Acute Mountain Sickness in a General Tourist Population at Moderate Altitudes

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■ *Objective*: To determine the incidence of acute mountain sickness in a general population of visitors to moderate elevations, the characteristics associated with it, and its effect on physical activity.

■ *Design:* A cross-sectional study.

■ *Setting:* Resort communities located at 6300 to 9700 feet elevation in the Rocky Mountains of Colorado.

■ *Participants:* Convenience sample of 3158 adult travelers, 16 to 87 years old (mean age [± SD], 43.8 ± 11.8 years).

■ *Results:* Twenty-five percent of the travelers to moderate elevations developed acute mountain sickness, which occurred in 65% of travelers within the first 12 hours of arrival. Fifty-six percent of those with symptoms reduced their physical activity. The odds favoring acute mountain sickness were 3.5 times as large for visitors whose permanent residence was below 3000 feet elevation as for those whose residence was above 3000 feet; 2.8 times as large for visitors with previous symptoms of acute mountain sickness; and twice as large in travelers younger than 60 years. Women, obese persons, those in poor or average physical condition, and those with underlying lung disease also had a higher occurrence of acute mountain sickness ($P < 0.05$).

■ *Conclusions:* Acute mountain sickness occurs in 25% of visitors to moderate altitudes and affects activity in most symptomatic visitors. Persons who are younger, less physically fit, live at sea level, have a history of acute mountain sickness, or have underlying lung problems more often develop these symptoms.

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Rapid ascent from low to high altitude is often followed by headache, fatigue, shortness of breath, sleeplessness, and anorexia, a symptom complex called acute mountain sickness. Although some of these symptoms may occur as a result of travel not associated with altitude, only 5% of adults traveling at sea level report similar symptoms (1). A long-standing interest has existed in the study of acute mountain sickness because it affects a large number of mountain visitors (2-4) and can progress to the life-threatening conditions of high-altitude pulmonary edema or high-altitude cerebral edema (5). Previous estimates of the incidence of acute mountain sickness have been obtained primarily from small groups of physically fit young men going to altitudes above 12 000 feet (2-4, 7-9). Little information exists on the frequency and severity of the disorder in the general population at moderate altitudes, yet the population at risk is large. For example, more than 13 million persons visited the Colorado mountains in 1990 for business, conferences, or recreational activities including skiing, climbing, hiking, hunting, and fishing (10).

More needs to be learned about the incidence of acute mountain sickness at moderate altitudes in the general population and about the characteristics of those most likely to be at risk for symptom development. We therefore surveyed groups of persons visiting resorts in the Colorado mountains for conferences and seminars. Specifically, we sought to determine 1) the incidence of acute mountain sickness in visitors exposed to moderate elevations; 2) the effect of acute mountain sickness on physical activity; and 3) the visitor characteristics associated with the development of acute mountain sickness. This information would be useful for developing strategies to minimize symptoms in travelers to moderate altitudes.

Methods

The study cohort consisted of 4212 adults attending 45 conferences at resorts located at elevations of 6300 to 9700 feet in the Rocky Mountains of Colorado from July 1989 to May 1991. Resorts were chosen on the basis of the willingness of conference organizers to participate. Conferences whose schedules required all participants to attend a meeting within 48 hours of arrival when the study questionnaire could be distributed were included. Study personnel attended these meetings, briefly introduced the study, and distributed the questionnaires. Questions by participants concerning acute mountain sickness or the effects of altitude on health were not answered until all questionnaires were collected. Completion of the survey usually took less than 10 minutes. The participants in each meeting were counted to calculate the response rate.

The questionnaire was completed by 3158 (75%) of the persons registered for these conferences, and information satisfactory for analysis was obtained from 99% of those completed. Visitors ranged in age from 16 to 87 years (mean age [± SD],

