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CASE REPORT

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Effectiveness of rehabilitation for young patients with extensive right hemisphere cerebral infarction: A report of two cases

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Key Clinical Message

In younger patients, including those with extensive infarction involving the anterior and middle cerebral artery regions of the right hemisphere, appropriate treatment for rare causes and goal-oriented long-term rehabilitation could improve severe hemiplegia and higher brain dysfunction, and allow for further education and employment.

Abstract

Although the number of young stroke patients is small, many have serious sequelae and rare causes. In addition to independence in activities of daily living, education and employment are desired. We present two cases of extensive infarction in the right cerebrum in patients who underwent rehabilitation with good outcomes.

KEYWORDS

cerebral infarction, employment, higher brain function, rehabilitation, young patients

1 | INTRODUCTION

The occurrence of stroke differs between young and older patients. According to the Strategies Against Stroke Study for Young Adults in Japan, young patients aged <40 years with stroke account for only 2.2% of all patients; however, 26.0% of them had a modified Rankin Scale (mRS) score of 3–5 at the time of hospital discharge.[1] The post hoc descriptive exploration from a very early rehabilitation trial after stroke showed that 30% of working-age stroke survivors (≤65 years) had a poor outcome with mRS ≥3, and 28% of them rated their quality of life as poor.[2] Young patients with stroke commonly remain severely disabled; however, only few reports are available on their long-term rehabilitation courses.

The occurrence of cerebral infarction due to causes other than atherothrombotic cerebral infarction, cardiogenic cerebral embolism, and lacunar infarction ranges from 2.8% in older patients to 25.1% in younger patients. In younger patients, cerebral infarction due to arterial dissection, moyamoya disease, cerebral arteriovenous malformations, and antiphospholipid syndrome are more common.[1] Therefore, younger patients sometimes experience from strokes with causes that have been poorly reported previously.[3]

We report the cases of two young patients with extensive infarction involving the anterior and middle cerebral

artery regions of the right hemisphere due to unusual causes, who underwent long-term rehabilitation from convalescent rehabilitation to school and employment with favorable results mRS 2. This case report was writed according to CARE (CAse REport) statement and checklist (Table 1).

2 | CASE REPORT

2.1 | Case 1

2.1.1 | Case history

The patient was a right-handed 15-year-old boy in the ninth grade who lived with his parents and older brother and had no relevant medical history. The patient presented with a headache and left hemiplegia and was transported to the Japanese Red Cross Ashikaga Hospital. He was diagnosed with cerebral infarction of the right basal ganglia based on brain magnetic resonance imaging (MRI) and was admitted. He showed no evidence of cardiac disease, arrhythmias, vascular malformations, coagulation system abnormalities, or autoantibodies. On Day 6 after onset, the right internal carotid artery was occluded, and the infarction lesion extended into the anterior cerebral artery territory. Subsequently, the patient was transferred to a university hospital and treated with immunosuppressive drugs for suspected idiopathic central nervous system vasculitis. However, the infarcted foci further expanded into the anterior and middle cerebral artery regions, and the patient underwent internal and external decompression on Day 9. He underwent cranioplasty 41 days after symptom onset. Owing to a lack of evidence of vasculitis on pathological examination, arterial dissection was also suspected; however, a definitive diagnosis was difficult to make. As a rehabilitation treatment, botulinum toxin therapy was initiated in the lower extremities, and a knee-ankle-foot orthosis was fabricated.

