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Arc welders' respiratory health evolution over five years

J. M. Mur[1], Q. T. Pham[2], D. Teculescu[2], N. Massin[1], C. Meyer-Bisch[1], J. J. Moulin[1], P. Wild[1], M. Leonard[3], J. C. Henquel[2], V. Baudin[1], M. Betz[1], J. M. Fontana[1], and J. P. Toamain[1]

[1]INRS, Avenue de Bourgogne, BP 27, F-54501 Vandoeuvre Cedex, France
[2]INSERM, U 115, Facultés de Médecine, BP 184, F-54505 Vandoeuvre Cedex, France
[3]Occupational medical doctor in the plant

Summary. The respiratory health of 138 arc welders and 106 control subjects in the same company was studied in 1981 and in 1986. Most of the subjects welded mild steel using the Metal Inert Gas (MIG) process. The controls were workers in the same company, not exposed to any known pulmonary risk. The welders and controls in the analysis had not changed their professional activity nor their smoking habits during these five years. The examinations consisted of a questionnaire on respiratory symptoms, a thoracic auscultation, a chest X-ray and lung function tests: flow-volume curve and steady state CO transfer test. The examinations in 1986 confirmed the risk of non specific radiological impairment (pulmonary reticulo-micronodulation) and of obstruction in the small bronchi, which had already been observed in 1981 in the arc welders in this company. These impairments did not seem to have evolved more than in the controls, but do however justify regular surveillance of the respiratory health of arc welders.

Key words: Arc welding – Respiratory health – Epidemiology – Longitudinal study

Introduction

Many epidemiological studies have been conducted to evaluate the risk of impairment in respiratory health through welding fumes and gases. The results of these studies, which have been given in synthesis in bibliographic articles [11, 32] and during scientific meetings [33] are mostly convergent; they reveal clinical, radiological, and functional respiratory risks in arc welders. However, the frequency and intensity of these anomalies differ depending on each study. Elsewhere, the time-course evolution of these changes in the respiratory system have not yet been studied (cross-sectional studies only).

In 1981, we conducted a cross-sectional epidemiological study in a factory producing industrial vehicles, in order to compare the respiratory health state of arc welders with those of workers in the same factory that were not exposed to a known risk of respiratory impairment (control group). This study showed mainly a greater frequency amongst the welders than amongst the controls for reticulo-micronodular shadows on X-ray, signs of bronchial obstruction (diminution of end-expiratory air flows, bronchial hyperreactivity to acetylcholin), and alterations in lung transfer capacity (diminution of lung transfer test indices) [22].

In order to check these differences in respiratory health between welders and controls, and to follow their evolution, we have tried to re-examine the same subjects five years later (longitudinal study).

Offprint requests to: J. M. Mur

Material and methods

The factory specialises in the manufacture of trailers and semi-trailers. Most of the bodies, trucks, tanks and industrial vehicles are manufactured in mild steel. About 20% of the tanks are aluminium and only some are stainless steel. Arc welding is widely used in their construction.

The welding process, developed over a period of time and practically used exclusively since 1981, is the Metal Inert Gas (MIG) process. Techniques and conditions of industrial hygiene in workplaces have not significantly evolved between 1981 and 1986. The pollution that the workers are exposed to is mainly metallic dust (iron and manganese mainly). For more precise details refer to a former publication [8] where C identifies the factory.

The work force has diminished from 1400 salaried workers in 1981 to approximately 960 in 1986. This staff reduction was mainly due to early retirement (from 55 years of age).