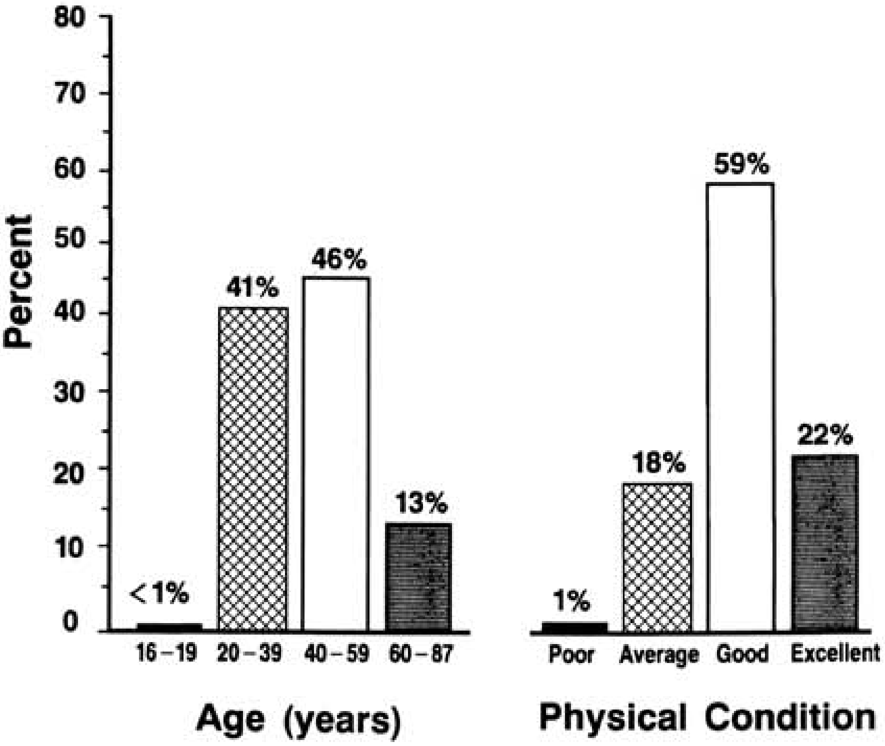

Figure 1. Distribution of visitors by age and physical condition. Physical condition was a self-assessed measure. Panel A (n = 3143); Panel B (n = 3119).

657e43.8 ± 11.8 years) (Figure 1). Of the completed surveys, 2023 (64%) were conducted at resorts located at elevations over 9000 feet and 2603 (82%) were completed in the winter season (November through April). The study was approved by the Human Research Committee of the University of Colorado Health Sciences Center.

The questionnaire was designed to obtain demographic information concerning age, gender, height, weight, and permanent residence for each visitor; previous or current medications; and the duration of stops, if any, made enroute. Questions asked regarding underlying health conditions included whether the participant had ever been treated for lung disease (asthma, bronchitis, or emphysema); heart conditions (angina or heart attacks); diabetes; high blood pressure; or pregnancy. Participants were asked "How do you rate your physical condition?" Responses were rated as great, good, average, or poor.

To determine whether participants had acute mountain sickness, they were asked if they had experienced any of the following symptoms while at the resort: loss of appetite, vomiting, shortness of breath, dizziness or lightheadedness, unusual fatigue, sleep disturbance (other than related to normal travel), and headache. If the response to headache was "yes," they were asked to describe it as mild or severe. Acute mountain sickness was defined as the presence of three or more of these symptoms in the setting of recent altitude exposure. This case definition was similar to that used by previous investigators (1, 2, 5, 6, 9, 12, 13) and is in accordance with the case definition recently developed and codified for international use by the International Hypoxia Symposium (14).

If participants had any of these symptoms of acute mountain sickness, they were asked to determine how the symptoms affected their activity. Response options included "no limitation," "reduced activity," and "required to stay in bed or room." A determination of symptom onset was assessed by asking participants "How long after arrival at the resort did symptoms begin?" Response options included "less than 12 hours," "12 to 24 hours," "25 to 48 hours," "49 to 72 hours," or "72 hours."

Alcohol use was measured as the number of beer, wine, or hard-liquor drinks consumed within the first 24 hours of arrival at the resort. Season was determined by the date of questionnaire administration, with winter defined as November through April in each of the study years. Body mass index was calculated as weight kg/in^2 and was used to identify obese persons (women with a body mass index >27.3 and men with a body mass index >27.8) (11).

Persons with or without acute mountain sickness were compared using the Wilcoxon rank-sum test for ordinal variables and using the chi-square test for categoric variables. The Student t-test was used for normally distributed variables. The Fisher exact test was used for small sample sizes. Associations were considered significant at $P < 0.05$.

