Spirometric Abnormalities Met among Senegalese Workers Exposed to Chlorine Gas

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Abstract: Introduction: Chlorine as a disinfectant has many side effects on respiratory function. This respiratory toxicity may be related to the exposure time. Materials and Methods: Measure the impact of the duration of chlorine gas exposure on the respiratory function of Senegalese workers who work in the national water production factory: Senegalaise Des Eaux (SDE), aged 35-54 years. Twenty-four (24) male subjects exposed to chlorine gas were divided into two groups, one (35-44) and the other (45-54). Clinical examinations were performed on each employee, followed by chest x-rays and spirometry. We included all subjects whose first or last two spirometry results were normal. Results: In the 35-44 years group, 50% of subjects had disturbed spirometry including 41.6% of obstructive syndrome (OS), at the second spirometry and 8.3% had a restrictive syndrome FVC at -25%, at the 3rd spirometry 4/12 had a normal spirometry. The duration of exposure was 10 years. For subjects in 45-54 years, 8/12 had persistent OS or accentuated, then at the 3rd spirometry we had 10 subjects. The duration of exposure was 17.5 years. Conclusion: Compared with (35-44) group, older (45-54) subjects had significant OS, which may be related to duration of exposure.

Key words: Spirometry, exposure, SDE.

1. Introduction

Raw water collected from nature contains micro-organisms that may be pathogenic to the body. These pathogenic micro-organisms that can infiltrate the drinking water distribution system may cause diseases for consumers. To fight against these diseases, methods of disinfection are used; one of them is chlorination of water. In Senegal, that is the method used by Sénégalaise Des Eaux (SDE), a national company that has been operating and managing the public drinking water service in urban areas since 1996. Chlorination of drinking water is undoubtedly one of the major advances in public health of the past century.

However, it would have adverse effects on life and health of workers and many studies demonstrate this: in vitro studies have demonstrated that hypochlorous acid and chloramines attack the thiol groups of structural proteins, resulting in disruption of the cytoskeleton and extracellular matrices [1]. These effects result in an almost instantaneous increase in epithelial or endothelial permeability. In 2002, Thickett [2] had demonstrated the asthmatogenic power of trichloramine in lifeguards. This same power had been reported in a study following the link between disinfection of medical instruments by dichloroisocyanurate [3] and occurrence of asthma in health professionals. Cases of development or worsening of asthma due to the irritating effects of

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Spirometric Abnormalities Met among Senegalese Workers Exposed to Chlorine Gas

chlorinated disinfectants have also been reported [4-6]. In Senegal, a study conducted at the Laboratory of Human Physiology of the University Cheikh Anta Diop of Dakar (UCAD) by Sarr et al. [7] on the employees of the Sénégalaise Des Eaux (SDE) had revealed the harmful effects of inhalation of chlorine gas on the respiratory apparatus. Would these effects be related to the position held and the duration of exposure to the position? To find this link, we measured the impact of the position held and the duration of exposure on the respiratory function of the SDE employees. To achieve that aim, we divided the employees according to the position occupied and the duration of exposure, diagnosed the different spirometric abnormalities found, established a link between the position occupied, the duration of exposure and the various troubles to finally propose a consistent prevention policy of occupational risks.

2. Methods

Our study aimed to measure the impact of the duration of exposure on the respiratory function of Senegalese workers aged 35 to 54 years. It was carried out at UCAD’s Laboratory of Human Physiology and Functional Explorations on 24 male subjects no-smoking exposed to chlorine and divided into two groups of 12 aged 35-44 and 45-54. It was a retrospective longitudinal study. For each employee we performed a medical examination including a physical examination, a chest x-ray and then spirometry (respiratory functional exploration—RFE). The spirometer used was the Vyntus® pneumo to the electrical standard ICE60601. We included all subjects whose first spirometry was normal, but also the last two results of spirometry performed. During the analysis of the spirometric data, we evaluated: forced expiratory volume in one second (FEV₁), forced expiratory flow at 25%-75% (FEF 25%-75%) of forced vital capacity (FVC) and maximum instantaneous flow rates at 75%, 50% and 25% of the FVC. Outside exposure time and age, our subjects had all other risk factors in common.

The CS pro 5.0 software and R version 3.5.3 have been used for statistical analysis of data, and the Word and EXCEL 2010 software for graphics.

3. Results

We divided the 24 patients into two groups, each with 12 cases. The clinical examination and chest x-ray of all our subjects were normal. The exposure duration (ED) of the groups was 10.4166 ± 4.44 years for the age group (35-44), and 17.58 ± 6.11 years for the age group (45-54), respectively. A comparison of the last 2 spirometries (Figs. 1 and 2) was performed according to the ED.

3.1 For the Group Whose ED Was about 10 Years (Figs. 1 and 2)

Forty-two percent (42%) had an obstructive syndrome (OS) and 8% had a restrictive syndrome at the 2nd spirometry, however in the 3rd, the percentage of OS had increased to 50%. A comparison according to the bronchial location of the OS (Figs. 3 and 4), found that in the group whose exposure time was 10.46 years, the majority of the obstructed patients had either bronchial obstruction averages only 40% or mixed obstruction 40% (middle and distal bronchi). At 2nd spirometry, the percentage of obstructive joint would have increased 26% or 66% of which 33% had distal and middle bronchi and 33% had proximal and distal bronchi (see Figs. 3 and 4).

3.2 For the Group with an ED of 17.58 Years (Figs. 5 and 6)

The majority of patients had an OS with 67% at the 2nd RFE and at 3rd RFE this rate had increased to 83%.

