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Original Research

Functional Trajectory of Childhood Stroke in the Inpatient Rehabilitation Setting

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Abstract *Objective:* To examine the functional outcomes of a group of infants, children, and adolescents admitted to acute inpatient rehabilitation for neurologic impairments caused by a new childhood stroke.

Design: Retrospective cross-sectional cohort study.

Setting: A pediatric inpatient rehabilitation program in a stand-alone inpatient rehabilitation facility (IRF) located within an academic medical center.

Participants: A total of 91 patients (N=91) aged 6 months to 17.8 years were admitted to a pediatric inpatient rehabilitation program with a new diagnosis of childhood stroke.

Interventions: Standard of care pediatric inpatient rehabilitation treatment.

Main Outcome Measures: Change in the functional independence measure in children (WeeFIM) score across inpatient rehabilitation treatment.

Results: The 51 boys/39 girls/and 1 transgender patient were 9.6±5.7 years old with ischemic stroke (n=53) or hemorrhagic stroke (n=38). At admission, they had moderate-to-severe functional impairments (WeeFIM total score=46.5±25.5 points). Inpatient rehabilitation length of stay was 33.7±28.5 (range, 3-134) days. WeeFIM total score improved to 71.2±31.6 points at IRF discharge. Hemorrhagic (compared with ischemic) stroke was associated with higher rates of craniectomy (X^2=4.6, *P*=.03) and older age at IRF admission (Z=1.98, *P*<.05). Older age was associated with higher age-corrected WeeFIM total scores at admission (F=7.9, *P*=.0007) and discharge (F=18.1, *P*<.001), but age did not affect change in WeeFIM score.

Conclusions: Pediatric inpatient rehabilitation results in functional improvements for new neurologic impairments caused by childhood stroke.

Persistent neurologic impairments in childhood stroke survivors[1] result in long-term effects on physical, psychosocial, and academic outcomes.[2,3] Although rates of childhood stroke are lower compared to adult stroke, the lifelong individual and societal burden is greater in childhood stroke, as these individuals have many more years living with subsequent disability.[4] Because childhood stroke survival has improved,[5] more patients are accessing rehabilitation treatments. However, there are limited studies examining outcomes in response to rehabilitation.[6-8] Although there is a robust literature on rehabilitation outcomes in adult stroke, childhood stroke is distinct compared with adult stroke, with hemorrhagic stroke occurring at significantly higher rates, and overall outcomes are generally more favorable.[9-12] These differences highlight etiologic variability in childhood and adult stroke and limit extrapolation of results from studies in adult populations to childhood stroke.[13]

Previous studies examining the functional effects of inpatient rehabilitation for childhood stroke report on relatively small sample sizes.[14,15] As a result, there are nearly no studies reporting subgroup analyses with respect to stroke type, age, and hospital course and their effects on pediatric inpatient rehabilitation outcomes. Furthermore, the relative shortage of studies limits the literature from which clinicians can reference when discussing functional prognoses with patients and families with respect to childhood stroke recovery. The current study sought to address some of the deficits in the childhood stroke literature by examining functional outcomes in the largest cohort to date of patients that we know of with childhood stroke admitted to pediatric inpatient rehabilitation.

Methods

Study design and population

This was a retrospective cross-sectional cohort study of patients aged 6 months to 17.8 years who were admitted to a pediatric unit at a free-standing rehabilitation hospital between January 1, 2017, and July 31, 2023. Inclusion criteria were patients <18 years old at admission to inpatient rehabilitation with a new diagnosis of stroke.[15,16] Potential study patients were identified by reviewing facility-specific case listings in the Uniform Data System for Medical Rehabilitation. Stroke diagnosis was confirmed through medical chart review, including history and physical, pediatric neurology notes, and radiographic examinations. All patients with a new, radiologically confirmed diagnosis of ischemic, hemorrhagic, embolic, or thrombotic stroke, which was documented by either a neurology or neuroradiology specialist during the preceding acute care hospitalization, were included in the study. Perinatal stroke was not included in this study. All study procedures were approved by the local institutional review board. Because of the retrospective design, the study was exempted from written and verbal consent procedures.