The patient was transferred to the convalescent rehabilitation ward of the Japanese Red Cross Ashikaga Hospital 99 days after onset. He had left hemiplegia with 9 and 12 upper and lower extremity points on the Fugl-Meyer assessment (FMA), respectively; spasticity of the left ankle dorsiflexion on the modified Ashworth scale (mAS) 2; and moderate left sensory dullness. The patient had left spatial neglect on the behavioral inattention test (BIT), impaired attentional function on the trail-making tests A (TMT-A) and TMT-B, and executive function disorders on the Behavioral Assessment of the Dysexecutive Syndrome (BADS; Table 2). Furthermore, his full-scale intelligence quotient (FIQ) of the Wechsler Adult Intelligence Scale Third Edition (WAIS-III) decreased. He had no abnormal cranial nerve findings, visual field deficits, dressing apraxia, or constructional apraxia. He required minor assistance with activities of daily living (ADL) using his wheelchair and scored 85 on the Functional Independence Measure (FIM) scale. Brain computed tomography (CT) (Figure 1) revealed extensive low-density areas in the anterior, middle, and posterior cerebral artery regions of the right hemisphere. Figure 2 shows timeline for case 1 presented according to CARE guidelines.

2.1.2 | Investigation and treatment

Brain MRIs were repeated without re-exacerbation, and immunosuppressive drugs were tapered off with no recurrence. The patient was not treated with antiplatelets or anticoagulants to prevent recurrence. Botulinum toxin therapy was continued in the lower extremities, and an Adjustable Posterior Strut-ankle foot orthosis (APS-AFO)[4] was fabricated. He underwent conventional rehabilitation, including joint range-of-motion training, muscle strengthening training of the affected and healthy limbs, physiotherapy such as electrical stimulation and ultrasound, upper extremity function training, gait training, ADL training, and higher brain function (HBF) training for attention and visuospatial cognition by physiotherapists, occupational therapists and speech-language-hearing therapists,3 h daily. In addition, body weight support treadmill training (BWSTT)[5] using a partial load lifting device, and upper extremity training using the upper limb robot ReoGo-J[6] and integrated volitional control electrical stimulation (IVES)[7] were provided several times a week. In HBF training, we focused on training to directly improve attention and visuospatial cognition, such as symbol finding training, mistake finding training, mazes, and puzzles. His left hemiplegia improved to 27 and 22 upper and lower extremity points on the FMA, respectively. Table 1 shows the progress of the HBF evaluation. The BIT scores were above the cutoff; TMT, verbal comprehension, and perceptual organization (PO) of WAIS-III improved, although not to above the cutoff. The patient could perform ADL independently with an AFO and scored 121 on the FIM scale. He was discharged 246 days after symptoms onset.

2.1.3 | Outcome and follow-up

He attended a junior high school graduation ceremony during hospitalization. As he celebrated graduation with his classmates, his desire to attend regular high school grew stronger. He continued rehabilitation in the outpatient department 2 h daily, 2 days/week with good adherence, and goal-oriented training in the form of tests, simulating a high school entrance exam, resulted

TABLE 1 CARE checklist of information to include when writing a case report.

