CASE REPORT

Case Report: Rehabilitation of bilateral below-knee and partial-hand amputations in a developing country [version 1; peer review: awaiting peer review]

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Abstract
Limb ischemia is a complication of peripheral artery disease (PAD) which can lead to amputation. Amputation occurs in approximately 3-4% of PAD patients. In Indonesia, post-amputation patients are only hospitalized for the acute phase and the post-amputation rehabilitation programs must be done as an outpatient. This could be a barrier to the continuity of rehabilitation programs. A solution is the application of home-based rehabilitation programs. A 57-year-old female was referred from the Cardiothoracic Surgery Outpatient Clinic post-amputation with bilateral below-knees and partial-hands amputation after being diagnosed with PAD. On initial examination, all her elbows, wrists, thumbs, hips, and knees showed weakness. The patient received neuromuscular electrical stimulations (NMES) as well as a home-based rehabilitation program. On the second examination, after considering the data from the clinical finding and supporting examination, the patient received bilateral below-knee prostheses and bilateral functional partial-hand prostheses, created using 3D printing technology with polylactic acid material. After a few months, she was able to do most of her activities of daily living (ADLs) independently, work as a shopkeeper in her store, and feel more confident interacting with others. A comprehensive rehabilitation program, patient adherence to exercise, and caregiver support are critical to improving functional capacity and the quality of life in a patient with bilateral below-knee and bilateral partial-hand amputation caused by PAD.

Keywords
amputation, below-knee, partial-hand, peripheral arterial disease, prosthesis, 3D printing technology
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Introduction
Peripheral artery disease (PAD) is defined as arteriosclerotic occlusion disease of the extremities when one or more peripheral arteries become blocked, resulting in a decrease in blood flow to the peripheral area. In developed countries, the prevalence of PAD is comparable between men and women, and the incidence rises steadily with age, from 5% in the population aged 45-49 years to 18% in the population over the age of 85 years. However, in developing countries, women have a higher prevalence than men, with 6.3% and 2.9% at 45-49 years old and 12.3% and 10.1% at 75-79 years old, respectively. Between 2000 and 2010, the prevalence of PAD increased by about 200 million cases, with developing countries (29%) having a higher prevalence than developed countries (13%), and Southeast Asia and Western Pacific countries having the highest prevalence.

Intermittent claudication, caused by the insufficient blood supply to the legs, is the most common symptom experienced by PAD patients. Some patients with PAD, including those with moderate to severe cases, are frequently asymptomatic. A complication of this disease is limb ischemia, which can lead to amputation, which occurs in approximately 3–4% of PAD patients.

In Indonesia, post-amputation patients are only hospitalized for the acute phase, which lasts less than a month. They must visit the rehabilitation center on a regular basis to receive the post-amputation rehabilitation programs. A barrier to implementing the rehabilitation programs is that the distance between the center and the patient’s home is sometimes great, requiring a significant amount of time and money to travel to the hospital. The solution to this problem is to create a home-based rehabilitation programs.

Case presentation
In September 2019, a 57-year-old female Javanese was referred from the Cardiothoracic Surgery Outpatient Clinic post-bilateral below-knee and partial-hand amputations. In May 2019, she felt a tingling sensation on both of her soles, and a week later, she was numb and unable to walk. One week later, her second, third, and fifth tips of her toes had turned black, as had the left tip of her fifth finger. At that time, she also felt her right hand heavy and could not move it. In June 2019, she had ulcers on the tips of her toes. She was taken to the hospital by her family and diagnosed with PAD. The doctor amputated both of her lower legs and both of her second to fifth fingers. According to the July 2019 Doppler ultrasound examination, she still has non-significant stenosis on her right brachial artery and radial artery. She had also had hypertension for over ten years but did not routinely take the antihypertensive drug. Before she suffered from this condition, she had worked as a kindergarten teacher and participated in community activities. She hoped that she would be able to perform her activities of daily living (ADLs) independently and participate in social activities as before.