Procedures

Patients completed pediatric inpatient rehabilitation in line with standard of care practice, which included a minimum of 15 hours per week of physical, occupational, and speech and language pathology therapies; patients completed an average of 3 hours per day of therapy, 5-6 days per week. Data on demographic characteristics, disease etiology, functional impairments, radiographic and laboratory studies, and surgical and pharmacologic treatments were obtained from the medical records.

The functional independent measure in children (WeeFIM)[17] is frequently used for tracking functional improvements in the pediatric inpatient rehabilitation setting[18,19] and was the primary outcome measure. The WeeFIM assessments were performed by each patient's primary therapy team and completed at IRF admission and discharge as part of clinical operations. The WeeFIM is a 126-point ordinal scale that assesses function across 18 items rated on a scale of 1 (dependent) to 7 (independent) in the domains of self-care, mobility, and cognition (table 1). To account for age-related effects on WeeFIM scoring, age-corrected WeeFIM scores were calculated from a product of the actual WeeFIM score and a ratio of the age-expected WeeFIM score divided by the overall maximum WeeFIM score.[20] Secondary outcome measures were the change in WeeFIM score and the IRF efficiency score, which was calculated from the ratio of WeeFIM score change and IRF duration and expressed as points/d.[21]

Statistics

Shapiro-Wilks test found that uncorrected and age-corrected WeeFIM totals and domain-specific scores were nonnormal. Therefore, nonparametric statistical methods were used throughout. Continuous variables were evaluated using the Spearman rank order test, and categorical variables were evaluated using the Wilcoxon signed rank order test.

Table 1 The WeeFIM scale for tracking functional gains in pediatric inpatient rehabilitation.

Domain 1: Self-care (maximum = 56)	Domain 2: Mobility (maximum = 35)	Domain 3: Cognition (maximum = 35)
Eating	Chair transfer	Comprehension
Grooming	Toilet transfer	Expression
Bathing	Tub transfer	Social interaction
Dressing-upper	Walk	Problem solving
Dressing-lower	Stairs	Memory
Toileting		
Bladder		
Bowel		

Contingency testing to compare categorical variables was performed using the Fisher exact test. All analyses were 2-tailed with α=0.05, Bonferroni corrected, and performed with Matlab R2015a (MathWorks Inc, Natick, MA).[a]

Results

Patient cohort

The final study group of 91 patients was 51 boys/39 girls/ and 1 transgender patient with a mean age OF 9.6±5.7 years. They ranged from 0.5 to 17.8 years old (median [IQR]=9.6 [4.1-15.0] y) at admission. Twelve individuals who had a previous IRF admission at an outside facility and 3 individuals who had 2 separate IRF admissions for different stroke injuries were excluded from the study group. Stroke type and etiologies across the group are shown in figure 1. Patients with ischemic stroke were younger compared with patients with hemorrhagic stroke (8.6±5.6y vs 10.9±5.7y, Z=1.98, P<.05). Although strokes spanned all cerebral and cerebellar vascular distributions, strokes affecting the middle cerebral artery distribution were the most common (n=46).

Acute hospital course

The acute care hospitalization (or time from stroke diagnosis to IRF admission) was 33.4±36.6 (median [IQR], 23 [12-40]) days. All patients were admitted to IRF directly from acute care. Neurosurgical interventions included decompressive craniectomy in 23 patients, ventriculoperitoneal (VP) shunt placement in 13 patients, and lobectomy in 5 patients. There were 5 patients who had both decompressive craniectomy and VP shunt placement. Two patients had decompressive craniectomy, VP shunt placement, and lobectomy. Acute hospitalization was longer for patients who required decompressive craniectomy (57.0±58.6d vs 26.3±23.0d, Z=3.05, P=.002) and VP shunt placement (71.8±70.9d vs 27.0±22.0d, Z=2.87, P=.004).
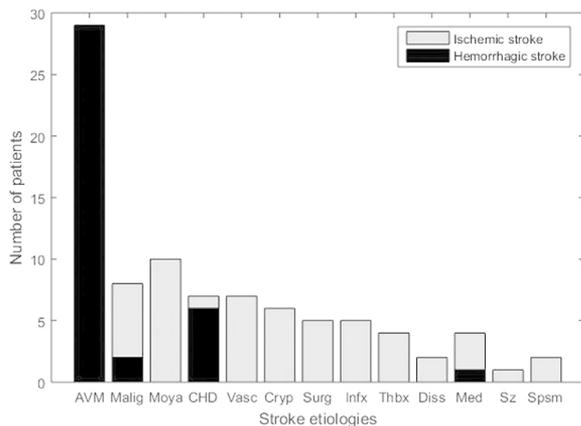

Fig 1   Stroke type and etiology in patients admitted to pediatric inpatient rehabilitation with childhood stroke.