Table 1. Comparison of re-examined and non re-examined subjects (controls) (values in 1981)

		Re-examined in 1986 ($N = 181$)		Lost to follow-up ($N = 72$)	
Age in 1981 (years)	[Mean (SD)]	35.6	(9.4)	42.5***	(11.7)
Smokers and ex-smokers	[Number (%)]	137	(75.7%)	64	(88.9%)
Chronic bronchitis	[Number (%)]	5	(2.8%)	3	(4.2%)
Breathlessness grade III or more	[Number (%)]	10	(5.5%)	7	(9.7%)
Rhinorrhea	[Number (%)]	29	(16%)	12	(16.7%)
Abnormal chest X-ray	[Number (%)]	9	(5%)	4	(5.6%)
FVC (% reference value)	[Mean (SD)]	105.9	(12.8)	105.4	(13)
FEV_1 (% reference value)	[Mean (SD)]	95.4	(13)	91.4*	(14.8)
FEV_1/FVC (% reference value)	[Mean (SD)]	93.3	(9.6)	89.9*	(11.4)
MEF 50% FVC (% reference value)	[Mean (SD)]	87	(26.6)	78.4*	(27.6)
MEF 25% FVC (% reference value)	[Mean (SD)]	71	(30)	60.4*	(29.6)
FuCO (% reference value)	[Mean (SD)]	101.7	(9.6)	98.4**	(8.8)

Significant differences * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 2. Comparison of re-examined and non re-examined subjects (welders) (values in 1981)

		Re-examined in 1986 ($N = 300$)		Lost to follow-up ($N = 79$)	
Age in 1981 (years)	[Mean (SD)]	34.7	(8.4)	36.7	(11.5)
Smokers and ex-smokers	[Number (%)]	246	(82%)	62	(78.5%)
Chronic bronchitis	[Number (%)]	10	(3.3%)	4	(5%)
Breathlessness grade III or more	[Number (%)]	16	(5.3%)	4	(5%)
Nasal catarrh	[Number (%)]	57	(19%)	16	(20%)
Abnormal chest X-ray	[Number (%)]	26	(8.7)	7	(8.9%)
FVC (% reference value)	[Mean (SD)]	105.4	(11.9)	103.5	(14.2)
FEV_1 (% reference value)	[Mean (SD)]	93.9	(12.2)	90.6	(18.1)
FEV_1/FVC (% reference value)	[Mean (SD)]	92.6	(10)	90.5	(14.4)
MEF 50% FVC (% reference value)	[Mean (SD)]	85	(25.1)	81.3	(34.3)
MEF 25% FVC (% reference value)	[Mean (SD)]	69.5	(28.8)	65.3	(35.5)
FuCO (% reference value)	[Mean (SD)]	100.3	(9.7)	100.2	(11.4)

There is no significant difference between the two groups

The number of subjects examined in 1981 (379 welders and 253 controls[1]) that were still working or not in the factory in 1986 were asked to undergo a new respiratory examination. It consisted of:

- completion of a standardized respiratory symptoms' questionnaire [5] and a physical examination of the chest (carried out by a different physician than in 1981);
- a chest photo-radiography (10 × 10 cm). Each X-ray was examined independently by two pneumologists (one of them was the same for both the studies). Only the reticular and micronodular shadows were taken into account (Type "p" and type "q" according to the ILO classification);
- the following functional respiratory tests:
  - A series of three forced expiratory tests, to obtain a flow-volume curve satisfying the recommendations of the American Thoracic Society [10]. This test was carried out using a "Spiromatic" apparatus. The following indices were calculated on the flow-volume curve, whose sum FVC + FEV_1 was the greatest: FVC (Forced Vital Capacity), FEV_1 (Forced Expiratory Flow in one second), FEV_1/FVC (the Tiffeneau index), MEF 50% FVC and MEF 25% FVC (maximum expiratory flows at 50% and 25% of the vital capacity).
  - A CO lung transfer test carried out according to the steady-state method, using the "Transfer Test C mini Morgan" apparatus. The fractional uptake of CO (FuCO) was calculated.

For both examinations, the functional respiratory tests were undertaken with the same apparati and operators. In the longitudinal analysis of the data, the pulmonary indices were related to the same reference values [17, 25][2].

