

Ablation effect of additional low-speed rotational atherectomy following high-speed rotational atherectomy



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Abbreviations

CE	clinical engineer
HS-RA	high-speed rotational atherectomy
IVUS	intravascular ultrasound
LS-RA	low-speed rotational atherectomy
MLA	minimal lumen area
PCI	percutaneous coronary intervention

Introduction

Current expert opinion supports the use of low-speed rotational atherectomy (LS-RA) as an optimal technique¹ because slower burr speeds reduced platelet aggregation and heat injury associated with RA in previous *in vitro* experiments^{2,3}. However, a previous *in vivo* trial did not show benefits of LS-RA over high-speed RA (HS-RA) in terms of prevention of slow flow following RA⁴. In contrast, another effect of LS-RA may be that it ablates more plaque than does HS-RA because the burr axis vibrates to a greater extent while the burr rotates at slower speeds, like the precessional movement of

a spinning top. However, this additional ablation effect of LS-RA following HS-RA has not been completely elucidated. We hypothesised that LS-RA following HS-RA can achieve more acute gain by ablating more plaque than does HS-RA alone. To test this hypothesis, we conducted intravascular ultrasound (IVUS) analysis before and after LS-RA following HS-RA.

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Methods

Of the 66 patients who underwent RA between January 2015 and July 2016, we examined 26 patients with 27 *de novo* severely calcified lesions who underwent LS-RA following HS-RA. Demographic, angiographic, and procedural data were collected from a prospectively entered dedicated database. This study was approved by the research review board of Ogaki Municipal Hospital and conducted according to the Declaration of Helsinki.

RotaLink™ Plus (Boston Scientific, Marlborough, MA, USA) was used in all patients. As wires, RotaWire™ floppy or

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RotaWire™ Extra Support (Boston Scientific) were used. The burr was advanced with a gradual push-forward/pull-back motion over short individual runs (<30 s) while attempting to avoid extreme deceleration. The rotational speed was set at 200,000 rpm at platform in the HS-RA protocol and at 115,000 rpm at platform in the LS-RA protocol. RA in both protocols was continued until the rotational speed deceleration of <2,000 rpm was achieved. Only one burr was used for each lesion. The study protocol was as follows: (1) HS-RA; (2) IVUS (before LS-RA); (3) LS-RA; and (4) IVUS (after LS-RA). Selection of wires and percutaneous coronary intervention (PCI) strategies, except for RA, was at the discretion of the treating physician.

The objective of this study was to compare the minimal lumen area (MLA) between IVUS findings before and after LS-RA. To obtain the corresponding MLA images before and after LS-RA, distances from at least two landmarks, such as side branches and calcifications, were used as references. Two experienced clinical engineers (CE) blinded to the study object independently measured IVUS. Any discrepancies between the two CEs were resolved by consensus.

MLA before and after LS-RA was compared using a paired t-test. All statistical analyses were performed using JMP software version 13.1 (SAS Institute Inc., Cary, NC, USA). $p < 0.05$ was considered statistically significant.

Results

Baseline characteristics are summarised in **Supplementary Table 1**. Regarding PCI indication, most were cases of stable angina pectoris; however, there were four cases of non-ST-elevation acute coronary syndrome. The target lesions were the right coronary artery in 9, and the left anterior descending artery in 14 patients. Before RA, an IVUS catheter could be passed through the lesion in 15 cases, and predilatation was attempted in 9 lesions. All but 2 lesions were ablated using RotaWire floppy; the burr size was 1.5 mm in 11, 1.75 mm in 11, and 2 mm in 5 lesions. While performing LS-RA, a rotational speed deceleration of >3,000 rpm was obtained even after after HS-RA which ablated until a rotational speed deceleration of <2,000 rpm.

MLA after LS-RA was significantly larger than that before LS-RA ($2.76 \pm 1.03 \text{ mm}^2$ vs $3.29 \pm 0.95 \text{ mm}^2$; $p < .0001$; **Figure 1A**). The larger the burr-to-minimum lumen diameter (before LS-RA) ratio, the greater the change in the MLA before and after LS-RA (**Figure 1B**). A representative case is presented in **Figure 1C**. Slow flow occurred in 4 lesions after LS-RA, which recovered immediately after intracoronary nitroprusside injection. Final Thrombolysis in Myocardial Infarction flow grade 3 could not be attained in 3 lesions, in which slow flow developed before LS-RA. No major vessel perforation was observed.

