Novel lateral transfer assist robot decreases the difficulty of transfer in post-stroke hemiparesis patients: a pilot study

Soichiro Koyamaa, Shigeo Tanabed, Yohei Otakac, Tomoya Katod, Shotaro Furuzawac, Tsuyoshi Tatemotod, Nobuhiro Kumazawaes, Hiroshi Yoshimutad, Katsuhiko Toriief, Shingo Tsukadag and Eiichi Saitohb

aFaculty of Rehabilitation, School of Health Sciences, Fujita Health University, Toyoake, Japan; bDepartment of Rehabilitation Medicine I, School of Medicine, Fujita Health University, Toyoake, Japan; cDepartment of Rehabilitation, Fujita Health University Hospital, Toyoake, Japan; dNTT DATA NJK Corporation, Chuo-ku, Japan; eImasen Engineering Corporation, Kakamigahara, Japan; fNTT Basic Research Laboratories, NTT Corporation, Atsugi, Japan

ABSTRACT

Purpose: The purpose of this study was to clarify whether the novel lateral transfer assist robot facilitates easier transfers compared with a wheelchair in post-stroke hemiparesis patients.

Methods: This cross-sectional study enrolled 20 post-stroke hemiparesis patients, and the task difficulty of transfers was compared between a wheelchair and lateral transfer assist robot. All participants were asked to transfer from either wheelchair or lateral transfer assist robot to a platform table and back. The primary outcome was the transfer score of the Functional Independence Measure. The secondary outcome was the time required for transfer.

Results: The transfer score of the Functional Independence Measure was significantly higher with lateral transfer assist robot than with wheelchair (p < .001). The transfer times from these devices to a platform table and back showed no significant differences (to device from platform table: 7.1 s, lateral transfer assist robot vs 8.0 s, wheelchair, p > .05; device to platform table: 7.1 s, lateral transfer assist robot vs 8.0 s, wheelchair, p > .05).

Conclusions: Transfer with a lateral transfer assist robot is easier than with wheelchair and facilitates independence in post-stroke hemiparesis patients.

IMPLICATIONS FOR REHABILITATION

- Transfer skill influences the functional independence and quality of life of a wheelchair user
- A novel structural mobility device—the lateral transfer assist robot (LTAR)—can facilitate transfers
- The LTAR could improve the degree of independence for transfers than the wheelchair, without any time loss, in post-stroke hemiparesis patients
- The LTAR could potentially reduce the risk for falls in various medical and care facilities

Introduction

Stroke is one of the most common neurological disorders. In 2019, the American Heart Association reported that approximately 800,000 people experience a stroke in the United States every year [1]. Stroke patients are unable to fully recover from hemiparetic motor and sensory deficits even after rehabilitative treatment. Many stroke survivors live in the community with prolonged long-term disability in daily life after hospital discharge [2,3]. Therefore, one of the crucially important purposes of the rehabilitative approach in stroke patients is to reduce the amount of assistance they require in fulfilling the activities of daily living.

Stroke patients with a gait disorder usually use a wheelchair for daily mobility. The wheelchair is an excellent mobility assistive device, although transferring from a wheelchair proves difficult for these patients because of the high burden on the upper limbs and risk of falls. Nonetheless, for wheelchair users, transferring from the wheelchair to another surface is an indispensable and essential factor for maintaining independence in daily life. Most wheelchair user performs approximately 15 transfers per day [4]. The transfer skill influences the functional independence and quality of life of a wheelchair user [5]. However, transfer is ranked as one of the most difficult factors among all wheelchair-related activities [6,7] and is the most frequently mentioned activity to have been undertaken at the time of a fall [8,9].

A common transfer method is the squat/stand pivot transfer, wherein patients lift themselves to raise their buttock over some obstacle (e.g., wheelchair armrest) and then rotate their buttock onto the desired surface during transfer while ensuring no contact of their buttock on those obstacles. However, many patients need caregiver assistance for lifting and rotating their buttocks during transfer [10]. The difficulty level of these transfers is affected by differences in height, width of gap (>8.9 cm), and...
presence of an obstacle (e.g., armrest or wheels) between the transfer surfaces [11].

We demonstrated that a novel approach of lateral transfer, which is defined as transferring laterally between surfaces without any height differences, gaps, or obstacles, and without using the flip-up-armrest and transfer-board, can facilitate independent transfers and decrease the need for transfer assistance in post-stroke hemiparesis patients [12]. In combination with the abovementioned approach, a novel structural mobility device—the lateral transfer assist robot (LTAR)—has been proposed to facilitate transfers [13]. In healthy participants, a previous study showed that the extent of vertical movement of the centre of mass of users was decreased with LTAR compared to that with the wheelchair [14].

