

Occupational asthma in snow crab-processing workers

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The prevalence of occupational asthma was studied in two snow crab-processing industries in operation since 1980. Before the 1982 season, all except 10 of the 313 employees were investigated by a questionnaire, prick skin tests with common allergens, crab and crab-boiling water extracts, and spirometry. The diagnosis was confirmed in 46 (15.6%) workers (including 33 of 64 subjects with a history highly suggestive of occupational asthma in the previous seasons) by (1) specific inhalation challenges in 33 subjects (one immediate, nine dual, and 23 late asthmatic responses) and/or (2) a combination of monitoring of peak expiratory flow rates ($n = 12$) and significant changes in bronchial responsiveness to histamine ($n = 16$) as well as in spirometry ($n = 18$) after reappearance of symptoms on return to work. Positive skin tests to crab ($p < 0.001$) and, to a lesser degree, smoking history ($p = 0.03$) but not atopy ($p > 0.05$) were related to the presence of occupational asthma. A high prevalence of rhinoconjunctivitis (35 of 46) and urticaria (16 of 46) was also documented in the affected individuals. (J ALLERGY CLIN IMMUNOL 74:261-9, 1984.)

Occupational asthma has been reported in workers exposed to a vast number of agents, and the list is steadily growing.^{1, 2} In the fishery industry, occupational asthma has been documented in oyster-,^{3, 4} prawn-,⁵ and fish-processing⁶ workers. To our knowledge only two reports have suggested that crab-processing workers can develop occupational asthma.^{7, 8} In these two studies an increased occurrence of respiratory symptoms among crab workers was reported. The diagnosis of occupational asthma, however, was confirmed in only one individual.⁷

The purposes of this study were to determine the prevalence of respiratory symptoms, atopy, and skin reactivity to crab among 303 snow crab-processing workers in two industries situated in the Iles de la Madeleine, Canada. In workers who reported asthma-like symptoms, the diagnosis of occupational

Abbreviations used

FEV ₁ :	Forced expiratory volume in 1 sec
FVC:	Forced vital capacity
PC ₂₀ :	The dose of histamine inducing a 20% fall in FEV ₁
PEFR:	Peak expiratory flow rate

asthma was confirmed in 46 subjects by the combination of the following: specific inhalation challenges and/or changes in spirometry and/or in bronchial responsiveness to histamine on return to work.

SUBJECTS AND METHODS

Snow crab processing

Snow crab (*Chionoectes opilis*) is harvested along the northeastern Atlantic coast from April or May until November or December of each year. The processing of crab involves several steps that are different in the two companies surveyed in the Iles de la Madeleine in the Gulf of St. Lawrence. The crab are brought fresh to the plants where they are first brushed. The legs and claws are separated from the body either manually or with saws. They are then boiled for a total of 8 min. In factory A, there are two small boiling pots in which the crab are immersed and which are located at one end of the plant. Each time crab are removed from the boilers, steam is released into the air as

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Received for publication Oct. 20, 1983.

Accepted for publication March 10, 1984.

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the covers over the boiling pots are lifted. The crab are then cooled for a few minutes, after which, still warm, they are taken to workers who extract the meat from the legs and claws. Finally, this meat is canned and stored in coolers. In factory B, there are three large boiling pots spaced out in the working area. Crab are then placed on straps in the boilers, cooled, and directed to workers who process it further. The steam in this latter factory is more evenly dispersed than in the first plant.

Ventilation over the boilers was poor in the 1980 fishery season when the two plants opened, but it was progressively improved in 1981 and 1982. Cooling of the crab was also improved. Furthermore, in factory A a wall was built in 1982 to separate boiling and cooling from the other processing steps.

Epidemiologic survey

In the months after the opening of the two companies, physicians of the islands noticed an increase in the occurrence of cough, wheezing, shortness of breath, and rhinitis among workers of these two plants. The regional Health Community Department conducted a first survey at the end of the 1981 season that revealed a high prevalence of respiratory symptoms among these workers. Two subjects were initially referred to the Workmen's Compensation Board, and specific inhalation challenges with crab boiling water (see results) confirmed the diagnosis of occupational asthma. It was thus decided to conduct this epidemiologic survey.

The two industries employed a total of 313 workers. Two hundred ninety employees were seen in April 1982 before the start of the fishery season. In addition, 13 workers were investigated after returning to work in that same season. Ten others were not seen as they did not return to work and could not be reached. The following investigation was undertaken.