Inpatient rehabilitation course

The admission total WeeFIM score was 46.5±25.5 points (maximum, 126 points) with domain-specific scores of 20.6±12.5 points in self-care (maximum, 56 points), 10.7±6.2 points in mobility (maximum, 25 points), and 15.2±9.4 points in cognition (maximum, 25 points). The IRF duration was 33.7±28.5 days, which ranged from 3 to 134 days (median [IQR], 24.0 [14-41] d). There were 72 patients who had continuous inpatient rehabilitation admission. Of 19 patients who required interval return to acute care for additional medical workup and stabilization, the average leave of absence was 13.8±23.0 days; these included 4 patients who had planned gastrostomy.

Statistically significant improvement in uncorrected and age-corrected WeeFIM scores was achieved during IRF treatment (fig 2). At discharge, total WeeFIM score improvement was 24.7±17.6 points with domain-specific improvement 10.9±9.1 points in self-care, 8.5±6.2 points in mobility, and 5.3±5.0 points in cognition; mean IRF uncorrected efficiency score was 1.17±1.5 (median [IQR], 1.0 [0.4-1.5]) points/d. There were no patients who experienced a decline in uncorrected total WeeFIM score; 6 patients did not improve their uncorrected WeeFIM score. For patients aged >3 years (n=70), the age-corrected WeeFIM score improvement was 31.1±16.1 points with domain-specific improvement 14.2±8.6 points in self-care, 10.5±5.6 points in mobility, and 6.4±5.1 points in cognition; the mean IRF age-corrected efficiency score was 1.5±1.6 (median [IQR] = 1.3 [0.8-1.6]) points/d.

Effects of stroke type on hospital course and functional outcome

Patients with hemorrhagic stroke had longer acute care hospitalization compared with patients with ischemic stroke, but this difference did not reach statistical significance (34.4±30.6d vs 32.6±40.7d, Z=1.89, P=.06). Craniectomy was also more common in those with hemorrhagic stroke (13/38 vs 8/53, X^2=4.6, P=.03). There was no difference in rates of VP shunt placement across hemorrhagic and ischemic strokes. Hemorrhagic compared with ischemic stroke type differences in mean age-corrected WeeFIM total score at IRF admission (49.8±23.7 vs 58.0±24.3, P=.1) were smaller at IRF discharge (84.1±21.6 vs 86.4±22.1, P=.6). Patients with hemorrhagic stroke had lower age-corrected WeeFIM mobility domain scores at admission (10.5±5.4 vs 13.2±6.7, Z=2.01, P=.04). Otherwise, there were no group differences in age-corrected WeeFIM domain scores at admission or discharge with respect to stroke type.

