［Original］

Differences in the Peak Cough Flow among Stroke Patients With and Without Dysphagia

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Abstract **:** Coughing is an important protective mechanism for keeping the airway clear, and adequate voluntary coughing reduces the risk of aspiration in patients with deglutition disorders. The purpose of this study was to compare the peak cough flow (PCF) of stroke patients with and without dysphagia and to identify the physical and respiratory determinants of PCF. Using a spirometer, we measured and compared the PCFs of 10 stroke patients with dysphagia (SPD), 20 stroke patients without dysphagia (SP) and 10 gender and age matched healthy controls (HC) recruited by using a notice at a clinic and in newspapers. The PCF of the SPD (mean ± SD, 160.1 ± 68.7 *l*/min) was significantly lower than that of the SP and HC (297.2 ± 114.2 *l*/min and 462.0 ± 84.4 *l*/min, respectively; one-way ANOVA, Scheffe's test, $P < 0.05$). The vital capacity (VC) and inspiratory reserve volume (IRV) of the SPD were lower than those of the HC. Stepwise multivariate regression analysis revealed that IRV and ambulation function (Functional Ambulation Categories, FAC) contributed 50% and 17% to the variance of PCF ($P < 0.05$), respectively. It is suggested that respiratory function, especially IRV, is important for maintaining PCF in SPD.

Key words **:** deglutition disorders, dysphagia, stroke, cough, inspiratory reserve volume.

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Introduction

Deglutition disorders are a frequent problems for stroke patients in the acute and chronic stages, and 38 to 64% of stroke patients in the acute stage and 50% of stroke patients in the chronic stage suffer from deglutition disorders [1−5]. Aspiration, entrance of food into the trachea, is a serious sign of deglutition disorders and often causes aspiration pneumonia [1]. In the acute stage, decreased pharyngeal sensation, dysphagia in a water swallow test and severe stroke significantly increase the risk of aspiration. On the other hand, Horner and Massey reported that there were differences in dysphagia, weak cough, and dysphonia between aspirating and non-aspirating patients in the chronic stage within 28 months from stroke onset [6].

Coughing is an important protective mechanism for keeping the airways clear, and adequate voluntary coughing reduces the risk of aspiration pneumonia [7]. However, it is uncertain whether stroke patients with aspiration pneumonia have a weak voluntary cough. If the peak cough flow (PCF), which is an objective measurement of maximum flow of a voluntary cough, is reduced in stroke patients with dysphagia (SPD), a low PCF may be one

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of the predictive factors for aspiration pneumonia. As the first step in a study on the prevention of aspiration pneumonia in SPD by physical therapies, we measured the PCF in stroke patients with and without dysphagia to reveal whether SPD have a lower PCF than stroke patients without dysphagia (SP) and healthy controls (HC). As our final goal is to investigate effective rehabilitative approaches to prevent aspiration in stroke patients, the second purpose of this study is to find any factors related to the volume of PCF, including respiratory functions.

Patients and Methods

The study subjects consisted of 45 consecutive male stroke in-patients who were referred to the department of rehabilitation for further rehabilitative treatments. The inclusion criteria for this study were as follows: 1) the patient was diagnosed with cerebral hemorrhage or infarction by magnetic resonance imaging and computed tomography of the head; 2) was male; 3) was 55～86 years old; 4) had no history of cardiopulmonary diseases; 5) had no physical disabilities induced by musculo-skeletal disorders; 6) could understand the examination; 7) was able to undergo spirometry with a maximum effort, sitting on a chair.

