Predictive value of the Movement Assessment Battery for Children - Second Edition at 4 years, for motor impairment at 8 years in children born preterm

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ABBREVIATIONS

GCA	General Conceptual Ability
MABC-2	Movement Assessment Battery for Children - Second Edition

AIM To assess the predictive validity at 4 years of the Movement Assessment Battery for Children - Second Edition (MABC-2) for motor impairment at 8 years in children born preterm. We also aimed to determine if sex, cognition, medical, or social risks were associated with motor impairment at 8 years or with a change in MABC-2 score between 4 years and 8 years.
METHOD Ninety-six children born at less than 30 weeks' gestation were assessed with the MABC-2 at 4 years and 8 years of age. Motor impairment was defined as less than or equal to the 5th centile. The Differential Ability Scales - Second Edition (DAS-II) was used to measure General Conceptual Ability (GCA) at 4 years, with a score <90 defined as 'below average'.
RESULTS There was a strong association between the MABC-2 total standard scores at 4 years and 8 years (59% variance explained, regression coefficient=0.80, 95% confidence interval [CI] 0.69–0.91, $p<0.001$). The MABC-2 at 4 years had high sensitivity (79%) and specificity (93%) for predicting motor impairment at 8 years. Below average cognition and higher medical risk were associated with increased odds of motor impairment at 8 years (odds ratio [OR]=15.3, 95% CI 4.19–55.8, $p<0.001$, and OR=3.77, 95% CI 1.28–11.1, $p=0.016$ respectively). Sex and social risk did not appear to be associated with motor impairment at 8 years. There was little evidence that any variables were related to change in MABC-2 score between 4 years and 8 years.
INTERPRETATION The MABC-2 at 4 years is predictive of motor functioning in middle childhood. Below average cognition and higher medical risk may be predictors of motor impairment.

Infants born preterm and very low birthweight (VLBW, birthweight <1000g) are at an increased risk of motor and other developmental delays compared with peers born at term and normal birthweight.[1,2] These motor delays vary greatly and can affect participation in age appropriate activities. Importantly, mild to moderate motor dysfunction has been reported to persist throughout childhood; however, the severity may change over time.[3]

Healthcare professionals and researchers require standardized assessment tools to identify, classify, and diagnose motor problems in children.[4] One of the most commonly used motor assessment tools in children born preterm is the Movement Assessment Battery for Children - Second Edition (MABC-2).[4] The MABC-2 assesses motor competence in Manual Dexterity, Aiming and Catching, and Balance domains in children aged 3 to 16 years. It is often used in both research and clinical settings.[5,6]

Follow-up motor assessments for children born preterm are often performed at ages associated with major motor and developmental milestones. The MABC-2 has been shown to detect a higher rate of motor impairment in children at 4 years who were born preterm compared with the Bayley Scale of Infant Development (Third Edition) assessment performed at 2 years of age.[4] However, the accuracy of the MABC-2 in predicting motor performance at older ages has not yet been adequately investigated.

There are several studies that identify risk factors for motor impairment in children born preterm.[7–9] These include high-risk medical issues such as brain abnormality/injury and postnatal corticosteroids, which have been linked with worse motor outcomes.[10] However, whether or not other factors – such as gestational age at birth, low birthweight, and bronchopulmonary dysplasia – affect long-term motor outcomes is contentious.[7] Importantly, there is currently no consensus

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on which factors are associated with improvement or decline in motor proficiency during school age.

Male sex has been linked with poorer overall motor outcomes in children born preterm who are free of major disability.[10] This is thought to be related to the protective qualities of sex hormones such as oestrogen in utero, as well as innate neurobiological differences between the sexes.[11] It is not known whether males born preterm with motor impairment show a greater improvement in motor competency than females born preterm with motor impairment over time.[3]

Environmental and social factors also impact on the motor development of children born preterm. The physical home environment, access to play materials, and primary caregiver interaction have been linked with early childhood gross motor outcomes.[12] However, whether these factors play a role in the progression of gross motor skills in school-aged children who were born preterm is not yet known.

The relationship between low cognition and poorer motor outcomes in children born preterm is well established,[10] and is related to the complex neuropathological process associated with very preterm birth.[13] Poorer cognition may impair children's ability to learn more complex motor skills throughout school, which may result in an increasing difference in motor function when compared with their peers.