Age and sex effects on stroke type, hospital course, and functional outcomes

Patients with hemorrhagic stroke were older compared with those with ischemic stroke (10.9±5.7y vs 8.6±5.6y, Z=1.98, P<.05). However, there was no effect of age on acute hospitalization duration or IRF length of stay. There were no differences in age in rates of craniectomy or VP shunt placement. Older age was associated with higher age-corrected WeeFIM total scores at IRF admission (F=7.9, P=.007)
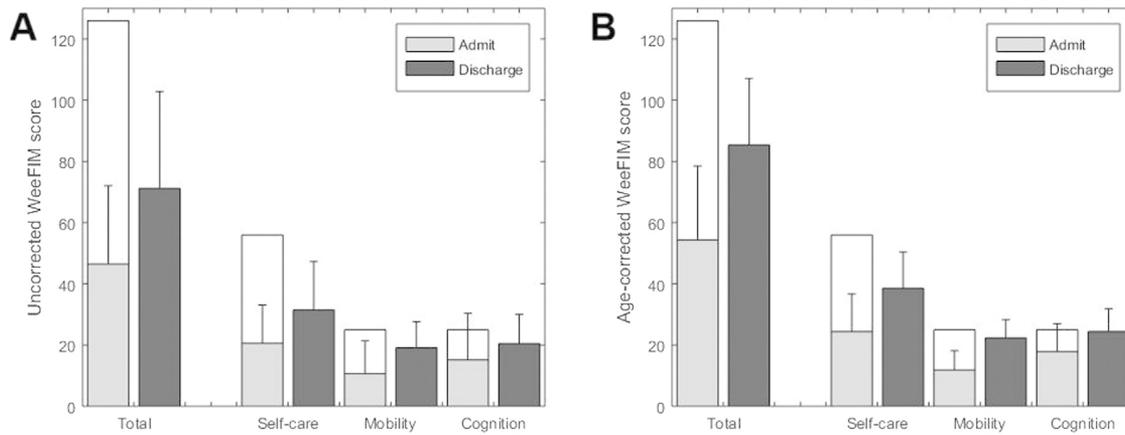
Fig 2 WeeFIM total and domain-specific scores were measured at IRF admission and discharge. The white bar demonstrates the maximum possible points for total score (126 points), self-care domain (56 points), mobility domain (25 points), and cognition domain (25 points). (A) Uncorrected WeeFIM score improvements for total score (24.7±17.6 points, Z=13.4, P<.0001), self-care domain (10.9±9.1 points, Z=11.5, P<.0001), mobility domain (8.5±6.2 points, Z=13.1, P<.0001), and cognition domain (5.3±5.0 points, Z=10.1, P<.0001). (B) Age-corrected score improvements for total score (31.1±16.1 points, Z=16.2, P<.0001), self-care domain (14.2±8.6 points, Z=13.7, P<.0001), mobility domain (10.5±5.6 points, Z=15.8, P<.0001), and cognition domain (6.4±5.1 points, Z=10.4, P<.0001).

and IRF discharge (F=18.1, P<.001). However, there was no effect of age on the change in the age-corrected WeeFIM total score (P=.3) or the age-corrected IRF efficiency (P=.9).

Boys (51/91) were more frequent compared with girls (39/91), but the difference was not statistically significant (X^2=1.9, P>.17). Sex also did not affect differences in stroke type, acute hospitalization duration (X^2=3.7, P=.2), or rates of craniectomy (X^2=2.8, P>.2) and VP shunt placement (X^2=2.7, P>.2). Boys had longer IRF length of stay (36.9± 30.5d vs 27.2±25.0d, X2=6.1, P<.05), but age-corrected WeeFIM total score at admission (52.3±23.9 vs 56.4±25.2 points, X^2=0.6, P>.7) and discharge (81.0±23.3 vs 89.8± 19.0 points, X2=4.6, P=.1) were similar across sexes.

Medical management in the inpatient rehabilitation setting

There were 33 patients requiring agitation medication at IRF admission. Most patients were on clonidine monotherapy (n=18), followed by benzodiazepine monotherapy (lorazepam=3, diazepam=2, clonazepam=1), clonidine with benzodiazepine dual therapy (diazepam=2, lorazepam=1), clonidine with propranolol dual therapy (n=2), and quetiapine monotherapy (n=2). There was also 1 patient on 4 agitation medications (clonidine, lorazepam, propranolol, quetiapine) and 1 patient on 3 agitation medications (clonidine, diazepam, propranolol). Patients on agitation medications were generally younger (7.8±5.6y vs 10.6±5.6y, Z=2.07, P=.04), had longer acute care hospitalization (57.2±50.0d vs 19.9±14.1d, Z=5.58, P<.0001), and had longer IRF length of stay (54.4±34.2d vs 22.0±15.3d, Z=5.63, P<.0001). Hemorrhagic vs ischemic stroke type did not affect rates of agitation medication at IRF admission (P>.1). However, patients who had either craniectomy (14/33 vs 7/ 58, X^2=10.9, P=.001) or VP shunt placement (8/33 vs 5/58, X^2=4.2, P=.04) were more likely to require agitation medication at IRF admission. Patients requiring agitation

medication had a lower age-corrected WeeFIM total score at admission (38.8±20.8 vs 60.9±22.6, Z=3.53, P=.004) and at discharge (60.1±25.8 vs 88.2±19.5, Z=2.66, P=.008). Continued agitation at IRF discharge was also associated with a smaller change in age-corrected WeeFIM total score (16.7± 9.3 vs 32.7±16.0, Z=2.64, P=.008) and lower age-corrected IRF efficiency (0.48±0.3 vs 1.58±1.7, Z=3.43, P=.0006).