Item	Checklist item description	Reported on Lines
1	The diagnosis or intervention of primary focus followed by the words "case report"	Lines 2–3
2	2–5 key words that identify diagnoses or interventions in this case report, including "case report"	Lines 23–24
3a	Introduction: What is unique about this case and what does it add to the scientific literature?	Lines 19–22
3b	Main symptoms and/or important clinical findings	Lines 14–17
3c	The main diagnoses, therapeutic interventions, and outcomes	Lines 14–17
3d	Conclusion—What is the main "take-away" lesson(s) from this case?	Lines 14–17
4	One or two paragraphs summarizing why this case is unique (may include references)	Lines 31–38
5a	De-identified patient specific information	Lines 47–48, 104
5b	Primary concerns and symptoms of the patient	Lines 48, 105
5c	Medical, family, and psycho-social history including relevant genetic information	Lines 48, 104–105
5d	Relevant past interventions with outcomes	Lines 49–60, 105–111
6	Describe significant physical examination (PE) and important clinical findings	Lines 62–72, 113–121
7	Historical and current information from this episode of care organized as a timeline	Figures XXXX and xxxxx
8a	Diagnostic testing (such as PE, laboratory testing, imaging, surveys)	Lines 50–52, 64–72, 107–109, 114–121
8b	Diagnostic challenges (such as access to testing, financial, or cultural)	Lines 57–59
8c	Diagnosis (including other diagnoses considered)	Lines 57–59, 105–107
8d	Prognosis (such as staging in oncology) where applicable	Lines 71–72, 118–120
9a	Types of therapeutic intervention (such as pharmacologic, surgical, preventive, self-care)	Lines 54–57, 59–60, 78, 109–111, 127–128
9b	Administration of therapeutic intervention (such as dosage, strength, duration)	Lines 75–87, 125–130
9c	Changes in therapeutic intervention (with rationale)	Lines 94–97, 135–139, 141–144
10a	Clinician and patient-assessed outcomes (if available)	Lines 87–91, 130–134, 139
10b	Important follow-up diagnostic and other test results	Lines 97–99, 144–148
10c	Intervention adherence and tolerability (How was this assessed?)	Lines 95, 138
10d	Adverse and unanticipated events	Lines 100, 148–149
11a	A scientific discussion of the strengths AND limitations associated with this case report	Lines 191–196, 204–209
11b	Discussion of the relevant medical literature with references	Lines 156–160, 163–189
11c	The scientific rationale for any conclusions (including assessment of possible causes)	Lines 163–189, 197–203
11d	The primary "take-away" lessons of this case report (without references) in a one paragraph conclusion	Lines 214–217
12	The patient should share their perspective in one to two paragraphs on the treatment(s) they received	Lines 93–99, 141–147
13	Did the patient give informed consent? Please provide if requested	Yes. Lines 235–236

in fewer careless mistakes and improved sustained attention. The FIQ of the WAIS-III improved to 90 points (Table 2). One year later, he attended a regular high school. He joined a broadcasting club, created a documentary about himself, and won a prefectural competition. He is currently ranked two on the mRS and is studying social work in college. The patient did not develop recurrence and epilepsy.

2.2 | Case 2

2.2.1 | Case history

The patient was a right-handed 33-year-old female office worker who lived alone and had no relevant medical history. The patient presented with left hemiplegia and was transported to another hospital. She was diagnosed with

TABLE 2 Progress in the evaluation of higher brain dysfunction in Case 1.

Days from the onset	Admission 99	Discharge to home 246	Enrollment in high school 529
WAIS-III			
FIQ	68	71	90
VC	82	93	113
WM	76	85	91
PO	65	60	85
PS	76	73	76
BIT	123	137	–
TMT-A (sec)	120	85	–
TMT-B (sec)	180	136	–

Abbreviations: BIT, behavioral inattention test; FIQ, full-scale intelligence quotient; PO, perceptual organization; PS, processing speed; TMT, trail-making test; VC, verbal comprehension;WAIS-III, Wechsler Adult Intelligence Scale Third Edition; WM, working memory.

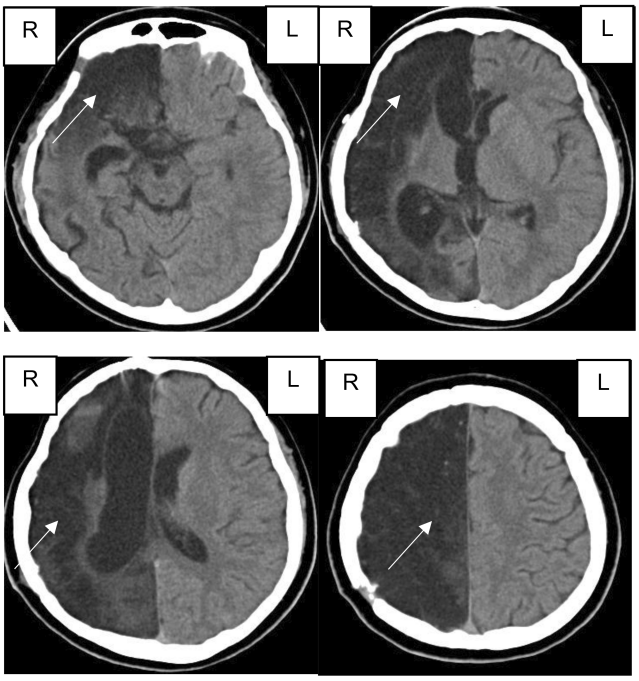

FIGURE 1 Brain computed tomography image for case 1 upon admission to the convalescent rehabilitation ward. Computed tomography images show extensive areas of low density in the right anterior, middle, and posterior cerebral artery regions (arrowheads).