The muscle strength was measured using the manual muscle testing (MMT) method, and it was scored on a five-point scale. After examination, the muscles of her elbows, wrists, thumbs, hips, and knees were all weak, with the right wrist and thumb muscle strength remaining zero. Table 1 shows the detailed muscle strength examination results. Her right hand had a 20% sensory deficit. The condition of the partial-hands and below-knees stumps was quite good, except that there were still phantom sensations, and the pulse of the right radial artery was slightly weaker than the left side. For mobility, she still required the assistance of others with the wheelchair. The Barthel Index (BI) was 30 out 100, indicating that the patient was severely dependent. As part of the rehabilitation programs, the patient received NMES on her right wrist and thumb with intensity until visible muscle contraction, ROM exercise for upper and lower extremities, sensory re-sensitization of the right hand, and pre-prosthesis preparation, namely gentle tapping on the stump, stump shaping using elastic bandage with figure of eight method, upper and lower extremities muscle strengthening, transfer exercise from bed to the wheelchair and vice versa, standing exercise with the knee and the forearm as the support, ADLs exercise and modification. Because the patient’s home was far from the hospital, she underwent a home-based rehabilitation programs. She did the exercise for about 1-2 hours every day with the help of her family. The doctor would oversee the exercise via telephone and instant massage weekly. The weekly evaluation included adherence to exercise, complaints felt before and after exercise and evaluating the patient’s ability to carry out daily activities. The patient would visit the Physical Medicine and Rehabilitation (PMR) outpatient clinic monthly to check her condition and evaluate the rehabilitation programs. Figure 1 depicts the rehabilitation timeline.

In November 2019, she had a Doppler ultrasound re-examination, and there was no occlusion on the artery in both her legs and arms (Table 2). Her muscle power in her upper and lower extremities improved significantly (Table 1). The patient met the requirements of the prostheses after considering the data from the clinical finding and supporting examination. The patient was fitted with bilateral below-knee prostheses as well as bilateral functional partial-hand prostheses. The hand prostheses were created using 3D printing technology with polylactic acid material. She was the first patient in our center to receive 3D-printed hand prostheses. The patient continued the pre-prostheses rehabilitation programs, which included standing balance exercises (while the patient held a chair), and the NMES was discontinued because it was no
longer required since the MMT was satisfactory. She continued to do the home-based pre-prosthetics rehabilitation programs for about 1-2 hours per day.

Unfortunately, due to the COVID-19 pandemic, the prostheses programs were delayed, but the patient continued to participate in the pre-prostheses home rehabilitation programs. In July 2020, the patient received her prostheses and

Table 1. The manual muscle testing (MMT) of the patient.

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<td>Elbow</td>
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<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
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<td>5</td>
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<tr>
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<td>3</td>
<td>5</td>
<td>4</td>
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<tr>
<td>Hip</td>
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<td>4</td>
<td>5</td>
<td>5</td>
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<td>5</td>
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<tr>
<td>Knee</td>
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<td>4</td>
<td>5</td>
<td>5</td>
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Table 2. The Doppler ultrasound examination of the patient.

<table>
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<th>Doppler Ultrasound Examination</th>
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<th>July 2019 Left</th>
<th>Nov 2019 Right</th>
<th>Nov 2019 Left</th>
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<td>A. axillaris</td>
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<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
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<td>A. brachialis</td>
<td>Non-significant Stenosis</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>A. radialis</td>
<td>Non-significant Stenosis</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
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<tr>
<td>A. ulnaris</td>
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<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>A. iliaca externa</td>
<td>Normal</td>
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<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>A. femoralis</td>
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<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>A. poplitea</td>
<td>Normal</td>
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<td>Normal</td>
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</tbody>
</table>
began the prostheses rehabilitation programs. Standing balance exercises and gait training were added during this rehabilitation phase. To help with the gait training program, the patient’s family built a parallel bar in their home. She was able to do the gait training intensively for about two hours per day. In October 2020, the patient was able to walk with a walker and perform the majority of her ADLs independently, and her BI had improved (Figure 2). She could also work as a shopkeeper in her store and gained confidence in interacting with others.

**Discussions**

Although amputation of the lower limb would impair the patients’ functional mobility, not all patients require a prosthesis. Some of them may get better mobility from the use of a wheelchair or crutches. Giving a prosthesis to the patient was challenging because the post-prosthetic outcome had to be predicted based on pre-prosthetic ability. The screening tools developed by Mduzana et al. could be used to screen candidates for lower-limb prosthetics. It is made up of 29 variables that could affect prosthetic use. Based on this tool, the patient was a potentially good candidate for lower limb prosthesis in this case. The below-knee prosthesis consists of a prosthetic foot, shank, socket, and suspension. The prosthetic foot allows the amputee to stand and aids in the stance phase. The solid ankle cushioned heel (SACH) foot is the most commonly used foot prosthetic. The shank is a prosthesis component that is located above the foot. The patient was fitted with an endoskeletal shank. This shank type was chosen because it allows for minor adjustment after the prosthesis has been fabricated, and it is lighter than the exoskeletal shank, making it suitable for patients who require bilateral below-knee prostheses. To support the load in the patellar tendon, the traditional patellar tendon bearing (PTB) socket was used, and the suspension was a total contact suspension.

