers with the balloon markers

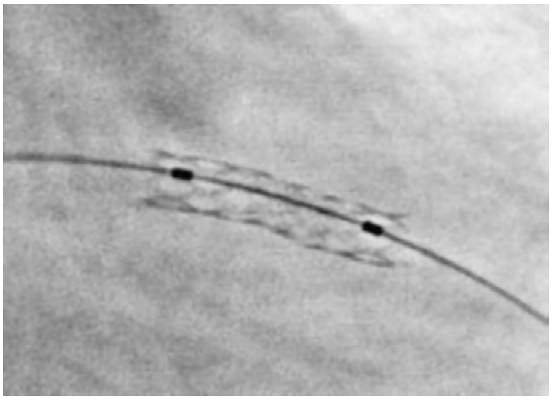

Figure 2. Display of stent structure after reconstruction.

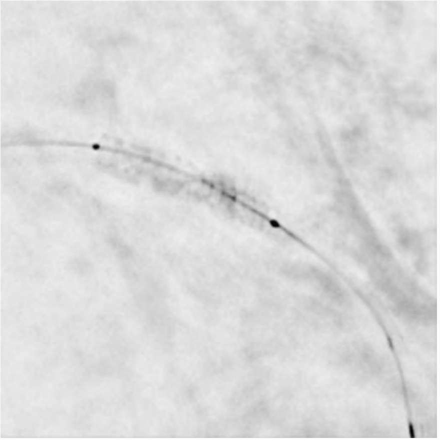

Figure 3a.

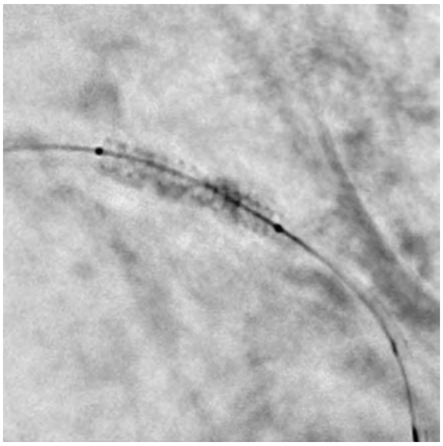

Figure 3b.

Figure 3a and 3b. Visualization of the same stent structure with increased kv (Figure 3a) and with decreased kv and increased mA (Figure 3b)

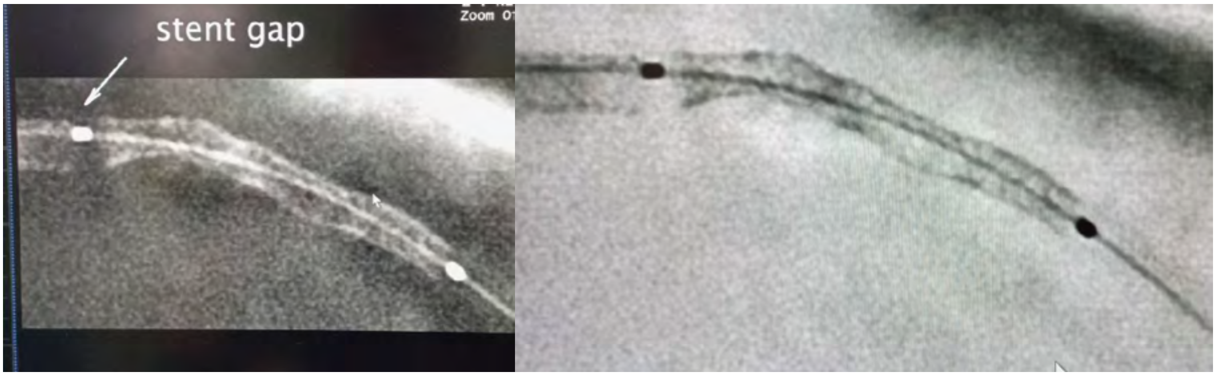

Figure 4.

Visualization of the stent structure using the SE algorithm can also be performed by utilizing balloon markers on previously implanted stents. The images show a gap between two stents where re-occlusion occurred after six months (Figure 4).