Fifteen patients were excluded from this study. Eight could not perform the trial of spirometry with a maximum effort, five had a history of ischemic heart disease or suspected chronic obstructive pulmonary disease, and two had physical disabilities due to a degenerative joint disorder. Finally, 30 patients met the inclusion criteria. They were divided into two groups according to their clinical signs and symptoms, 10 SPD patients and 20 SP patients, by a physiatrist (M.T.) at the dysphagia clinic. We recruited three screening tests for dysphagia and videoflurography (VFG), if necessary. These screening tests consisted of the Repetitive Salvia Swallowing test (RSST: a patient is asked to swallow his saliva as many times as possible in 30 seconds), the water swallowing test (WST: a patient is asked to swallow 3 ml of water poured on his tongue), and the pudding swallowing test (PST: a patient is asked to swallow 4 g of pudding placed on his tongue). The summed scores of the PST and WST had a sensitivity of 90% and a specificity of 56%. The sensitivity of RSST was previously reported to be 98%, and it had the advantage of being simple, safe and inexpensive [8]. The high sensitivity of these non-VFG tests means that they have a low rate of false negatives, so we suspected dysphagia if the results of any one of these tests was judged to be abnormal, or if coughing occurred during swallowing, if there was difficulty with eating, if there was wet hoarse dysphonia after deglutition, or if the subject had a past history of suffocation, we suspected dysphagia. Finally, 10 stroke patients suspected to have dysphagia underwent VFG to confirm the dysphagia.

Healthy men were recruited as HC by using a notice at the clinic and in newspapers. The inclusion criteria for a control were as follows: 1) had no medical history of stroke or dysphagia, and the same as 2) ~ 7) of the inclusion criteria for the stroke patients. Finally, 10 men were adopted as HC.

Approval for this study by the ethics committee.

Degree of penetration aspiration scale *of SPDs*

A physiatrist (M.T.) at the dysphagia clinic measured the degree of penetration aspiration scale (P/A) from VFG. This scale is one of the most standard scales for the degree of dysphagia (Table 1) [9].

Table 1. Penetration aspiration scale

Score	Contrast	P/A
1	Contrast does not enter the airway	No penetration
2	Contrast enters the airway; remains above the vocal folds	Penetration
3	Contrast remains above the vocal folds with visible residue	Penetration
4	Contrast contacts vocal folds; no residue	Penetration
5	Contrast contacts vocal folds; visible residue	Penetration
6	Contrast passes glottis; no subglottic residue	Aspiration
7	Contrast passes glottis; visible subglottic residue despite response	Aspiration
8	Contrast passes glottis; visible subglottic residue; absence of response	Aspiration

P/A: penetration aspiration scale (Reproduced from ref. [9] with permission of CHEST (American College of Chest Physicians))

Measurement of pulmonary function and PCF

One of the authors (Y.K.) carefully explained the maneuver of the spirometer (Autospiro AS-505, Minato Medical Science, Osaka) and measured pulmonary functions including tidal volume (TV), vital capacity (VC), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), and PCF to all the subjects. A subject was asked to sit on a chair, wearing a face mask instead of a mouthpiece attached to the spirometer, to prevent leakage from the mouth and nose. The subject was instructed to breathe out, breathe in deeply, and then cough as hard as possible under shouts of encouragement. First, they tried a few times to get accustomed to the measurement and then were asked to make their maximal efforts for three times. PCF was defined as the highest point of the flow volume curve obtained during a cough, and a maximum value of three measurements was used for analysis.

Severity of hemiplegia and gait disturbance

The severity of hemiplegia was assessed with Brunnstrom's recovery stage [10] for upper and lower extremities, and the mode and median values were obtained for the SPD and SP groups. The ambulatory function was assessed based on function ambulation categories (FAC), and was coded as follows for analysis: 0 for "ambulator-independent" and "ambulator-independent, level surfaces only", 1 for "supervison" and "ambulatory-dependent for physical assistance-level I", 2 for "ambulator-dependent for physical assistance-level II," and 3 for "non-functional ambulatory" [11].

One of the authors (Y.K.) explained the purpose and details of this study to all the participants, and obtained their written consent to participate in this study under approval of the institutional ethics committee.

Data analysis

Data of the three groups were stored in a spreadsheet; interval scales were expressed as means and standard deviation, and ordinal scales were expressed as median and mode. Age, height, weight, body mass index, and spirograms in the three groups were analyzed with analysis of variance (ANOVA), followed by post hoc Scheffe's tests, if the difference was significant. The difference in number of days since the onset of stroke were compared between SP and SPD groups by using a Student *t*-test, and the severity of hemiplegia and FAC were compared between the two groups by using a Mann-Whitney *U* test. Pearson's correlation coefficients were obtained to determine the correlation between PCF and other variables: age, days since onset, pulmonary functional parameters, (VC, TV, IRV, ERV), and Spearman's rank correlation coefficients to determine the correlation between PCF and ambulatory function. Stepwise multivariate regression analysis was then applied to determine the influence of the independent variables on the PCF. The independent variables were selected based on the Pearson's correlation coefficients and Spearman's rank correlation coefficients with significance. A statistical software package (SPSS 17.0J, SPSS Japan, Tokyo) was used for these analyses, and their level of significance was set at $P < 0.05$.

