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Chinese Food Cooking and Lung Cancer in Women Nonsmokers

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Cigarette smoking cannot fully explain the epidemiologic characteristics of lung cancer in Taiwanese women, who smoke rarely but have lung cancer relatively often. In a previous study, the authors suspected that exposure to fumes from cooking oils was an important risk factor for lung cancer in Taiwanese women nonsmokers in the Republic of China. In a new case-control study conducted in 1993–1996, they further explored the association of oil fumes with lung cancer in women. Two sets of controls were used concurrently. The subjects were 131 nonsmoking incident cases with newly diagnosed and histologically confirmed primary carcinoma of the lung, 252 hospital controls hospitalized for causes unrelated to diseases of smoking, and 262 community controls; all controls were women nonsmokers matched by age and date of interview. Details on cooking conditions and habits were collected, in addition to other epidemiologic data. Lung cancer risk increased with the number of meals per day to about threefold for women who cooked these meals each day. The risk was also greater if women usually waited until fumes were emitted from the cooking oil before they began cooking (adjusted odds ratios = 2.0–2.6) and if they did not use a fume extractor (adjusted odds ratios = 3.2–12.2). These results suggest that a proportion of lung cancer may be attributable to the habit of waiting until the cooking oil has been heated to a high temperature before cooking the food. *Am J Epidemiol* 2000;151:140–7.

lung neoplasms; mutagens; oils; risk factors; temperature; women

Lung cancer has been the leading cause of cancer death among women in Taiwan, Republic of China, since 1986. Although cigarette smoking is considered the most important cause of lung cancer, it cannot fully explain the epidemiologic characteristics of lung cancer in Taiwanese women (1), who smoke rarely but have lung cancer relatively often, as do Chinese women in the United States (2), Australia (3), Hong Kong (4), Singapore (5), Malaysia (6), Japan (7), and some cities on mainland China (8). The prevalence of cigarette smoking among adults in Taiwan is 55–60 percent for men but only 3–4 percent for women. The reported rates of smoking for Chinese women with lung cancer are lower (from 22 percent in Hawaii to 56 percent in Hong Kong) than those for all women with lung cancer in Europe and America (70–90 percent) (9). In Taiwan, the rate of smoking is even lower; only 10 percent of female lung cancer patients smoke, whereas 86 percent of male lung cancer patients have a history of smoking.

What causes women nonsmokers in Taiwan to be affected needs further investigation. In addition to smoking, occupational exposure to carcinogens (10–13) is another well-established risk factor for lung cancer, but it is limited to specific groups. For female lung cancer patients in general, various potential factors have been reported to be associated with lung cancer, including environmental tobacco smoke (14), ambient air pollutants (15, 16), diet (17–20), cooking fuels (21, 22), indoor air pollution (23), and a family history of lung cancer (24, 25).

Chinese cooking involves frying ingredients in oil, which produces ample oil fumes to which the cook is exposed. In our previous case-control study (1), we suspected that exposure to fumes emitted from cooking oils, when not reduced by an extractor such as a fume hood, appeared to be an important risk factor for lung cancer in Taiwanese women nonsmokers. The purpose of the present study was to further explore the role of oil fumes for women lung cancer patients who cook.

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Abbreviations: CI, confidence interval; OR, odds ratio.

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We used two sets of controls (hospital and community controls) concurrently to increase sample size and reduce hospital selection bias.

MATERIALS AND METHODS

Study samples

This study used a case-control design. Subjects were residents of the greater Kaohsiung area of Taiwan, which includes a city and some suburban and rural communities. Each case was matched by age and date of interview to two types of controls (hospital and community controls). The cases and hospital controls were drawn from Kaohsiung Medical University Hospital, a leading teaching hospital in southern Taiwan.

The cases were nonsmoking incident patients with newly diagnosed and histologically confirmed primary carcinoma of the lung (*International Classification of Diseases*, Ninth Revision code 162). A total of 148 eligible lung cancer cases were identified between 1993 and 1996. Excluded from this analysis were those who had died ($n = 6$), those who were too sick ($n = 5$), and those who refused to participate ($n = 6$), leaving 131 cases for analysis. Among these cases, 26 (19.8 percent) had squamous cell carcinoma, 82 (62.6 percent) had adenocarcinoma, 18 (13.7 percent) had small cell carcinoma, 3 (2.3 percent) had large cell carcinoma, and 2 (1.5 percent) had unclassified carcinoma.