A forward, stepwise, multiple logistic regression analysis was used to examine the independent effects of participant characteristics on the occurrence of acute mountain sickness. All variables associated with the occurrence of acute mountain sickness at $P < 0.25$ were initially included in the regression analysis. Data acquired in year 2 (June 1990 to May 1991), comprising 1241 cases after the revision of the questions concerning underlying health conditions and habitual activity level before travel, were used for the regression analysis. Variables were dichotomized for ease in presentation. The adjusted odds ratios were computed with 95% confidence intervals (CIs). All calculations were done using the Statistical Analysis Systems statistical package (Cary, North Carolina) (15).

Results

Most of the visitors were middle-aged men whose permanent addresses were at sea level, who did not smoke, and who considered themselves to be in good physical condition (Table 1, *see* Figure 1). Approximately one third (28%) stopped overnight at an intermediate altitude (5280 feet) enroute to their destination. Most (64%) had consumed one or more alcoholic beverages in the first 24 hours after arrival. Small proportions of the visitors were obese, pregnant, or had chronic illnesses (Table 1).

Twenty-five percent (CI, 24.98% to 25.01%) of the visitors reported having three or more symptoms and thus met the case definition for acute mountain sickness, whereas 73% had at least one reported symptom. The most common symptom was headache, and the least common was vomiting (Figure 2). For most participants (65%), the onset of symptoms occurred within the first 12 hours after arrival at altitude; symptom onset occurred between 12 and 36 hours in 34% and after more than 36 hours in 1%. Most (58%) of those with symptoms took analgesics (for example, aspirin, acetaminophen, or ibuprofen). Although 44% of persons with acute mountain sickness had no reduction in activity, 51% had moderate activity reduction, and a small proportion (5%) stayed in bed.

Visitors whose permanent residence was at an elevation below 3000 feet were more likely to develop acute mountain sickness (*see* Table 1). The frequency with which it developed was inversely related to age and physical condition (Figure 3). Altitude visited and a previous history of acute mountain sickness were associated with an increased occurrence, whereas development was inversely related to alcohol consumption. Visitors who stopped over at lower elevations for more than 38 hours were less likely to develop acute mountain sickness than were those who did not. Obesity, female gender, and chronic lung disease were also associated with the development of acute mountain sickness.

The following nine variables were entered into the regression analysis as dichotomous variables: age (younger than 60 years), sex, altitude of permanent residence (below 3000 feet), obesity, lung disease, diabetes, overnight stops before arrival at the resort, previous symptoms during past altitude travel, and self-reported physical condition (poor or average). Although alcohol was statistically associated with acute mountain sickness, it was not included in the model because of the inability to exclude a temporal effect (that is, participants may have become sick and subsequently decided not to drink). The five independent predictors of acute mountain sickness, based on the logistic regression, were residence at an altitude less than 3000 feet; symptoms of acute mountain sickness during previous altitude travel; age younger than 60 years; physical condition self-assessed as poor or average; and the presence of lung disease. The goodness-of-fit chi-square value was 5.51 ($P = 0.23$, $DF = 4$), indicating a good fit of the logistic model. The odds ratios, each adjusted for the other variables in the model, are shown in Table 2.

Discussion

The main finding of this study was that 25% of the visitors traveling to moderate elevations (6300 to 9700 feet) developed acute mountain sickness. Residence at or near sea level, a previous history of altitude illness, poor to average physical condition, and lung disease increased the risk for acute mountain sickness. This study is the largest conducted in the general population of visitors to moderate altitudes. Participants in our present study resembled the typical recreational visitor to Colorado (10) and exhibited a broad range of age, body size, self-reported physical condition, and health characteristics. Although the sample size used was larger than that of previous studies, we were still unable to obtain symptom information from all persons in the groups surveyed, and some of the questionnaires were incomplete. If the 25% of conference attendees who did not complete the questionnaire developed acute mountain sickness, the incidence would then increase to 67%. Alternatively, if all those not completing the questionnaire were well, the incidence would decrease to 19%. An additional limitation of this study is that the regression model has not been validated. As with most modeling procedures, degradation of model prediction is expected with future validation efforts. In addition, tests for variable interaction were not done.

