Luigi Parmeggiani and Carlo Sassi

ON A NEW METHOD FOR THE EVALUATION OF RESPIRATORY FUNCTION IN SILICOTICS

The authors propose a new method for the evaluation of the respiratory function in silicotics. Their chief aim was to devise a procedure which would not require costly apparatuses, would be easily applicable and would give precise results. They use a common Benedict apparatus. The concentration of exygen is expressed by a formula. The method is objective and does not depend on the subject's will to cooperate.

At present the evaluation of the respiratory function and of disability of workers exposed to dust hazards, and of silicotics, is a problem which can be solved only by applying complicated physiological methods, easily subject to errors, and which require the use of very costly apparatus (such as the methods of Knipping, of Rossier, of Margaria and of Pelnar). These methods in practice cannot be used outside of physiological laboratories.

The tests most commonly used (vital capacity, voluntary apnoea, maximum breathing capacity, pneumotacography, etc.) are limited to the examination merely of the mechanics of the respiration, that is they explore functions that are collateral and unspecific as regards the gas exchange in the lungs, the transport of oxygen and carbon dioxide, and the internal respiration. Some Aa. have thought that they could avoid this obstacle by increasing the number of tests; that is they subject the patient to a series of tests, and form their judgment on the basis of the general course of the tests; but in this way, not only is the inner process of the respiratory function not explored, but the different behavior from one test to another of the patients makes a conclusion still more difficult. In the estimation of disability this state of things results in a diversity of opinions which do not coincide, and are subjective, and in which estimates lack the element of proportion; measure in percentages of the harm is quite arbitrary.

We have set ourselves the task of studying a method for estimating respiratory function, which 1) does not require costly apparatus, 2) is rapidly and – above all – easily performed, 3) gives precise results that can be expressed numerically for medicolegal purposes. To this end we measure the tension of oxygen at which a certain decrease is found in its consumption when, in a closed circuit, the subject breathes in the midst of a mixture of oxygen whose concentration becomes lower and lower; by this criterion we investigate the efficiency of the

gas exange at the level of the alvcolar membrane and do not require the performance of exercise; in this way our method differs from those already mentioned of KNIPPING, PELNAR, MARGARIA, ROSSIER etc.

We have already exhibited this method at the Medico-scientific Meeting on Silicosis in Bochum (18th–20th October 1951); we have now had a greater experience, and, by this time, have examined about a hundred cases. In a large number of these we have been able to check our results against those provided by MARGARIA'S method, which is commomly used in the Physiological Laboratory of our Clinic, by means of the treadmill-ergometer. Our results encourage us to make public the process which we have devised.

We use a common Benedict apparatus, the total capacity of which we increased to 30 l, by means of a reservoir of 18 l which we fit on the exhaust hose of the bell, immediately after the basket of soda-lime. The increase in the capacity of the apparatus brings a number of advantages: 1) the magnitude of error caused by eventual changes in the volume of the patients' lungs during the test is reduced; 2) the magnitude of error caused by the different size of the dead space in the various subjects is reduced; 3) all the errors are reduced, which may have an influence on the measurements of the volume of the respiratory mixture (changes in the volume of the rubber tubes, changes in the volume of soda-lime, incomplete filling of the apparatus at start of experiment, etc.); 4) the modifications in volume of the respiratory mixture caused by the increase in temperature produced by breathing during the test are so much lessened that it is no longer necessary to take account of them in the interpretation of the results; 5) at last the duration of the test is about tripled and therefore the test is more physiological, the values are more exact, and the graph is more easily read.

We determine the concentration of oxygen in the apparatus by a simple volumetric process. Indeed, the lungs plus spirometer circuit contains a mixture of nitrogen and oxygen, in which the nitrogen remains unchanged, while the oxygen decreases more and more; for this reason, the concentration percent of oxygen is given at every moment by the formula:

$$O_2\% = \frac{v_i - v_c}{V_i - v_c} \cdot 100$$

where v_i = volume of oxygen in the apparatus at start of the experiment, v_c = volume of oxygen consumed up to the moment of examination, V_i = total volume of the apparatus at start of the experiment. In order to obtain greater exactitude in the estimation of the concentration of oxygen breathed by the subject, we also take account of the volumes of oxygen and nitrogen in the patient's lung at start of experiment; besides, we have adopted a calibration curve based on the application of the aforesaid formula, and checked several times by a Haldane apparatus.