The hospital controls were new female patients hospitalized for causes unrelated to diseases of smoking. Among them, 77 percent had eye problems (cataract or glaucoma) and 23 percent had bone fractures. These controls were drawn from the same geographic areas as the cases, were selected within 3 weeks after the case had been identified, and were matched to cases on age (within 2 years) and smoking status. A total of 281 hospital controls were available, and 252 agreed to participate in the study. The community controls were selected randomly from a computerized population database of the greater Kaohsiung area. We first chose 18 communities from a total of 82. We then selected 641 households in these communities. Information regarding smoking status was obtained and the ages of the selected subjects were verified through telephone interviews. A total of 1,240 women who were older than age 40 years and were lifetime nonsmokers were eligible to be controls. Once a case was identified, two community controls matched by age (within 2 years) were selected on the basis of their sequence on the list. If the selected woman refused to participate in the study, the next eligible woman on the list was chosen until two healthy controls had been recruited. Thirty-two healthy women refused to or could not participate in the study. The reasons given were that they were too busy for the interview, were out of town, or were moving out of the study area and could not be located. A total of 262 age-matched community controls participated in the study.

Data specification

Two trained interviewers conducted personal interviews to collect epidemiologic data. A structured questionnaire had been developed to obtain information on demographic characteristics, socioeconomic status, smoking history, passive smoke exposure, history of lung diseases, occupation, dietary habits, lifetime residence, general air pollution inside the home, and ventilation conditions as well as cooking habits. Details of the data specification are described elsewhere (1).

A nonsmoker was defined as a woman who had never smoked one cigarette during her lifetime. Subjects who lived or worked with a smoker during their childhood and adulthood, such as a parent, husband, cohabitant, or coworker, were considered passive smokers. A detailed smoking history for smokers was collected, including the year in which smoking started, the year in which smoking stopped (if applicable), and how many cigarettes they had smoked during their lifetime. The number of smoker-years, calculated as the number of years exposed to smokers multiplied by the number of smokers to whom the subject had been exposed, was used as the indicator of passive smoking. Chronic bronchitis, emphysema, asthma, and tuberculosis were included in the history of lung diseases. The occupational history portion of the questionnaire listed all types of jobs divided into five categories: administration, hazardous industry, farmer, housewife, and chef. Subjects were asked to list all jobs they had held for at least 1 year. Hazardous industry included iron, petroleum, chemical, and cement production facilities; chefs usually have restaurants and work in their homes, according to Taiwanese custom. Information on daily dietary habits was collected regarding 12 food items, and subjects were asked about the frequency and quantity of consumption of meat, vegetables, fruit, smoked food, and pickles, for example. The place in which the subject had resided for the longest period of time was considered her main residence (average duration, 46.3 (standard deviation, 17.2) years for cases and 45.2 (standard deviation, 18.0) years for controls). If this place was within 1 km of a major industrial site, the subject was classified as living adjacent to an industrial district. Air pollution factors inside the home were also assessed. Information included the types of incense used (e.g., Taiwanese yellow and black incense) and the duration and frequency of burning Chinese incense and mosquito coils.

Furthermore, the interviewers asked each housewife who had to cook for her family about the types of cooking fuel and cooking oils she used, her preferred cooking method, the number of windows in the kitchen, the sizes of openings to the outside, and ventilation conditions (a dichotomous variable) and the use of a fume extractor in the home kitchen. Because stir frying, frying, and deep frying are three types of cooking techniques that involve frying food in oil and are usually used to prepare Chinese food, we also measured how frequently housewives used each technique. We also asked about their regular cooking habits, such as whether they waited for fumes to be emitted from cooking oils before they began to cook. According to the concepts of traditional Chinese cooking, quick frying in oils that have been heated to reach high temperatures keeps food as fresh as possible. Age at which cooking started was determined to be a housewife's age when she started to cook daily.

