EFFECT OF THE BIOLOGICAL AGGRESSIVENESS OF QUARTZ ON THE ROLE OF POLYMORPHS IN ALVEOLAR PHAGOCYTOSIS OF QUARTZ DUST

S. K. Starikova, B. A. Katsnel'son, G. V. Aronova, and I. M. Shnaidman

UDC 612.112.3.553.62

During chronic inhalation of quartz dust, the ratio between the number of macrophages and polymorphs in the lungs of rats changes in favor of polymorphs. This change is less marked if the resistance of macrophages to the cytopathogenic action of quartz is increased. Polymorph phagocytosis is regarded as an additional factor in the self-cleansing of the lungs from particularly aggressive particles.

It was Starikova [3] who first observed that during chronic inhalation of quartz dust by rats polymorphs (neutrophils) predominate among the free alveolar phagocytes. Conversely, in the lungs of control rats following deposition of the ordinary town dust, macrophages are much more numerous than polymorphs, just as has been described following the intratracheal injection of various dusts with low fibrogenicity [9].

The object of the present investigation was to continue the study of alveolar phagocytosis and to determine the connection between polymorph phagocytosis of quartz dust and the biological aggressiveness of the dust.

EXPERIMENTAL METHOD

The conditions of inhalation of dust by the rats and the method of investigation of alveolar phagocytosis in all the experiments were the same as described previously [3], but in one experiment films of cells from lung perfusion fluid were also stained for acid phosphatase by Gomori's method. The polyvinylpyridine-N-oxide (PNO) used in this experiment was synthesized at the Department of Organic Chemistry, Urals Polytechnical Institute, under the direction of Professor I. Ya. Postovskii. The compound was injected in a dose of 15 mg subcutaneously once a week. Treatment of the quartz dust with trimethylchlorosilane (TMCS) was carried out at 150° for 6 h, after preliminary thermal dehydration of the surface of the particles [1]. In view of its hydrophobic character, this dust and also the untreated quartz dust were suspended in rat serum diluted 1:10 with physiological saline; the rats received 1.5 mg of one or the other dust in 1 ml of diluted serum or the serum alone by intratracheal injection.

EXPERIMENTAL RESULTS

It is clear from Table 1 that whereas macrophages predominated in all rats of the control groups, after inhalation of quartz dust this predominance either was substantially reduced or (more often) was replaced by the opposite relationship. This difference between the experimental and corresponding control groups, conventionally described below as the "polymorph shift," is statistically significant in all cases.

Sverdlovsk Institute of Work Hygiene and Occupational Diseases. Kazakh Institute of Work Hygiene and Occupational Diseases, Karaganda. (Presented by Academician V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 70, No. 9, pp. 113-116, September, 1970. Original article submitted January 18, 1970.

TABLE 1. Mean Ratios between Numbers of Polymorphs and Macrophages in Perfusion Fluid from Lungs of Control and Experimental Rats

No. of experiment and its duration	Group of rats	Mean ratio between number of polymorphs and number of macrophages	
		for all cells	for cells with visible dust particles
Experiment No. 1, 4 mos.	Control	0,84	0,16
	Experimental	2,70	2,41
Experiment No. 1, 8 mos.	Control	0,11	0,01
	Experimental	2,24	1,35
Experiment No. 1, 5 mos. after inhalation of dust for 8 mos.	Control	0,71	0,13
	Experimental	3,48	1,34
Experiment No. 2, 4 mos.	Control	0,13	0,05
	Experimental	1,90	1,40
Experiment No. 3, 4 mos.	Control	0,36	0,14
	Experimental	2,09	0,91
Experiment No. 3, 8 mos.	Control	0,12	0,06
	Experimental	1,69	1,34

TABLE 2. Some Indices of the Phagocytic Response of the Lungs to Chronic Inhalation of Quartz Dust and Treatment with PNO

Duration of experiment (in months)	Group of rats	Total number of cells ($\times 10^6$)	% of degenerated macrophages with dust	Ratio between number of polymorphs and numbers of macrophages	
				for all cells	for all cells with dust
3½	Control	1,531+	6,4+	0,30+	0,17+
	Inhaling dust	2,764+	19,8+	0,64+	0,39+
	Inhaling dust and treated	2,091	8,8	0,39	0,14
6	Inhaling dust	10,688++	54,8++	4,40++	4,50++
	Inhaling dust and treated	3,429++	16,6++	0,58++	0,41++

Note. Mean values belonging to the same criteria within a given period of the experiment, but belonging to different groups and differing significantly from each other ($P < 0.05$) are marked with identical signs.