cerebral infarction in the anterior and middle cerebral artery regions due to vasospasm and hyperthyroidism. She had no evidence of cardiac disease, arrhythmias, vascular malformations, coagulation system abnormalities, or autoantibodies other than the thyroid-stimulating hormone (TSH) receptor antibody (TRAb). On Days 2 and 5 of onset, the patient underwent internal and external decompression. She underwent cranioplasty 41 days after symptom onset. Hyperthyroidism was treated using thiamazole.

The patient was transferred to the convalescent rehabilitation ward of the Japanese Red Cross Ashikaga Hospital 50 days after onset. She had left hemiplegia with 9 and 10 upper and lower extremity points on the FMA, respectively, and moderate left sensory dullness. The patient had left spatial neglect on the BIT and impaired attentional function on the TMT-A and TMT-B (Table 3). The PO and processing speed (PS) scores of the WAIS-III were low. She had no abnormal cranial nerve findings, visual field deficits, dressing apraxia, constructional apraxia, or executive function disorders according to the BADS. She performed ADL with guidance in a wheelchair and scored 95 on the FIM scale. Brain MRI revealed an occluded right internal carotid artery, and the infarcted lesion extended into the right anterior and middle cerebral artery territories (Figure 3). Laboratory tests results for thyroid function were as follows: free triiodothyronine (FT3), 4.13 pg/mL; TSH, <0.01 μIU/mL; and TRAb, 4.9 IU/L. Figure 4 shows timeline for Case 2 presented in accordcance with CARE guidelines.

2.2.2 | Investigation and treatment

An endocrinologist regularly assessed the FT3 and TSH levels and adjusted the thiamazole dosage. Normalization of thyroid function prevented recurrent stroke, and the patient was not treated with antiplatelet or anticoagulant agents to prevent recurrence. She was provided with conventional daily rehabilitation as in Case 1 for 3 h daily. In addition, BWSTT and upper extremity functional training using the IVES were conducted. HBF training included training to promote visuospatial cognition to the left, as well as training using a computer that she was familiar with from her former work. Her left hemiplegia improved to 20 and 23 upper and lower extremity points on the FMA, respectively. Table 2 shows the progress of the

