



Case Report

Posturographic Improvement After Virtual Reality-Guided Rehabilitation in Ataxia After Pontine and Cerebellar Infarction: A Case Report

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KEYWORDS

Ataxia;
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Abstract Pontine and cerebellar infarction—related ataxia can cause persistent balance impairment, limiting activities of daily living and mobility. Virtual reality (VR)-guided rehabilitation may be useful for balance impairment; however, reports objectively evaluating changes in postural control using stabilometry in patients with cerebellar ataxia remain limited. This case report describes a man in his 70s who developed ataxia after right pontine and cerebellar infarction. At admission, his FIM, Scale for the Assessment and Rating of Ataxia (SARA), and Berg Balance Scale (BBS) scores were 81, 25.5, and 9, respectively, indicating severe ataxia and balance impairment. After 8 weeks of conventional physiotherapy, these scores improved to 102, 19, and 23, respectively; however, trunk sway during sitting, standing, and walking remained. Therefore, VR-guided rehabilitation was added for 2 weeks, involving one 20-minute session per day. After the intervention, the SARA and BBS scores improved further to 16 and 28, respectively. Stabilometry performed before and after the VR intervention showed improvements in total path length and outer peripheral area in both eyes-open and eyes-closed conditions. This case suggests that VR-guided rehabilitation may serve as an adjunctive intervention for balance impairment in patients with ataxia after pontine and cerebellar infarction. Stabilometry may also be useful for objectively evaluating improvements after VR-guided rehabilitation.

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List of abbreviations: ADL, activity of daily living; BBS, Berg Balance Scale; SARA, Scale for the Assessment and Rating of Ataxia; VR, virtual reality.

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Ataxia is defined as impaired coordination of voluntary movements without muscle weakness, motor paralysis, or disturbance of consciousness, resulting in inadequate regulation of movement direction, speed, amplitude, and timing.¹⁻³ Cerebellar ataxia commonly occurs after cerebellar infarction, with a reported prevalence of 51.3% to 67.5%.⁴ One systematic review reported gait ataxia in approximately 70% of patients with cerebellar infarction (95% confidence interval, 56%-82%).⁵ Balance impairment is a major clinical issue in patients with cerebellar ataxia because impaired postural control and gait coordination increase body sway, gait instability, and fall risk, restricting mobility and activities of daily living (ADLs).⁶⁻⁸

Conventional rehabilitation involves balance training, gait training, coordination exercises, Frenkel exercises, and trunk and postural control training.⁹⁻¹¹ However, in clinical practice, these approaches can become monotonous, and tailoring task difficulty to the patient's condition can be challenging.¹² Virtual reality (VR) technology has been used to address some of these limitations, with previous studies reporting beneficial effects of VR-guided training on balance in poststroke patients and older adults.^{13,14} VR- and game-based approaches have been used in patients with various forms of ataxia, including spinocerebellar and acquired cerebellar ataxia, and systematic reviews and controlled trials have reported clinical improvements in balance and gait using measures such as the Berg Balance Scale (BBS) and ataxia rating scales.¹⁵⁻²⁰ In Japan, mediVR KAGURA^a was approved as a medical device for VR-guided rehabilitation in March 2019.^{21,22} Rehabilitation with mediVR KAGURA may improve balance and gait function in patients with neurologic disorders, including cerebellar ataxia.^{4,22,23}

Balance and ataxia are commonly evaluated using the BBS,²⁴ the timed Up and Go test,²⁵ and the Scale for the Assessment and Rating of Ataxia (SARA).²⁶ However, these scales do not directly quantify subtle postural sway or the spatial characteristics of center-of-pressure displacement during quiet standing. Stabilometry can objectively quantify postural sway using parameters such as total path length and outer peripheral area,^{27,28} and measurements in eyes-open and eyes-closed conditions may provide information about visual dependence and sensory integration. To our knowledge, no prior report has objectively documented improvements in postural control using stabilometry after VR-guided rehabilitation for ataxia attributable to pontine and cerebellar infarction.

This report describes a patient who developed cerebellar ataxia after infarcts involving the pons, cerebellar peduncle, and cerebellar hemisphere and achieved improvements in ataxia and balance impairment after VR-guided rehabilitation, with changes in postural control objectively assessed using stabilometry.