When we compared the evolution of the OS, 75% of the obstructed patients had an OS with a single lesion of the distal bronchi at the 2nd RFE and 25% had a mixed obstruction (average and distal) (see Figs. 7 and 8). As for the 3rd spirometry, the distal syndrome
Spirometric Abnormalities Met among Senegalese Workers Exposed to Chlorine Gas

Fig. 1  Distribution of obstructive syndrome at 2nd RFE (ED = 10, 46 years).

Fig. 2  Distribution of obstructive syndrome at 3rd RFE (ED = 10, 46 years).

Fig. 3  2nd RFE (ED = 10, 46 years).
Fig. 4  3rd RFE (ED = 10, 46 years).

Fig. 5  Distribution of obstructive syndrome at 2nd RFE (ED = 17, 58 years).

Fig. 6  Distribution of obstructive syndrome at 3rd RFE (ED = 17, 58 years).
had decreased by 15% or 60% and the mixed obstruction had increased by 5% or 30% (20% of average and distal damage and 10% of the proximal and distal bronchi). But also we noted, an appearance of involvement of the bronchi averaged 33.33% at the 3rd spirometry.

3.3 Intergroup Comparison (Figs. 9 and 10) Was Done according to the ED

The percentage of OS increased from 2nd to 3rd spirometry. But also, subjects with exposure duration of about 18 years were the most exposed. During the 3rd spirometry, in addition to the mixed obstruction (middle and distal bronchi), there was a progression towards another mixed obstruction which was the involvement of the proximal and distal bronchi.

3.4 Occurrence of the Disease according to the Duration of Exposure

Survival curve was obtained by the Kaplan-Meier method. Fig. 11 represents the function of occurrence of the disease.

The median is 14; it represents the duration of exposure that had been necessary for half of the workers to have developed the disease.

For Fig. 12, people in age group 45-54 had the probability of having the chronic obstructive pulmonary disease (COPD) faster based on the duration
Fig. 9  Intergroup comparison of 2nd RFE intergroup.

Fig. 10  Intergroup comparison of 3rd RFE intergroup.

Fig. 11  Representation of the curve of global occurrence of the disease among workers.
of exposure (ED = 8 years) than younger people aged 35-44 (ED = 10 years).

This difference is statistically significant $p = 0.034$. Indeed, young subjects were 3.84 times less likely to have the disease depending on the duration of exposure. So age would be a risk factor.

4. Discussion

Our results had found respiratory disorders, including an OS that increased from the 2nd to the 3rd spirometry for all our groups, and the latter was mostly of distal type. Indeed, for the group whose exposure time was about 10 years it had increased by 18%, and for that of 18 years of 16%.

This aggravation of the OS had been described in several studies [7], had obtained 64% of distal OS of minor type. But also, in addition to the increase in the percentage of OS, it was noted, an evolution of bronchial attacks. But also, in addition to the increase in the percentage of OS, there was a change in bronchial involvement. That is, OS with single distal involvement evolved from the 2nd to the 3rd spirometry to OS with multiple lesions either middle and distal or proximal and distal with respectively a difference of $+26\%$ for ET = 10 years and $+5\%$ for ET = 18.

However, the OS remained the most important in the group whose ED = 18 years (83%) compared to the group whose ED = 10 years (50%). Chieralkul et al. [8] in 2013 concluded that long-term exposure would have significant effects on respiratory health. Another similar study in India, of 64 patients exposed to acute chlorine, 100% of which had acute dyspnea of which 8 patients had developed an OS [9]. As for Evans, he had found a significant risk of pulmonary lesions in industrial exposures, particularly obstructive disorders [10-13], thus according to these studies, the increase in obstructive disorders would be a function of the duration of exposure. This would expose workers in addition to respiratory disorders, to the occurrence of other occupational diseases. In fact, it can on one hand, increase the risk of installation of pathologies of the nervous system including dementia, cerebral atrophy and Parkinson’s disease [14, 15]. On the other hand, it can lead to the occurrence of cancer (Gila Neta) such as gliomas, meningiomas and bladder. Indeed, Steve [16] evaluated the link between chlorination disinfection by-product exposure and the risk of developing bladder cancer. Authors such as Amy et al. [17], Cantor et al. [18], are moving in the same sense. This supports the idea that long-term average exposure levels can be a good indicator of lifetime risk, especially if changes in exposure levels over time are moderate [19]. Studies have also
suggested that people exposed to chlorinated derivatives by inhalation or skin contact would have higher blood concentrations of chlorinated derivatives after a 10-minute shower than 1 L of water [20]. In the SAR Fatou Bintou study, total or partial reversibility of OS after β mimetic administration was observed in 64% of cases, and noted an increase in FEF at 25% of more than 45%, and FEF at 25-75% of more than 22% (bronchial outflow specific to distal bronchi) [7]. This reversibility was in favor of a functional impairment of the lungs, which had directed it more towards a chlorinated intoxication than towards the effects of tobacco which would be organic and therefore irreversible [21, 22].

As for the age and occurrence of COPD, Boyer and others have shown the link between cellular senescence and COPD [23, 24]. Cellular senescence and the inflammatory processes that are closely linked to it could contribute to the systemic manifestations associated with the disease and its comorbidities [25].

5. Conclusions

It appears from our results that more than half of the SDE workers in our chlorine exposure study have an obstructive syndrome. This syndrome seems to be accentuated with the duration of exposure. Certainly, even if an annual visit of the respiratory function would seem to be carried out for the personal, however, the overall care should be increased with a reclassification of affected workers, in order to limit respiratory disorders.

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