1. *Questionnaire.* A standardized questionnaire was administered to all workers studied (303) by four physicians to detail any history suggestive of asthma, rhinoconjunctivitis, or urticaria before beginning of exposure, during the previous working seasons, and since they had stopped work. Workers were specifically questioned about nocturnal and/or diurnal symptoms of cough, shortness of breath, or wheezing. Triggering factors related or not to work were detailed. Smoking habits and family history of atopy were also obtained.

During the 1982 season, all workers were interviewed on several occasions about any occurrence or exacerbation of respiratory symptoms, rhinoconjunctivitis, or urticaria.

2. *Skin tests.* Prick skin tests were administered with eight commonly inhaled allergens: tree and grass pollens, *Alternaria*, *Aspergillus fumigatus*, house dust, and *Dermatophyoides farinae* (Bencard, Toronto, Canada) as well as cat and dog danders (Hollister-Stier, Mississauga, Canada), three different commercial crab extracts (Bencard, Hollister-Stier, and Omega, Montreal, Canada), and a crab-boiling water extract. The latter was obtained in the previous fishery season, cooled to -20°C , unfrozen, filtered through a 22-micron Millipore membrane (Millipore Corp., Bedford, Mass.) and then dialysed for 24 hr.

The dialysate was then heated at 56°C for 1 hr, and serum albumin was added (concentration of 0.03%). This dialysate was then used for the skin tests. The wheal size was recorded 10 to 15 min after prick testing. A positive immediate skin reaction was defined as any wheal diameter $>2\text{ mm}$ as compared to the control reaction. Atopy was present if one or more positive reaction(s) to the eight commonly inhaled allergens were elicited.

3. Blood was drawn to determine the total white blood cell count and percentage of eosinophils. Significant eosinophilia was defined as a total count of $>500\text{ cells/cc}$.

4. Spirometric indices (FEV_1 , FVC, FEV_1/FVC) were determined before and 15 min after inhaled salbutamol ($200\text{ }\mu\text{g}$) that was administered with the standard metered-dose inhaler. Spirometry was done according to the standards defined by the American Thoracic Society Snowbird workshop.⁹ Pregnant women ($n = 8$) were not given salbutamol, and five other subjects were unable to perform an adequate spirometric test.

5. A histamine inhalation test was done in all workers giving a history suggestive of asthma (related or not to work) according to the method described by Cockcroft et al.¹⁰ with histamine phosphate concentrations ranging from 0.03 to 16 mg/ml . PC_{20} histamine was determined. Pregnant women were not tested nor were four other workers who were unable to perform an adequate spirometric test.

6. Workers giving a history suggestive of asthma were administered a Wright mini-peak flow meter (Clement Clarke Int., London, England) and were asked to record their PEFR every 2 hr during the days before and after return to work. The best of three values at each time was kept for analysis. In addition, buccal temperature was recorded at the same time intervals. Because of poor compliance or misunderstanding, however, a proper analysis of PEFR was possible in only 14 of the 32 workers who developed occupational asthma on return to work.

7. Specific inhalation tests were performed in 32 of 64 workers who gave a previous history highly suggestive of occupational asthma as well as in 14 workers who had an exacerbation of asthma on return to work. These tests were carried out in two different ways.

In nine workers crab-boiling water extract, prepared as described previously, was administered through a Wright nebulizer (output, 0.14 ml/min) via a loose face mask for progressive exposure periods of $\frac{1}{2}$, 1, 2, 4, 8, 16, and up to a maximum of 125 min. FEV_1 and FVC were recorded 10 min after the end of each nebulization. The exposure was stopped if the FEV_1 dropped by 20% or more or if the maximum nebulization time was reached. FEV_1 and FVC were then recorded every 10 min in the hour after the challenge and then every 30 min for 1 hr and hourly up to 9 hr after the challenge. Oral temperature was obtained before and hourly after the exposure. Blood was drawn before the challenge and at the end of the day. A control study day by use of the same protocol but with a 15-minute nebulization of phosphate-buffered saline instead of the crab boiling water was done on the day preceding the actual challenge.

In 37 workers the occupational-type exposure was performed at work by asking the subject to stand close to the

TABLE I. Distribution of workers according to history and final diagnosis in the two plants

Group	Factory A	Factory B	Total
0	54 (2)	65 (3)	119 (5)
1	26 (0)	31 (2)	57 (2)
2a	12 (1)	12 (1)	24 (2)
b	16 (2)	23 (2)	39 (4)
c	26 (10)	38 (23)	64 (33)
Total	169	134	303

The subjects are divided into the following groups: 0 = asymptomatic; 1 = symptoms of chronic bronchitis or dyspnea with no bronchospastic component; 2a = asthma not related to work; 2b = asthma possibly related to work; 2c = history highly suggestive of occupational asthma. Figures in parentheses represent the number of subjects in whom the diagnosis of occupational asthma was confirmed.

boiling pots for periods varying from 5 to 125 min. The same monitoring of the response (spirometry, oral temperature, and blood cell counts) was performed as described above. Before this challenge a control study day was also scheduled for these workers.