Case presentation

This case report was prepared in accordance with the CARE Report (CARE) guidelines. After obtaining verbal consent from the patient, written informed consent was obtained with assistance from a proxy writer. Per institutional policy, approval from the institutional ethics review board was not required for this single-case report.

The patient was a previously healthy man in his late 70s who was independent in his ADLs. He developed dizziness and vomiting and was transported to a hospital. At presentation, right facial nerve palsy, right-sided limb ataxia, diplopia, and dysphagia were observed. Diffusion-weighted brain magnetic resonance imaging performed on the day of onset revealed infarcts in the right pons, cerebellar peduncle, and cerebellar hemisphere (fig 1). Continuous heparin infusion and oral aspirin were administered. Brain magnetic resonance imaging performed on day 10 revealed no marked changes.

On day 42 postonset, the patient was transferred to our hospital. On admission, the patient had no muscle weakness, altered consciousness, or cognitive impairment. He predominantly exhibited right-sided limb ataxia, truncal ataxia, and balance impairment. He required handheld support to maintain sitting at the edge of the bed and assistance with bed mobility and standing.

Other symptoms included lagophthalmos because of facial nerve palsy, dysarthria with a speech intelligibility rating of 3, and dysphagia. Rehabilitation was initiated to improve ataxia symptoms and achieve independence in ADLs.

Outcome measures

Ataxia was assessed using SARA, which quantitatively evaluates cerebellar ataxia severity, with higher scores indicating

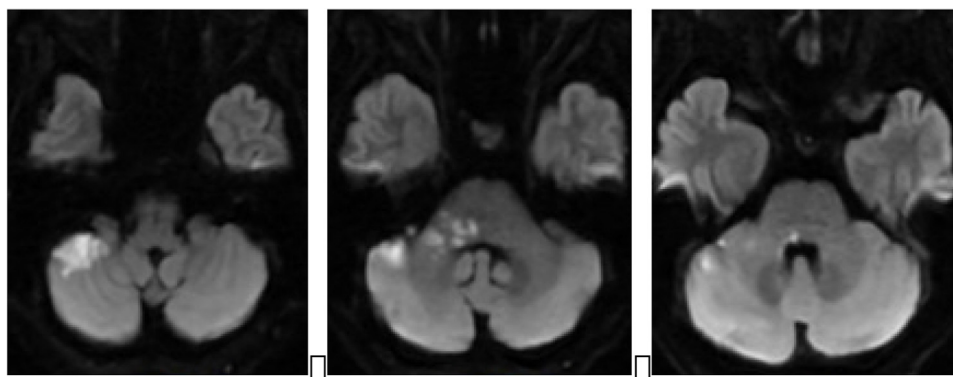


Fig 1 Brain magnetic resonance imaging findings on admission. Diffusion-weighted magnetic resonance imaging demonstrating high-intensity lesions in the right pons, right cerebellar peduncle, and right cerebellar hemisphere, consistent with acute infarction.

more severe ataxia.²⁶ Clinical balance was assessed using the BBS, with higher scores indicating better static and dynamic balance.²⁴

Objective balance function was assessed using a stabilometer (GraviCorder GP-31)^b while the patient stood unsupported. The total path length, outer peripheral area, and Romberg ratio were measured. Total path length reflects center-of-pressure displacement and postural instability, whereas outer peripheral area reflects the spatial extent of postural sway. The Romberg ratio reflects visual dependence and sensory integration by comparing sway in eyes-open and eyes-closed conditions.²⁷ Physical function was assessed using the FIM, which evaluates the level of independence in ADLs.²⁹

Intervention

After transfer to our hospital, the patient underwent 8 weeks of conventional rehabilitation for cerebellar ataxia, including balance training,^{10,30} gait training,^{30,31} coordination exercises,^{11,32} and trunk and postural control training.⁹ Gait training was performed using parallel bars and a fixed walker, with assistance. Although improvement was observed, stability during sitting, standing, and gait later appeared to plateau.

VR-guided rehabilitation using mediVR KAGURA was subsequently introduced to further improve balance function. The horizontal game mode was used (fig 2A), in which the patient performed seated upper-limb reaching tasks with targets presented in frontal space within a 3-dimensional virtual environment. These repeated reaching movements were intended to facilitate trunk control and center-of-gravity shifts (fig 2B).