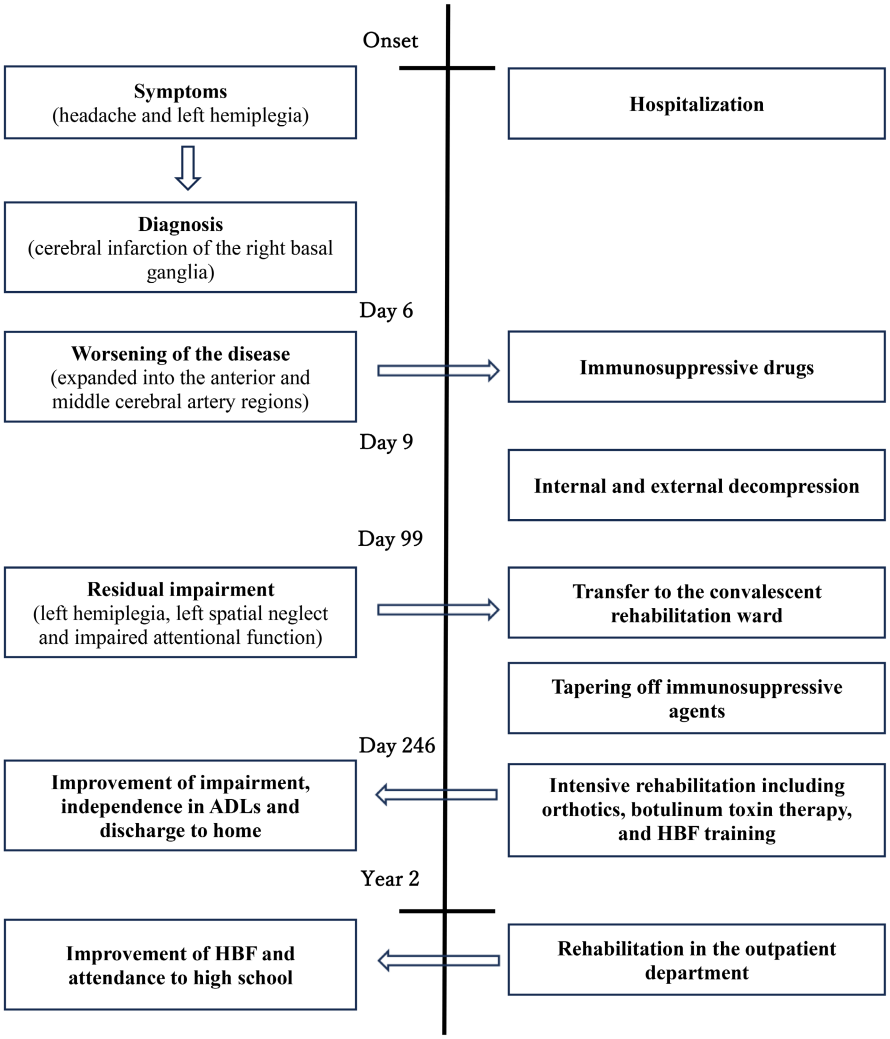

FIGURE 2 Timeline for Case 1 presented according to CARE guidelines. ADL, activities of daily living; HBF, higher brain function.

TABLE 3 Progress in the evaluation of higher brain dysfunction in Case 2.

Days from the onset	Admission 50	Discharge 153	Employment support 279	Starting work 837
WAIS-III				
FIQ	83	93	105	110
VC	111	116	111	131
WM	109	111	107	103
PO	57	61	70	89
PS	63	72	81	97
BIT	105	144	–	–
TMT-A (sec)	320	–	78	–
TMT-B (sec)	272	–	87	–

Abbreviations: BIT, behavioral inattention test; FIQ, full-scale intelligence quotient; PO, perceptual organization; PS, processing speed; TMT, trail-making test; VC, verbal comprehension;WAIS-III, Wechsler Adult Intelligence Scale Third Edition; WM, working memory.

HBF evaluation; the BIT scores were above the cutoff. The TMT, PO, and PS improved, although not to above the cut-off levels. The patient performed ADL independently with APS-AFO and scored 121 on the FIM. She was discharged 246 days after the onset and continued rehabilitation in the outpatient department. Flexion spasticity of the left elbow and fingers worsened to a score of three on the mAS; therefore, botulinum toxin therapy was initiated on