Occupational asthma was confirmed by either a positive specific inhalation test (sustained fall in $FEV_1 > 15\%$ as compared to baseline and/or control day values for the same hour of the day) or a combination of at least two of the following: (1) significant ($> 15\%$) decrease in FEV_1 on return to work as compared to preseason, (2) significant changes (≥ 3.2 -fold drop) in PC_{20} on return to work (the 95% confidence interval on the basis of a single determination being a ± 3.2 fall difference in PC_{20}^{11}), and (3) a pattern of changes in PEFr suggesting work-related asthma.

The G test of independence was used for the statistical analysis.¹² A p value of less than 0.05 was considered significant.

RESULTS

Preseasonal survey

According to their history, the 303 workers studied were divided into three groups. Table I illustrates the distribution of workers in each factory according to these groups. The 119 workers of group 0 had no respiratory complaints. The 57 workers of group 1 had symptoms of dyspnea and/or cough and phlegm with no bronchospastic component nor any relationship to work. Finally, workers of group 2 had symptoms suggestive of asthma. These were divided into three subgroups: 24 workers (group 2 a) whose symptoms were not related to work, 39 workers (group 2 b) whose symptoms were possibly related to work (symptoms only on a few occasions at work), and 64 (group 2 c) giving a history highly suggestive of work-related asthma (symptoms on most working days). There is no significant difference in the prevalence of symptoms among workers in the two factories.

TABLE II. Relationship between atopy and skin reactivity to crab

Crab skin test	Atopy		Total
	+	-	
+	21	44	65
-	11	222	233
Total	32	266	298

Atopy is defined as the presence of at least one positive immediate skin reaction to commonly inhaled allergens. Crab skin reactivity was positive in the presence of at least one positive skin reaction to three commercial crab extracts or crab boiling water. The value of the G test of independent (Gadj) and its level of statistical significance are illustrated.

Gadj = 32.8, $p < 0.001$.

TABLE III. Distribution of preseason PC_{20} s in group 2 workers

Group	PC_{20} (mg/ml)				Not done
	> 16	> 8 to 16	> 2 to 8	≤ 2	
2a	15	4	4	—	1
2b	20	9	6	—	2
2c	17	9	15	15	6
Total	52	22	25	15	9

See Table I for the legends of groups.

Fifty-five workers gave a history of rhinitis and/or conjunctivitis at work. Skin rash at work was reported by 72 workers.

Two hundred ninety-eight subjects had interpretable skin reactions, five workers demonstrating dermographism. Table II illustrates the number of workers with at least one positive skin test to the common allergens and/or at least one positive reaction to crab extracts. Thirty-two (10.7%) workers were atopic, and 65 workers (21.8%) reacted to crab. Of the latter subjects, 21 were atopic, which demonstrated a strong association between atopy and skin reactivity to crab (Gadj = 32.8, $p < 0.001$).

Nine workers had a significant eosinophilia when they were observed in April 1982, that is, before the fishery season.

Thirteen of 298 subjects (five in group 0, five in group 1, and three in group 2) had significant (FEV_1/FVC less than 70%) airway obstruction. Only two of these were smokers. Of the 290 subjects who had spirometry repeated after salbutamol, none demonstrated changes more than 20%, whereas four subjects (two in group 1 and two in group 2) had improvement between 15% and 20%.