Statistical analysis

In this case-control study, odds ratios and their 95 percent confidence intervals were used as estimates of relative risk. Univariate conditional logistic regression was applied to test the potential risk factors mentioned above. The significant risk factors identified as a result of this univariate analysis were occupation, previous lung disease, and passive smoking (table 1). All multivariate logistic regression models were adjusted for these variables and socioeconomic status, which is probably related to the use of a fume extractor in the kitchen.

RESULTS

All demographic data for the cases and the two groups of controls are shown in table 1. Age, residential area, ethnicity, religion, education, and socioeconomic status of the cases were well matched to both groups of controls. There were more chefs among the cases than the controls (6.9 percent of cases versus 1.2 and 3.1 percent of hospital and community controls, respectively). More cases also had preexisting lung disease (18.3 percent of cases versus 6.8 and 8.4 percent of controls, respectively) and exposure to passive smoking (78.6 percent of cases had ever been exposed to passive smoking versus 65.9 and 59.5 percent of controls, respectively).

Almost all subjects cooked daily, which is consistent with the practice of traditional Chinese women (table 2). The odds ratio for cooking was not significantly related to the development of lung cancer. The age at which cooking started and the number of years spent cooking at home did not differ between the cases and either group of controls. However, number of meals per day was significantly associated with lung cancer and reflected a dose-response trend: women who cooked three meals per day had an almost threefold increased risk of lung cancer (odds ratio (OR) = 2.8, 95 percent confidence interval (CI): 1.2, 6.3 compared

TABLE 1. Distributions of demographic and confounding factors (%†) among Taiwanese women nonsmokers, Republic of China, 1993–1996

Factor	Cases (*n* = 131)	Hospital controls (*n* = 252)	Community controls (*n* = 262)
Age (years)			
<41	4.6	5.2	4.6
41–50	16.0	17.1	16.0
51–60	25.2	25.4	25.2
61–70	32.1	32.9	32.1
>70	22.1	19.4	22.1
Residential area			
Urban	32.8	35.7	37.4
Suburban	16.1	16.7	13.0
Rural	51.2	47.6	49.6
Ethnicity			
Fukienese	88.6	86.1	82.1
Mainlander	5.3	6.4	9.9
Other	7.6	7.9	8.0
Religion			
Buddhism	29.0	36.1	32.4
Taoism	3.8	6.8	7.3
Folk	59.5	49.2	50.8
Other	7.6	7.9	9.5
Education (years)			
None	60.3	52.8	53.4
1–9	28.2	34.5	37.8
>9	11.5	12.7	8.8
Socioeconomic status			
Low	20.6	21.8	18.7
Median	58.8	57.1	60.7
High	20.6	21.0	20.6
Occupation*			
Administration	29.0	34.5	34.0
Hazardous industry	3.1	3.6	0.8
Farmer	25.2	25.4	15.7
Housewife	35.9	35.3	46.6
Chef	6.9	1.2	3.1
Previous lung disease*			
No	81.7	93.2	91.6
Yes	18.3	6.8	8.4
Passive smoking (smoker-years)*			
0	21.4	34.1	40.5
1–20	8.4	9.1	8.0
21–40	26.0	24.2	20.2
41–60	15.3	15.9	15.3
>60	29.0	16.7	16.0

* $p < 0.05$ for both comparisons with hospital and community controls.

† Some percentages do not total 100 because of rounding.

TABLE 2. Adjusted odds ratios (OR) and 95% confidence intervals (CI) of lung cancer associated with cooking and ventilation conditions in the home kitchens of Taiwanese women nonsmokers, Republic of China, 1993–1996

Factor	No. of cases	Hospital controls		Community controls	
		No.	OR (95% CI)	No.	OR (95% CI)
Daily cooking					
No	1	5	1.0	10	1.0
Yes	130	247	1.9 (0.2, 18.1)	252	5.9 (0.7, 53.6)
Age cooking started (years)					
>20	47	97	1.0	113	1.0
≤20	83	150	1.0 (0.6, 1.7)	139	1.5 (0.9, 2.4)
Years spent cooking at home					
1–20	36	71	1.0	75	1.0
21–40	74	149	1.0 (0.5, 1.8)	137	1.3 (0.6, 2.6)
>40	20	27	1.2 (0.4, 3.4)	40	1.0 (0.4, 2.9)
Meals per day					
1	13	47	1.0	73	1.0
2	71	135	1.9 (0.9, 4.0)	111	3.1 (1.6, 6.2)
3	46	65	2.8 (1.2, 6.3)	68	3.4 (1.6, 7.0)
Windows in kitchen					
<2	62	110	1.0	148	1.0
≥2	69	142	0.9 (0.5, 1.3)	114	1.3 (0.8, 2.1)
Size of openings to the outside					
Small or moderate	100	197	1.0	200	1.0
Large	31	55	1.1 (0.6, 2.0)	62	0.9 (0.5, 1.5)
Ventilation in the kitchen					
Poor	71	129	1.0	138	1.0
Good	60	123	0.9 (0.6, 1.4)	124	0.9 (0.6, 1.4)