Task difficulty was adjusted by modifying the target position, number of targets, reaching timing, and target size according to the patient's condition. VR training was performed for 2 weeks, comprising one 20-minute session per day, 7 days per week, under therapist supervision. Conventional physiotherapy continued during the VR-guided rehabilitation period.

Treatment effects were assessed at admission, before VR-guided rehabilitation, and after the final VR session.

Results

At admission, the FIM, SARA, and BBS scores were 81, 25.5, and 9, respectively, indicating severe balance impairment. After approximately 8 weeks of conventional physiotherapy, these scores improved to 102, 19, and 23, respectively (table 1); however, trunk sway persisted.

Subsequently, VR-guided balance training was added, after which the FIM, SARA, and BBS scores further improved to 106, 16, and 28, respectively. Stabilometry could not be performed on admission because the patient could not stand without upper-limb support; therefore, this assessment was performed immediately before and after the 2-week VR-guided rehabilitation period. In unsupported standing, total path length in the eyes-open condition decreased from 331.09 cm before VR-guided rehabilitation to 150.72 cm after VR-guided rehabilitation, and from 395.13 to 345.64 cm in the eyes-closed condition (fig 3). The outer peripheral area also decreased from 76.06 to 20.55 cm² with

eyes open and from 130.56 to 44.36 cm² with eyes closed. However, the Romberg ratio increased from 1.72 before VR-guided rehabilitation to 2.16 after VR-guided rehabilitation, indicating persistent relative instability in the eyes-closed condition, despite overall improvement in postural sway.

No adverse events occurred during the VR sessions. The patient showed functional improvements in wheelchair sitting, standing, and short-distance walking. At discharge, he could walk short distances with a fixed walker under supervision, without physical assistance.

Discussion

Ataxia can interfere with movement during ADLs and broader social activities, including mobility, social participation, and return to work.^{3,31} In the present case, conventional physiotherapy improved clinical scores; however, trunk sway persisted, and stability appeared to plateau. In rehabilitation, the appropriate level of task difficulty depends on the interaction among the individual's abilities, task characteristics, and practice conditions; therefore, it cannot be set uniformly.³³⁻³⁵ Conventional training may therefore have been limited in setting task difficulty and ensuring sufficient repetitive practice for higher-level balance control. Accordingly, VR-guided rehabilitation was introduced because it has been shown to improve balance impairment after stroke and in older adults,^{13,14} and case reports have also described improvements in higher-level balance ability among individuals of working age.⁴

The mediVR KAGURA system allowed quantitative adjustment of task parameters, enabling task settings tailored to the patient's abilities and potentially contributing to functional recovery.

Another possible mechanism involves accurate feedback after each trial. When the patient touched a target, mediVR KAGURA immediately provided multimodal feedback through visual information, auditory cues, and controller vibrations. Feedforward control based on internal models of the body and environment plays an important role in cerebellar motor control.^{36,37} Internal models can predict movement outcomes and compensate for sensory feedback delays.³⁸ Because predictive feedforward control may be impaired in cerebellar ataxia, accurate external feedback may help correct movement errors and facilitate motor learning.³⁹ Immersion in a VR environment with immediate multisensory feedback may therefore have facilitated motor learning more efficiently than conventional training, possibly contributing to improved balance function.

Although the VR tasks were performed in a seated position, improvements were observed in standing and gait stability. The head, arms, and trunk account for approximately two-thirds of body mass, and their center of mass is located high above the ankle joints; thus, the upper body plays an important role in postural control.⁴⁰ Moreover, the patient repeatedly reached beyond the base of support, requiring lower-limb loading responses associated with trunk movement. Therefore, seated reaching tasks may have improved standing and walking stability through trunk control and weight shifting.^{14,21}

One key feature of this case was that improvements were observed not only in the SARA and BBS but also in