Because the symptoms of acute mountain sickness are relatively nonspecific, the extent to which the symptoms result from travel or minor illnesses rather than from altitude exposure needs to be addressed. The find-

Table 1. Characteristics and Incidence of Acute Mountain Sickness in Visitors to Areas of Moderate Altitude*

Characteristics	Total	Acute Mountain Sickness	*P* Value
	n	*n*(%)	
Gender (*n* = 3140)			
Male	2159	510 (23.6)	0.01
Female	981	274 (27.9)	
Residence (*n* = 3108)			
Sea level	2774	750 (27.0)	<0.001
>3000 feet	334	28 (8.4)	
Season (*n* = 3129)			
Winter	2603	636 (24.4)	0.049
Nonwinter	526	150 (28.5)	
Stop over (*n* = 2035)†			
Yes	565	127 (22.5)	
No	1470	405 (27.5)	<0.02
Previous acute mountain sickness (*n* = 2711)‡			
Yes	1492	514 (34.5)	<0.001
No	1219	149 (12.2)	
Alcohol use (*n* = 3108)			
Yes	1996	464 (23.2)	
No	1112	317 (28.5)	<0.001
Current smoker (*n* = 3141)			
Yes	191	47 (24.6)	NS
No	2950	739 (25.0)	
Obesity (3140)			
Yes	397	123 (31.0)	0.003
No	2743	661 (24.1)	
Lung disease (*n* = 1241)§			
Yes	136	47 (34.6)	0.02
No	1105	279 (25.2)	
Heart disease (*n* = 1241)§			
Yes	26	7 (26.9)	NS
No	1215	319 (26.3)	
Hypertension (*n* = 1241)§			
Yes	81	19 (23.5)	NS
No	1160	307 (26.5)	
Diabetic (*n* = 1241)§			
Yes	10	4 (40.0)	NS
No	1231	322 (26.2)	
Chronic medication (*n* = 1244)			
Yes	299	79 (24.6)	NS
No	945	246 (26.0)	
Pregnant (*n* = 981)§			
Yes	26	10 (38.5)	NS
No	955	263 (27.6)	

* Numbers in parentheses for each characteristic represent total respondents to that item. NS = not significant.
† Only respondents from sea level.
‡ Only year 2 respondents.
§ Only respondents with previous altitude travel.

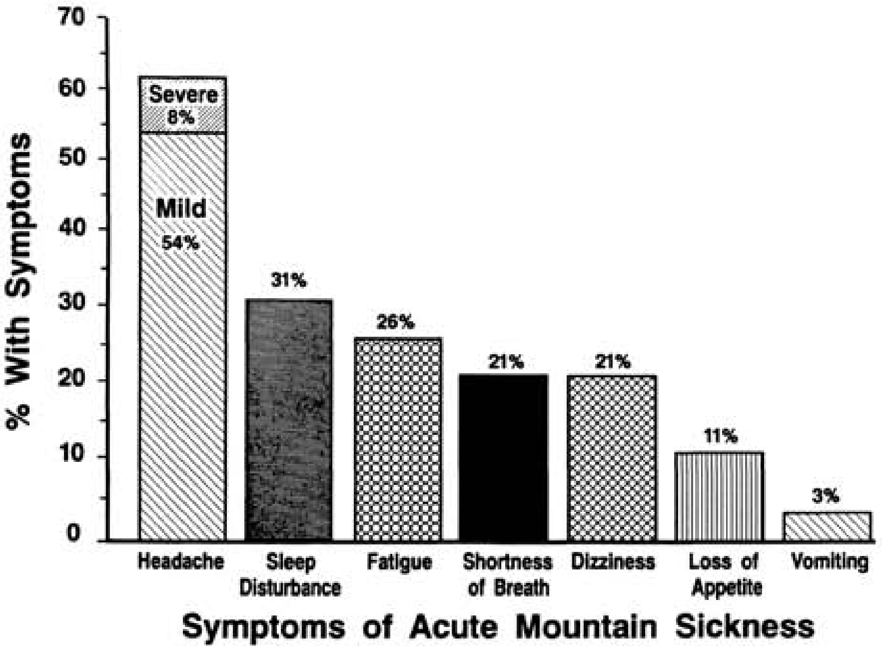

Figure 2. Distribution of symptoms of acute mountain sickness in 3072 visitors.

ing that the percentage of visitors with symptoms was greater at the highest elevations supports a direct relation between altitude and acute mountain sickness. In addition, the risk attributed to altitude in our study was 19% (acute mountain sickness in sea-level residents minus symptoms in visitors living at moderate elevations). This finding is similar to the attributable risk of 20% shown by Montgomery and colleagues (1) (incidence of 25% among travelers to high-altitude resorts compared with 5% among travelers to sea-level resorts).

