■ SHORT COMMUNICATION

Short-term stent strut coverage: optical coherence tomography versus high-definition intravascular ultrasound

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INTRODUCTION

Early healing response following stent implantation plays an essential role in preventing stent thrombosis [1]. Jinnouchi et al. [2] have evaluated the cut-off value of the strut neointimal thickness measured by optical coherence tomography (OCT) using histology as a gold standard. They found that the neointimal thickness of ≥40 µm in OCT is the most sensitive cut-off for the identification of competent strut coverage defined as the presence of endothelial cells along with >2 layers of smooth muscle cells. Hence pathology studies have demonstrated that uncovered struts are the most powerful predictor of late and very late stent thrombosis, those findings are important in daily practice [3]. Therefore, the precise assessment of in vivo stent coverage might be considered a surrogate for a favourable healing response. Intravascular ultrasound (IVUS) guided percutaneous coronary intervention (PCI) has shown its value in reducing adverse events and cardiovascular death [4], but its low resolution remains the main limitation in the assessment of early strut coverage. Furthermore, the rates of IVUS-guided PCI in daily clinical practice remains low [5, 6]. Consequently, high-definition intravascular ultrasound (HD-IVUS) gained interest due to higher resolution and improved image quality. In contrast to OCT, HD-IVUS does not need the additional contrast flush for blood clearance and enables deeper tissue penetration.

Based on the study performed by Jinnouchi et al. [2], we investigated whether HD-IVUS is a viable alternative to OCT for the evaluation of early healing response following stent implantation.

METHODS

Study population

In this prospective, single-centre study, patients aged 18 years and older undergoing PCI for treatment of de novo coronary lesions with implantation of a bioresorbable polymer sirolimus-eluting stent (BP-SES, Alex PLUS, Balton, Warsaw, Poland) for any clinical indication were enrolled. Major exclusion criteria were renal failure (glomerular filtration rate less than 45 ml/min/1.73 m²), allergy to contrast media or any of the stent components, hemodynamic compromise at presentation, pregnancy as well as participation in other clinical trials. The study was approved by Bioethical Committee and conformed to the Declaration of Helsinki. All patients signed informed consent.

Stent system description

BP-SES is composed of a laser-cut cobalt-chromium alloy stent platform with open-cell geometry and a 71 µm struts with a fully biodegradable circumferential coating (copolymer of poly-L-lactic and glycolic acid) and the anti-proliferative drug sirolimus. Experimental studies showed a 95% release of the drug after 28 days and practically full polymer biodegradation after eight weeks following stent implantation [7].

Optical coherence tomography and high-definition intravascular ultrasound

We performed the analysis of in vivo strut coverage one month after the implantation of 3 BP-SES using HD-IVUS and OCT as a reference. The images were anatomically matched based on vessel branches, calcifications and stent

edges. We performed OCT using the iLumien OPTIS Medical system (Abbott Vascular, Santa Clara, CA, USA) and HD-IVUS using ACIST Kodama IVUS catheter device (ACIST Medical System, Eden Prairie, MN, USA). For the OCT image offline analysis of the treated segment, we used the Review Workstation (Abbott, Santa Clara, CA, USA) while HD-IVUS image analysis was performed using CAAS intravascular software (Pie Medical Imaging BV, Maastricht, The Netherlands).

The region of interest was selected between the proximal and distal edges of the stent. The analysis was performed every 1 mm. Malapposition was defined as a distance between the strut blooming and lumen counter more than 71 μm. Furthermore, we measured the number of visible struts, number of covered struts and neointimal thickness at each frame. Definition of the covered strut was explained previously [8]. The neointimal thickness of ≥ 40 μm measured by OCT was defined as a cut-off value for neointinal strut coverage [2]. The analysis was performed by one observer with at least 5 years of experience with OCT and IVUS images analysis.

Statistical analysis

The Shapiro-Wilk test was used to analyse the continuous data distribution. Continues variables were presented as medians with interquartile intervals (IQR). Categorical variables were summarized using percentages and counts. To compare the neointimal thickness measured by OCT and HD-IVUS the Wilcoxon test for paired samples was used. Spearman's correlation was applied to measure the correlation between OCT and HD-IVUS in the number of detected and covered struts. To measure the agreement on struts detection between OCT and IVUS methods we used the concordance correlation coefficient and presented with a 95% confidence interval (CI). The analysis was performed on a frame level. A P-value <0.05 was considered statistically significant. Receiver operating characteristics (ROC) curve was used to find the cut-off value for neointimal thickness measured by HD-IVUS and was presented with area under the curve and 95% CI. Statistica (Statistica v. 13, Tibco Software Inc. Palo Alto, USA) was used for statistical analysis.

