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Application of a Quantum Cascade Laser in the 5.7 μm Wavelength Range for Less-Invasive Laser Treatment of Atherosclerotic Plaque

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1. Introduction

Laser angioplasty is one of the catheter treatments of atherosclerosis that is suitable for difficult-to-treat lesions such as in-stent restenosis and total occlusions. In clinical practice, excimer laser coronary angioplasty has been applied. However, conventional XeCl excimer laser (wavelength: 308 nm) have the risk of injuring normal vessels [1]. Therefore, safer laser devices have been required.

Atherosclerotic plaques consist mainly of cholesteryl esters. Radiation with a wavelength of 5.75 μm is strongly absorbed by the C=O stretching vibration mode of choresteryl esters. Awazu *et al.* reported the possibility of selective treatment of atherosclerosis using a free electron laser with a wavelength of 5.75 μm [2]. For applying this technique, a compact laser is required. Quantum cascade lasers (QCLs) are recently developed semiconductor lasers that can emit in the mid-infrared range [3]. They are sufficiently compact and have recently realized high output powers [4]. In this study, the effects of QCL irradiation to atherosclerotic and normal aortas were investigated and the efficacy of a QCL in the 5.7 μm wavelength range for less-invasive laser angioplasty was evaluated.

2. Materials and Methods

An atherosclerotic thoracic aorta was resected from a female 24-month-old myocardial infarction-prone Watanabe heritable hyperlipidemic rabbit (WHHLMI rabbit, provided from Institute for Experimental Animals, Kobe University Graduate School of Medicine, Japan) and a normal thoracic aorta was resected from a female 2-week old Japanese white rabbit. They were cut into pieces of about 5 × 5 mm^2.

The pulse width and pulse repetition rate of the QCL in the 5.7 μm wavelength range (Hamamatsu Photonics, K.K., Japan) [5] were set to 500 ns and 1000 kHz, respectively. The output wavelength spectrum extended over 5.57-5.92 μm; the maximum intensity was observed at 5.74 μm. The average power density and the irradiation time were respectively varied in the ranges 120-180 W/cm^2 and 1-10 s. After irradiation, the samples were sliced to a thickness of 3 μm and stained with hematoxylin and eosin. This study was carried out according to Animal Experimentation of Osaka University.

3. Results and Discussion

Figure I illustrates the cross-sectional views of the QCL-irradiated atherosclerotic and normal aortas. At 180 W/cm^2, the ablation of atherosclerotic aorta was observed for 1 s and over, while that of the normal aorta was observed over 10 s. This shows that the selective ablation of the atherosclerotic aorta was achieved. However, the increase in ablation depth became moderate as the irradiation time was increased. It was considered that coagulation and carbonization of the sample surface made the laser absorption higher, and prevented laser from penetrating deeply. For more effective ablation of the lasers, reducing thermal effects by improving the irradiation conditions is required.

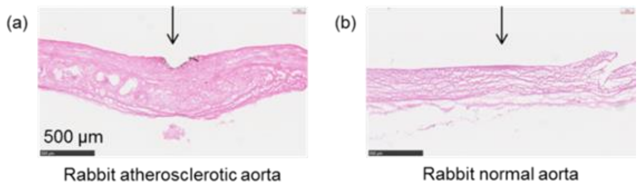

Figure I Cross-sectional views of QCL irradiated (a) atherosclerotic and (b) normal aortas at the average power density of 180 W/cm^2 and the irradiation time of 5 s.

4. Conclusion

The QCL in the 5.7 μm wavelength range achieved the selective ablation of the atherosclerotic lesions and it indicates the potential for the less-invasive laser angioplasty. For more effective ablation of the lesions, it is necessary to improve the pulse structure.

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