Our finding of a 25% incidence of acute mountain sickness is similar to that noted by Montgomery and associates (25%) (9) and by Dean and coworkers (25%) (12). The incidence of acute mountain sickness ranges from 12% to 60%, with higher figures reported with rapid ascent and more extreme altitudes (1, 2, 3, 6, 9, 12, 16).

According to our logistic regression model, the strongest predictors for the development of acute mountain sickness were permanent residence below 3000 feet and a history of acute mountain sickness during previous altitude ascent. A protective effect of residence at moderate elevations (5000 to 6000 feet) confirms previous observations that staging of altitude ascent reduces the incidence of acute mountain sickness (2, 17-20). In addition, certain persons may have an inherent predisposition to recurrent acute mountain sickness, such as retention of fluid and relative hypoventilation (4, 21-24).

Other factors that had a major effect on increasing the risk for developing altitude illness were younger age,

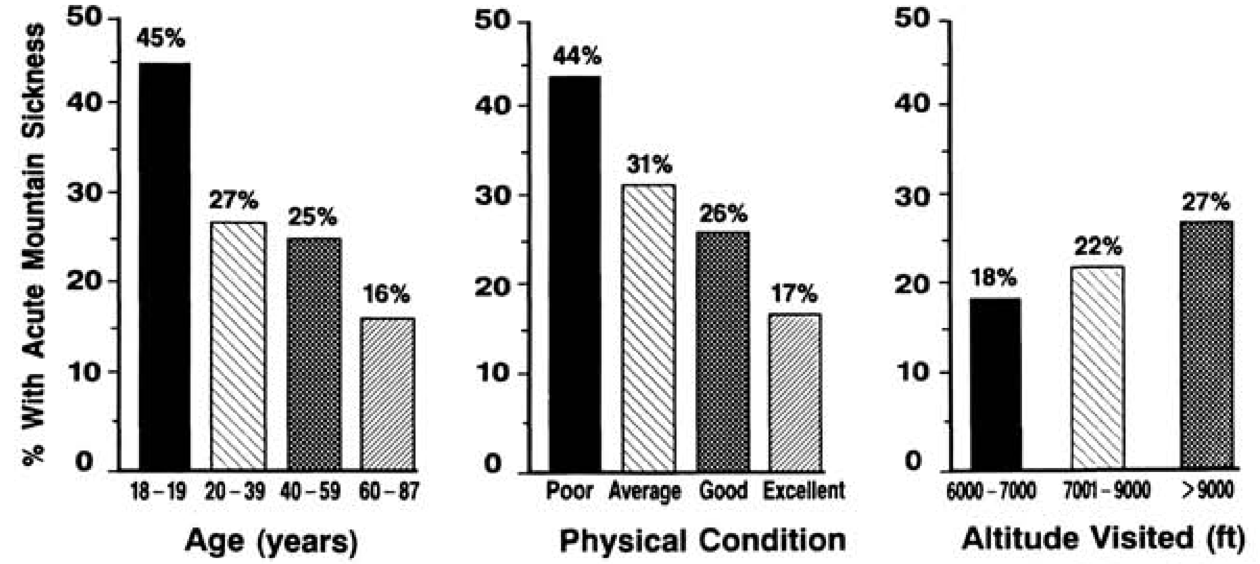

Figure 3. Percentage of acute mountain sickness in visitors to moderate altitudes according to age, physical condition, and altitude visited. Physical condition was a self-assessed measure. Panel A (n = 3143, $P < 0.001$); Panel B (n = 3119, $P < 0.001$); Panel C (n = 2812, $P < 0.001$). AMS = acute mountain sickness.