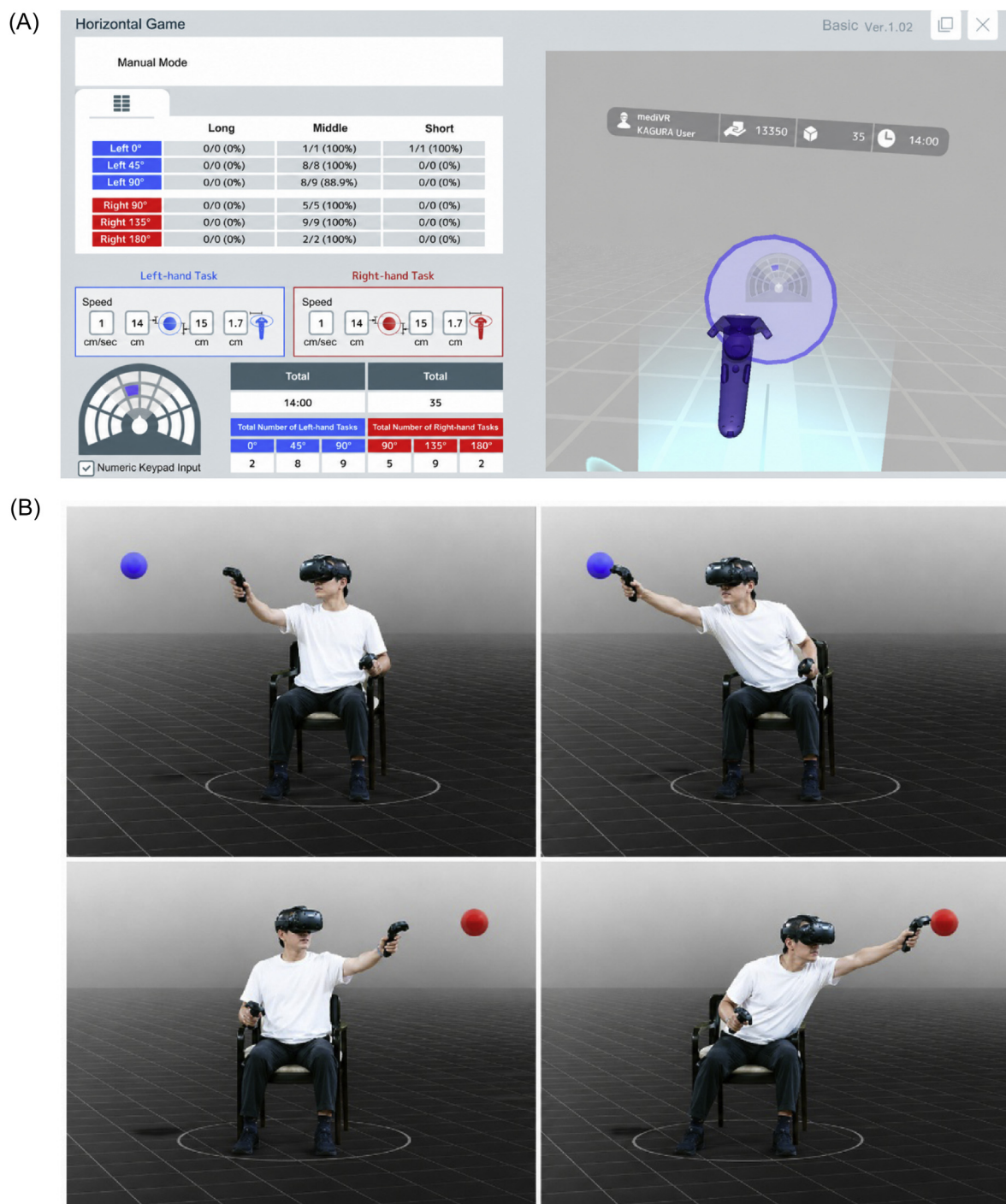


Fig 2 (A) The VR-guided horizontal tracking task used for rehabilitation. Screenshot of the horizontal tracking task used in the VR-guided rehabilitation program. The task required the patient to perform repeated reaching movements in multiple horizontal directions, while the task count, speed, and training time were displayed in real time. (B) Three-dimensional visualization of the mediVR KAGURA horizontal reaching task. The patient is seated, wearing a VR headset, and holding controllers in both hands. In this task, the patient reaches for colored targets moving horizontally in a virtual space, requiring smooth lateral adjustments of the center of balance and coordinated upper-limb movements. The patient catches blue and red targets with the left and right hands, respectively.

stabilometric parameters in both eyes-open and eyes-closed conditions. Although previous studies of VR- and game-based rehabilitation for ataxia have reported improvements primarily using clinical rating scales such as the BBS and SARA,¹⁵⁻²⁰ objective quantification of postural sway using

stabilometry has not been reported in this context. Stabilometry should not replace clinical scales; clinical scales evaluate functional ability related to ADLs, whereas stabilometry quantitatively demonstrates postural control during quiet standing. In addition to the patient's perceived

Table 1 Time series data for ataxia and balance measures.