The diagnostic acceptability of the images was evaluated by three examiners using a rating scale from 1 to 5:

- 1 - non-diagnostic (means that the obtained structures cannot be analyzed),
- 2 - indistinct anatomical details with deteriorating image quality,
- 3 - clearly increased image blurriness, which is not yet reflected in the diagnostic quality of the image,
- 4 - clearly visible anatomical details with medium image blur,
- 5- clear outlining of fine structures with well-defined anatomical details and sharply outlined stent structures

The presence of artifacts was also rated from 1 to 5:

- 1 - unacceptable,
- 2 - average artifact reduction,
- 3 - average and acceptable,
- 4 - less than average,
- 5 - minimum or nothing).

5. RESULTS

In the control group of 287 participants, selected based on the study inclusion criteria, the image quality was evaluated. There were 196 (68.6%) males and 91 (31.4%) females. By applying the chi-squared test, a statistically significant difference was found in the gender distribution of participants, with males being more prevalent, $\chi^2 = 7.078$; $p = 0.008$.

		Frequency	Percent	Valid Percent	Cumulative Percent
Gender	Male	196	68.6	68.6	100.0
	Female	91	31.4	31.4	31.4
	Total	287	100.0	100.0	
χ^2=7.078; p=0.008					

Table 1.

The average age of the respondents included in this study was 50.45±5.38 years. The ANOVA test found a statistically significant difference in the age of respondents in relation to gender, F=9,919; p=0.003. The average age of male respondents was 60.68±6.23 years, and of female respondents 56.97±4.28 years, as shown in Table 2.

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	N	X	SD	SEM	95% CI		Minimum	Maximum
					Lower	Upper		
Male	196	50.68	6.23	1.55	25.50	77.01	66.00	77.00
Female	91	65.97	4.28	0.72	17.36	87.44	55.00	87.00
Total	287	52.45	5.38	0.75	68.93	71.96	55.00	87.00
F=9.919; p=0.003								

Table 2.

According to the subjective assessment of image quality with implanted stents, the evaluators rated the images on a scale from 1 to 5. The quality scores of two groups of images (Table 3) were compared: with (90 kV and 900 mA) and (150 kV and 600 mA), where a statistically significant difference was found in the image quality score of the two groups depending on the electrical potential ($p<0.05$).

		N	X	SD	SEM	Minimum	Maximum
150 kV 600 mA	Evaluator 1	26	1.96	1.14	0.22	1.00	3.00
	Evaluator 2	25	1.12	1.01	0.20	1.00	1.00
	Evaluator 3	51	2.03	1.07	0.15	1.00	3.00
							F=1.272; p=0.704
90 kV 900 mA	Evaluator 1	26	3.50	4.10	0.21	2.00	5.00
	Evaluator 2	25	3.68	4.18	0.23	2.50	4.00
	Evaluator 3	51	3.58	2.53	0.15	3.50	5.00
							F=0.316; p<0.5

Table 3.

Table 4 presents the evaluation of image quality for implanted stents. The image quality ratings of two groups with different pulse widths were compared, and no statistically significant difference was found between the two groups depending on the pulse width ($p=0.767$).

		N	X	SD	SEM	Minimum	Maximum
140 kV 700 mA Puls width: 15 mm	Evaluator 1	26	1.96	1.14	0.22	1.00	3.00
	Evaluator 2	25	1.12	1.01	0.20	1.00	1.00
	Evaluator 3	51	2.03	1.07	0.15	1.00	3.00
							F=1.272; p=0.704
140 kV 700 mA Puls width: 8 mm	Evaluator 1	26	3.50	4.10	0.21	2.00	5.00
	Evaluator 2	25	3.68	4.18	0.23	2.50	4.00
	Evaluator 3	51	3.58	2.53	0.15	3.50	5.00
							F=0.316; p=0.676

Table 4.

A statistically significant correlation was found between the scanning parameters kV and mA and the diagnostic acceptability of the image (**p < 0.051).**

	N	X	SD	SEM	95% CI		Minimum	Maximum
					Lower	Upper		
Evaluator 1	32	3.81	0.69	0.12	4.05	3.56	3.00	5.00
Evaluator 2	5	3.80	0.44	0.20	4.35	3.24	3.00	4.00
Evaluator 3	14	4.14	0.53	0.14	4.45	3.83	3.00	5.00
								F=1.387; p<0.051

Table 5.