Table 2. Independent Predictors of Acute Mountain Sickness from Stepwise Logistic Regression*

Predictors	Adjusted Odds Ratio (95% CI)
Residence <3000 ft	3.52 (1.84 to 6.73)
Previous symptoms of acute mountain sickness	2.88 (2.10 to 3.95)
Age <60 years	2.07 (1.15 to 3.72)
Poor or average physical condition	2.03 (1.47 to 2.81)
Lung disease	1.61 (1.05 to 2.47)

* Variables in the model that were not predictive of an association with acute mountain sickness included season, gender, obesity, diabetes, and overnight stops before resort arrival.

presence of lung disease, and poor physical condition. Increased susceptibility to acute mountain sickness among younger persons was also noted by Hackett and colleagues (2). This finding is surprising because some physiologic components of gas exchange that maintain oxygenation, such as vital capacity and hypoxic ventilatory drive, decrease with age (25, 26). Although not studied, elderly persons who visit high altitudes for recreational activities may be self-selected to include the more healthy persons who curtail their activities on arrival in ways that decrease the incidence of acute mountain sickness. The evidence that those visitors with underlying lung disease (for example, asthma, bronchitis, and chronic obstructive lung disease) had a higher incidence of acute mountain sickness supports the views of Hackett (6) and Houston (27). Marginal gas exchange and abnormal pulmonary mechanics are expected to result in exaggerated hypoxia at high altitudes (3, 28-30). Other underlying health conditions, such as heart disease, diabetes, and hypertension, did not appear to influence the risk for developing altitude illness in our study sample. It is not clear from our questionnaire, however, whether persons who were treated successfully for one or more of these conditions considered themselves to be healthy and therefore did not report the presence of the disease.

The influence of physical condition on the development of acute mountain sickness is unclear. Some studies suggest that the incidence is increased in those with greater baseline aerobic fitness (31), whereas others report that aerobic fitness increases a person's tolerance to altitude symptoms (6, 18). Our measurement of physical fitness, although self-assessed and not a clinical measurement, supports an increased risk for acute mountain sickness among less fit persons. This information may be useful to clinicians in assessing the risk for acute mountain sickness in their practice and in developing educational material for the public.

Several articles and texts (6, 17, 27) recommend minimizing alcohol use to prevent or ameliorate altitude symptoms. Although our data seem to contradict the conventional wisdom that alcohol worsens the symptoms and increases the incidence of acute mountain sickness, our questionnaire could not exclude a temporal effect (that is, persons may develop symptoms and subsequently decide not to drink, or they may feel well initially and drink in excess). This area requires further investigation before changing standard recommendations.

Previous reports also have indicated that women are protected from acute mountain sickness (17, 32), perhaps because of the presence of higher levels of the ventilatory-stimulating hormone progesterone; other studies, however, do not show any sex difference (2, 8). Our results do not support a gender-based advantage and provide evidence that an increased susceptibility to acute mountain sickness may exist among women.

Because more than one half (65%) of the visitors developed symptoms within the first 12 hours after arrival, health care providers, educators, and sojourners can use this information to initiate prophylactic and therapeutic measures early in their visits to higher altitudes to minimize these symptoms and to maximize their return to normal activity.

Although acute mountain sickness is usually a self-limited disease, approximately one half of the visitors with altitude illness reduced their activity and took analgesics to relieve their discomfort. These findings are important for an appreciation of the magnitude of the problem of altitude illness in the general population of visitors to the mountains of Colorado, other western states, and world regions for recreational activities in a mountainous setting. Our findings also provide insights into the economic impact of the disease and possible solutions for minimizing its occurrence or its severity. One strategy for minimizing the economic, personal, and medical impact of acute mountain sickness includes prophylactic and therapeutic interventions (for example, recommending a stopover at an intermediate altitude such as Denver [elevation, 5280 feet] for more than 38 hours, which, in our study, was associated with a reduction in the incidence from 27.5% to 22.5%). The drug acetazolamide has also been shown to be an effective prophylactic agent (2, 16, 33). Participating in less strenuous activity immediately after arrival to the higher altitude also may be beneficial. Further understanding of the natural history, evolution, and risk factors associated with acute mountain sickness will help the clinician determine the appropriate prophylactic, educational, and therapeutic regimens to offer patients before travel to higher altitudes. In addition, these findings will help provide important recommendations for visitors and resort operators that can be immediately cost-effective, given the frequency of acute mountain sickness.

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