Both examinations were carried out during the workshift in autumn. The day in the week and the time in the workshift

[1] These numbers include foremen, who had not been taken into account in our preceding paper

[2] In our preceding paper, we used different reference values for spirometric indices, because those of Quanjer had not yet been published

Table 3. Pulmonary function indices (non-smokers). Mean (SD)

		Curr welders ($N = 32$)			Controls ($N = 31$)			Mild steel welders ($N = 16$)		
Age [86]	(years)	37.0	(7.1)		38.8	(9.3)		40.4	(7.2)	
Height [86]	(cm)	172.5	(6.8)		171.6	(5.7)		171.6	(7.1)	
Weight [81]	(kg)	76.4	(8.1)		75.3	(12.1)		79.1	(8.7)	
Weight [86]	(kg)	76.5	(8.4)		75.8	(14.1)		79.3	(9.0)	
Length employment [86]	(years)	16.7	(6.5)		15.4	(7.8)		18.9	(7.8)	
FVC [81]	(ml)	5009	(711)		4897	(593)		4925	(800)	
FVC [86]	(ml)	4915	(643)		4848	(655)		4866	(661)	
FVC [81]	(% reference values)	107.0	(11.2)		106.6	(11.2)		107.5	(10.7)	
FVC [86]	(% reference values)	107.0	(10.4)		107.6	(13.2)		108.5	(7.9)	
FEV_1 [81]	(ml)	3861	(624)		3891	(503)		3717	(684)	
FEV_1 [86]	(ml)	3903	(530)		3953	(579)		3811	(627)	
FEV_1 [81]	(% reference values)	98.1	(11.6)	↕ **	100.8	(12.8)	↕ **	96.7	(10.4)	↕ *
FEV_1 [86]	(% reference values)	102.2	(11.0)		105.6	(14.2)		102.4	(10.7)	
FEV_1/FVC [81]	(%)	77.2	(7.0)	↕ **	79.7	(7.3)	↕ *	75.6	(7.6)	↕ *
FEV_1/FVC [86]	(%)	79.6	(6.6)		81.6	(5.9)		78.3	(7.0)	
FEV_1/FVC [81]	(% references values)	94.9	(8.1)	↕ ***	98.3	(8.5)	↕ **	93.4	(8.7)	↕ **
FEV_1/FVC [86]	(% reference values)	99.0	(7.7)		101.7	(7.2)		97.9	(8.1)	
MEF 50% FVC [81]	($ml \cdot s^{-1}$)	4899	(1527)	↕ *	5120	(1516)		4729	(1520)	↕ *
MEF 50% FVC [86]	($ml \cdot s^{-1}$)	4527	(1264)		4845	(1274)		4356	(1421)	
MEF 50% FVC [81]	(% reference values)	94.9	(26.6)		100.8	(28.4)		92.9	(24.6)	
MEF 50% FVC [86]	(% reference values)	90.2	(24.9)		98.0	(25.5)		88.1	(25.8)	
MEF 25% FVC [81]	($ml \cdot s^{-1}$)	1810	(780)		2035	(960)		1682	(780)	
MEF 25% FVC [86]	($ml \cdot s^{-1}$)	1653	(607)		1963	(757)		1603	(606)	
MEF 25% FVC [81]	(% reference values)	79.1	(31.3)		90.8	(39.3)		76.0	(31.7)	
MEF 25% FVC [86]	(% reference values)	76.7	(28.6)	* ⟷	92.8	(35.9)		76.8	(27.4)	
FuCo [81]	(%)	52.6	(5.1)		52.2	(5.5)		51.3	(4.1)	
FuCO [86]	(%)	52.8	(7.2)		51.3	(5.6)		52.8	(6.8)	
FuCO [81]	(% reference values)	105.6	(6.7)		108.9	(11.1)		106.8	(7.4)	
FuCO [86]	(% reference values)	105.8	(9.6)		105.4	(7.0)		106.1	(11.5)	

⟷ Significant difference between two groups

↕ Significant difference, within a group, between 1981 and 1986 (paired t-test)

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

There is no significant difference between groups in the evolution of the functional indices

could not be the same for each subject, but they did not differ, on average, between the two surveys.