with hospital controls; OR = 3.4, 95 percent CI: 1.6, 7.0 compared with community controls). Cooking two meals per day was associated with a significantly higher risk of lung cancer when cases were compared with community controls (OR = 3.1, 95 percent CI: 1.6, 6.2), but the risk was only marginally higher when they were compared with hospital controls (OR = 1.9, 95 percent CI: 0.9, 4.0). In addition, as shown in table 2, there was no difference in the ventilation conditions in the home kitchens of cases and controls.

Because a large proportion of housewives cooked less frequently after age 40 years (when their daughters or daughters-in-law took charge of the cooking) and some started to cook before age 20 years, these age cutpoints (i.e., 20, 40 years) were used to analyze the role of a fume extractor in the kitchen. As shown in table 3, subjects who cooked when they were 20–40 years of age (the main ages for cooking among Taiwanese housewives) without using a fume extractor had a significantly higher risk of lung cancer than the hospital controls (OR = 5.4, 95 percent CI: 2.7, 10.8) and the community controls (OR = 2.2, 95 percent CI: 1.3, 3.8). The association of lung cancer with the use of a fume extractor before age 20 and after age 40 years was not significant, but a 1.3-fold significant increased risk of lung cancer was found in comparison with hospital controls. We further examined how women habitually cooked the food. The purpose was to investigate whether the risk of lung cancer was associated with the temperature of the cooking oil when the women placed the food into the frying pan.

As shown in table 4, eye irritation when cooking was significantly associated with lung cancer (OR = 2.2, 95 percent CI: 1.3, 3.8 compared with hospital controls; OR = 2.1, 95 percent CI: 1.3, 3.5 compared with community controls), indicating that some hazardous, irritating substance from the cooking oil may spread to the air during cooking. Subjects who were frequently exposed to cooking fumes had a higher risk of lung cancer (OR = 1.7, 95 percent CI: 1.0, 2.9 compared with hospital controls; OR = 2.5, 95 percent CI: 1.4, 4.3 compared with community controls). Furthermore, subjects who usually waited until fumes were emitted from the oil and then stir fried, fried, and deep fried had a significantly higher risk of lung cancer, although, when compared with community controls, the significance was only marginal for the deep-frying procedure (table 4). These significantly higher

TABLE 3. Adjusted odds ratios (OR) and 95% confidence intervals (CI) of lung cancer associated with cooking* conditions among Taiwanese women nonsmokers, Republic of China, 1993–1996

Using fume extractor	Cooking before age 20 years					Cooking at age 20–40 years					Cooking after age 40 years				
	No. of cases	Hospital controls		Community controls		No. of cases	Hospital controls		Community controls		No. of cases	Hospital controls		Community controls	
		No.	OR (95% CI)	No.	OR (95% CI)		No.	OR (95% CI)	No.	OR (95% CI)		No.	OR (95% CI)	No.	OR (95% CI)
Yes	40	95	1.0	87	1.0	85	216	1.0	207	1.0	114	225	1.0	223	1.0
No	43	55	2.3 (1.1, 5.0)	52	0.9 (0.4, 2.0)	45	31	5.4 (2.7, 10.8)	45	2.2 (1.3, 3.8)	12	12	1.8 (0.7, 4.7)	16	1.3 (0.6, 2.8)

* Excluded from the analyses were housewives who did not cook during the three different cooking periods (numbers of cases, hospital controls, and community controls, respectively: 48, 102, 124; 1, 5, 10; and 5, 15, 25).

risks were also observed for each cooking method, even when the frequency of cooking was taken into account (data not shown).