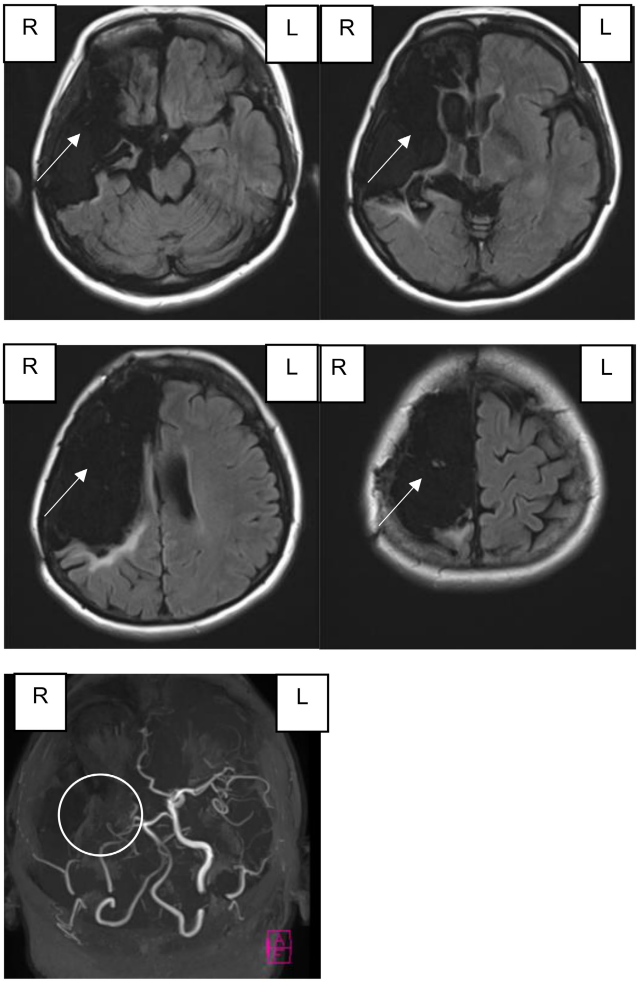

FIGURE 3 Brain magnetic resonance imaging for Case 2 upon admission to the convalescent rehabilitation ward. Diffusion-weighted images show extensive areas of high signal intensity in the right anterior and middle cerebral artery regions (arrowheads). Magnetic resonance angiography showing an occluded right internal carotid artery (circle).

the upper extremities, and the mAS improved from 1^{+}–2. She continued rehabilitation in the outpatient department 2 h daily, 1 day/week with good adherence. Goal-oriented training for clerical work resulted in fewer errors and a faster PS. The FIQ of the WAIS-III improved by over 100 points (Table 3).

2.2.3 | Outcome and follow-up

She began using employment support services with disability certificates from 246 days after the onset. The vocational center for persons with disabilities conducted an evaluation of her vocational skills. She started using employment transition support services 1 year after the onset of the disease, and acquired the knowledge and skills necessary for employment through actual work experience. Two years after the disease onset, she was hired from the disabled employment bracket, which promotes at least 2.5% of a company's workforce and requires reasonable consideration for disabilities in Japan, and was responsible for transcribing minutes and data entry. She travels nationally and internationally as a leisure activity. She is currently ranked two in mRS. She has no evidence of epilepsy nor the appearance of recurrence or vascular abnormalities on brain MRI.

3 | DISCUSSION

We present two cases of young patients with extensive infarction in the right anterior and middle cerebral artery regions, which differed from those of older patients regarding causes and outcomes. None of the patients were treated with antiplatelet agents or anticoagulants to prevent the recurrence of rare causes of stroke. Case 1 was suspected to have vasculitis or dissection; therefore, other than a temporary immunosuppressant, no medication was prescribed to prevent recurrence. Although aspirin treatment can be considered for an embolic stroke of an undermined source,[8] this case was carefully monitored without treatment. Case 2 was complicated by hyperthyroidism. Hyperthyroidism can cause atrial fibrillation, prothrombotic change,[9] and moyamoya disease, which were not observed in this case; therefore, the patients were treated with thiamazole alone. Both cases required appropriate collaboration between hospitals and departments, as well as careful follow-up.

In the present cases, the patients had good outcomes with regards to ADL and social reintegration despite extensive cerebral infarction. Patients with stroke aged 18–44 have significantly higher FIM scores than older patients.[10] Furthermore, return to work 12 months after stroke is associated with young age, acute stroke severity, and 3-month disability.[11] Case 2 required more than 12 months to return to work owing to the severe disability but was able to find new employment. Notably, younger patients with stroke need a higher prediction of ADL and return to societal goals regardless of stroke severity.

Age >35 years, the presence of cardiovascular risk factors, and large-artery atherosclerosis in the carotid territory are predictors of negative long-term outcomes, including higher mortality, recurrent stroke, and poorer functional recovery.[12] Aging and arteriosclerosis may contribute to a decline in residual brain function. The two patients in this report were aged <35 years old and had no cardiovascular risk factors or atherosclerosis, which resulted in a favorable functional prognosis.

