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Immediate effectiveness of single-session therapeutic interventions in pusher behaviour

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ABSTRACT

Some stroke patients with hemiparesis exhibit a so-called pusher behaviour, i.e., they actively push away from the unaffected side and lean towards the hemiparetic side. This impairs their postural balance to such a degree that they are often unable to sit or stand. Pusher behaviour thus substantially hampers the rehabilitation of these patients. So far only a few case studies on treatment strategies have been performed. This study investigated the immediate after-effects of galvanic vestibular stimulation (GVS), machine-supported gait training with the Lokomat, and physiotherapy with visual feedback components (PT-vf). Fifteen pusher and 10 non-pusher patients participated in an observer-blinded cross-over pilot study. Patients were measured on the scale for contraversive pushing (SCP) and on the Burke lateropulsion scale (BLS) immediately before and after a single-session of the specific intervention. Compared to PT-vf, Lokomat therapy had a significant effect on the BLS of pusher patients but no significant effect on the SCP values. GVS had no significant effect on these values on either scale. BLS is more useful than SCP to detect small changes for clinical trials and routine treatment. Forced control of the upright position during locomotion seems to be an effective method for immediately reducing the pushing behaviour of stroke patients, probably because it recalibrates a biased sense of verticality, via the somatic graviception. This finding, however, does not allow prediction of its long-term effects. Furthermore, it would be interesting to evaluate repetitive, multi-session DGO therapy and the amount of therapy needed to effectively reduce the pusher behaviour.

1. Introduction

A substantial proportion of hemispheric strokes are associated with deficits in body orientation with respect to gravity. Some hemiparetic patients attempt to align their body with an internal vertical reference that is tilted in the coronal (roll) plane. Some researchers found it to be tilted to the side opposite the stroke [1,2] and some to the ipsilesional side [3]. This shifts the centre of gravity towards the paretic side (whether this is to actively align an erect posture with a vertical reference [1] or to compensate for an erroneous verticality reference [3]), impairing postural balance so severely that sitting or standing becomes impossible sometimes. When patients actively push with the non-affected extremities towards the paretic side and exhibit resistance to passive correction, the condition is called pusher behaviour [3–6]. It is typically associated with posterior thalamic stroke, less frequently with extra-thalamic lesions [7,8].

Although the syndrome is becoming more familiar, the frequency of pusher behaviour in rehabilitation clinic inpatients and its influence on their rehabilitation outcome is still inadequately investigated. The frequency of pushing behaviour has been reported to range from approximately 5% to 63% of examined stroke patients [9]. This disparity is due to heterogeneous diagnostic criteria as well as to the diversity of patient groups.

Pusher behaviour is considered a negative predictive factor for recovery time but not for functional gain. Pusher patients need approximately 3.6 weeks longer to reach the same final outcome levels as patients without pusher behaviour [10,11]. Thus, it is an important aim of research in pusher behaviour to find effective therapeutic approaches to improve the patients' postural control and thereby shorten the length of hospitalisation [12].

In 1985 Davies recommended bringing patients with pushing behaviour into an upright position so as to prevent pushing behaviour by engaging the non-paretic extremities in activities and, if necessary, by supporting the paretic leg with a knee

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extension splint [4]. Since then only a few case reports have been published on successful treatment strategies for pusher behaviour. For instance, Broetz et al. [13] treated eight pusher patients with a visual feedback therapy for 3.5 weeks and found a significant improvement on the scale for contraversive pushing (SCP). However, since there was no control group or control intervention, the amelioration of the pusher behaviour in the reported patients cannot be reliably differentiated from spontaneous remission. Paci and Nannetti [14] treated one patient for three weeks using different forms of feedback and found an improvement only after visual and auditory feedback.

Patients with pusher behaviour experience a mismatch between visual vertical, based on vestibular and visual inputs on the one side, and the tilted orientation of subjective body verticality on the other [1,3]. Thus, treatment strategies to reduce the pusher behaviour should focus on or manipulate these different sources of postural information in order to recalibrate the biased sense of verticality.

Using visual cues about the earth vertical, therewith focusing on visual inputs, has been described as an effective therapy strategy (see above) [13,14].

Walking in a robotic gait orthosis might focus on the body verticality by enhancing somatic input in an earth-vertical position. After therapy with a robotic gait orthosis, some pusher patients have been shown to develop improved postural control [15].

Another experimental and potentially useful approach to treat pusher behaviour could be galvanic vestibular stimulation (GVS). GVS causes asymmetric vestibular perception in the roll plane (illusionary rotation) and has been used successfully to treat neglect syndrome in stroke patients [16]. GVS is an attractive tool for investigating the vestibular contribution to whole body control. GVS enables a selective stimulation of vestibular afferents in contrast to ‘natural’ stimulation, which activates several sensory systems [17]. Binaural galvanic stimulation causes the illusion of rotation to the cathodal side in the roll plane signalled by semicircular canal afferents [18] and therewith a body sway response to the side of anodal stimulation when the patient is standing [19,20]. He/she deviates to the anodal side when walking [21]. Galvanic stimulation can also modify the perception of the vertical [22]. Since these subjects tilt to the anodal side during the stimulation, GVS might correct or alleviate body tilt in pusher behaviour.

The present randomised cross-over study with a blinded assessor examined the immediate after-effect of one single-session of transmastoidal direct current stimulation (GVS), of machine-supported gait training (DGO), and physiotherapy in the rehabilitation of patients with pusher behaviour. It was hypothesised that DGO therapy is more effective in reducing pusher behaviour than physiotherapy. It was questioned if GVS can be effective in treating pusher behaviour.