We also tested whether there was an interaction between cooking habits and use of fume extractors (table 5). We found that women who did not use a fume extractor and waited for the cooking oil to reach a high temperature before beginning to cook (adding the food when the oil fumes were emitted consistently) had consistently higher risks of lung cancer (OR = 3.2–12.2) than either hospital or community controls. Subjects who did not use a fume extractor and did not wait until the oil was hot before they cooked the food also had significantly higher risks of lung cancer in comparison with hospital controls (OR = 3.5–7.6); the risk was higher but not statistically significant when compared with community controls. The risk of lung cancer was marginally higher for subjects who cooked when the pan and cooking oil were hot and did use a fume extractor, indicating that the fumes released into the air from evaporating, high-temperature oil could not be cleaned completely by the fume extractor. In addition, no interaction was found between exposure to cooking fumes and passive smoking.

DISCUSSION

This study presents evidence that cooking habits are associated with lung cancer in Taiwanese women nonsmokers. As shown in this and our earlier study (1), women who do not use fume extractors during cooking are at high risk of developing lung cancer. Furthermore, women who wait until the oil has reached a high temperature before cooking the food (stir frying, frying, and deep frying) and do not use a fume extractor have a consistently higher risk of lung cancer when compared with both hospital and community controls.

We used two sets of controls concurrently to explore the study goals. The purpose of such a design is to reduce potential bias from the use of either the hospital-based or community-based approach and to secure the study findings, especially when results from two groups of controls are consistent. Our results from both comparisons were quite consistent, although the estimates of odds ratios were somewhat different. Because subjects did not know the hypothesis of the present study, recall bias, if existent, should have been limited and should not have influenced our conclusions. All patients were newly diagnosed cases, and controls were matched by date of interview; therefore, the survival effect was not very likely. Although a small proportion of potential subjects were excluded because they had died, were too sick, or refused to participate, these subjects were not related to the mea-

TABLE 4. Adjusted odds ratios (OR) and 95% confidence intervals (CI) of lung cancer associated with the cooking habits of Taiwanese women nonsmokers, Republic of China, 1993–1996

Factor	No. of cases	Hospital controls		Community controls	
		No.	OR (95% CI)	No	OR (95% CI)
Eye irritation when cooking					
Rarely	84	199	1.0	207	1.0
Frequently	46	48	2.2 (1.3, 3.8)	45	2.1 (1.3, 3.5)
Smokiness when cooking					
Rarely	83	190	1.0	202	1.0
Frequently	47	57	1.7 (1.0, 2.9)	50	2.5 (1.4, 4.3)
Stir frying after fumes emitted					
No	22	79	1.0	87	1.0
Yes	108	168	2.0 (1.1, 3.7)	165	2.4 (1.4, 4.2)
Frying after fumes emitted					
No	17	68	1.0	73	1.0
Yes	113	179	2.0 (1.1, 3.8)	179	2.6 (1.4, 4.9)
Deep frying after fumes emitted					
No	31	113	1.0	86	1.0
Yes	99	134	2.1 (1.3, 3.5)	166	1.5 (0.9, 2.4)

surement of exposures of interest and hence should not have substantially biased our results.

The association of cooking habits, fume extractor use, and lung cancer is biologically plausible because the substances emitted from oil fumes have proven to be mutagenic; we identified polycyclic aromatic hydrocarbon carcinogens in three different commercial cooking oils frequently used in Taiwan (26). It also has been reported that two of these hydrocarbons (benzene and formaldehyde) were identified in rapeseed oil fumes (27, 28), although rapeseed oil was never used in Taiwan. Restaurant cooks not only in Asian countries (29) but also in western countries (30–32) also have been reported to have higher risks of lung cancer. One study showed that this occupation was associated with lung cancer; the cases included more professional chefs than either group of controls. We have suggested that a proportion of lung cancer may be attributable to the carcinogens emitted from the fumes of high-temperature cooking oil. These fumes are generated not only in Asian countries but also in western countries when housewives or cooks fry food and do not use efficient fume extractors.