Results

The characteristics of the subjects are shown in Table 2. There were no significant differences in age, height, weight or body mass index among the SPD, SP and HC groups (one-way ANOVA, $P > 0.05$), and there was no significant difference between the SPD and SP groups in the number of days since the onset of stroke between the SPD and SP groups (Student *t*-test, $P > 0.05$). Although there were no significant differences in the severity of hemiplegia (Mann-Whitney *U* test, $P > 0.05$), the gait disturbance of the SPD group was significantly worse than that of the SP group (Mann-Whitney *U* test, $P < 0.05$).

Magnetic resonance imaging and computed tomography of the head showed that 17 patients had unilateral hemispheric lesions, three had bilateral hemispheric lesions, and 10 had lesions in the brain stem or cerebellum. 70% of the SPD and 30% of the SP group had lesions in bilateral hemispheres or a lesion in the brain stem or cerebellum and the difference in the rate of lesions was significant (Fisher's exact test, $P < 0.05$).

The PCF of the SPD group was significantly lower than that of the SP and HC groups, and the PCF of the SP group was also significantly lower than that of the HC group (one-way ANOVA, Scheffe's test, $P < 0.05$, Table 3). The VC of the SPD and SP groups was significantly lower than that of the HC group, and IRV of the SPD group was also significantly lower than that of the HC group (one-way ANOVA, Scheffe's test, $P < 0.05$). No significant differences in TV or ERV were found among the three groups (one-way ANOVA, $P > 0.05$).

The P/A score and PCF of the SPD group are shown in Table 4. Their PCF tended to be lower regardless of their P/A score (PCF range 37.8 - 293.4 *l*/min). The PCF score of only one patient (No. 9) was equal to the average PCF of SP group.

The PCF of the stroke patients had significant Pearson's correlation coefficients with IRV (r = 0.72, $P < 0.01$), VC (0.73, $P < 0.01$), and age (r = −0.56, $P < 0.01$), and also had significant Spearman's rank correlation coefficients with FAC (Fig. 1, r = −0.72, $P < 0.01$). According to a stepwise multivariate regression analysis, the IRV and FAC were found to be significant independent variables, and these variables predicted 67.0% of the variance in the PCF (Table 5).

Table 2. Characteristics of the subjects

Characteristic	SPD group (N=10)	SP group (N=20)	HC group (N=10)
Age (yr)	74.1 ± 10.2	65.7 ± 8.1	68.2 ± 7.2
Height (cm)	162.3 ± 6.1	162.6 ± 4.8	163.3 ± 6.2
Weight (kg)	56.6 ± 8.4	58.3 ± 8.7	61.5 ± 10.3
Body Mass Index ($kg \cdot m^{-2}$)	21.5 ± 2.8	22.2 ± 3.0	23.0 ± 2.9
Days since onset	35.7 ± 20.3	38.2 ± 50.6	
Severity of hemiplegia (median, mode)			
BRS of upper extremity	5, 6	5 , 5	
BRS of lower extremity	5, 6	5 , 6	
Functional Ambulation Category (median, mode)	3, 3	0.5, 0	
Brain lesion			
Unilateral cerebral hemisphere	3	14	
Bilateral cerebral hemisphere	2	1	
Brain stem or cerebellum	5	5	

SPD: stroke patients with dysphagia, SP: stroke patients without dysphagia, HC: healthy controls, BRS: Brunnstrom's recovery stage. Age, height, weight, Body Mass Index and days since onset are expressed as the means ± standard deviation