The groups described as experimental in Table 1 include subgroups receiving dust only and also subgroups exposed to certain additional factors, but a "polymorph shift" was observed in all these subgroups, and aggregated data are given in Table 1. At the same time, within the limits of each experiment, the smallest shift toward polymorphs was found in the cell composition of perfusion fluid from animals of those subgroups in which fewest macrophages containing dust had degenerated. For instance, in the first period of experiment No. 3, in the subgroup of rats receiving dust only, these macrophages numbered on the average 12%, while in the subgroup exposed to hydrogen sulfide on alternate days, it was 4.9% ($P < 0.05$). The ratios between the numbers of polymorphs and macrophages were 2.76 compared with 1.42 for all cells, and 1.25 compared with 0.57 for cells containing dust. A similar effect in other experiments was given by physical training, acclimatization to cold, and injections of dibasol. This means that the increase in resistance of the macrophage to the cytopathogenic action of quartz can be associated with the development of a state of nonspecifically increased resistance by analogy with other cases described in the literature [2].

The anticytopathogenic action of PNO has been demonstrated in experiments with cultures of various cells phagocytosing quartz [4, 6, 8]. It evidently is due to competitive interaction with the phospholipids of the intracellular membranes [8, 10]. The experiment showed that in films of perfusion fluid from the lungs of rats inhaling dust and receiving PNO there were far fewer cells with partial and, in particular, with complete diffusion of acid phosphatase into the cytoplasm and, conversely, there were more cells with a discrete deposition of lead granules (indicating the phagolysosomal localization of the enzyme) compared with rats receiving dust only (the first two forms after 3.5 months, 9% compared with 30%, $P < 0.01$; after 6 months, 14% compared with 47%, $P < 0.01$.

Under the influence of PNO (Table 2), the percentage of visibly degenerated (judging from the ordinary morphological and staining properties) macrophages with dust also was significantly reduced. There was a corresponding decrease in the "polymorph shift," and in the second period this was replaced by predominance of macrophages.

Quartz whose silanol groups were replaced by trimethylsilyl groups following reaction with TMCS is characterized by a greatly reduced power of causing the development of silicosis [5]. For this reason it was chosen for additional confirmation of the hypothesis regarding the relationship between the "polymorph shift" and the pathogenicity of the quartz dust. The experiment showed that, whereas the ratio between polymorphs and macrophages in the group of rats receiving untreated quartz dust by intratracheal injection was 4.6 for all cells and 2.3 for cells with dust, in the group of rats receiving the same dust but treated with TMCS this ratio was 2.6 and 1.5, respectively, i. e., predominance of neutrophils over macrophages in the second case was less marked. Only the first two values differ by a statistically significant margin from the corresponding values in the group of rats receiving diluted serum only (2.1 and 0.7, respectively). Injection of serum into the lungs itself evokes a neutrophil response, but against this background the original quartz gave a significant additional "polymorph shift" while quartz with diminished pathogenicity gave a less marked shift, not statistically significant.

In vitro, neutrophils are more resistant to the cytopathogenic action of silica than macrophages [7]. Judging from the morphological and cytochemical changes observed in the alveolar phagocytes, this difference also exists in vivo.

It can thus be concluded from the facts described in this paper that neutrophil phagocytosis of particles is actually a reserve mechanism of self-cleansing of the lungs from quartz dust, due to its particularly strong biological aggressiveness. Trigger mechanisms of this response are evidently connected both directly with dust irritation and also with the action of products of increased degeneration and disintegration of macrophages.

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