We hypothesised that LTAR can contribute to easier transfers and higher degree of independence among post-stroke hemiparesis patients. The aim of this study was to test whether LTAR is easier to transfer than WC among hemiparetic stroke patients.

Methods

Study design, setting and participants

The present study used a cross-sectional design for convenience sampling among inpatients in the subacute recovery phase in a rehabilitation ward at a university hospital. The study included 20 hemiparesis patients, with a mean age of 65.4 years (standard deviation [SD] 16.9; 15 men, 5 women), after a subacute stroke who were using a standard wheelchair for activities of daily living. The exclusion criteria were the presence of bilateral, cerebellar, and/or brain-stem lesions; severe upper-extremity pain and/or injury; severe injury of the lower extremity on the non-paretic side; other neuromuscular disease; and pressure sores. The study protocol was approved by the institutional ethics committee (approval no. HM16-311). All patients provided written informed consent prior to study participation. This study was performed in accordance with the principles of the Declaration of Helsinki and its later amendments.

Experimental setup

The experimental setup consisted of a platform table and two mobility devices: the standard wheelchair and LTAR. The seat of the wheelchair and that of the LTAR was adjusted to the same height as that of the platform table. In preparation for transfer from/to the wheelchair, the footrest was removed. In the starting position, the wheelchair was set close to the platform table at a 20–45° angle to the non-paretic side of the participant. On the other side, the LTAR was placed in close contact with the other side of the platform table. All wheels of the devices were locked in place. Both soles of the participants’ feet were placed on the floor during the squat/stand on the wheelchair or LTAR.

All participants were asked to perform two transfer methods using the specified devices. For the wheelchair transfer, the participants were asked to carry out a squat/stand-pivot transfer in a similar manner to what they do in daily living. For the LTAR transfer, the participants were asked to perform a lateral transfer, as described in previous studies [12–14]. In every trial, an occupational therapist closely supervised the patients to prevent a fall during the transfers. Based on the patient’s transfer ability, an occupational therapist supported the lifting and/or rotating of participants’ buttocks with minimal assistance for both methods. All participants were allowed to rest for a few minutes between transfers of the wheelchair and LTAR based on their fatigue levels.

Lateral transfer assist robot

The LTAR (Figure 1) has been previously described in some reports [13,14]. Briefly, the LATR is a novel mobility device that raises and lowers the footrest and armrest on the side of transfer. The seat is raised and lowered to the same level as the transfer surface. The wheels are retracted under the seat to ensure that these do not interfere with the user’s movement. These key features achieve a setting wherein there are no height differences,
gaps or obstacles (e.g., armrests or wheels) between the transfer surfaces, and no complicated brake operations are required during the transfer. As another feature, the LTAR has 360° manoeuvrability for facilitating easy movement close to the transfer surface because of the mecanum wheels, which have free rollers with axes tilted at 45° from the wheel plane to the outer circumference of each wheel.

Assessment

An item of the bed-transfer—Functional Independence Measure (FIM)—was used as a primary outcome [15,16]. The FIM transfer score represents the amount of physical assistance and level of independence during transfers based on an ordinal scale from 1 (maximum assistance) to 7 (independent). The secondary outcome was the amount of time required for transfers to assess the temporal efficiency between two transfer methods. All transfers were video-recorded for assessment by three occupational therapists (including the therapist who supervised or assisted the transfer). Disagreements between the raters were resolved by discussion until a consensus was obtained.

Statistical analysis

The Wilcoxon signed rank test was used to compare the transfer score of the FIM for squat/stand-pivot transfer and lateral transfer using the wheelchair and LTAR, respectively. Performance times for transfers were compared between the wheelchair and LTAR using paired t-test and were analysed based on the transfer direction: 1) from the platform table to the wheelchair or LTAR and 2) from the wheelchair or LTAR to the platform table. To eliminate the effect of degree of assistance, patients who needed assistance during the transfer were excluded from the analysis of the secondary outcome. All statistical analyses were performed with R (version 3.4.3; Institute of Statistical Mathematics, Tokyo, Japan). The statistical significance level was set at a p-value of .05.

Results

The transfer score of the FIM for each device is shown in Figure 2. The transfer score was higher for the LTAR than for the wheelchair in almost all patients (p = .0003). Moreover, 10 and 13 patients did not need any physical assistance during transfers with the wheelchair and LTAR, respectively.