RESULTS AND DISCUSSION

In this preliminary study, we analyzed 53 well anatomically-matched image frames from 3 stents that were implanted in 3 patients. Altogether, HD-IVUS detected 487 struts while OCT identified 508 struts. However, there was a poor agreement in the detection of stent struts between the two methods on frame-level analysis ($\rho_c = -0.23$; 95% CI, –0.46–0.04). Additionally, within identified struts, 130 were covered according to the HD-IVUS method and 190 were recognised as covered by OCT. Nevertheless, there was a positive correlation between the number of covered struts detected by OCT and HD-IVUS (r = 0.4; P <0.01). Furthermore, the neointimal thickness measured by HD-IVUS was significantly lower than the neointimal thickness measured by OCT (respectively:

0.01 mm [0.00–0.02] vs 0.07 mm [0.00–0.1]; P <0.001) (Figure 1). Following the study of Jinnouchi et al. [2], the influence of neointimal cut-off value set on 40 μm was investigated. Notwithstanding its histological significance, there was no correlation between covered struts detected by OCT with neointimal thickness ≥40 μm and covered struts detected by HD-IVUS (r = –0.11; P = 0.5). Additionally, we did not find the cut-off value of neointimal thickness measured by HD-IVUS, which would predict the neointimal thickness of 40 μm measured by OCT (AUC, 0.067; 95% CI, 0.475–0.749; P = 0.06).

The major finding of this study is that HD-IVUS is not as accurate for neointimal coverage assessment as OCT.

Prior studies that have noted the importance of HD-IVUS in the assessment of bioresorbable scaffolds, did not aim to investigate the early healing response [9, 10]. The aim of this study was to assess the early stent strut coverage which is a surrogate for stent thrombosis prevention. Previously, we assessed a one-month coverage of thin-strut Alex which showed a favourable healing profile [8]. To investigate the HD-IVUS accuracy in early stent coverage assessment, we analysed the same thin-strut Alex with OCT as a reference method. Okada et al. [9] highlighted the superior ability of HD-IVUS to visualise every stent strut as compared to IVUS. Notwithstanding its improved spatial resolution as compared to conventional IVUS, HD-IVUS still characterizes lower resolution as compared to OCT. It may indicate the reason for the lack of agreement in strut detection on a frame level. Furthermore, it also explains the lower value of neointimal thickness measured by HD-IVUS. However, it did not reveal why there was no significant difference in the total number of detected struts. Importantly, HD-IVUS did not detect the 40 μm thickness of neointima which was defined as a gatekeeper for a completed healing process.

Based on these preliminary results, HD-IVUS is not a reliable method for the measurement of neointimal thickness over stent struts and the assessment of early stent strut coverage. However, a large randomized clinical trial is needed to confirm the results of this study. Nevertheless, because HD-IVUS is used in everyday clinical practice, it might be of interest to investigate its value in the assessment of stent coverage using histology as a gold standard.
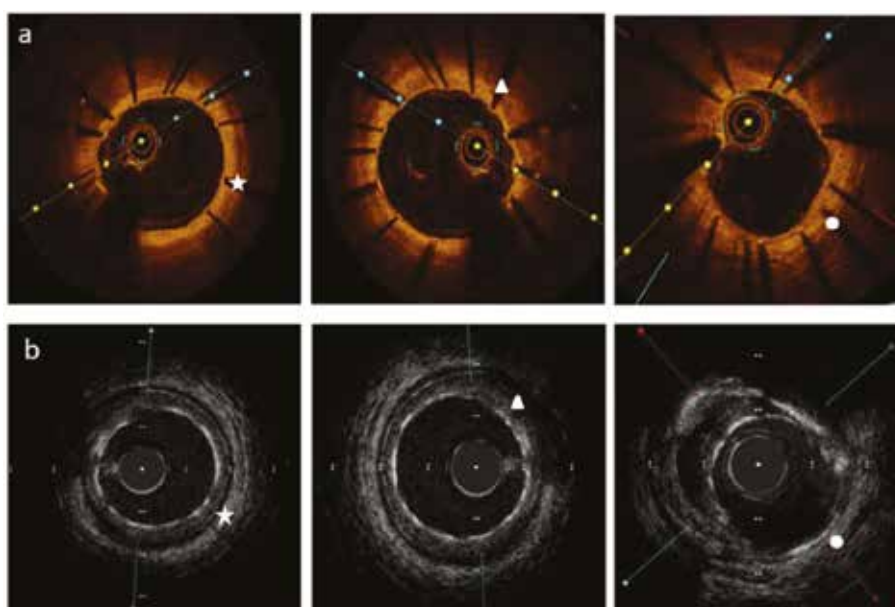
Limitations

There are several study limitations that have to be mentioned. First, the small number of analysed frames might bias the final results. Additionally, the study assessed only the bioresorbable scaffold and did not provide data for a control group.

Article information

Figure 1. Matched optical coherence tomography and high-definition intravascular ultrasound images of the stented vessel after 1-month follow-up. **A.** Optical coherence tomography images are displayed in the upper panel, and matched high-definition intravascular ultrasound images are displayed in the lower panel. There is a discrepancy in the number of visible stent struts between OCT and **B.** HD-IVUS overestimates the neointimal thickness lower than 40 μm (asterisks) and underestimates neointimal thickness greater than 40 μm (circles) measured by OCT. Additionally, HD-IVUS improperly misjudges the position of stent struts as compared to OCT (triangles).

Abbreviations: HD-IVUS, high-definition intravascular ultrasound; OCT, optical coherence tomography

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