2. Methods

2.1. Participants

The study was approved by the Ethics Committee of the University Hospital Munich, and all patients or their legal representatives gave written informed consent.

Patients participating in the study were inpatients in a rehabilitation hospital and had hemiparesis caused by left or right hemispheric ischemic stroke or intracerebral haemorrhage with (n = 15) and without (n = 10) a diagnosis of pusher behaviour according to the SCP (see assessments). All met the following additional inclusion criteria: age >18 years, body height between 1.60 and 1.90 m and body weight below 150 kg, no other neurologic or orthopaedic disorder, no cardiac pacemaker, no bone fractures or severe osteoporosis, no contractures or spasticity of the lower extremities, no metal implants, no epilepsy, no brain tumours or meningitis, no vestibular disorder or eye-muscle paralysis. While the patients had been able to walk independently before the stroke, they could not stand unaided at the beginning of the trial.

A neurological and a neuroophthalmologic examination were conducted prior to the interventions to test for neglect, aphasia, hemihypaesthesia, hemiparesis, visual acuity, and the subjective visual vertical.

2.2. Interventions

2.2.1. Galvanic vestibular stimulation (GVS)

GVS was delivered by a battery-driven, constant-current stimulator (Eldith DC-Stimulator, NeuroConn, Ilmenau, Germany). Two electrodes were covered with fitting saline-soaked sponges (45 cm^2). The anodal electrode was placed over the ipsilesional mastoid, the cathodal electrode over the contralesional mastoid. The vestibular threshold was determined by applying consecutively 1 mA, 1.25 mA, 1.5 mA, 1.75 mA and 2 mA for 30 s (fading in and fading out each time with 0.1 mA/s). The patients were asked to indicate when they experienced a tilting sensation. The therapeutic stimulation was then performed at the threshold current or, if no tilting sensation was perceived, at 1.5 mA, for which positive effects in stroke patients with neglect have been reported [22,23]. The stimulation lasted 20 min in all sessions in order to adhere to the safety criteria for tDCS stimulation duration [16,24,25]. During therapy patients sat in their wheelchairs and were frequently asked if they sensed any tingling, burning, or pain at the stimulation site.

2.2.2. Driven-gait orthosis (DGO) Lokomat

The DGO Lokomat (Hocoma, Switzerland) was used for the locomotion training. The DGO is an exoskeleton with bilateral drives for hip and knee joints. It allows assisted locomotion on a treadmill by means of guiding the subjects' legs along a predefined trajectory. The guidance force was set to 100% for both legs, i.e. walking trajectory was provided completely by the orthosis. Subjects were attached to the DGO with a harness around the pelvis and cuffs around the legs. Passive foot lifters supported ankle dorsiflexion during the swing phase bilaterally. Subjects were connected to a weight-support system. The body weight support was reduced to 50% if possible. The treadmill speed was kept constant at 2 km/h. Cadence was adjusted to individual leg length. Considering the time necessary to prepare the patient and the material, the real walking time amounted to 20 min. Patients were scheduled for one preparatory DGO session to adjust the device to the patient in the week before the real therapy session. A detailed overview of publications on this device has been provided by Riener et al. [26].

2.2.3. Physiotherapy with visual feedback components (PT-vf)

Patients received 30 min of a one-on-one physiotherapy session. If the time necessary to prepare the patient and the material is subtracted, the net active training time amounted to 20 min. The focus was on spatial orientation; activities like the changing of position (sitting–standing) and the shifting of weight were exercised. The patient was presented external references (e.g., wall, bedframe) on his/her unaffected side and was requested to align him-/herself with visual vertical references (e.g., doorframe) following the instructions of Broetz and Karnath [27].

2.3. Assessment of pusher behaviour

2.3.1. Scale for contraversive pushing (SCP)

The SCP is based on the criteria of Davies [4], which assess the behaviour of the patient while sitting or standing: (1) symmetry of spontaneous posture, (2) the use of the arm or the leg to extend the area of physical contact to the ground, (3) resistance to passive correction of posture. The total score ranges from 0 to 6. Patients were considered to have contraversive pushing if all three criteria were met. This gave a total score greater than zero for each criterion (sitting plus standing). This cut-off criterion was chosen to ensure better validity estimation compared to the original criterion (each greater than one) [9].

2.3.2. Burke lateropulsion scale (BLS)

BLS is an additional assessment tool. It was used because it is the only scale that includes lateropulsion assessment during supine rolling and walking [5]. It also shows a wider metric range, which was considered more useful when looking for small changes [6]. The BLS rates the patient's resistance to passive rolling, to passive postural correction when sitting and standing, and to assistance in transfer and walking. The total score ranges from 0 to 17. Patients were considered to show lateropulsion if the total score was $\geq$2.

Both scales have yielded good to excellent validity and reliability values with good clinical applicability [6]. For the BLS also a high level of measurement responsiveness was documented [28]. SCP and BLS were assessed by one trained experimenter who was blinded as to the allocated interventions and their sequence.

An assessment procedure was defined to apply both scales at the same time. First, the patient was helped to transfer from the wheelchair to the therapy bench. Reaction to transfer was assessed (SCP, BLS). While the patient was lying down on the bench, the supine rolling test (BLS) was performed. Then the patient was seated on the bench with his/her feet touching the ground and knees at a 90° angle. Spontaneous posture and reaction to passive correction were assessed (SCP). The bench was elevated until the patient's feet were off the floor. The patient was asked to keep both hands in his/her lap. He/she was then passively tilted and the sitting posture was corrected (BLS).