At admission, 42 patients were on anticoagulant or antiplatelet therapy. Most patients were on aspirin monotherapy (n=29), with aspirin/clopidogrel being the most common dual therapy (n=4). There were also patients on clopidogrel (n=2), warfarin (n=2), enoxaparin (n=2), rivaroxaban (n=1), and apixaban (n=1) monotherapy; there was 1 patient on aspirin/enoxaparin dual therapy. Patients with ischemic stroke were more likely to be admitted with anticoagulant or antiplatelet therapy compared with those with hemorrhagic stroke (39/53 vs 3/38, X^2=38.4, P<.001). Anticoagulant or antiplatelet therapy status did not show an effect on acute hospitalization course, including requirement for craniectomy (P>.06) or VP shunt placement (P>.2) or acute hospitalization duration (P>.2). However, patients on anticoagulant or antiplatelet therapy at IRF admission had shorter IRF length of stay (25±17.9d vs 41.2±33.5d, Z=2.47, P=.01), higher age-corrected WeeFIM total score at admission (65.3±21.5 vs 46.5±23.2, Z=3.25, P=.001), and higher age-corrected IRF efficiency (1.49±0.9 vs 1.44±2.0, Z=1.71, P=.09).

Eighteen patients started on stimulant therapy during IRF treatment. The most common stimulant at discharge was immediate-release methylphenidate monotherapy (n=12), followed by long-acting methylphenidate monotherapy (n=5) and immediate-release methylphenidate with guanfacine dual therapy (n=1). The youngest patient trialed on stimulant therapy was 4.1 years old, and younger age was associated with increased likelihood of stimulant therapy (9.5±4.2y vs 12.7±4.1y, Z=2.6, P=.009). Patients with a stimulant trial had lower age-corrected WeeFIM total scores at IRF admission (38.6±17.8 vs 59.3±24.0 points, Z=3.03,

P=.003) and at IRF discharge (75.6±21.0 vs 88.5±21.2 points, Z=2.4, P=.02), with group differences primarily driven by domain-specific differences in age-corrected Wee-FIM Cognition scores at admission (13.3±6.0 vs 19.4±9.5 points, Z=2.27, P=.02) and discharge (21.3±7.3 vs 25.3±7.2 points, Z=1.96, P=.05). Furthermore, those discharged on stimulant therapy generally showed larger gains in both age-corrected WeeFIM total score (36.9±18.7 vs 29.2±14.9 points, Z=1.8, P=.07) and cognition domain score (8.0± 4.6 vs 5.9±5.2 points, Z=1.8, P=.07).

Discussion

The study found that infants, children, and adolescents with childhood stroke demonstrated global and domain-specific functional improvements across 34 days of inpatient rehabilitation treatment. Like previous studies of pediatric stroke, which show a sex disparity,[15,22] there was a slight predominance of boys and a higher frequency of hemorrhagic stroke compared with adult populations. Patient age, stroke type, and acute hospital course showed variable effects on inpatient rehabilitation outcomes for childhood strokes. Several aspects of medical management also showed significant functional effects.

Repeated WeeFIM assessments found that the group of infants, children, and adolescents experienced global and domain-specific improvements in childhood stroke-related impairments. Total WeeFIM score improved from 46.5 points at admission to 71.2 points at discharge, which corresponds to clinical improvement from maximum assistance at admission to moderate assistance at discharge,[20] and is comparable with previous studies on pediatric acquired brain injury.[23,24] Compared with pediatric patients with nontraumatic hypoxic or anoxic brain injury, childhood stroke is associated with lesser impairment and improved functional gains.[25] However, patients with traumatic brain injury show higher IRF efficiency relative to this group of patients with childhood stroke.[26] The group showed domain-specific improvements of 10.9 points in self-care, 8.5 points in mobility, and 5.3 points in cognition, exceeding previously published minimum clinically important differences in each WeeFIM domain-specific score.[27] Together, these results support that pediatric inpatient rehabilitation is beneficial for optimizing recovery in childhood stroke.