Evaluation Items	Transfer (for Rehabilitation)	First VR Session (8 wk Posttransfer)	After the Final VR Session (10 wk Posttransfer)
FIM total score (pts)	81	102	106
Motor subscale	48	69	73
Cognitive subscale	33	33	33
SARA (pts)	25.5	19	16
BBS (pts)	9	23	28
Total path length (cm)			
Eyes open	—	331.09	150.72
Eyes closed	—	395.13	345.64
Outer peripheral area (cm ²)			
Eyes open	—	76.06	20.55
Eyes closed	—	130.56	44.36
Romberg ratio	—	1.72	2.16

NOTE. Higher FIM scores indicate greater independence in ADLs; higher BBS scores indicate better balance; higher SARA scores indicate more severe ataxia. Smaller total path length and outer peripheral area values indicate less postural sway, ie, better postural stability. A Romberg ratio closer to 1 indicates less visual dependence in postural control. Stabilometry could not be performed at transfer because the patient could not stand without upper-limb support.

Abbreviations: —, not measured; pts, points.

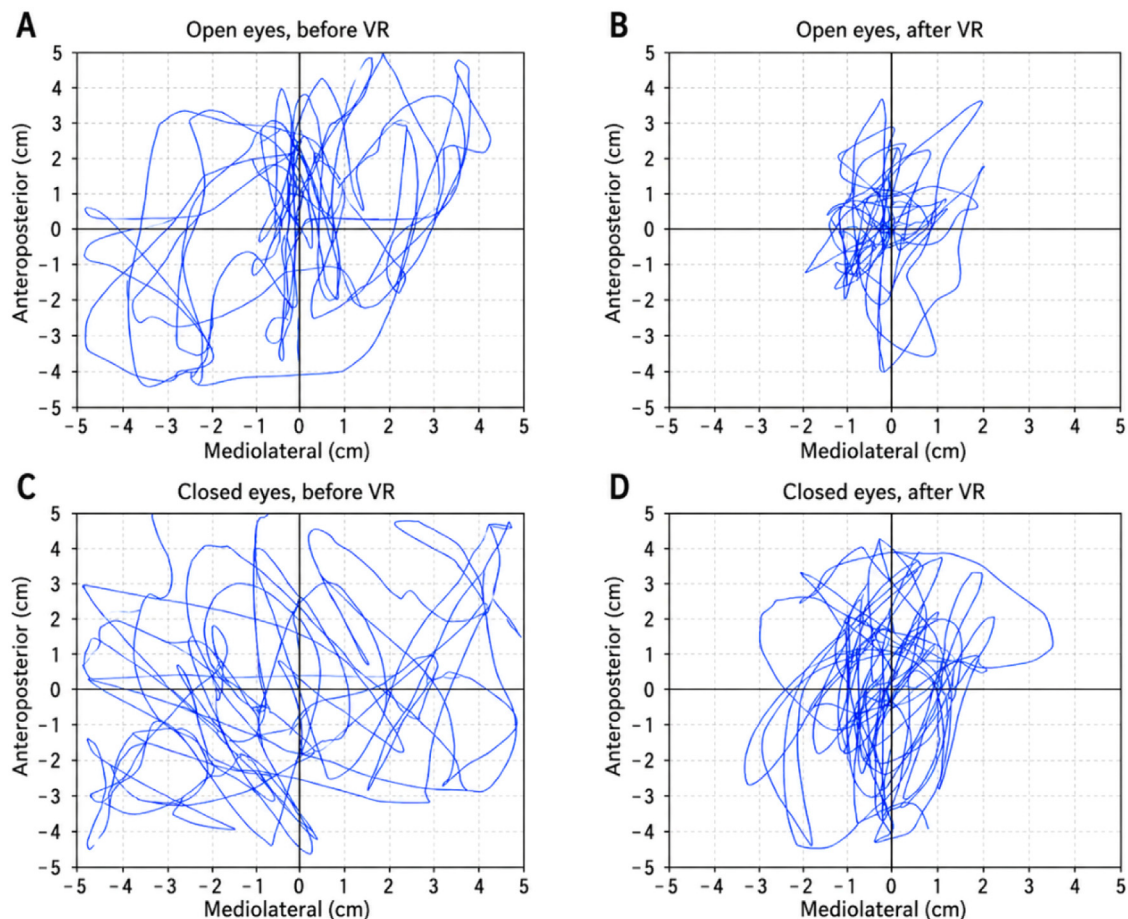


Fig 3 Representative center-of-pressure trajectories are shown in the eyes-open condition before (A) and after (B) VR-guided rehabilitation and in the eyes-closed condition before (C) and after (D) the intervention. The mediolateral axis is shown on the horizontal axis, and the anteroposterior axis on the vertical axis. Compared with the preintervention condition, the center-of-pressure trajectory became more compact after VR-guided rehabilitation, indicating improved postural stability.