Table III gives the distribution of PC_{20} in subjects

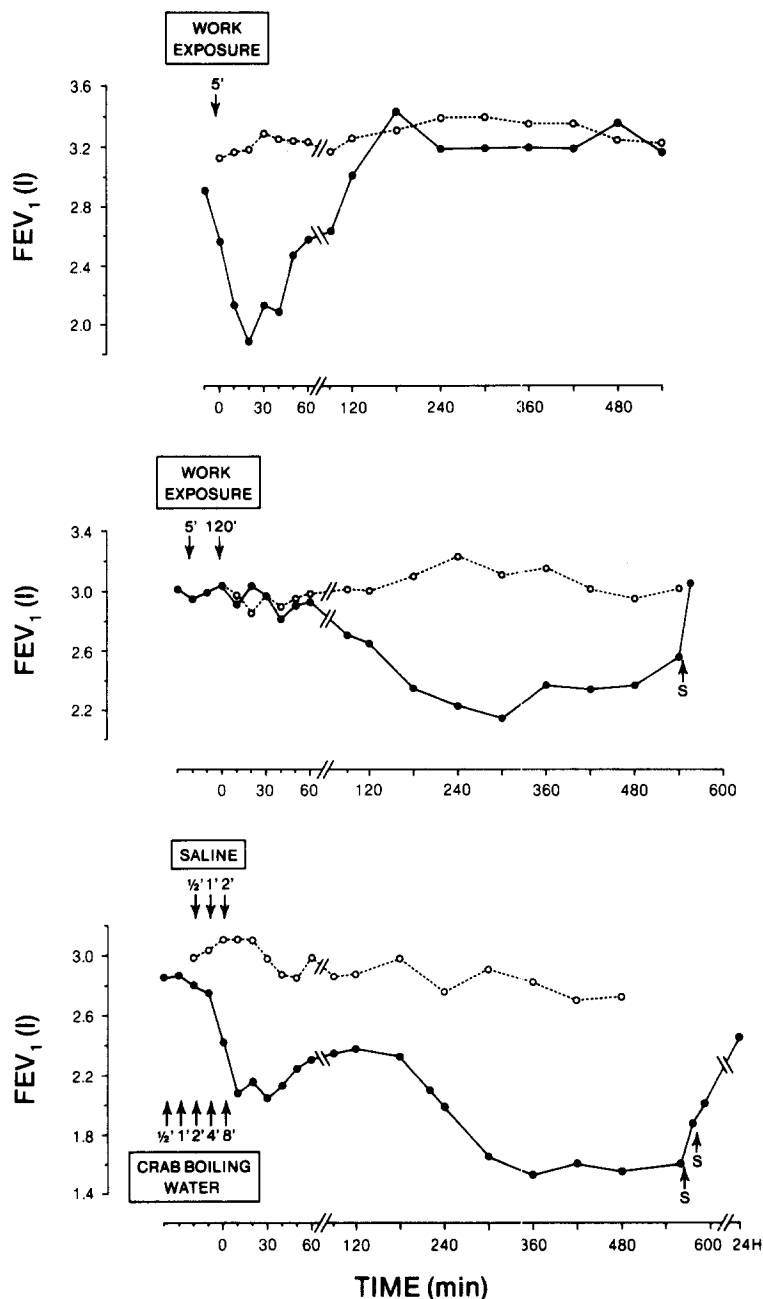


FIG. 1. Examples of the three patterns of asthmatic response (immediate, late or nonimmediate, and dual) are illustrated on the *upper, middle, and lower panels, respectively*. *Open and closed circles* are values obtained on control and exposure days, respectively. The examples on the *upper and middle panels* illustrate challenges performed in the work environment, whereas the one on the *lower panel* was carried out under laboratory conditions by nebulization of saline (*open circles*) and crab-boiling water extract (*closed circles*). S = salbutamol (albuterol) inhalation.

of group 2. Significantly, more subjects (39 of 56; $G_{adj} = 10.5$, $p < 0.01$) of group 2 c demonstrated a positive histamine inhalation test ($PC_{20} < 16$ mg/ml) as compared with groups 2 a and 2 b (23 of 58) for whom the diagnosis of occupational asthma was less likely.

Seasonal study

The diagnosis of occupational asthma by use of the criteria listed above (see methods) was confirmed in 46 workers. As illustrated in Table I, the diagnosis of occupational asthma was confirmed in 33 of the group 2 c subjects in comparison to four, two, two, and five