For an evaluation of the performance time, 10 patients who could independently transfer with both methods were included in the further analysis of the secondary outcome. The mean performance time in the LTAR was 7.8 s (from the platform table) and 7.1 s (to the platform table), whereas that in the wheelchair was 7.6 s (from the platform table) and 8.0 s (to the platform table) (Figure 3). There was no statistical difference in the performance times between the two devices, regardless of the transfer direction. All patients performed all transfers without any adverse events.

Discussion

This study showed that LTAR could better improve the degree of independence for transfers than the wheelchair in post-stroke hemiparesis patients. In addition, there was no difference in the transfer time between the two devices.

A previous report showed that the transfer score of the FIM was strongly associated with balance function [17]. Other studies have reported that the lower limbs play an important role in truncal support and control of sitting balance during forward movements, particularly with regard to the centre of gravity in a sitting position that occurs during wheelchair transfer [18,19]. With regard to the difference in the degree of independence for transfers, one of the main reasons might be that the lateral transfer method does not require a high balancing ability or application of pedal force for interrupting the forward momentum of the body mass to prevent a fall in the forward direction during transfer. In the typical squat/stand-pivot transfer, patients must lift their buttocks to avoid hitting the armrest and wheel of the wheelchair to perform the transfer from a wheelchair to another surface [10,20–25]. However, for LTAR, patients do not need to raise their centre of gravity and shift their centre of gravity mainly laterally along a horizontal plane [12–14].

With regard to the performance time required for a transfer with the two methods, there was no difference between the two transfer methods. This finding is a crucially important factor of relevance in hospitals and nursing homes because of the limited amount of care-time per patient. Several transfer-assistive devices (i.e., mechanical lifts and power-assisted systems) have been developed, although these previously developed devices require more time from patients or caregivers to perform transfers than with a wheelchair. Alamir et al reported that transfers with ceiling lift-type transfer-assistive device require 52.1 s (wheelchair to bed) and 57.9 s (bed to wheelchair), excluding the preparatory time, in a long-term care facility [26]. For a floor lift-type device, transfers require 104.6 s (wheelchair to bed) and 100.6 s (bed to wheelchair) [26]. In contrast, the results of this study showed that the mean performance time for transfers with the LTAR was 7.1 s (from the platform table) and 7.8 s (to the platform table).

Transfers between the wheelchair and desired surface have to surmount several barriers (e.g., the height difference, armrest, and
wheel). To overcome these barriers, various older low-tech devices have included transfer boards, slides, and slings [25,27,28]. Despite the advantage of low cost with those devices, they require greater effort from participants to operate them and are incapable of completely reducing participants’ load [14,29]. Based on the findings of the present study, the LTAR might have a clinical benefit as a novel transfer assistive device that completely eliminates these barriers while maintaining performance times that are equal to those for the wheelchair.

One of the most important aspects of rehabilitative care is to ensure safe independence in the activities of daily living. Falls are one of the most frequent complications in community-dwelling stroke survivors [9,30–32]. Consequences of falls can cause further physical complications in community-dwelling stroke survivors (e.g., soft tissue injuries [33], lumbar compression fracture [8], and hip fracture [34,35]). Therefore, this newly developed mobility assistive device might facilitate reduction in the risk of falls because of improved level of independence for transfers.

The present pilot study had some limitations. First, the degree of participants’ disability severity only ranged from 2 to 7 in the FIM transfer score. For patients who require maximal assistance for transfer, it is unclear whether the extent of assistance needed would decrease when caregivers use the LTAR. This point should be clarified in further studies among patients who require maximal assistance for transfers. Second, this study only examined the effectiveness and efficiency of LTAR with regard to the difficulty of transfer and transfer performance time. Further research should examine the effectiveness of LTAR with regard to various outcomes (e.g., reduction of the risk of falls, decrease in caregiver burden, and usability within the home environment) to identify the target populations where LTAR has the most efficacy.

In conclusion, LTAR transfer is easier than wheelchair transfer, without any time loss, in post-stroke hemiparesis patients. Therefore, the LTAR could improve the transfer ability in post-stroke hemiparesis patients and potentially reduce the risk for falls.

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ORCID
Soichiro Koyama http://orcid.org/0000-0001-5837-8477
Shigeo Tanabe http://orcid.org/0000-0003-1993-5896
Yohei Otaka http://orcid.org/0000-0002-6797-2782
Tomoya Kato http://orcid.org/0000-0002-8797-788X
Eiichi Saitoh http://orcid.org/0000-0001-5069-6198

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