In order to have a good homogenity of the groups studied, data analysis was carried out only on the subjects who had not changed their smoking habits (never smokers, smokers: subjects smoking about 1g of tobacco a day at the time of the study), and who had not changed their exposure category (welders/controls) between 1981 and 1986.

Statistical analysis consisted of comparing, for smokers and non smokers separately, the data from the respiratory examinations of 1981 and 1986 and their evolution over five years, between the welders still working in 1986 and the controls. A more homogenous subgroup of welders, welding only mild steel, was isolated and also compared with the control group.

Comparisons were carried out using the chi-square test for the qualitative data and the Student's t-test for the quantitative data. Elsewhere mean evolution over time of pulmonary functional indices was tested in each group, using the paired Student's t-test (comparison to 0 of the average individual differences, between 1981 and 1986, for each lung functional index). Significance of these statistical tests is indicated for the threshold risk levels: 5%, 1%, 1‰.

Results

Out of 379 welders, 300 (79.2%) and 181 controls out of 253 (71.5%) were re-examined in 1986. All those not re-examined in 1986 had left the company. Six of the subjects had died. The others did not wish to be, or could not be (change of address for example), re-examined in 1986.

The non re-examined controls were significantly older and had less performant lung functions in 1981

Table 4. Pulmonary function indices (smokers). Mean (SD)

		Curr welders ($N = 106$)			Controls ($N = 75$)			Mild steel welders ($N = 66$)		
Age [86]	(years)	37.6	(7.2)		38.5	(7.8)		37.2	(6.9)	
Height [86]	(cm)	171.1	(6.1)	** ⟷	174.5	(6.6)	*** ⟷	171.1	(5.9)	
Weight [81]	(kg)	72.4	(11.4)	** ⟷	76.6	(12.3)	* ⟷	72.0	(11.9)	
Weight [86]	(kg)	71.8	(12.5)	* ⟷	75.7	(12.6)	* ⟷	71.3	(13.0)	
Smoking daily [81]	($g \cdot j^{-1}$)	19.8	(8.8)		19.1	(7.1)		19.4	(9.0)	
Smoking daily [86]	($g \cdot j^{-1}$)	18.4	(8.1)		18.2	(9.1)		18.4	(8.2)	
Smoking totally [86]	(pcks · yrs)	17.4	(10.0)		18.2	(10.9)		16.9	(9.7)	
Length employment [86]	(years)	16.1	(6.2)		14.0	(8.1)		15.8	(6.0)	
FVC [81]	(ml)	4914	(677)		5056	(689)	↕ *	4956	(658)	
FVC [86]	(ml)	4818	(673)		4967	(721)		4877	(617)	
FVC [81]	(% reference values)	106.2	(11.4)		105.4	(11.3)		106.8	(11.9)	
FVC [86]	(% reference values)	106.5	(11.5)		105.6	(11.0)		107.6	(11.6)	
FEV_1 [81]	(ml)	3702	(515)		3747	(641)		3729	(492)	
FEV_1 [86]	(ml)	3689	(569)		3798	(682)		3757	(472)	
FEV_1 [81]	(% reference values)	94.6	(11.2)	↕ ***	93.3	(12.0)	↕ ***	95.3	(10.5)	↕ ***
FEV_1 [86]	(% reference values)	98.1	(10.2)		97.2	(13.2)		99.3	(10.6)	
FEV_1/FVC [81]	(%)	75.4	(8.2)	↕ **	74.2	(8.3)	↕ **	75.7	(7.9)	↕ *
FEV_1/FVC [86]	(%)	77.1	(6.1)		76.3	(7.1)		77.3	(5.7)	
FEV_1/FVC [81]	(% references values)	92.7	(10.0)	↕ ***	91.4	(9.7)	↕ ***	92.9	(9.6)	↕ ***
FEV_1/FVC [86]	(% reference values)	95.8	(7.5)		95.0	(8.6)		95.9	(7.1)	
MEF 50% FVC [81]	($ml \cdot s^{-1}$)	4451	(1153)	↕ ***	4368	(1425)	↕ **	4516	(1112)	↕ ***
MEF 50% FVC [86]	($ml \cdot s^{-1}$)	4007	(1041)		4044	(1309)		4129	(1041)	
MEF 50% FVC [81]	(% reference values)	87.1	(21.5)	↕ ***	83.3	(25.0)	↕ *	88.1	(21.2)	↕ **
MEF 50% FVC [86]	(% reference values)	80.6	(20.5)		79.3	(24.0)		83.0	(21.1)	
MEF 25% FVC [81]	($ml \cdot s^{-1}$)	1581	(591)	↕ ***	1591	(704)		1606	(567)	↕ ***
MEF 25% FVC [86]	($ml \cdot s^{-1}$)	1419	(454)		1503	(590)		1425	(426)	
MEF 25% FVC [81]	(% reference values)	69.4	(23.5)	↕ *	67.4	(26.1)		70.3	(23.3)	↕ *
MEF 25% FVC [86]	(% reference values)	66.0	(18.9)		67.2	(22.7)		66.1	(18.1)	
FuCO [81]	(%)	48.4	(6.2)		50.7	(6.1)	* ⟷	47.6	(5.7)	
FuCO [86]	(%)	49.0	(6.8)		50.4	(7.2)	* ⟷	48.2	(6.1)	
FuCO [81]	(% reference values)	99.2	(9.3)		101.1	(9.0)		99.0	(8.9)	
FuCO [86]	(% reference values)	98.6	(11.2)		100.7	(11.5)		97.2	(10.1)	

