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AUG - 5 1996

# Cancer Risks Among National Institutes of Health Iron and Steel Workers in Anshan, China, Part I: Proportional Mortality Ratio Analysis

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*A standardized proportional mortality ratio (SPMR) study of 8,887 deaths during 1980-1989 among male workers in a large integrated iron-steel complex in Anshan, China, was conducted to provide clues to occupational risk factors. Accidents and cancer accounted for a higher proportion of deaths among the iron-steel workers than among the general male population (SPMR = 1.21; 95% CI = 1.12-1.31 and 1.14; 95% CI = 1.10-1.18, respectively). Among all workers, SPMRs were significantly elevated for stomach, lung, and colorectal cancers (SPMR = 1.37, 1.37, 1.38, respectively), but not other cancers. Risks of stomach cancer appeared to be highest among workers employed in jobs with exposure to iron and coal dust, whereas significant increases in colorectal cancer were seen for loading and other dusty jobs and for administrative and sedentary jobs without dust exposure. Risks of lung cancer appeared increased for a variety of jobs throughout the complex, especially those with probable high levels of exposure to polycyclic hydrocarbons and asbestos. Risk of esophageal cancer was significantly elevated for fire-resistant brick makers, and risk of nonmalignant respiratory disease was significantly elevated for those employed as furnace workers, foundry workers, and fire-resistant brick makers. © 1996 Wiley-Liss, Inc.\**

**KEY WORDS:** accidents, asbestos, colorectal neoplasm, esophagus neoplasm, foundry workers, lung neoplasm, polycyclic aromatic hydrocarbons, respiratory disease, silica, stomach neoplasm

## INTRODUCTION

A number of epidemiologic studies have indicated that employment in dusty industries, especially metallurgical,

ferrous and nonferrous metal manufacturing, and mining, is associated with increased cancer mortality [Andjelkovich et al., 1992; Blot et al., 1983; Coggon et al., 1990; Egan-Baum et al., 1981; Finkelstein et al., 1991; Siemiatycki et al., 1989; Wright et al., 1988]. The Anshan iron-steel complex, the largest integrated iron-steel company in China with about 150,000 acting and 50,000 retired employees, employs workers in many of these dusty industries. The complex began production over 70 years ago. Its many related factories and facilities include: mines; ore grinding, sintering, and steel rolling operations; iron and steel smelters; foundries; machine manufacturing; coke and chemical plants; electric power and gas fuel plants; a fire-resistant brick factory; and a cement factory. All are concentrated in an area of about 24 km<sup>2</sup>. In addition, the company has many facilities and sectors such as construction, transportation,

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Accepted for publication June 22, 1995.

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housing, logistics, and health and cultural services (environmental protection, public health, hospitals, schools, and research institutes) scattered throughout the city. As a first step in evaluating potential cancer risks associated with employment in the Anshan iron-steel complex, a standardized proportional mortality ratio (SPMR) analysis contrasted mortality patterns of the 8,887 male complex workers who died during 1980-1989 with those of male Anshan city residents.

## MATERIALS AND METHODS

All deaths during 1980-1989 among active and retired Anshan iron-steel complex employees were collected from the death registry of the complex. The cause of death listed on each death certificate was reported by local hospitals of the complex, and confirmed by specific occupational health commissioners in each factory. For each deceased worker, the health officials supplied the following information: factory, workshop, and job title for the job held the longest, and birth date. Workers were classified, using existing complex administrative categories, into one of nine "factory systems": sintering and smelting, steel rolling, machine manufacturing, fire-resistant brick plant, coking and chemical operations, transportation, energy supply, construction, and administrative and logistic services. Information was also available on dust levels in each polluted workplace since 1956.

Death certificates were collected for citizens of Anshan city using the Municipal Death Registry, which had information available for all deaths during 1982-1989. So that a mortality data base could be used as the referent, deaths among individuals employed at the complex were excluded. Cause of death was classified according to the Chinese Classification for Diseases (CCD) issued by the Ministry of Health of China. Since only a small proportion of females was employed at the complex, the analyses were limited to males.