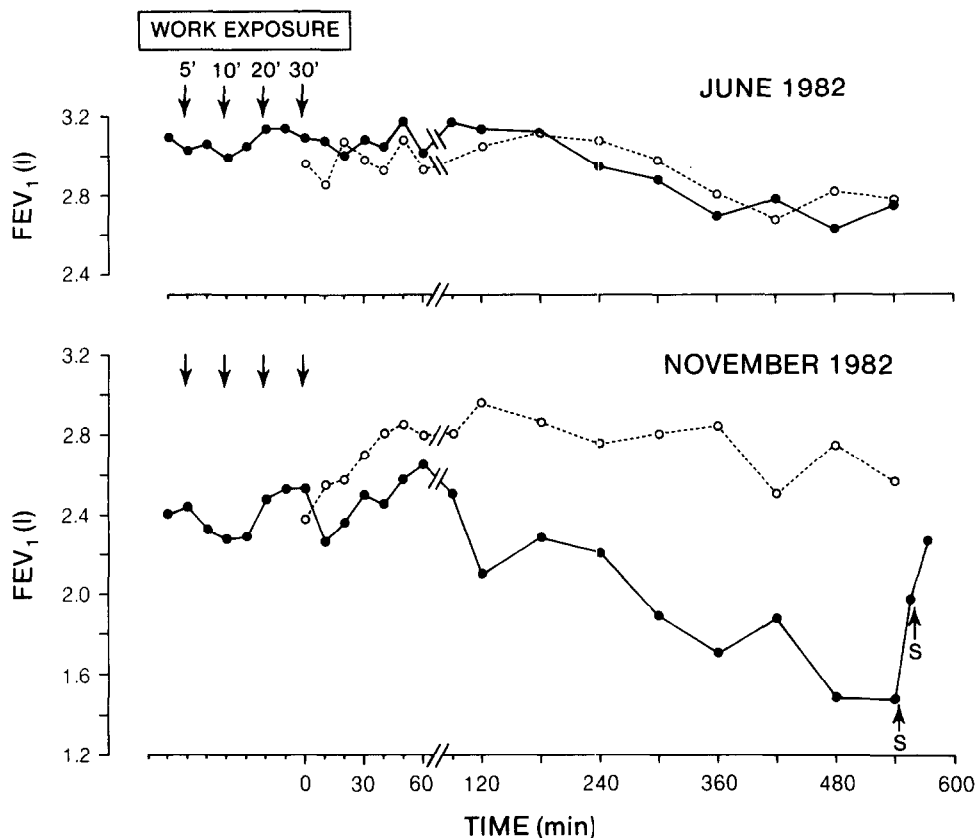


FIG. 2. Specific inhalation challenges carried out in the same individual in June 1982 (*upper panel*) after almost 1 yr off from work and in November 1982 (*lower panel*) after reappearance of symptoms on return to work. Open and closed circles are values obtained on control and exposure days, respectively. S = salbutamol (albuterol) inhalation.

subjects in group 2 b, 2 a, 1, and 0, respectively. Therefore, seven workers who did not give any history of asthma before the 1982 fishery season developed occupational asthma on return to work. There was no difference in the incidence of occupational asthma among workers of the two plants. Furthermore, 16 workers (three in group 0, two in group 1, one in group 2 a, three in group 2 b, and seven in group 2 c) did not return to work in the 1982 fishery season for various reasons. It is likely that some of the workers in group 2 c had, in fact, occupational asthma. In the analysis of the data, however, we have considered all these workers as not having occupational asthma. Of the 46 workers with occupational asthma, 35 and 16, respectively, had symptoms of rhinoconjunctivitis and urticaria at work.

Specific inhalation tests

Four of the nine inhalation challenges with the Wright nebulizer were positive, whereas 29 of the 37 tests performed in the work place produced significant bronchoconstriction. This latter figure includes four of five subjects in whom the challenge with the

Wright nebulizer had been negative and for whom challenge in the work place was positive. Thirty six of 64 subjects of group 2 c (history highly suggestive of occupational asthma) underwent specific inhalation tests that were positive in 25 individuals. One subject demonstrated an isolated, immediate asthmatic response, 23 demonstrated a nonimmediate response, and nine demonstrated a dual (immediate followed by a late or nonimmediate) asthmatic response. Fig. 1 illustrates a typical example of each reaction. Of these 33 subjects with positive challenges, none had a FEV₁/FVC ratio less than 70% before the fishery season. Four subjects had a PC₂₀ larger than 16 mg/ml before the challenge, and 29 subjects had a PC₂₀ smaller than 16 mg/ml before the challenge.

Significant fever (>37.5° C) developed in three subjects challenged with the Wright nebulizer and in two subjects challenged in the work place. Leukocytosis (absolute white blood count >10,000 cell/cc with an increase >2500 cell/cc on the challenge with no such changes on the control day) was documented in two of these after challenge with the Wright nebulizer. In addition, four other workers had sig-