Older age at admission was correlated with a higher Wee-FIM total score at both admission and discharge. These results align with previous reports demonstrating that older age is generally associated with better outcomes after childhood stroke.[9,28] However, age did not show a statistical relationship to change in WeeFIM score across pediatric inpatient rehabilitation treatment, a result consistent with a previous report from Saudi Arabia,[14] and supports the overall finding that pediatric patients across all ages functionally benefit from inpatient rehabilitation treatment after childhood stroke.

Agitation that required pharmacologic treatment was associated with worse functional outcomes. The current cohort had 33 of 91 patients (36%) admitted with agitation medication. In contrast, studies of adult stroke find that <10% of individuals require agitation medication.[29] This difference is partially attributed to higher rates of hemorrhagic stroke in pediatric compared with adult populations[30]; although the frequency of agitation in this study is higher than previously cited rates for hemorrhagic and ischemic adult stroke.[29,31] This study found that agitation in adult stroke was associated with longer IRF treatment and smaller functional gains. Notably, the rates of agitation in this study are similar to rates in severe pediatric traumatic brain injury.[32] Given strong associations between agitation and poor clinical outcomes in pediatric traumatic brain injury,[33] the high rates of agitation in this study highlighted the need for vigilant assessment and management of agitation for all pediatric acquired brain injuries.

Anticoagulation and antiplatelet therapy were correlated with higher WeeFIM scores at admission and higher IRF efficiency. In adult stroke, aspirin and antiplatelet therapies have shown benefits with respect to decreasing mortality and recurrent stroke.[34,35] Expert clinical opinions generally support antiplatelet agents for secondary stroke prophylaxis in children and adolescents,[36,37] but there are limited studies examining rehabilitation outcomes in response to secondary stroke prophylaxis. This study found that patients admitted with anticoagulation and antiplatelet therapy demonstrated less impairment at admission and higher IRF efficiency. Potentially, the functional differences noted with respect to anticoagulation or antiplatelet therapy suggest microvascular differences in cerebral blood flow that optimize recovery.[34,38] However, the high proportion of patients with ischemic stroke in this group limits generalizability across stroke types. Potential effects of stroke types on differences in rehabilitation outcomes with respect to secondary stroke prophylaxis could be evaluated in future studies.

Patients with lower cognition domain scores at admission were more likely to have a stimulant trial. Patients who had an IRF stimulant trial also demonstrated larger gains in age-corrected WeeFIM total score and cognition domain score. Early acceleration of cognitive function with stimulant therapy in the IRF setting could have long-term implications for academic and psychosocial outcomes after childhood stroke.[39,40] With rates of attention disorders as high as 50% after childhood stroke,[40,41] studies examining the short- and long-term effects of stimulants for cognition recovery are especially salient in childhood stroke. To date, literature supporting the use of stimulant therapy in rehabilitation settings is focused on pediatric traumatic brain injury.[42,43] The current results support ongoing evaluation of stimulants to treat disorders of attention and executive function in other pediatric brain injury conditions, including childhood stroke.

Study limitations

The current study is limited by its retrospective design. Prospective, multicenter studies are needed to characterize the natural history, short- and long-term outcomes, and therapeutic targets for improving rehabilitation in childhood stroke. Broad generalizability of the current findings is also limited by the significant diversity of patients regarding age, stroke etiology, and stroke type. However, as the largest cohort of inpatient rehabilitation patients with childhood stroke to date, this study provides critical baseline metrics for future, more targeted prospective studies examining the effects of rehabilitation interventions. In addition, the

group differences noted with respect to medical management represent new avenues for investigating mechanisms underlying variability in clinical outcomes and developing new methods for maximizing neurorecovery.

Conclusions

Childhood stroke results in a wide range and variety of deficits, leading to lifelong implications for health and wellness. Recovery is often at the forefront of patients' and families' concerns, and prognosis conversations at this stage can often be challenging. The current study found inpatient rehabilitation results in statistically and clinically significant gains with medical management in the IRF setting to enhance overall functional outcomes.

Supplier

a. Matlab R2015a.
b. MathWorks.

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Disclosure

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