The standardized proportional mortality ratio (SPMR) and corresponding 95% confidence intervals (CI) were used to evaluate risks for cancers and other diseases for different factory groups and specific occupations [Monson, 1974]. The observed proportion of deaths from a particular disease in the exposure group of interest (e.g., workers in one of the nine factory systems) was compared with the expected proportion of deaths from that disease based on the Anshan city population, standardized by age (in 5 year groups).

## RESULTS

A total of 8,887 male workers at the Anshan complex died during 1980-1989, while 22,005 deaths occurred in the referent (iron-steel nonworker) male population in Anshan city. Accidents (SPMR = 1.21) and cancer (SPMR = 1.14)

TABLE I. SPMRs by Cause of Death Among Male Anshan Iron-Steel Complex Workers, 1980-1989

Disease	Obs	Exp	SPMR	95% CI	
All causes	8,887	8,887.0	1.00	—	—
Total cancer	2,850	2,496.3	1.14	1.10	1.18
Nasopharynx	30	31.9	0.94	0.63	1.34
Esophagus	158	171.6	0.92	0.78	1.08
Stomach	487	354.4	1.37	1.25	1.50
Colon/rectum	142	102.5	1.38	1.17	1.63
Liver	541	551.5	0.98	0.90	1.07
Lung	1,033	755.7	1.37	1.28	1.45
Leukemia	58	66.2	0.88	0.67	1.13
Heart disorders	1,348	1,584.3	0.85	0.81	0.90
Cerebral disorders	2,192	2,244.3	0.98	0.94	1.02
Respiratory disorders	615	640.7	0.96	0.89	1.04
Digestive disorders	399	489.9	0.81	0.74	0.90
Accidents	683	563.2	1.21	1.12	1.31

accounted for a higher proportion of deaths among iron-steel workers than the general population (Table I). The SPMRs were significantly elevated for stomach, colorectal, and lung cancers (SPMR = 1.37, 1.38, 1.37, respectively), but not for other cancers.

Listed in Table II are the SPMRs for the major causes of death among workers according to factory administrative system. Risks were significantly elevated for cancer and accidents in most of the factory systems, and for nonmalignant respiratory disease in foundry and machine repairing and in the fire-resistant brick plant. For specific types of cancer (Table III), elevated SPMRs for cancer of the esophagus were observed among workers in the fire-resistant brick plant, and for stomach cancer in workers employed in sintering and smelting, steel rolling, transportation, dynamic and energy supply, and administrative service. Lung cancer mortality was elevated throughout the complex, with relatively minor variation among the nine factory systems.

SPMRs for major causes of death for specific occupations are shown in Table IV. There were slight but significant elevations in total cancer mortality for workers employed in ore grinding and sintering, rolling operations, the coke ovens, loading and other dusty jobs, and administrative work. Significant elevations in mortality from nonmalignant respiratory disease were found for those employed as furnace workers (SPMR = 1.7), fireproof brick makers (SPMR = 3.6), and in the foundry (SPMR = 1.6). Mortality from accidents was significantly elevated for several occupations, with the greatest risk seen for foundry workers (SPMR = 1.4).

In evaluating specific forms of cancer (Table V), risks were significantly elevated for esophageal cancer among fireproof brick makers (SPMR = 2.4) and for stomach can-

TABLE II. SPMRs by Cause of Death Among Male Anshan Iron-Steel Complex Workers According to Factory Administrative System