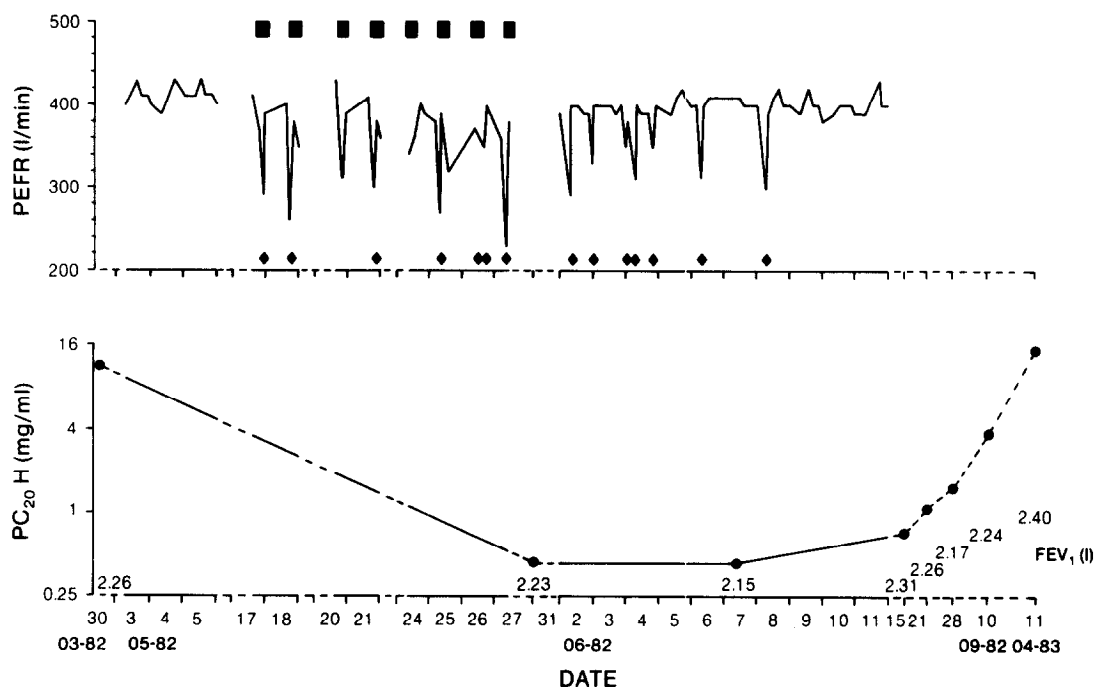


FIG. 3. Combined monitoring of PEFR (*upper panel*) and PC₂₀ (*lower panel*) in the same subject before and after return to work. *Squares* represent the time spent at work, whereas *lozenges* illustrate the use of inhaled salbutamol (albuterol). Baseline FEV₁ values before each histamine inhalation tests are illustrated. They vary by no more than 6% from one test to another.

nificant leukocytosis without fever, all after challenges in the work place. Finally, two subjects had a significant eosinophilia 9 hr after the challenge.

Fig. 2 illustrates the case of a worker who gave a clinical history suggesting occupational asthma in 1980. She was removed from work in September 1980. She returned to work in April 1981 and had to leave work after only 1 wk because of a recurrence of asthma. In June 1982 while she was still symptomatic of asthma, even after being away from work for more than 1 yr, she had a negative specific inhalation challenge after a total exposure of 65 min at work, and changes in FEV₁ were no more pronounced than on the previous control day. She then returned to work for 6 days in October, and once again her asthma worsened. She was removed from work and 2 wk later underwent another specific inhalation test at work. The procedure followed was identical to the previous test in June 1982. Although baseline FEV₁ in November was lower than in June 1982, PC₂₀s at the end of both control days were similar (1.45 and 1.1 mg/ml in June and November, respectively). Moreover, in November, control day FEV₁ values improved rapidly during the first hour, reaching a level comparable to the control values obtained in June. On the exposure day, there was a progressive fall in FEV₁

from 120 min onwards, thus indicating a late asthmatic reaction.

Other diagnostic criteria

Spirometry. A significant fall in FEV₁ as compared to preseason values (greater than or equal to 15%, ranging from 15% to 51%) in exposed workers who developed symptoms was noted in 18 of 27 workers.

PEFR monitoring. In the 14 subjects for whom satisfactory recordings of PEFR were obtained, 12 had a pattern of progressive deterioration of PEFR at work with improvement on cessation of exposure. This includes eight subjects of group 2 c (history highly suggestive of occupational asthma) who did not undergo specific inhalation challenges. A typical example of this is illustrated on the upper panel of Fig. 3.

Changes in PC₂₀. A significant fall in PC₂₀ after return to work (greater than a 3.2-fold concentration drop) was noticed in 16 instances. In 15 of these instances, baseline FEV₁ before each test was $\pm 10\%$. Twelve subjects had measurable PC₂₀s (less than 16 mg/ml) initially with subsequent decreases ranging from a 3.6- to a 32.9-fold concentration difference. The four others had negative histamine inhalation tests (>16 mg/ml) before returning to work, and their

TABLE IV. Relationship between occupational asthma, rhinitis and/or conjunctivitis skin rash at work and crab skin tests

Crab skin tests	Occupational asthma		Rhinitis and/or conjunctivitis		Skin rash at work		Total
	+	−	+	−	+	−	
+	27	38	26	39	27	38	65
−	17	226	29	204	45	188	233
Total	44	254	55	243	72	226	298

See legend of Table II for definition of positive crab skin tests. The values of G test of independence (Gadj) and their levels of statistical significance are illustrated. Five subjects (two with occupational asthma) had dermatographism. Gadj = 39.5, $p < 0.001$; Gadj = 22.5, $p < 0.001$; Gadj = 12.6, $p < 0.001$.