⟷ Significant difference between two groups

↕ Significant difference, within a group, between 1981 and 1986 (paired t-test)

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

There is no significant difference between groups in the evolution of the functional indices

than the re-examined controls (Table 1). It was the same for the welders (Table 2) but to a lesser degree (the differences were not significant).

Setting aside from the analysis those subjects who had changed their exposure category or smoking habits, there remained 138 welders still in activity in 1986 (76.8% smokers), of which 82 welded mild steel exclusively (80.5% smokers) and 106 controls (70.8% smokers).

In the following results, the denomination welders, except where specified, describes all the welders as well as the subgroup (in fact the majority), who welded only mild steel.

The average age of the welders and the controls was not significantly different. It was the same for the morphology (height, weight) amongst the non smokers. However, amongst the smokers, the welders were significantly smaller and lighter in weight than the controls (Tables 3, 4).

The evolution over five years of respiratory symptoms (chronic bronchitis, breathlessness grade III or more, asthma, rhinorrhea, bronchial rales) in each of

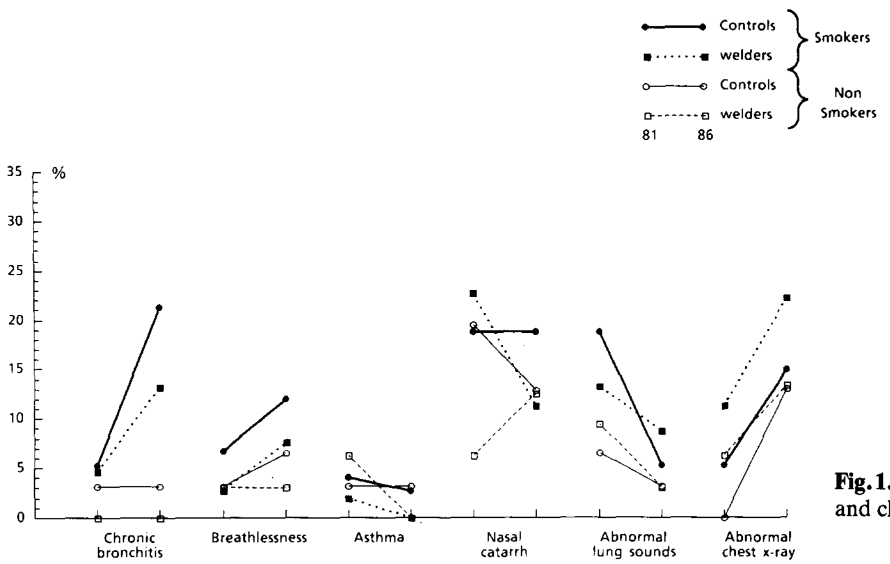

Fig. 1. Symptoms, clinical findings and chest X-ray

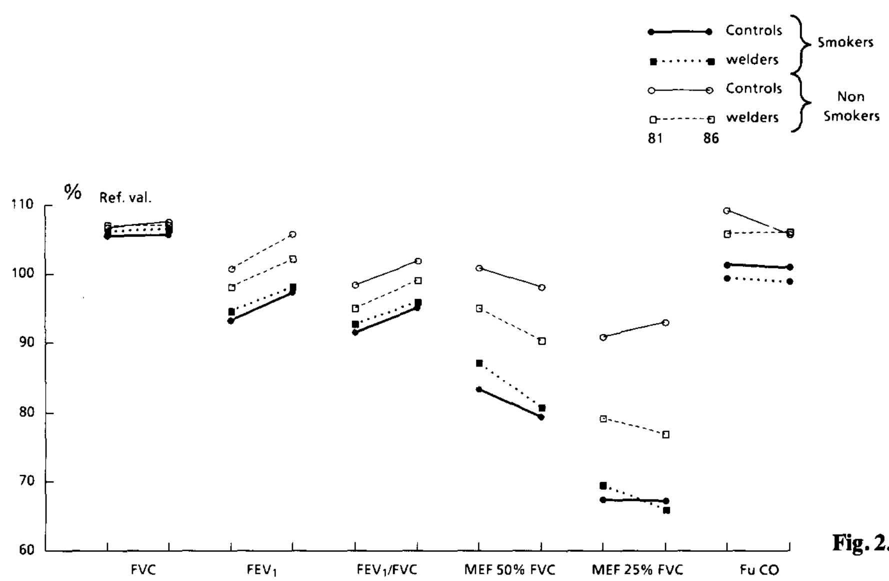

Fig. 2. Pulmonary function indices

the groups, and the differences between welders and controls were not statistically different (Fig. 1). However, it was noted that:

- there was an increase in the frequency of chronic bronchitis and breathlessness (stage III or more) amongst the smokers, whatever their exposure (welders or controls),