Factory system	Cause of death (disorders)					
	Cancer	Heart	Cerebral	Respiratory	Digestive	Accidents
	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)
1. Sintering & smelting	1.2 [565] (1.1-1.3)	0.9 [266] (0.8-1.0)	0.9 [401] (0.8-1.0)	1.0 [127] (0.8-1.2)	0.7 [66] (0.5-0.9)	1.4 [160] (1.2-1.6)
2. Steel rolling	1.2 [547] (1.1-1.3)	0.8 [234] (0.7-0.9)	1.1 [439] (1.0-1.2)	0.8 [92] (0.7-3.5)	0.8 [73] (0.6-1.0)	1.2 [120] (1.0-1.4)
3. Foundry & machine repairing	1.0 [190] (0.8-1.1)	0.7 [94] (0.6-0.9)	1.1 [193] (0.9-1.2)	1.4 [74] (1.1-1.7)	1.0 [36] (0.7-1.3)	1.4 [52] (1.0-1.8)
4. Fire-resistant brick plant	1.1 [129] (0.9-1.3)	0.6 [43] (0.4-0.8)	0.8 [84] (0.6-1.0)	2.5 [73] (2.0-3.2)	0.9 [18] (0.5-1.4)	1.2 [26] (0.8-1.7)
5. Coke & chemical plant	1.2 [127] (1.0-1.4)	0.8 [56] (0.6-1.0)	1.1 [111] (0.9-1.3)	0.7 [20] (0.4-1.0)	1.0 [21] (0.6-1.6)	1.2 [26] (0.8-1.8)
6. Transportation	1.2 [386] (1.1-1.3)	0.9 [188] (0.8-1.1)	1.0 [290] (0.9-1.1)	0.6 [47] (0.4-0.8)	0.7 [48] (0.5-1.0)	1.1 [88] (0.8-1.3)
7. Dynamic & energy supply	1.3 [195] (1.1-1.5)	1.0 [93] (0.8-1.2)	0.8 [105] (0.6-1.0)	0.6 [24] (0.4-0.9)	0.9 [29] (0.6-1.3)	1.2 [51] (0.7-1.6)
8. Construction	1.0 [144] (0.9-1.2)	0.7 [64] (0.5-0.9)	1.0 [139] (0.7-1.2)	1.2 [50] (0.9-1.6)	0.9 [24] (0.6-1.4)	1.3 [35] (0.9-1.8)
9. Administrative & logistics services	1.1 [567] (1.0-1.2)	1.0 [310] (0.8-1.1)	0.9 [430] (0.8-1.0)	0.8 [108] (0.7-1.0)	0.9 [84] (0.7-1.1)	1.1 [125] (0.9-1.3)

cer among ore grinding and sintering workers (SPMR = 2.1); rolling operators (SPMR = 1.4); coke oven workers, boiler workers, and cooks (SPMR = 1.6); and those engaged in loading and unspecified dusty jobs (SPMR = 1.4). Colon cancer mortality was also significantly elevated for loading and dusty jobs (SPMR = 1.4), but the risk was highest for workers in administrative and nondusty jobs (SPMR = 1.7). The lung cancer risks were highest for those employed as furnace workers (SPMR = 1.5), coke oven workers (SPMR = 1.5), and pipe fitters (SPMR = 1.9).

## DISCUSSION

The association between occupational dust exposure and chronic disease has been studied for many decades, with excesses of nonmalignant respiratory disease found among foundry workers and those exposed to asbestos and silica [Chen et al., 1992; Egan-Baum et al., 1981; Forastiere et al., 1989]. Recent attention has focused on cancer risks, especially of the digestive and respiratory tracts. In western countries, several studies have reported excess risks of stomach cancer following long-term exposures to iron and other metal dusts, silica or mineral dusts, and oil aerosols among iron, gold, and coal miners and among steel, foundry, metallurgical, and ceramic workers [Coggon et al., 1990; Sie-

miatycki et al., 1989; Wright et al., 1988]. However, the results have not been entirely consistent. In Shanghai, an occupational survey of nearly 13,000 incident cases of stomach cancer revealed excess risks associated with jobs involving exposures to metal, wood, and other dusts and to fossil fuel combustion products [Kneller et al., 1990]. Elsewhere in China, a large-scale cohort study of silica-exposed workers in southern provinces found no rising trend in stomach cancer risk with increasing silica exposure, and risk was not elevated among silicotics [Chen et al., 1992].

Asbestos is one of the few occupational exposures that have been linked to esophageal cancer [Neugut and Wylie, 1987], although risks may also be elevated for exposure to metal dusts [Yu et al., 1988]. These exposures may contribute to excess risks of esophageal cancers seen in fire-resistant brick makers in our study. Also noteworthy is the excess risk of colorectal cancer associated with loading and other dusty jobs, possibly related to asbestos exposure or to metal dust, wood dust, or soot [de Verdier et al., 1992; Neugut and Wylie, 1987]. The excess risk of colorectal cancer associated with administrative and other sedentary jobs is also consistent with previous studies [Andjelkovich et al., 1992; de Verdier et al., 1992; Neugut and Wylie, 1987; Slattery et al., 1988].