PC₂₀s subsequently dropped to 1.55, 2.75, 4.4, and 4.6 mg/ml, respectively. In addition, two other workers observed after return to work had a significant improvement in their PC₂₀ after removal from work. Five workers had no significant fall in PC₂₀ on return to work. All, however, did have a positive specific inhalation test demonstrating an isolated late asthmatic reaction (maximum fall in FEV₁ ranging from −16% to −29%). Moreover, there was no significant correlation ($r = 0.19$, $n = 10$) between the change in PC₂₀ on return to work and the degree of the nonimmediate reaction.

Fig. 3 (*lower panel*) illustrates the serial changes in PC₂₀ in a worker whose changes in PEFR were suggestive of occupational asthma. At the end of a period at work, PC₂₀ dropped to 0.35 mg/ml from an initial PC₂₀ of 11.5 mg/ml. PC₂₀ progressively improved only 3 wk after the end of exposure and was back to baseline after 1 yr. At the time of each inhalation test, baseline FEV₁ value was at the same level (within $\pm 6\%$) as the first FEV₁ value documented.

Blood eosinophilia. A significant increase in blood eosinophilia was documented in 15 of the 27 workers in whom it was sought on return to work while they were symptomatic.

In summary, the diagnosis of occupational asthma was confirmed in 46 workers, in 33 with inhalation challenges and in 13 by a combination of two or three of the following: significant changes in PEFR, PC₂₀, or FEV₁ on return to work. Three subjects who had a positive inhalation test also had significant changes in PC₂₀ and FEV₁ on return to work. Finally, seven subjects had a concomitant change in PEFR, PC₂₀, and FEV₁ on return to work.

Predisposing factors

Atopy and skin reactivity to crab. There was no relationship between occupational asthma and the

presence of atopy. Only eight of 44 subjects with occupational asthma and 24 of 254 subjects without this diagnosis were atopic; the other five demonstrated dermatographism. However, Table IV illustrates that there was an association between occupational asthma, rhinitis and/or conjunctivitis as well as skin rash at work on one hand and the presence of a positive skin test to crab on the other hand.

Table V illustrates that 29 subjects had positive skin test to commercial crab extracts and crab boiling water, whereas 11 and 25, respectively, had positive skin tests either to crab boiling water or the commercial crab extracts. There was thus a strong statistical association between the skin test results with crab boiling water and the commercial extracts.

Twenty-seven of 46 subjects for whom the diagnosis was confirmed and 13 of 33 subjects with positive inhalation challenges had positive skin reactions to crab boiling water and/or crab commercial extracts.

Smoking history

There was a significant, although weak, relationship (Gadj = 5.54, $p < 0.05$) between present smoking habits and the occurrence of occupational asthma (Table VI). This relationship was also present but somewhat weaker (Gadj = 3.89, $p < 0.05$), if previous smokers were included.

DISCUSSION

This study demonstrates that a significant proportion (15.6%) of snow crab—processing workers can develop occupational asthma. The diagnosis was confirmed through specific inhalation challenges and/or a combination of changes in spirometry, nonallergic bronchial responsiveness to histamine, and/or serial measurements of PEFR. Although occupational asthma was known to exist among the snow crab—

TABLE V. Skin reaction to crab

Skin reaction to crab boiling wa- ter	Skin reaction to commercial crab extracts		Total
	+	-	
+	29	11	40
-	25	233	258
Total	54	244	298

Skin reaction elicited by the prick method and considered as positive in the presence of a wheal >2 mm to crab boiling water or at least one commercial extract as compared to the control reaction. The value of the G test of independence (Gadj) and its level of statistical significance are illustrated. Gadj = 70.8, $p < 0.001$.