- a decrease in the frequency of broncho-pulmonary rales on lung auscultation in all the groups, whatever the smoking habits and category of work.

On the X-rays we noticed an increase (not significant) in the frequency of reticulo-micronodular shadows in all groups. These appeared to be more frequent (but not significantly) amongst the welders than amongst the control smokers, in 1981 as well as in 1986.

As regards respiratory function (Tables 3, 4, Fig. 2) it was noted:

- a relative stability in the vital capacity (shown as a % of the reference values), with no difference between welders and controls;
- a significant increase in all groups of FEV_1 (% of reference values) and of FEV_1/FVC (measured values and % of the reference values), with no significant difference between welders and controls;
- a reduction of MEF 50% FVC and of MEF 25% FVC in all the groups. However, when these indices were related to the reference values, the reduction of MEF 50% FVC was significant only amongst the smokers (more significantly for the welders than for the controls) and the reduction of MEF 25% FVC was significant only amongst the

smoking welders. The initial values and the evolution of expiratory flow indices were pratically identical for the smoking welders and the controls. On the other hand, amongst the non smokers, the average values in 1981 and 1986 of these indices, related to the reference values, were much weaker in the welders as compared to the controls. In 1986 the average value of MEF 25% FVC (related to the reference values) of the non smoking welders was significantly lower than those of the non smoking controls. The evolution of these indices in five years was parallel between the two groups.