These two patients were successfully enrolled in school and were employed as their HBF improved. In

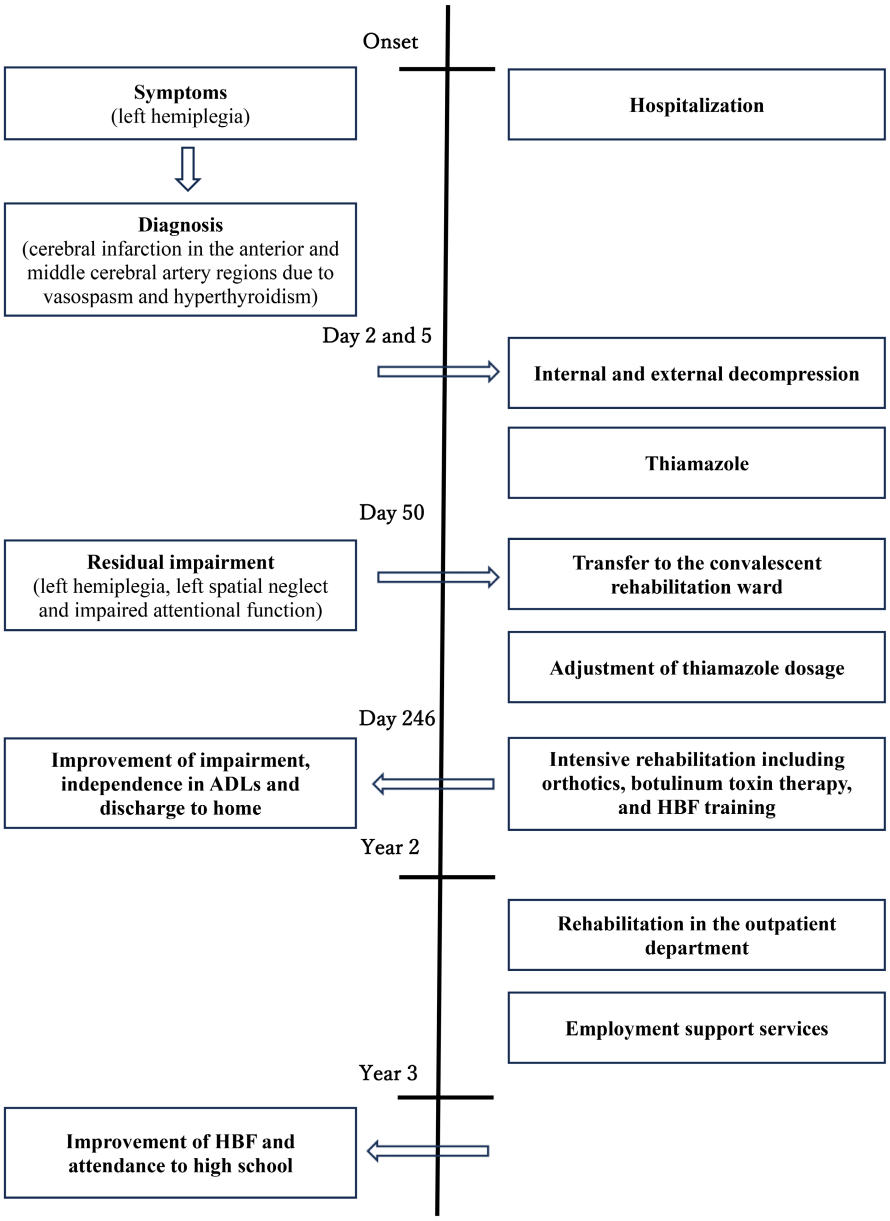

FIGURE 4 Timeline for Case 2 presented according to CARE guidelines. ADL, activities of daily living; HBF, higher brain function.