Table 3. Spirogram in the SPD, SP and HC groups

Variables	SPD group (N=10)	SP group (N=20)	HC group (N=10)
PCF ($l\,min^{-1}$)	160.1 ± 68.7*†	297.2 ± 114.2‡	462.0 ± 84.4
VC (m*l*)	2316.0 ± 583.7*	2741.0 ± 856.2‡	3565.0 ± 374.5
TV (m*l*)	537.0 ± 221.9	711.0 ± 336.1	721.0 ± 336.4
IRV (m*l*)	728.0 ± 477.6*	1128.5 ± 581.5	1645.0 ± 563.8
ERV (m*l*)	1051.0 ± 563.4	896.5 ± 504.6	1199.0 ± 538.0

SPD: stroke patients with dysphagia, SP: stroke patients without dysphagia, HC: healthy controls, PCF: peak cough flow, VC: vital capacity, TV: tidal volume, IRV: inspiratory reserve volume, ERV: expiratory reserve volume. Values are expressed as the means ± standard deviateon. *: $P < 0.05$, one-way ANOVA, Scheffe's test; SPD group vs. HC group, †: $P < 0.05$, one-way ANOVA, Scheffe's test; SPD group vs. SP group, ‡: $P < 0.05$, one-way ANOVA, Scheffe's test; SP group vs. HC group

Table 4. P/A score and PCF of the SPD

Patients	Sex	P/A score	VC (m*l*)	VCpred (%)	TV (m*l*)	IRV (m*l*)	ERV (m*l*)	PCF (*l*/min)
1	M	1	2290	79	650	410	1230	209.4
2	M	3	1330	46	430	470	430	86.4
3	M	3	2360	69	780	340	1240	162
4	M	7	2460	80	620	600	1240	136.2
5	M	7	2690	87	300	1980	410	154.2
6	M	1	1940	65	660	370	910	152.4
7	M	1	1430	49	450	790	190	188.4
8	M	8	2990	92	530	850	1610	180.6
9	M	1	2910	84	840	780	1290	293.4
10	M	6	2760	90	110	690	1960	37.8
avg.			2316	74	537	728	1051	160.1
sd.			583.7	16.4	221.9	477.6	563.4	68.7

PCF: peak cough flow, SPD: stroke patients with dysphagia, VC: vital capacity, VC pred: VC predicted, TV: tidal volume, IRV: inspiratory reserve volume, ERV: expiratory reserve volume, M: male, avg: average, sd: standard deviation