The primary aim of this study was to assess the predictive validity of the MABC-2 at 4 years for subsequent motor outcomes at 8 years in children born preterm. Further we aimed to explore the association between male sex, higher medical risk, higher social risk, and below average cognition at age 4 years on motor impairment at 8 years, and on the change in motor skills from age 4 to 8 years in children born preterm. We hypothesized that there would be an association between each of these factors and motor impairment at age 8 years, and that children of higher medical or social risk, females, and those with low cognition would show a decline on the MABC-2 total standard scores between 4 years and 8 years.

METHOD

Participants

The study cohort comprised 120 children who were born very preterm (defined as <30wks' gestation) and had been admitted to the Royal Women's Hospital or The Royal Children's Hospital, Melbourne, Australia, between January 2005 and January 2007. These children were recruited as a part of a previously published randomized controlled trial investigating the role of a preventative care programme on developmental outcomes.[14] The children were followed up at 4 years and 8 years of age. There was little evidence of a difference in the motor outcomes between the intervention and control groups at 4 or 8 years of age, and therefore outcomes were pooled for the current study.[4,14,15] At 8 years of age, families were invited to participate in a further follow-up assessment.

Ethical approval for the original and follow-up studies was obtained through the Royal Children's Hospital and Monash University ethics committees.

What this paper adds

- Rates of motor impairment in children born before 30 weeks gestational age are stable between 4 years and 8 years.
- MABC-2 performed at 4 years is predictive of motor impairment at 8 years in children born before 30 weeks gestational age.
- Below average cognition and higher medical risk may be associated with increased odds of motor impairment at 8 years in children born before 30 weeks gestational age.

Data collection

Perinatal data including gestational age, birthweight, and sex were obtained at baseline. Diagnosis of cerebral palsy (CP) and the Gross Motor Classification System (GMFCS) level[16] were made at 4 years of age by the child's paediatrician based on a neurological examination. This diagnosis was confirmed by one of two physiotherapists in the research study who also assigned a GMFCS level to the children. Children were assessed at 4 years and 8 years for motor, cognitive, social, and behavioural outcomes. Assessors were blinded to the child's previous assessments and perinatal history.

Outcome measures

Movement Assessment Battery for Children - Second Edition (MABC-2)

The primary outcome for the current study was motor function at 8 years as measured on the MABC-2 by a physiotherapist trained in its administration. The MABC-2 has been shown to be a valid and reliable measure of motor competence.[17–20] The raw score for each subtest was converted to a subtest standard score based on the child's age. The subtest standard scores were then combined to give the total test score. This was then converted to the total standard score and centile rank using the reference tables supplied in the manual. A score less than or equal to the 5th centile was used to classify the child as having a 'significant movement difficulty' or 'motor impairment' and a score from the 6th to 15th centile as 'at risk of movement difficulty'. The children with major motor impairments who were unable to complete the MABC-2 were assigned a centile of 1. Those who commenced but were unable to complete the MABC-2 were also assigned a centile of 1 as per the MABC-2 manual.[6]

Predictors of motor outcome

Medical risk

Higher medical risk was defined as a child who had cystic periventricular leukomalacia (PVL), grade 3 or 4 intraventricular haemorrhage (IVH), bronchopulmonary dysplasia (oxygen dependence at 36wks postmenstrual age), or was treated with postnatal corticosteroids.

Social risk

Social risk was determined by six aspects of social status (primary caregiver education, primary income earner employment status, primary income earner occupation, family structure, language spoken, maternal age), as previously described.[21] Participants were assessed for social risk at both term-equivalent age and at 4 years. If they scored

2 or more out of 12 on either assessment they were classed as higher social risk.