recovery, the family also reported subjective improvements in stability. Thus, stabilometry may provide clinically useful information that complements clinical impressions. Nevertheless, the Romberg ratio increased after the intervention, indicating improved overall postural sway, while relative instability in the eyes-closed condition persisted, possibly reflecting residual visual dependence in postural control.^{41,42} This finding should be interpreted with caution for several reasons. First, the Romberg ratio is calculated as the ratio of sway with eyes closed to sway with eyes open; because sway with eyes open improved markedly, the ratio may increase even when absolute sway decreases in both conditions. Second, stabilometry was performed once per time point, with a limited number of trials; however, repeated, longer recordings are recommended to obtain reliable center-of-pressure measures.²⁸ Third, the Romberg ratio's test–retest reliability is limited.⁴²

VR-guided rehabilitation allows precise adjustment of task speed and presentation conditions, enabling reproducible, feasible, and individualized task difficulty.^{19,21,43} Moreover, because diverse feedback can be readily provided, VR-guided rehabilitation may complement conventional physiotherapy for patients whose improvement has plateaued.

No adverse events occurred in this case. In a Cochrane review of VR for stroke rehabilitation, adverse events in the monitored trials were rare and relatively mild (including pain, headache, and dizziness), with no serious events.⁴⁴ However, symptoms of cybersickness (eg, nausea, disorientation, headache, eye strain) have been described with head-mounted displays and should be monitored, particularly in patients with cerebellar/vestibular dysfunction.⁴⁵ VR delivered while standing also carries a potential risk of falls. In this case, the intervention was delivered in a seated position under therapist supervision, consistent with prior reports on the safety and feasibility of this program,²¹ which may have minimized this risk.

Study limitations

This report has some limitations. First, this was a single-case report, which limits the generalizability of the findings. Second, the possibility that natural recovery contributed to the patient's improvement cannot be excluded. Third, because conventional physiotherapy continued during the VR intervention, the effects of VR-guided rehabilitation alone could not be isolated.

Conclusions

This case highlights the potential usefulness of VR-guided rehabilitation as an adjunctive intervention for ataxia-related balance impairment after infarcts involving the right pons, cerebellar peduncle, and cerebellar hemisphere. In particular, the observation that conventional clinical assessments and objective stabilometric evaluations supported improvement may provide clinically useful insights. However, because this report is based on a single case, the generalizability of the findings is limited, and further case accumulation is warranted.

Suppliers

- a. mediVR KAGURA; mediVR, Inc., 2-4-1 Terauchi, Ryokuchi-Eki Building 3F, Toyonaka, Osaka 561-0872, Japan.
- b. GraviCorder GP-31; ANIMA Corporation, 3-65-1 Shimoishiwara, Chofu, Tokyo 182-0034, Japan.

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Disclosure

mediVR, Inc provided the mediVR KAGURA system to the authors' institution on a 1-year loan basis for research purposes, in accordance with the Japanese Fair Trade Commission guidelines. The company had no role in the study design, data collection, data analysis, interpretation of results, manuscript preparation, or the decision to submit the manuscript for publication.

Authorship contributions/CRediT statements

Y.F.: Conceptualization, Investigation, Data curation, Writing – original draft. R.Y.: Supervision, Writing – review & editing. R.K.: Supervision, Writing – review & editing. W.S.: Supervision, Writing – review & editing. R.H.: Supervision, Writing – review & editing. Y.S.: Supervision, Writing – review & editing. All authors read and approved the final manuscript.

Data statements

All data generated or analyzed during this study are included in this published article.

Patient consent statement

The authors attest that written informed consent for the publication of this case report and accompanying images was obtained from the patient. The signed consent form has been archived in the patient's medical record at the authors' institution, where the original document is also retained. Patient anonymity has been preserved throughout this report.

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