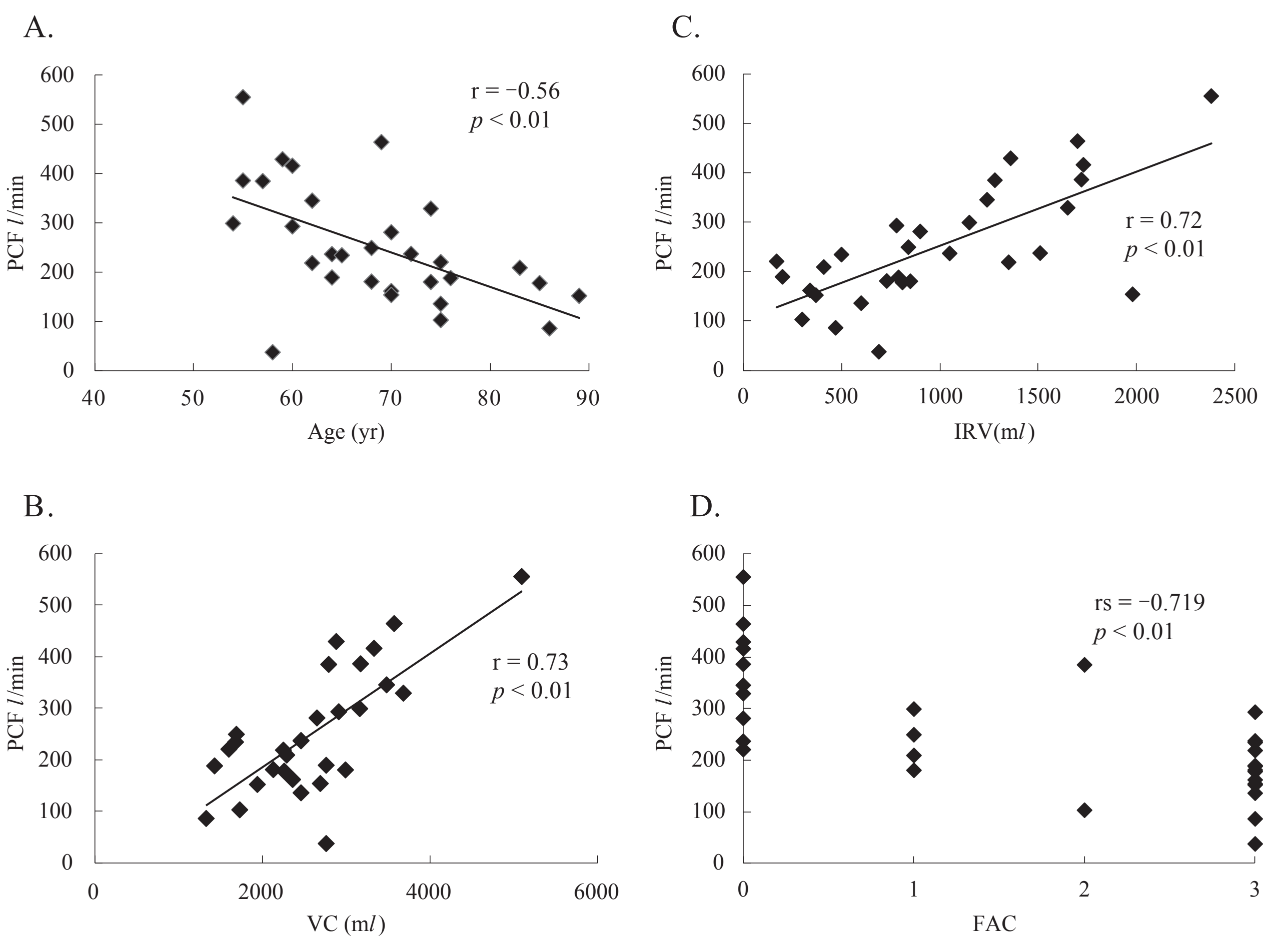

Fig. 1. Correlation between age, VC, IRV, FAC and PCF of all stroke patients (SPD and SP). A. Correlation between PCF and age, B. Correlation between PCF and VC, C. Correlation between PCF and IRV, D. Correlation between PCF and FAC, Age, VC, IRV, and FAC are all correlated with PCF ($P < 0.01$). VC: vital capacity, IRV: inspiratory reserve volume, FAC: functional ambulation categories, PCF: peak cough flow.

Table 5. Multiple linear regression analysis of PCF

Variables	R^2	*P*
IRV	0.50	0.0001
FAC	0.17	0.0005

IRV: inspiratory reserve volume, FAC: functional ambulation category, R^2: adjusted R-squared, PCF: Dependent variable, IRV, FAC: Independet variables

Discussion

In this study, we found that stroke patients had a reduced capacity for voluntary cough compared with age-matched healthy males, and, moreover, that the SPD group had a still lower capacity for voluntary cough than the SP group. Although there have been only a few reports on the measurement of voluntary cough in stroke patients, Hammond *et al* reported that objective measures of voluntary cough can identify stroke patients who are at risk for aspiration. Patients with Parkinson's disease also show a decreased capacity for voluntary cough and a swallowing disturbance from the early stages [12]. Pitts, *et al* described that the decreased ability to adequately clear material from the airway with a voluntary cough may exacerbate symptoms resulting from airway penetration in patients with Parkinson's disease [13]. Ebihara, *et al* measured the PCF of patients with Parkinson's disease, and reported that it was 230 ± 74 *l*/min in the early stage and 186 ± 60 *l*/min in the advanced stage [14]. The PCF of patients with advanced Parkinson's disease approximates that of our SPD group.