TABLE VI. Relationship between occupational asthma and smoking history (excluding previous smokers)

Smoking habits	Occupational asthma		Total
	+	-	
+	35	140	175
-	8	80	88
Total	43	220	263

The value of G test of independence (Gadj) and its level of statistical significance are illustrated. Gadj = 5.54, $p < 0.05$.

processing workers of the Canadian East Coast, its importance was not recognized until recently, and a proper epidemiologic study had not been carried out. There have been reports of asthma in the king crab-processing workers of the United States West Coast,^{7,8} but the diagnosis was confirmed in only one worker by specific provocation tests. We have also demonstrated that the diagnosis of occupational asthma can be confirmed by other means than the standard specific inhalation tests such as careful monitoring of PEFR and serial assessment of nonallergic bronchial responsiveness to histamine. Others have demonstrated the usefulness of serial measurements of PEFR¹³⁻¹⁶ and of PC₂₀.¹⁵⁻¹⁷ The changes in PC₂₀ that were observed could have been predicted, as all except one of our subjects who had specific inhalation tests developed dual or late asthmatic reactions. Others^{18, 19} have demonstrated that late asthmatic reaction can induce significant changes in PC₂₀ that would thus explain our findings. However, there appear to be a few exceptions to this rule as five of our workers with late asthmatic reactions had no change in PC₂₀ upon return to work.

In this survey, we did not study the relative spec-

ificity and sensitivity of monitoring of PEFR and PC₂₀ as compared with specific inhalation challenges in diagnosing occupational asthma. These tests were performed when significant changes in only one of the three other means (PEFR, PC₂₀, FEV₁) had been documented on return to work. However, we find instructive the case of a subject for whom the first specific inhalation test was negative after almost 1 yr away from work but developed occupational asthma when she returned to work. Specific inhalation test was then repeated and found positive. This phenomenon may perhaps be explained in one or both of the following ways: (1) loss of sensitivity after a prolonged period off from work as this has been described in another type of occupational asthma²⁰ and which would reappear after a sufficient time of reexposure, and (2) the second challenge might have been more potent than the first one, as we had no means to compare the antigenicity of the crab boiling water, and therefore the real degree of exposure.

The patterns of bronchial response observed in most of our workers were either dual or isolated late reactions. The time course of such reactions and the fact that similar challenges were negative in 13 subjects with a history suggestive of occupational asthma would tend to exclude the possibility of a nonspecific mechanism. Such dual or isolated late reactions similar to those obtained in some of our workers have also been described in other studied types of occupational asthma, as with red cedar²¹ and isocyanates.^{22, 23} The mechanisms of these reactions are still unknown. Although the immunologic investigation carried out in our workers is still not completed, we have reason to suspect that an immunologic process is involved. Indeed, we found a highly significant correlation between a positive skin test to crab extracts on one hand and occupational asthma, rhinitis and/or conjunctivitis and skin rash at work on the other hand. Moreover, 27 of 46 subjects with occupational asthma had positive skin tests to crab extracts and/or boiling water. This suggests that at least one antigen derived from the crab was nebulized during the boiling process and then inhaled by the workers. The commercial crab extracts used for the skin tests originated from different species of crab (Alaska king crab, dungeness crab, and stone crab) but did not include snow crab extracts, indicating a possible immunologic cross-reactivity between these different subspecies. However, not all affected workers had a positive skin reaction, and some individuals developed leukocytosis and fever. This may suggest that either another type of immunologic response plays a role in these reactions or that the antibody response is not relevant in some workers.

Atopy did not appear to be a predisposing factor in developing occupational asthma to crab. It was already known that atopy is not a predisposing factor to many types of occupational asthma.^{1, 2} Smoking, on the other hand, was a predisposing factor to occupational asthma in our population. We can speculate that smoking, by altering bronchial permeability,²⁴ could allow penetration of the antigen to the effector cells.

When the workers were first assessed in 1982, 64 gave a highly suggestive history of occupational asthma. When 57 of these were actually reintroduced or challenged in their working environment, 24 did not develop occupational asthma. This discordance could be explained by the following: (1) our questionnaire was retrospective, and it is possible that it was too sensitive, (2) some workers might have been malingerers, and (3) preventive measures such as improvement in ventilation and cooling of the crab were introduced before the 1982 fishery season, thereby diminishing the degree of exposure, perhaps sufficiently to prevent the reappearance of symptoms.

We wish to express our gratitude to workers, employers, nurses, secretaries, and technicians of the Iles de la Madeleine without whom this study would have been impossible. We also thank Daniel Smola, Marie Chagnon, and Roland Auger of the Département de Santé Communautaire de Gaspé for administrative help, Jean-Pierre Arseneault and Guy Martineau of the Commission de Santé et de Sécurité du Travail du Québec for their sustained collaboration, Heberto Ghezze for epidemiologic advice, Lyette Rochon for secretarial assistance, and Patricia Hudson for reviewing the manuscript.

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