Cardiac rehabilitation (CR), consisting of patient education and conventional exercise therapy such as aerobic or resistance muscle training, has been demonstrated to improve exercise capacity, quality of life, and long-term prognosis in patients with acute myocardial infarction (AMI), which is the reason why the introduction of CR after AMI is strongly recommended by clinical practice guidelines. However, a nationwide survey of all cardiology training hospitals in Japan revealed that the implementation rate of out-patient CR is low (18%), whereas that of emergency percutaneous coronary intervention is very high (91%) in patients with AMI. A systematic review of the existing literature on the participation and adherence to CR following AMI revealed that patients with comorbidities, such as chronic obstructive pulmonary disease (COPD) or depression, had a low participation rate, even if they underwent successful coronary revascularization. Because the number of AMI patients with comorbidities will most likely increase in rapidly aging societies, in the near future, the implementation rate of CR may in fact decrease. In addition to the patients with comorbidities, it is unlikely that AMI patients suffering from cardiac instability, who are obliged to have bed rest, will perform conventional exercise training. For such patients, low-intensity resistance muscle training in bed is recommended by clinical practice guidelines. Nevertheless, even low-intensity resistance muscle training could be a burden for patients with cardiovascular instability.

Functional electrical stimulation or neuromuscular electrical stimulation (NMES) of muscles is expected to be an alternative mode of rehabilitation for AMI patients who are intolerant to conventional exercise training. The NMES of leg muscles is a modality that induces muscular contraction of the quadriceps and the gastrocnemius by the percutaneous stimulation of peripheral nerves through self-adhesive surface electrodes (Figure). NMES is a passive muscle training to maintain muscle mass and strength and prevent muscular atrophy. Additionally, long-term NMES therapy of lower limb muscles was recently reported to improve vascular endothelial function, exercise capacity, and quality of life, and relieve emotional stress in chronic heart failure (CHF) patients with preserved left ventricular ejection fraction (LVEF) as well as those with reduced LVEF. Could this NMES be a substitute for conventional exercise training? A meta-analysis of randomized, controlled trials in CHF patients comparing NMES with conventional exercise training showed that conventional cycle training produced superior improvements in exercise capacity to that of NMES. Also, compared with NMES therapy, conventional exercise training is more simple and practical in that no special apparatus is needed. Therefore, it is proper that conventional exercise training is recommended in all patients who can exercise by themselves. NMES therapy should be performed only as a bridge therapy to conventional exercise training in patients with comorbidities or unstable hemodynamic status. Therefore, the introduction of NMES is expected to raise the implementation rate of CR in patients who are intolerant of exercise training. However, the safety and efficacy of NMES therapy for such patients remain to be elucidated.

In a prospective, open-label, controlled clinical trial, Tanaka, et al first reported that a single session of NMES could be safely performed in patients with AMI without any excessive cardiovascular responses. Although the low-frequency component of blood pressure variability, an indicator of cardiac sympathetic nerve activity, was increased during NMES, heart rate did not significantly change and the elevation of systolic and diastolic blood pressure was within 10 mmHg. Neither arrhythmia, ischemic ST-T change, nor chest pain was induced by NMES. In this study, all patients received NMES after they received coronary revascularization, percutaneous coronary intervention, or coronary artery bypass. In addition, they were able to walk in the hospital ward without severe adverse events such as arrhythmia or angina. Patients with post-AMI angina, uncontrolled arrhythmia, acute pericarditis, or congestive heart failure of New York Heart Association function class IV were excluded in advance. The mean duration from the onset of AMI to a single session of NMES was 13 days. Since Tanaka, et al did not mention patient comorbidities, it is unclear how many patients among them otherwise could have received conventional exercise rehabilitation such as active cycling or other aerobic or resistance muscle training recommended by clinical practice guidelines. It is also unclear whether NMES can be safely performed both in patients with preserved LVEF and those with reduced LVEF.

Tanaka, et al only examined the immediate effect of a single session of NMES on microvascular endothelial function evaluated by use of reactive hyperemia peripheral arterial tonometry (RH-PAT). The immediate effect of exercise on...
macrovascular endothelial function evaluated by use of brachial flow-mediated dilatation (FMD) is quite controversial. Some studies reported an increase, whereas others reported a decrease or no change in FMD. There may be a biphasic response in FMD after exercise; a decrease in FMD occurs immediately after exercise cessation followed by a (supra) normalization response. In this way, the evaluation of vascular endothelial function by use of RH-PAT may also vary depending on the timing of the measurement after NMES. The time-course changes in effects of NMES on endothelial function should be evaluated using FMD and RH-PAT. More importantly, the effects of NMES performed continuously during hospitalization on exercise capacity, quality of life, and cardiovascular outcomes should be further examined.

We would like to determine whether NMES could be safely performed also in AMI patients with comorbidities such as COPD or unstable hemodynamic status who are unable to exercise, and which of low-intensity resistance muscle training or NMES is more desirable for such patients. Finally, the way to switch from NMES to conventional exercise training needs to be clarified, which will enable us to apply NMES as an appropriate bridge therapy to conventional exercise training for such patients.

Although many issues remain to be solved, the report by Tanaka, et al first showed the safety of NMES in AMI patients, providing us with an initial step towards further investigations on the various effects of NMES in patients suffering from AMI.

**References**