Differential Ability Scales - Second Edition (DAS-II)

The Differential Ability Scales - Second Edition (DAS-II) was administered by study psychologists. This measure assesses cognitive ability in children based on their performance across six core subtests evaluating verbal, nonverbal, and spatial reasoning.[22] Raw scores for each subtest obtained at 4 years of age were converted to age-based standard scores. For analysis in the current study we used the General Conceptual Ability (GCA) scale, which is an age standardized composite of the core subtests (mean=100, standard deviation [SD]=15), providing an overall measure of reasoning and conceptual abilities. The GCA has been shown to have good construct validity.[23] Children who were incapable of completing the DAS-II had their results coded as 'missing' (Table SI, online supporting information). A GCA composite score of <90 was classified as 'below average' as per the test classification system.[24]

Data analysis

Data analysis was performed using Stata version 14 (StataCorp, College Station, TX, USA). The current study participants were compared with those lost to follow-up using summary measures (mean and SD for continuous variables and numbers and proportions for binary variables).

Associations between MABC-2 total standard scores at 4 years and 8 years were assessed using scatterplots and linear regression. Linear regression was performed using Generalized Estimating Equations (GEEs) with results presented using sandwich estimates of standard error to allow for the non-independence (clustering) of twins. The R^2 value is also presented to demonstrate the proportion of the variability in the outcome at 8 years that is explained by the score at 4 years. Sensitivity, specificity, positive predictive value, and negative predictive values with 95% confidence intervals (CI) were used to assess the ability of the total motor score on the MABC-2 at 4 years to predict motor impairment at 8 years. MABC-2 scores at 4 years were explored as predictors of motor impairment at 8 years using logistic regression. This was repeated with medical risk, sex, cognition, and social risk as predictors of motor impairment at 8 years, using separate models for each predictor because of the small number of events. Logistic regression models were again fitted using GEEs with results presented as odds ratios and 95% CI from the models. Analyses were performed including and excluding participants with a confirmed diagnosis of CP.

Finally, medical and social risk, sex, and cognition were explored as predictors of change in MABC-2 score from 4 to 8 years using separate linear regression models. Models were again fitted using GEEs with sandwich estimates of standard errors, with results presented as regression coefficients per unit change in the predictor and 95% CIs. Again, analyses were performed including and excluding participants with a diagnosis of CP.

To investigate the impact of the missing data (20%) in the regression analysis, a secondary analysis was performed using multiple imputation to handle the missing data where we assumed that data were missing at random. All outcomes were imputed using a single imputation model (using chained equations) using demographics, birth and medical history, and motor and cognitive ability of the child as auxiliary variables. Twenty imputations were generated and pooled for analysis. Logistic regression after multiple imputation was performed using the methods specified previously.

RESULTS

Of the 120 children born at less than 30 weeks' gestation from the original cohort, 106 completed the MABC-2 at 4 years (two were deceased and 12 withdrew or were lost to follow-up), and a further 10 of these either withdrew from the study or were lost to follow-up at 8 years. The remaining 96 children were included in the initial data analysis (presented below), with all 120 children included in the secondary analysis (presented in Table SII, online supporting information). There were six children diagnosed with CP included in the study (three with quadriplegia, two with hemiplegia, and one with diplegia). On the GMFCS three children were level 2, two were level 3, and one was level 5.[16] Of note, all children with CP were in the lowest 5th centile at both 4 years and 8 years. The children born preterm included in the analysis had some differences to those who were recruited but did not complete follow-up. These differences were evident in birthweight, higher social risk, and proportion of GCA scores <90 (Table I). The mean age at the 4 year assessment was

Table I: Characteristics of study participants and non-participants

	Children born preterm included (*n*=96) Mean (SD)	Children born preterm not included (*n*=24) Mean (SD)
Gestational age at birth	27wks 2d (10d)	27wks 1d (12d)
Birthweight (g)	1034 (263)	916 (262)
	n (%)	*n* (%)
Multiple births	33 (34)	6 (25)
Male	53 (55)	8 (33)
Bronchopulmonary dysplasia	29 (30)	6 (25)
Postnatal corticosteroids	4 (4)	1 (4)
Grade 3/4 intraventricular haemorrhage	8 (8)	0 (0)
Cystic periventricular leukomalacia	3 (3)	0 (0)
Higher medical risk	36 (38)	6 (25)
4y of age		
CP	6 (6)	0 (0)
MABC-2		
≤5th centile	24 (25)	4/10 (40)
6–15th centile	3 (3)	0/10 (0)
>15th centile	69 (72)	6/10 (60)
Not assessed	0 (0)	14 (58)
General Conceptual Ability <90[a]	17/93 (18)	4/10 (40)
Higher social risk	50/91 (55)	16/16 (100)

[a]From the Differential Ability Scales - Second Edition. SD, standard deviation; CP, cerebral palsy; MABC-2, Movement Assessment Battery for Children - Second Edition.