The evidence linking occupational dust exposure with

TABLE III. SPMRs for Selected Cancers Among Male Anshan Iron-Steel Complex Workers According to Factory Administrative System

Factory system	Type of cancer						
	Nasopharynx	Esophagus	Stomach	Colon/rectum	Liver	Lung	Leukemia
	SPMR [OBS] (95% CI)						
1. Sintering & smelting	1.1 [7] (0.5-2.4)	1.1 [35] (0.7-1.5)	1.6 [109] (1.3-1.9)	1.4 [27] (0.9-2.0)	1.0 [112] (0.9-1.3)	1.3 [184] (1.1-1.4)	0.8 [11] (0.4-1.5)
2. Steel rolling	1.6 [10] (0.8-3.0)	0.9 [28] (0.6-1.3)	1.3 [88] (1.1-1.6)	1.3 [25] (0.8-1.9)	1.1 [120] (0.9-1.3)	1.3 [183] (1.1-1.5)	1.2 [15] (0.7-2.0)
3. Foundry & machine repairing	0.8 [2] (0.1-3.0)	0.8 [11] (0.4-1.4)	0.9 [25] (0.6-1.3)	1.2 [9] (0.5-2.2)	0.7 [28] (0.4-1.0)	1.3 [77] (1.0-1.6)	1.5 [7] (0.6-3.1)
4. Fire-resistant brick plant	0.7 [1] (0.0-3.8)	2.2 [18] (1.3-3.5)	1.0 [17] (0.6-1.6)	0.4 [2] (0.1-1.6)	0.9 [23] (0.6-1.4)	1.5 [53] (1.1-2.0)	0.0 [0] (0.0-1.4)
5. Coke & chemical plant	0.8 [1] (0.0-4.2)	0.5 [4] (0.1-1.4)	1.0 [15] (0.5-1.6)	1.4 [6] (0.5-3.0)	1.2 [29] (0.8-1.8)	1.4 [46] (1.0-1.9)	1.5 [4] (0.4-3.9)
6. Transportation	0.7 [3] (0.1-2.0)	1.4 [30] (0.9-1.9)	1.4 [65] (1.1-1.8)	1.4 [20] (0.9-2.2)	0.9 [64] (0.7-1.1)	1.4 [143] (1.2-1.7)	0.6 [6] (0.2-1.3)
7. Dynamic & energy supply	2.1 [4] (0.6-5.3)	0.7 [7] (0.3-1.5)	1.9 [39] (1.3-2.5)	1.6 [10] (0.8-2.9)	1.2 [41] (0.8-1.6)	1.4 [62] (1.1-1.8)	0.6 [3] (0.1-1.9)
8. Construction company	0.0 [0] (0.0-2.2)	0.7 [7] (0.3-1.4)	1.4 [27] (0.9-2.0)	1.6 [9] (0.8-3.1)	0.6 [19] (0.4-1.0)	1.4 [58] (1.0-1.8)	0.3 [1] (0.0-1.8)
9. Administrative & logistics services	0.3 [2] (0.0-1.1)	0.5 [18] (0.3-0.8)	1.4 [102] (1.2-1.7)	1.6 [34] (1.1-2.3)	1.0 [105] (0.8-1.2)	1.5 [227] (1.3-1.7)	0.8 [11] (0.4-1.5)

lung cancer is more extensive [Blot et al., 1983; Finkelstein et al., 1991; Siemiatycki et al., 1989], with several agents being implicated such as asbestos, inorganic arsenic, polycyclic aromatic hydrocarbons (PAHs), nickel refining dusts, and chromium compounds. In several studies [Smith et al., 1995], the risk of lung cancer has been increased among silicotics, but gradients in risk with amount of silica exposure are less clear [IARC, 1987; McLaughlin et al., 1992]. Also uncertain are the effects of iron dust. Little or no excess risk has been reported among hematite miners in various countries, including China, except those exposed to radon [McLaughlin et al., 1992]. Other studies of the steel industry have revealed excess risks of lung cancer, especially among coke oven workers [Dong et al., 1988], but also in foundry and other operations [Blot et al., 1983; Tossavainen, 1990] associated with PAH exposure.