Those women who used a fume extractor but waited to cook the food until the oil was very hot also had a higher risk of lung cancer, indicating that the fume

TABLE 5. Interaction effects of lung cancer associated with cooking habits and use of a fume extractor in the kitchens of Taiwanese women nonsmokers, Republic of China, 1993–1996

Cooking habit	Using fume extractor		Not using fume extractor		Using fume extractor		Not using fume extractor	
	No. of cases/ hospital controls	OR* (95% CI*)	No. of cases/ hospital controls	OR (95% CI)	No. of cases/ community controls	OR (95% CI)	No. of cases/ community controls	OR (95% CI)
Stir frying after fumes emitted								
No	14/70	1.0	8/9	5.9 (1.5, 23.3)	14/77	1.0	8/10	2.8 (0.8, 10.0)
Yes	71/146	2.2 (1.1, 4.1)	37/22	12.2 (4.5, 33.1)	71/130	2.5 (1.3, 4.9)	37/35	5.0 (2.2, 11.0)
Frying after fumes emitted								
No	12/61	1.0	5/7	3.5 (0.8, 16.2)	12/68	1.0	5/5	3.1 (0.8, 13.2)
Yes	73/155	1.8 (0.9, 3.7)	40/24	10.5 (3.9, 28.4)	73/139	2.7 (1.3, 5.5)	40/40	5.3 (2.2, 12.3)
Deep frying after fumes emitted								
No	22/103	1.0	9/10	7.6 (2.1, 26.9)	22/77	1.0	9/9	2.7 (0.9, 8.5)
Yes	63/113	2.1 (1.2, 3.9)	36/21	9.5 (3.9, 23.3)	63/130	1.6 (0.9, 3.1)	36/36	3.2 (1.4, 7.3)

* OR, odds ratio; CI, confidence interval.

extractor did not completely clean the hazardous substance from the air in the kitchen. We have hypothesized that the fume extractor might have been positioned too high above the oil surface to capture the fumes completely. This hypothesis was recently tested in our study group (33); we found that fume samples were mutagenic when the fume extractor was located 70 cm above the oil surface, whereas the samples were not mutagenic or weakly mutagenic when the distance was 50 cm or less. Interestingly, women who did not wait to cook until the oil was very hot and did not use a fume extractor also had a marginally higher risk. It may be that, although there were no visible fumes from the cooking oil, some invisible substance was emitted and was not cleaned by the fume extractor.

Over 96 percent of the women nonsmokers who participated in the present study stated that they regularly cooked the family meals. Epidemiologic studies have shown that lung cancer risk increases with the number of meals cooked per day (22, 23). These results provide the first clue that factors related to cooking are associated with lung cancer. In the present study, we found that women who cooked without using a fume extractor and usually waited until fumes were emitted from the oil developed cancer because of long-term exposure to cooking oil fumes. Therefore, we suggest that some proportion of lung cancer in women should be preventable. For example, changing cooking habits or cooking at lower temperatures and installing a well-designed fume extractor in the home kitchen should be encouraged. Although most western women do not cook at home as often as Chinese women do, the possibility of a cumulative toxic effect cannot be ignored.

Since the use of fume extractors is now very popular in Taiwan, one could question why mortality from lung cancer remains steady and has not been reduced significantly in comparison with earlier decades. Possible explanations are that the fume extractors are not positioned appropriately, as described above, and that ventilation is not efficient because modern housing is small; most Taiwanese people live in small apartments in high-rises, especially in big cities such as Kaohsiung. Another important explanation is that most modern Taiwanese women, like westerners, use vegetable oil rather than lard oil because it is low in cholesterol. In Taiwan, the market for vegetable oil increased from less than 50 percent to 85 percent between 1950 and 1990. However, vegetable oil containing unsaturated fatty acids was found to be more unstable than lard oil at higher temperatures and could emit benzo*a*pyrene, which was not found in lard oil fumes (26). Other reasons may include a cohort effect, longer life expectancies (people in the early decades of life may die young before they have a chance to develop cancer), and other risk factors such as smoking, passive smoking, air pollution, and the possible effects of the interaction between the mutagenicity of cooking oil fumes and these factors. In summary, we found that women nonsmokers were at higher risk for lung cancer if they were exposed to cooking oil fumes emitted at high temperatures and that the risks were strengthened when the fumes were not reduced by an extractor.

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