4 years 4 months (range 4y–5y 5mo), and the mean age at follow-up at the 8 year assessment was 7 years 11 months (range 7y–9y 9mo).

While the rates of motor impairment remained stable at 25% from 4 years and 8 years, the sex proportions changed over time. At 4 years, 40% of males and only 7% of females had MABC-2 scores in the 5th centile. However, at 8 years of age the percentage of females with motor impairment had risen to 16%, and males had decreased to 32%.

There were strong positive associations between the MABC-2 total standard scores at 4 years and MABC-2 total standard scores at 8 years for the total cohort including those with CP (59% variance in MABC-2 score at 8y explained by the score at 4y, regression coefficient=0.80, 95% CI 0.69–0.91, $p<0.001$; Fig. 1), and when children with CP were excluded (50% variance in MABC-2 score at 8y explained, regression coefficient=0.75, 95% CI 0.62–0.89, $p<0.001$). This relationship was stronger in the secondary analysis using multiple imputation to handle the missing data (62% variance in MABC-2 score at 8y explained, regression coefficient=0.82, 95% CI 0.68–0.96, $p<0.001$).

Diagnostic accuracy of MABC-2 at 4 years for MABC-2 at 8 years

The sensitivity, specificity, positive, and negative predictive values of the MABC-2 cut offs at 4 years for predicting motor impairment at 8 years were all high (Table II). They were slightly better using 5th centile than 15th centile.

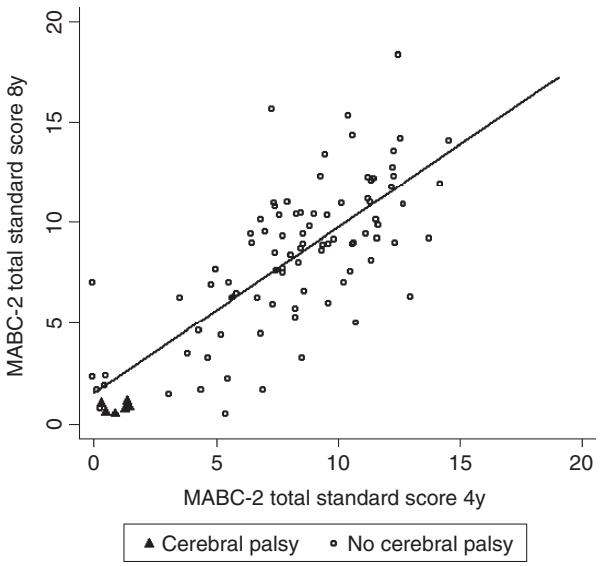

Figure 1: Relationship between the Movement Assessment Battery for Children - Second Edition (MABC-2) total standard scores at 4 years and 8 years of age with fitted regression line. Jittering (the addition of spherical random noise) was added to avoid points being plotted on top of one another.

Predictors of motor impairment at 8 years

Motor impairment at 4 years of age was strongly associated with motor impairment at 8 years, regardless of inclusion or exclusion of participants with CP (Table III). Higher medical risk and below average cognition were associated with motor impairment at 8 years. There was little evidence that social risk was associated with motor outcome

Table II: Movement Assessment Battery for Children - Second Edition. Study participant results and diagnostic values for classifications at 4y in predicting classifications at 8y in children born preterm

		8y			
		≤5th centile	6–15th centile	>15th centile	Total
4y	≤5th centile	19[a]	1	4	24
	6–15th centile	0	2	1	3
	>15th centile	5	4	60	69
	Total	24	7	65	96

4y	8y	Sensitivity (95%CI)	Specificity (95%CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)
≤5th centile	≤5th centile	79 (58, 93)	93 (85, 98)	79 (58, 93)	93 (85, 98)
≤15th centile	≤15th centile	71 (52, 86)	92 (83, 97)	81 (62, 94)	87 (77, 94)

[a]Includes six children with cerebral palsy. CI, confidence interval.