- a relative stability in the fractional uptake of CO values in all groups. Amongst the smokers the average FuCO values of mild steel welders were significantly lower in 1981 and in 1986 compared to the controls. However, the difference was not significant when this index was related to the reference values.

Discussion

The aim of this study was to evaluate the evolution of the respiratory state of health over five years in 379 arc welders and 253 controls in the same company. In fact the analysis was carried out only on 138 welders and 106 controls, for the following reasons. Some of the subjects, who had left the company, could not be re-examined (around 25% of the initial number). The non re-examined subjects were older and their lung function values were not as good as the re-examined subjects. The differences were significant for the controls but not for the welders, thus with a tendency to increase the initial differences between these two groups.

Elsewhere, some of the re-examined subjects had changed their type of work and/or their smoking habits between the two studies. We carried out our analysis on two stable subgroups, from the point of view of professional exposure and smoking habits (about half the subjects who were re-examined). This selection brings with it an important reduction in effectiveness and therefore in the power of the statistical tests. However, we considered that the global power ot the statistical analysis would be better with preference to group homogeneity to the detriment of the importance of effectiveness.

Another difficulty with which we were confronted concerned the modification in the time of the techniques of clinical examinations and lung function investigations. The same doctors did not carry out the chest examinations of the subjects for the two studies. This, without doubt, explains the unexpected reduction in the frequency of the bronchopulmonary rates observed in all groups. The systematic increase over five years in the FEV_1 and FEV_1/FVC values was equally surprising, but harder to attribute to a modification in technique, because the other indices of the flow-volume curve were reduced. The hypothesis of a training effect in the spirographic tests has been put forward by several authors [6, 26], who observed a similar evolution. These remarks show the difficulty in carrying out longitudinal studies in the workplace.

This second study seemed to confirm a greater frequency, amongst welders compared to the controls, of reticulo-micronodular lung shadows amongst the smokers and signs of bronchial obstruction, especially of the small bronchi, amongst the non smokers.

As for radiography, the size of the X-rays did not allow us to dismiss with certainty the diagnosis of siderosis amongst the welders, already noticed by several other authors [9, 16, 27, 30]; but they would seem to be rather non specific abnormalities, whose frequency was equally greater in the welders as compared to the controls in many other studies [3, 4, 7, 13].

The obstructive signs of the small bronchi (decrease of MEF 50% FVC and of MEF 25% FVC) have also been noticed in other studies [4, 7, 14, 15, 20, 34], without, however, being considered as specific manifestations of respiratory function impairment by welding smokes or gases. However these functional impairments were not observed in other surveys on welders [2, 12, 28, 31]. As in certain studies [1, 23, 27], this peripheral bronchial obstruction amongst the welders compared to the controls was only noticeable in the non smokers. It is highly likely that the effects of smoking on respiratory health are such that they can hide the real effects of exposure to welding fumes and gases.

In 1981 we noticed a reduction in the CO lung transfer capacity amongst the welders compared to the controls. This difference could not be confirmed by a longitudinal study, neither for the values of this index measured in 1981 amongst the re-examined subjects (probably due to the bias in subjects' selection), nor for the values measured in 1986. Some transversal studies on respiratory function in welders include this functional test, but their results do not agree. A reduction in CO lung transfer capacity has been observed in some studies [14, 16, 29], but not in others [1, 24].

The abnormalities noticed (radiographic and spirometric) seem to have the same evolution in welders and controls. We do not know of any other epidemiological study which has explored the risks of non neoplasic respiratory impairment amongst welders in a longitudinal manner. Due to the risk of selection bias in this study, this result, which is a first sight re-assuring, needs to be checked.

In conclusion, this study confirms the risk of non specific radiological lung impairment (reticulo-micronodular shadows) and the obstruction of small bronchi, which was already noticed in the previous study on arc welders in this company. These impairments do not seem to be more evolutive than in the controls, but do justify a regular surveillance of the respiratory health of arc welders.

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