As a first step toward clarifying risks of stomach, lung, and other cancers associated with employment in the dusty environment of the Anshan iron-steel complex, we looked at the proportionate mortality of various groups of workers exposed to several types of dust. Despite the limitations of this methodologic approach, the study had the advantage of large numbers (nearly 9,000 deaths among 200,000 workers) and relatively stable job titles, and thus seemed an appropriate means to generate leads for in-depth studies. The results of the SPMR analysis suggested that workers employed in the sintering factory, especially those working

in iron ore and raw material grinding or as sintering operators, had the highest risk of stomach cancer. Also at excess risk were rolling operators exposed mainly to ferric oxide; foundry workers exposed to silica, ferric oxide, and PAHs; and other workers heavily exposed to mixed dusts. Risks were increased in various groups exposed to pitch and coal dust and their combustion products, notably PAHs as measured by benzo(a)pyrene monitoring levels. The workers at high risk included boiler workers, cooks, coke oven workers, and those employed in smelting and rolling operations.

Lung cancer risks were elevated throughout the iron-steel complex, especially among furnace workers, coke oven workers, and pipefitters potentially exposed to PAHs and asbestos. The increased risk of lung cancer across a variety of jobs in the complex resembles the pattern of elevated risk seen among long-term steel workers in a large U.S. facility [Blot et al., 1983].

Risks of colorectal cancer were elevated for loading workers possibly exposed to asbestos and other dusts such as metal, wood, and soot, and for administrative and other workers with less physically demanding jobs. Esophageal cancer was significantly elevated for workers in the fire-resistant brick plant exposed to asbestos and dust.

In summary, this exploratory analysis based on the longest-held job of Anshan iron-steel workers lacked information on exposure to specific types of dust or on confounding factors such as smoking and dietary habits, but it

TABLE IV. SPMRs by Cause of Death Among Male Anshan Iron-Steel Complex Workers According to Specific Occupation

Occupation	Cancer	Cause of death (disorders)				
		Heart	Cerebral	Respiratory	Digestive	Accidents
	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)	SPMR [OBS] (95% CI)
1. Ore grinding & sintering	1.2 [132] (1.0-1.4)	0.8 [61] (0.6-1.1)	0.9 [94] (0.7-1.1)	1.2 [36] (0.8-1.6)	0.7 [14] (0.4-1.2)	1.1 [24] (0.7-1.7)
2. Furnace workers, ingot, & casting	1.1 [125] (0.9-1.3)	0.8 [57] (0.6-1.0)	0.9 [92] (0.7-1.1)	1.7 [54] (1.3-2.2)	0.7 [15] (0.4-1.1)	1.1 [30] (0.7-1.5)
3. Rolling	1.1 [507] (1.0-1.2)	0.8 [222] (0.7-0.9)	1.1 [418] (1.0-1.2)	0.8 [86] (0.7-1.0)	0.8 [69] (1.0-5.5)	1.2 [113] (1.0-1.4)
4. Foundry	1.0 [176] (0.8-1.1)	0.7 [86] (0.6-0.9)	1.0 [172] (0.9-1.2)	1.6 [76] (1.2-2.0)	0.9 [33] (0.6-1.3)	1.4 [51] (1.1-1.9)
5. Fire-proof brick maker	1.0 [45] (0.7-1.3)	0.4 [13] (0.2-0.8)	0.9 [40] (0.7-1.3)	3.6 [41] (2.6-4.8)	0.7 [5] (0.2-1.6)	1.2 [9] (0.6-2.3)
6. Coke oven worker, boilermaker, cook	1.2 [246] (1.1-1.4)	0.8 [110] (0.7-1.0)	1.0 [197] (0.9-1.2)	0.6 [34] (0.4-0.8)	0.8 [29] (0.5-1.1)	1.0 [39] (0.7-1.4)
7. Pipefitter	1.0 [42] (0.8-1.4)	1.0 [26] (0.6-1.4)	1.2 [44] (0.8-1.6)	0.8 [9] (0.4-1.5)	0.8 [6] (0.3-1.7)	0.8 [7] (0.3-1.7)
8. Loading & other dusty jobs	1.1 [1440] (1.0-1.2)	0.9 [737] (0.8-0.9)	1.0 [1176] (0.9-1.0)	1.0 [334] (0.9-1.1)	0.7 [186] (0.6-0.8)	1.3 [405] (1.2-1.5)
9. Administrative & nondusty jobs	1.2 [815] (1.1-1.3)	0.9 [342] (0.8-1.0)	1.0 [545] (0.9-1.1)	0.7 [103] (0.6-0.8)	1.0 [143] (0.9-1.2)	1.1 [169] (1.0-1.3)