Table III: Predictors of motor impairment (MABC-2 ≤5th centile) at 8y of age

	Motor impairment			
Predictive variables	Yes *n* (%)	No *n* (%)	OR (95% CI)	*p*
Children with cerebral palsy excluded				
	n=18	*n*=72	*n*=90	
≤5th centile at 4y	13 (72)	5 (7)	33.8 (9.34, 122.7)	<0.001
Male	11 (61)	36 (50)	1.41 (0.50, 3.95)	0.512
GCA <90[a]	9 (50)	5 (7)	15.3 (4.19, 55.8)	<0.001
Higher social risk[b]	11 (61)	37 (51)	1.37 (0.47, 4.00)	0.568
Higher medical risk[c]	11 (61)	21 (29)	3.77 (1.28, 11.1)	0.016
Children with cerebral palsy included				
	n=24	*n*=72	*n*=96	
≤5th centile at 4y	19 (79)	5 (5)	50.5 (14.1, 181)	<0.001
Male	17 (71)	36 (38)	2.37 (0.90, 6.28)	0.082
GCA <90[d]	12 (50)	5 (5)	17.9 (5.29, 60.7)	<0.001
Higher social risk[e]	13 (54)	37 (39)	1.45 (0.53, 3.91)	0.468
Higher medical risk[c]	15 (63)	21 (22)	4.06 (1.55, 10.7)	<0.005

[a]Missing for one participant; [b]Missing for two participants; [c]Higher medical risk=any of bronchopulmonary dysplasia, postnatal corticosteroids, cystic periventricular leukomalacia, or intraventricular haemorrhage grade 3 or 4; [d]Missing for three participants; [e]Missing for five participants. OR, odds ratio; CI, confidence interval; GCA, General Conceptual Ability score.

at 8 years, whether or not children with CP were excluded. The association between sex and motor impairment was only significant in the secondary analysis using multiple imputation (Table SII, online supporting information).

Predictors of change in MABC-2 total standard scores from 4 to 8 years of age

There was little evidence of an association between sex, medical risk, social risk, or GCA score and a change in MABC-2 total standard score, irrespective of whether children with CP were included in the analysis (Table IV). This finding was unchanged in the secondary analysis using multiple imputation (Table SIII, online supporting information). Multiple birth was also not associated with motor impairment or a change in MABC-2 total standard score.

DISCUSSION

There was a strong relationship between the MABC-2 at 4 years and the MABC-2 at 8 years in this study of children born preterm, and the predictive validity of the MABC-2 at 4 years for subsequent motor impairment at 8 years was strong. Apart from the MABC-2 scores at 4 years of age, higher medical risk and the GCA score at 4 years also appeared to be related to motor impairment at 8 years. Male sex was also weakly associated with motor impairment at 8 years of age. When assessing these predictors, our results yielded large odds ratios with wide CIs for MABC-2 scores, medical risk, and GCA, which likely reflect the low number of children with motor impairment, and relatively high number of variables in the analysis. These results do indicate the direction of relationships, but should be interpreted with caution. There was little evidence that medical or social variables were related to a change in motor skills from age 4 to 8 years.

The prevalence of motor impairment in children born preterm between the ages of 4 years and 8 years was relatively stable in this study, with few children changing descriptive categories on the MABC-2. The 25% prevalence of motor impairment in the preterm population at both 4 years and 8 years of age was slightly higher than the rate of 19% reported in a meta-analysis by Williams et al.[25] It should be noted, however, that the meta-analysis included children who were more mature at birth than the current study, and included studies that used measures other than the MABC-2, with different rates of motor impairment detected by different assessment tools.[25] Interestingly, 32% of participants in the current study were in the lowest 15th centile, which is slightly less than the rate of 40% reported by Williams et al.[25]

Table IV: Predictors of change in motor score between 4y and 8y

Predictive variables	Coefficient (95% CI), *p*
Children with cerebral palsy excluded	
	n=90
Male	0.35 (−0.73, 1.44), 0.522
GCA <90[a]	0.31 (−1.57, 2.18), 0.7495
Higher social risk[b]	0.02 (−1.12, 1.17), 0.968
Higher medical risk[c]	−0.85 (−1.98, 0.28), 0.140
Children with cerebral palsy included	
	n=96
Male	0.36 (−0.69, 1.40), 0.504
GCA <90[d]	0.23 (−1.33, 1.80), 0.769
Higher social risk[e]	−0.01 (−1.11, 1.09), 0.990
Higher medical risk[c]	−0.79 (−1.83, 0.25), 0.135

[a]Missing for one participant; [b]Missing for two participants; [c]Higher medical risk=any of bronchopulmonary dysplasia, postnatal corticosteroids, cystic periventricular leukomalacia or intraventricular haemorrhage grade 3 or 4; [d]Missing for three participants; [e]Missing for five participants. CI, confidence interval; GCA: General Conceptual Ability.