After receiving bilateral below-knee prostheses, the patient began gait training in accordance with the International Committee of the Red Cross (ICRC) recommendations. The first step was to begin gait training on the parallel bar, starting with partial weight-bearing and partial weight-shifting training. After the patient was able to do it, she began to perform the prosthetic-leg step forward, backward, and through. The last gait training was walking between parallel bars. Because she was unable to attend the rehabilitation center on a regular basis, her family assisted the rehabilitation programs by constructing the parallel bars in their home. The patient diligently completed the gait training program while being monitored by the doctor via phone. She was able to return to the rehabilitation center after three months, and according to the evaluation, she was able to train to walk with a walker. The walker was chosen because it would assist the patient in maintaining her balance while walking. The patient was unable to use the crutches due to her hand condition. Initially, the patient used four-footed walkers. The patient stated that moving the walker was still challenging because she has difficulty grasping and lifting the walker while ambulating. The walker was converted to two-wheeled walker to accommodate the patient’s needs. The patient was satisfied after the modification. She was able to walk faster while remaining safe. This was similar to previous research that compared the use of four-footed and two-wheeled walkers in people with lower-limb amputation. The researchers concluded that the two-wheeled walker allowed people wearing lower-limb prostheses to walk faster and with less interruption, but it was no less safe than the four-footed walker.

The bilateral functional partial-hand prostheses for this patient were created using 3D printing technology with polylactic acid material. She was the first patient in our center to receive 3D-printed hand prostheses. The scan of the extremity from various angles was required to create the computerized model for the 3D-printed prostheses. When compared to traditional prostheses, 3D-printed prostheses have advantages and disadvantages. The advantages of the 3D method are that it is less expensive because it requires less material and labor than the traditional one. Another advantage of this

**Figure 2. The patient’s Barthel Index improvement.**
method is that the device is highly customizable. Because the 3D files were saved digitally, they were simple to modify to meet the needs and comfort of the patient. The disadvantages of 3D-printed prostheses include decreased grip strength, durability, fine motor skill, and difficulty lifting heavy objects. This patient found the hand prostheses to be uncomfortable and found it difficult to use them on a daily basis. She broke the first-hand prosthetic models. To accommodate the patient’s needs, the prostheses were revised, using more sturdy models and the robotic hand 3D prostheses model. Unfortunately, she chose not to use the hand prostheses, but she could perform the majority of her ADLs independently. Overall, after the rehabilitation programs, the patient felt satisfied, and her confidence increased. Apart from being able to perform most of her ADLs independently, the patient began to feel confident in running her grocery shop at home as a cashier.

The home-based rehabilitation programs applied in this case study have advantages but also some limitations. The home programs could reduce contact between the doctor or physiotherapist (PT) and the patients, which was essential to address, especially during the COVID-19 pandemic. It also gave the patient flexibility to choose the exercise time, reduced physical barrier (because the patient home was far from the rehabilitation center), reduced transportation fee for car rental, and reduced the caregiver’s absence from work caused by accompanying the patient to the hospital. The limitations of the home-based rehabilitation programs are that the doctor and PT cannot supervise the exercise directly. In order to overcome this limitation, before the home programs started, the doctor would explain it to the patient and caregiver. Once a week, the doctor will evaluate the exercise by phone: the symptom that the patient felt before and after exercise, to ensure that the patient exercises regularly and rehabilitation program adjustments if needed.

Conclusions
A patient who has had PAD and amputation must undergo rehabilitation programs as soon as possible. The key to improving functional capacity and the quality of life in a patient with bilateral below-knee and bilateral partial-hand amputation caused by PAD is a comprehensive rehabilitation programs, patient adherence to exercise, and caregiver support. Prostheses and walking aids also played an essential role in assisting them in achieving their functional abilities.

Consent
Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient.

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Data availability
Underlying data
All data underlying the results are available as part of the article and no additional source data are required.

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