Japan, of those in school, 94.7% were able to return to school, and of those in employment, 68.5% were able to return to their original job, and 3.9% were able to change jobs.[1] In Australia, the United Kingdom, and Southeast Asia, 57% of the respondents returned to work.[2] In young patients with stroke, independence in ADL and discharge from home, schooling, and employment may be desirable. Greater independence in ADL, fewer neurological deficits, and better cognitive ability are the most common predictors of return to work,[13] whereas absence of aphasia, attention dysfunction, or walking ability are identified as significant predictors of returning to work.[14] Improvement in HBF and independence in walking and ADL are important for social reintegration.

Damage to the right cerebral hemisphere or frontal lobe often causes anosognosia and impaired self-awareness, which inhibits rehabilitation.[15] However, these two cases did not show such symptoms despite extensive infarction of the right cerebral hemisphere, including the frontal lobe. Impaired self-awareness is associated with bilateral cerebral dysfunction in the frontal lobe.[16] Lack of lesions in the left hemisphere and preserved brain function at a young age may have contributed to the retention of self-awareness. Furthermore, psychological and sociocultural factors can cause unawareness.[17] A stable personality, family support, and the provision of appropriate information about the disease may have prevented impaired self-awareness.

In the cases reported here, long-term and continuous rehabilitation, including botulinum toxin therapy and orthotic treatment in the acute, convalescent, and outpatient phases, led to favorable outcomes. For patients with moderate-to-severe acquired brain injury, continued

outpatient therapy could help sustain the gains made in early post-acute rehabilitation.[18] An intensive, patient-centered, interdisciplinary rehabilitation approach can considerably improve different domains, maximizing spontaneous recovery.[19] Focusing on the individual and developing age-appropriate person-centered stroke care is important.[20] Goal-oriented rehabilitation may be effective in returning to school and work.

The two cases in this report had the desired outcomes with the cooperation of parents, schools, and employment services. Family and school contexts often play a much larger role in pediatric stroke.[21] Similarly, socioeconomic factors are the most critical factors influencing the return to work, along with individual abilities, healthcare factors, and disabilities resulting from stroke.[22] Participants who received vocational rehabilitation reported being more satisfied with their work than those who received conventional care.[23] An active cooperation between medical institutions and work support agencies is critical.[24] Therefore, family, school, and employment services are important for positive patient outcomes. The limitation of this study is that it is a case report of only two cases due to rare causes, so it is not possible to determine whether the favorable outcomes are universal. In addition, both cases were right-sided cerebral lesions, and it is unclear whether similar results would be obtained with left or bilateral cerebral lesions. Furthermore, because rehabilitation is an individualized program, it is difficult to examine the effectiveness of each training program. Nationwide accumulation of data on outcomes of rehabilitation of young patients with cerebrovascular disease is desirable in the future.

In conclusion, for two young patients with extensive cerebral infarction of the right cerebrum, management was provided in the convalescent ward and outpatient clinics, including disease management in collaboration with various departments, rehabilitation including orthotics, botulinum toxin therapy, and HBF training, and support for further education and employment. The patients were able to attend higher education and work. As a take home message, young stroke patients may have a better course of rehabilitation than more common strokes, although treatment strategies for rare etiologies should be considered. Goal-oriented and long-term rehabilitation can help young patients with stroke achieve their goals, even those with severe disabilities.

AUTHOR CONTRIBUTIONS

Tomoyuki Nakamura: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; writing – original draft. **Shuhei Kurosaki:** Supervision; writing – review and editing. **Mikoto Baba:** Supervision; writing – review and editing. **Hiroshi Irisawa:** Supervision; writing – review and editing. **Takashi Mizushima:** Supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Not applicable.

ETHICS APPROVAL

Ethical approval was obtained from the Japanese Red Cross Ashikaga Hospital before the submission of this manuscript.

CONSENT

Written informed consent was obtained from the patient to publish this report in accordance with the journal's patient consent policy.

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