6. DISCUSSION

SE was originally developed as a tool for detecting improper stent expansion; however, according to current literature, it also shows certain usefulness in situations such as stent malposition (stent is not pressed against the vessel wall), stent deformation (mechanical alteration of the stent shape), edge dissection at the stent margin, or stent fracture (disruption of the stent structure). The main limitation of SE compared to IVUS and OCT is that it visualizes only the stent structures, not providing any information about the vessel wall and plaque. In addition, even if we focus on stent evaluation, intravascular imaging technology provides serial axial images of the implanted device, therefore not missing any eccentric defects; on the contrary, stent enhancement generally shows longitudinal stent reconstruction, which

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could miss insufficient expansion depending on the acquisition plane. It is evident that SE cannot reliably depict in-stent thrombosis, neoatherosclerosis, or intimal hyperplasia, as well as microdissections or the no-reflow phenomenon—all of which are important determinants of immediate and long-term PCI outcomes. Moreover, the spatial resolution of intravascular imaging (particularly OCT) is much higher than what can be achieved with X-ray–based techniques. Finally, although the role of IVUS and OCT is clearly established by current literature and guidelines, the use of SE is supported only by small case studies and series.

On the other hand, the fact is that IVUS and OCT are mostly underused in most countries. Several explanations can be proposed, including the cost (which is not reimbursed in many countries), additional procedure time, difficulties in image interpretation (particularly with IVUS), the need for contrast (in the case of OCT), and the high frequency of findings with uncertain clinical significance. Another factor that potentially influences the use of intravascular imaging is the operator's confidence in the immediate and long-term outcomes of newer-generation stents. (1)

The stent enhancement algorithm was primarily used to visualize insufficient stent expansion. Allows easy visualization of the area of insufficient stent placement for balloon positioning after dilatation. SE has been reported to be associated with better angiographic and clinical outcomes, as well as stent fracture identification. SE adds a little extra time to the procedure, provides better image resolution compared to angiography without the risk of mechanical complications, and uses less contrast. It has been found to be particularly useful for obese patients, long lesions, in-stent restenosis, and bifurcation lesions. Although the accuracy and resolution of SE are lower than those of intravascular imaging, stent diameter measurements showed good correlation. Its main drawback could be an increased radiation dose, however this does not have a significant impact on the patient. SE remains a useful and fast tool that can be used in conjunction with intravascular imaging during PCI. (2)

Case reports and case series confirmed the use of StentBoost Subtract System® (Philips Healthcare, Best, Netherlands) and StentViz® (GE Healthcare, Milwaukee, WI, USA) in various clinical scenarios. Achenbach et al. published a case report related to the use of the ClearStent Live system, assessing stent deformation during bifurcation stenting. Several studies have investigated ESV systems in different settings. Fysal et al evaluated the use of StentBoost in 8 patients with a dedicated bifurcation stent (Tryton™, Tryton Medical, Durham, NC, USA). The visibility of the stent ring was considered "optimal" in seven patients. In two cases, incomplete stent apposition at the carina was observed. StentBoost has helped identify issues to achieve full adhesion with post dilation. In a retrospective study, Blicq et al confirmed the usefulness of StentBoost in detecting underdeployed stents in 168 consecutive PCI procedures. Silva et al. in a prospective study evaluated 97 patients who underwent bifurcation PCI using the StentBoost system. In 79.6% of cases, they achieved optimal visualization of stent struts and the guidewire, while poor visualization of stent struts or the guidewire was observed in only 1% of cases. A recent retrospective observational analysis conducted by Oh et al included 870 patients who underwent PCI with DES, with or without the use of StentBoost. After six months, the StentBoost group showed significantly lower rates of late stent loss and binary restenosis. After 12 months, the StentBoost group had a significantly lower incidence of target lesion revascularization (TLR) and TLR-related adverse cardiac events compared to the non-StentBoost group. (3)

7. CONCLUSION

- The SE algorithm for stent structure visualization can be useful in assessing certain complications and abnormalities following stent implantation.
- The use of the SE algorithm is limited due to artifacts caused by pacemaker electrodes or patient obesity, as well as cardiac motion artifacts that prevent SE reconstruction in certain positions.
- According to the study results, stent structure visualization is of better quality at higher mA values and lower kv values
- For detailed analysis, IVUS (ultrasound) or OCT (optical coherence tomography) are used because SE is less detailed.

8. LITERATURE

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