Stroke patients were reported to have a reduced VC and forced expiratory volume in one second ($FEV_{1.0}$), which may have been due to the affected neurologic control of respiratory function and decreased lung volume excursions due to deteriorated movement of the chest wall caused by weakness or spasticity of the rib cage and abdominal muscles [15]. In the present study, the IRV was a major factor for reduction of VC in stroke patients, because VC is composed of TV, ERV and IRV, and there were no differences in TV and ERV between the SPD, SP and HC groups. The decrease in IRV explained approximately 50% of the variance in the PCF of the stroke patients. Khedr *et al* examined the effect of stroke on the corticodiaphragmatic pathway and described that central diaphragmatic impairment may cause hypoxia and respiratory dysfunction in acute stroke patients [16]. In the initial phase of stroke, a decrease in the expiratory capacity, rather than the inspiratory capacity, causes restrictive pulmonary dysfunction, and inspiratory capacity appears to decrease with time. Because the diaphragm muscles are the main factor of ventilation, decreased hemidiaphragmatic excursion and reduced rib cage expansion due to contracture may cause inspiratory restriction [17]. Trebbia *et al*. also reported that the maximal inspiratory capacity contributed 44% of the variance in the PCF of 155 neuromuscular patients, while the ERV contributed 13% of the variance [18]. They concluded that augmenting inspiration was crucial to the improvement of PCF, but that the role of the expiratory muscles could not be ignored. On the other hand, we demonstrated that expiration was not an essential factor for maintaining PCF in this study. This difference may come from the differences in the diseases of the subjects. For example, the subjects examined by Trebbia *et al*. consisted of patients with myotonic dystrophy, Duchenne muscular dystrophy, spinal cord injury, and poliomyelitis, and the % predicted value of ERV was only 33 ± 29, whereas the ERV of our stroke patients was as much as the HC group.

In the present study, the second strongest predictor of PCF was the ambulatory function. Although the SPD and SP groups had the same severity of hemiplegia, the ambulatory function of the SPD group was worse than that of the SP group. Possible reasons why the SPD group had lower ambulatory function may be reduced progress in training induced by dysphagia-related conditions, general fatigue due to low nutrition, low activity in daily life, or a chance relationship.

We didn't include VC in the stepwise regression, because VC has a strong correlation with TV, IRV and ERV, and it is a sum of these respiratory factors. If we had included VC in our stepwise multivariate regression model, the result would have been that not IRV but VC became the most significant independent variable.

Our study has some limitations because it was a preliminary cross-sectional study of a small number of male stroke patients. It will be necessary to perform a prospective study on a larger number of stroke patients with or without dysphagia, including the measurement of daily activity and other factors, to reveal whether inspiratory training prevents aspiration pneumonia.

Conclusion

We measured the peak cough flow (PCF) in stroke patients with and without dysphagia (SPD and SP) to reveal whether SPD have a lower PCF than SP and healthy controls (HC). The factors relating with the volume of PCF, including respiratory functions, were then investigated to find effective rehabilitative approaches to prevent aspiration in stroke patients. The results were that the PCF of the SPD group was lower than that of the SP and HC groups, and the decrease in the inspiratory reserve volume (IRV) was a major factor associated with the low PCF.

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脳血管障害患者における嚥下障害の有無による最大咳流速の差

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要　　旨： 咳嗽は気道の浄化における重要な防御機構であり，十分に強い咳嗽は，嚥下障害を有する患者の誤嚥リスクを抑制する．今回の研究目的は，脳血管障害患者の嚥下障害の有無による最大咳流速（PCF）の違いを調べることであり，さらにはこれらの患者におけるPCFの身体および呼吸関連因子を明確にすることである．肺活量計を用いて，嚥下障害を有する10名の脳血管障害患者（SPD），嚥下障害を有しない20名の脳血管障害患者（SP）と臨床や新聞で募集した性･年齢の一致する10名の健常コントロール群（HC）のPCFを測定し比較した．その結果，SPDのPCFは160.1 ± 68.7 *l*/minであり, SPの297.2 ± 114.2 *l*/min, HCの462.0 ± 84.4 *l*/minと比べて有意に低下していた（one-way analysis of variance, ANOVA, Scheffe's test, $P < 0.05$）．また, SPDの肺活量（vital capacity, VC）と予備吸気量（inspiratory reserve volume, IRV）は, HCのVCやIRVより減少していた．多変量回帰分析より, IRVと移動能力（Functional Ambulation Categories, FAC）のPCFに対する寄与率は, それぞれ50%と17%であることが分かった．呼吸機能特にIRVが, SPDのPCF維持に重要であることが示唆された．

キーワード： 嚥下障害, 脳血管障害, 咳嗽, 予備吸気量.

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