TABLE V. SPMRs for Selected Cancers Among Male Anshan Iron-Steel Complex Workers According to Specific Occupation

Occupation	Type of cancer						
	Nasopharynx	Esophagus	Stomach	Colon/rectum	Liver	Lung	Leukemia
	SPMR [OBS] (95% CI)						
1. Ore grinding & sintering	0.7 [1] (0.0-4.0)	1.0 [8] (0.4-2.0)	2.1 [33] (1.4-2.9)	1.0 [4] (0.3-2.4)	1.1 [25] (0.7-1.6)	1.2 [40] (0.8-1.6)	2.1 [5] (0.7-4.8)
2. Furnace workers, ingot, & casting	1.4 [2] (0.2-5.0)	0.5 [4] (0.1-1.3)	0.9 [14] (0.5-1.4)	1.1 [5] (0.3-2.5)	1.1 [28] (0.8-1.6)	1.5 [52] (1.1-2.0)	0.0 [0] (0.0-1.2)
3. Rolling	1.5 [9] (0.7-2.9)	0.8 [24] (0.5-1.2)	1.4 [86] (1.1-1.7)	1.3 [24] (0.9-2.0)	1.1 [107] (0.9-1.3)	1.3 [167] (1.1-1.4)	1.3 [15] (0.7-2.2)
4. Foundry	0.9 [2] (0.1-3.2)	0.8 [10] (0.4-1.4)	1.0 [25] (0.6-1.4)	1.2 [9] (0.6-2.3)	0.7 [26] (0.4-1.0)	1.2 [68] (1.0-1.6)	1.4 [6] (0.5-2.9)
5. Fire-proof brick maker	0.0 [0] (0.0-6.3)	2.4 [8] (1.0-4.7)	1.2 [8] (0.5-2.3)	0.6 [1] (0.0-3.2)	0.8 [8] (0.4-1.6)	1.1 [16] (0.6-1.8)	0.0 [0] (0.0-4.1)
6. Coke oven worker, boiler worker, cook	0.4 [1] (0.0-2.2)	0.8 [12] (0.4-1.4)	1.6 [48] (1.2-2.2)	1.0 [8] (0.4-2.0)	1.1 [45] (0.8-1.4)	1.5 [91] (1.2-1.8)	0.8 [4] (0.2-2.1)
7. Pipefitter	0.0 [0] (0.0-7.2)	0.4 [1] (0.0-2.0)	1.4 [8] (0.6-2.7)	1.1 [2] (0.1-4.1)	0.5 [4] (0.1-1.2)	1.9 [23] (1.2-2.8)	1.0 [1] (0.0-5.6)
8. Loading & other dusty jobs	1.0 [16] (0.6-1.6)	0.9 [80] (0.7-1.1)	1.4 [255] (1.2-1.6)	1.4 [74] (1.1-1.7)	0.9 [271] (0.8-1.1)	1.3 [520] (1.2-1.4)	0.8 [30] (0.6-1.2)
9. Administrative & nondusty jobs	1.1 [10] (0.5-2.1)	1.0 [45] (0.8-1.4)	1.3 [120] (1.1-1.5)	1.7 [48] (1.2-2.2)	1.0 [160] (0.9-1.2)	1.4 [289] (1.3-1.6)	1.0 [18] (0.6-1.5)

provided etiologic leads for stomach and lung cancers that could be evaluated in nested case-control studies that are reported in the following paper.

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