The current study demonstrates the value of completing a motor assessment on children born preterm at 4 years of age, as this was sensitive and specific for predicting motor impairment at 8 years of age. While the MABC-2 is not primarily designed as a predictive tool, its standardized methods and large age range lend itself to sequential tests throughout childhood. Many tertiary centres now have high-risk follow-up clinics for children born preterm, providing an opportunity to identify any concerns with motor skills before they start school. The current study suggests that 4-year-olds with MABC-2 scores below the 5th centile are likely to have motor impairment at 8 years of age. For clinicians working with limited time and resources, this information can be used to further prioritize intervention and follow-up services.

There have been several studies published exploring predictors of motor impairment in the preterm population. In a recent meta-analysis by Linsell et al.,[7] male sex was associated with lower MABC-2 scores at 5 years of age in children born preterm or very low birthweight without other major disability. In our study, male sex only appeared to be associated with motor impairment at 8 years in our secondary analysis.

In our sample there was a correlation between cognitive impairment at 4 years and motor impairment at 8 years that was retained in the secondary analysis using multiple imputation. This was expected as motor impairment has been previously linked with neurobehavioral and cognitive disorders.[8] It was hypothesized that lower cognitive ability may also cause a decline in MABC-2 score as tasks become more complex requiring higher cognitive functioning as they get older. The results from the current study suggest that this is not the case, with approximately equal numbers of children with cognitive impairment improving/declining and remaining unchanged in their total standard scores on the MABC-2.

There was minimal change in scores on the MABC-2 between 4 years and 8 years; subsequently, we were unable to identify any factors associated with a change in MABC-2 scores from 4 years to 8 years.

The current study has some limitations. The children included in this study were initially recruited as a part of a randomized controlled trial of early intervention in the first year of life. We have previously reported no evidence of differences in motor outcome between the groups at 8 years,[15] and the authors feel that the benefit of increasing

the sample size by combining the two groups outweighed any limitations of the random allocation as a possible confounder. There was a 20% attrition rate from recruitment to data collection at 8 years, with differences noted at baseline between those included and those lost to follow-up. Our secondary analysis using multiple imputation to handle the missing data did not meaningfully change the results.

Our analysis was also limited by the small number of children assessed as having a motor impairment (19 out of 96), which limits the power to detect predictors and to draw definitive conclusions regarding the predictors that we identified. Hence the results from this study should still be considered exploratory, with findings needing to be replicated in other studies.

While some children with CP did not complete the tasks as they were physically incapable, some may have been capable but uncooperative. This may have skewed the results towards more children being classified as motor impaired. Although this is in line with the recommendation of scoring the MABC-2 in the test manual, it may not represent clinical practice where there are opportunities to retest children if required.

The MABC-2 is a measure of activity limitation and as such further research assessing the impact of children's motor impairment on their function and participation levels would be beneficial.

CONCLUSIONS

The MABC-2 performed at 4 years has excellent sensitivity and specificity for predicting motor impairment at 8 years of age in children born at less than 30 weeks' gestation. A score below or equal to the 5th centile on the MABC-2 is highly predictive of future motor impairment in this population. There was some evidence that general conceptual ability at 4 years and higher medical risk are predictive of motor function at 8 years in children born at less than 30 weeks' gestation, but not social risk. No factors were identified as predictive of change in MABC-2 scores in this population.

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SUPPORTING INFORMATION

The following additional material may be found online:

Table SI: Distribution of obtained data: all children

Table SII: Predictors of motor impairment (MABC-2 ≤5th centile) at 8 years of age using multiply imputed data

Table SIII: Predictors of change in motor score between 4 years and 8 years using multiply imputed data

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