Discussion

In this study, we demonstrated that a significantly larger acute gain was achieved with additional LS-RA following HS-RA. Although we did not demonstrate the relationship between adding LS-RA and optimal stent expansion compared with standard RA, the mean

additional ablation of 330 μm (calculated from MLA) may be helpful, considering that a previous study demonstrated the thresholds of calcium thickness of 450 μm as the predictor of calcium crack⁵. Because the burr-to-artery ratio is the significant determinant of slow flow⁴, performing additional LS-RA following HS-RA, rather than increasing the burr size, may be better to reduce complications and cost. The gyro effect may explain these results; the gyro effect is the principle that a burr rotating at a high-speed with a high moment of inertia proportional to the rotational speed produces less degree of change in the rotation axis direction⁶.

Limitations

This is a pilot study with a retrospective nature. Eventually, this hypothesis needs to be tested in a prospective trial with proper randomisation. The wire bias may have influenced the ablation effect of LS-RA, suggesting that this technique may not be applied to all lesions, for example, eccentric calcified lesions. The burr speed used in the HS-RA protocol was in excess of the expert consensus speed¹, which might compromise the MLA increase or lead to more complications than might occur in the recommended high-speed protocol. Furthermore, the optimal speed for LS-RA has not yet been elucidated. Finally, although HS-RA was continued until the rotational speed deceleration of <2000 rpm was achieved, the increase in MLA may simply have been gained by additional ablation rather than the effect of LS-RA. Furthermore, image analysis was not performed by a core laboratory.

Conclusions

Additional LS-RA following HS-RA ablated more plaque volume and achieved significantly larger MLA than HS-RA alone.

Impact on daily practice

Additional LS-RA following HS-RA could achieve more acute gain by ablating more plaque than HS-RA alone, and might contribute to decreased incidence of slow flow and medical costs compared to increasing the burr size.

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Conflict of interest statement

H. Ishii received lecture fees from Astellas Pharma Inc., Bayer Pharmaceutical Co., Ltd., Daiichi-Sankyo Pharma Inc., and MSD K. K. T. Murohara received lecture fees from Bayer Yakuhin, Ltd., Daiichi-Sankyo Co., Ltd., MSD K. K., Mitsubishi Tanabe Pharma Co., Nippon Boehringer Ingelheim Co., Ltd. The other authors have no conflicts of interest to declare.

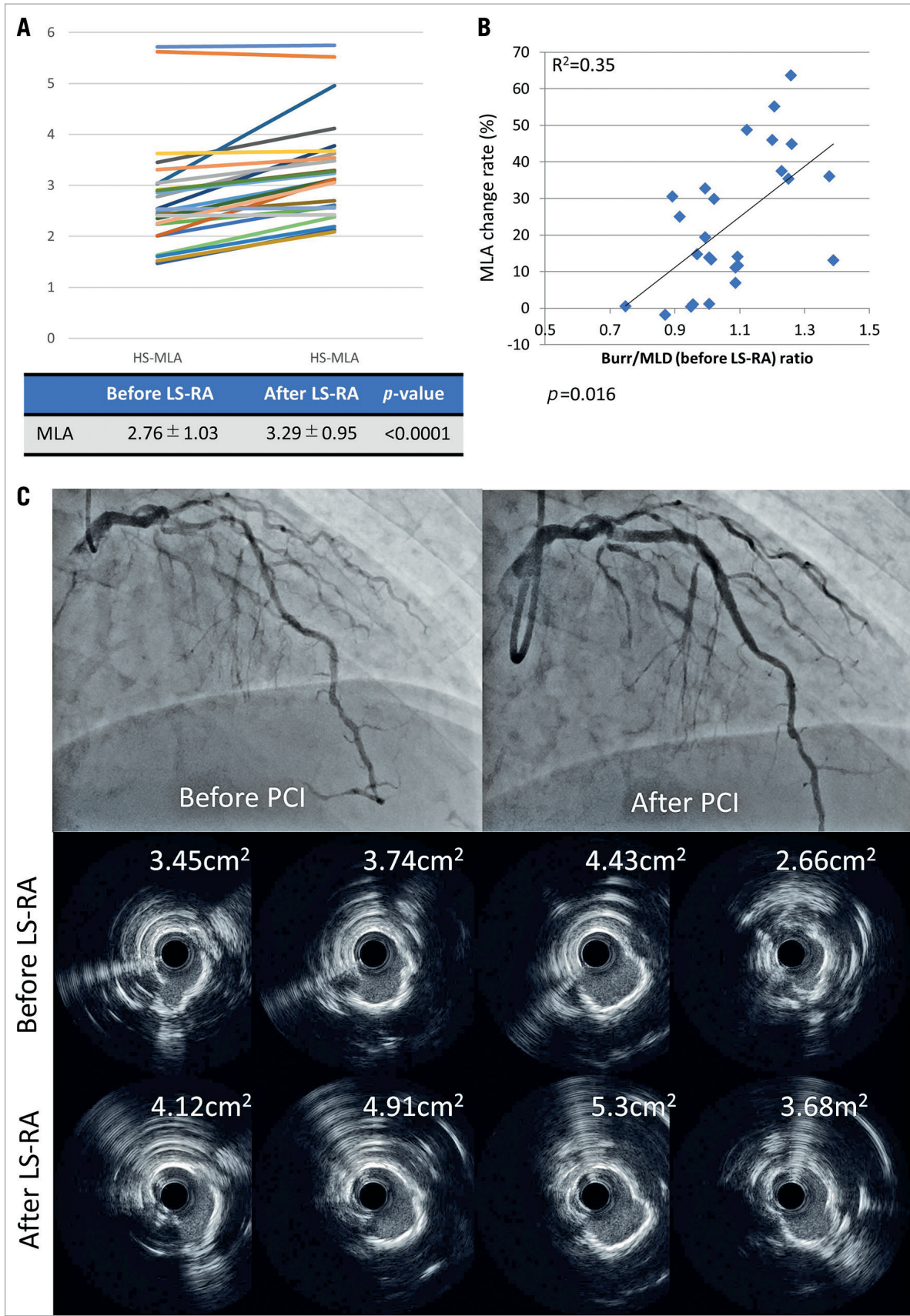


Figure 1. Changes in minimum lumen area. (A) The change in MLA before and after low-speed rotational atherectomy (LS-RA) in each patient. (B) The relationship between minimal lumen area (MLA) change and burr-to-minimal lumen diameter (MLD) ratio. (C) Representative case. At each point, larger lumen areas were obtained following additional LS-RA.

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Supplementary data

Supplementary Table 1. Patient's clinical and procedural characteristics.

The supplementary data are published online at:
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Supplementary data

Supplementary Table 1. Patient's clinical and procedural characteristics.

Clinical baseline characteristics		N=26
Age		74.6 (8.6)
Male sex		18 (69.2%)
Diabetes mellitus		16 (61.5%)
Hypertension		17 (65.4%)
Dyslipidaemia		18 (69.2%)
Haemodialysis		2 (7.7%)
Smoking history		18 (69.2%)
Prior PCI		20 (76.9%)
Prior CABG		2 (7.7%)
Lesion and procedural characteristics		N=27
Indication for PCI	Stable angina pectoris	23 (85.2%)
	Non-ST-elevation acute coronary syndrome	4 (14.8%)
Target vessels	Right coronary artery	9 (33.3%)
	Left main	1 (3.7%)
	Left anterior descending	14 (51.9%)
	Left circumflex	3 (11.1%)
Radial access		9 (33.3%)
Chronic total occlusion		3 (11.1%)
Procedure time (min)		100 [91, 126]
Contrast volume (ml)		100 [60, 135]
ROTAWIRE Floppy		25 (92.6%)
Burr size	1.5 mm	11 (40.7%)
	1.75 mm	11 (40.7%)
	2 mm	5 (18.5%)
Burr-to-artery ratio		0.56 [0.53, 0.68]
High-speed RA	Session number	5.5 [4, 8]
	Total ablation time (sec)	70 [50, 113]
	Maximum speed deceleration (rpm)	5500 [4750, 7000]
Low-speed RA	Session number	5 [4, 7]
	Total ablation time (sec)	85 [51, 111]
	Maximum speed deceleration (rpm)	5500 [3000, 7000]

Pre-intravascular ultrasound passed	15 (55.6%)
Pre-dilatation	9 (33.3%)
Small balloon un-passed before RA	2 (7.4%)
Drug-eluting stent	21 (77.8%)
Drug-coated balloon	6 (22.2%)
Stent number	2 [1, 2.5]
Stent length (mm)	51 [29, 76]
Success and complication	
Final TIMI 3	24 (88.9%)
Peri-procedure myocardial infarction	3 (11.1%)
Slow flow	5 (18.5%)
Wire perforation	1 (3.7%)
Peak CK-MB (IU)	14 [11, 25]

Values are the mean \pm standard deviation (SD), n (%), or median (interquartile range) as appropriate.

Peri-procedure myocardial infarction was defined as an increase in CK-MB above the normal upper limit.

CABG: coronary artery bypass graft; CK-MB: creatine kinase-myocardial band; PCI: percutaneous coronary intervention; RA: rotational atherectomy; TIMI: Thrombolysis in Myocardial Infarction