The subject being made to breathe in a closed circuit in our apparatus, which is filled with air at the beginning, the partial tension of oxygen in the mixture breathed in is gradually lessened. The consumption of oxygen at a given moment begins to grow less, at first slightly, but afterwards more and more. This lessening of consumption is found at a tension of oxygen more or less high according to the efficiency of respiratory exchanges at the level of the alveolar membrane. We determine to what tension of oxygen reductions in the

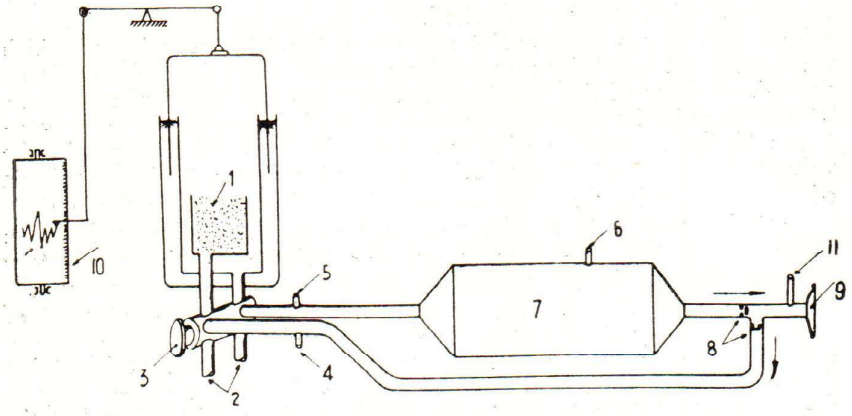

Fig. 1. Diagram of the apparatus

1. Basket of soda-lime, 2. Outside communication, 3. Two-way double tap, 4. Air intake-tap from the intake tube, 5. Air intake-tap from the exhaust tube, 6. Air intake-tap from the reservoir, 7. 18-liter reservoir, 9. Mouth-piece, 10. Kymograph, 11. Air intake-tap from the mouth-piece

Sl. 1. Dijagram aparata

1. Posuda s natronskim vapnom, 2. Spoj s vanjskim zrakom, 3. Dvosmjerni dvostruki pipac, 4. Pipac za uzimanje zraka iz ulazne cijevi, 5. Pipac za uzimanje zraka iz izlazne cijevi, 6. Pipac za uzimanje zraka iz rezervoara, 7. Rezervoar od 18 litara, 8. Ventili s membranama, 9. Pisak za usta, 10. Kimograf, 11. Pipac za uzimanje zraka iz piska za usta

consumption of oxygen per minute correspond, that is reductions of 25%, 50%, and 75%, as compared with the initial average consumption registered in the first 3–4 minutes of the test. Of course we do not examine subjects who at rest show in the respiration of air a smaller consumption of oxygen with respect to the respiration of oxygen, because such patients evidently have already a disability of 100%.

We have demonstrated that in normal subjects reduction in the consumption of oxygen of 25% is found at a partial tension of oxygen of 12,7% ± 0,38%, of 50% at a partial tension of oxygen of 10,9 ± 0,46%, of 75% at a partial tension of oxygen of 9,2% ± 0,44%. For

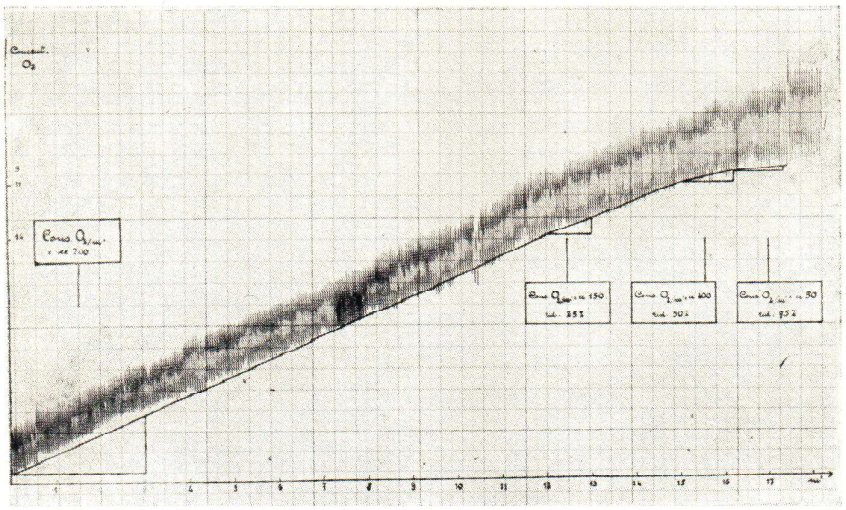

Fig. 2. Spirometric tracing of a normal subject
Sl. 2. Spirometrijska krivulja normalnog ispitanika

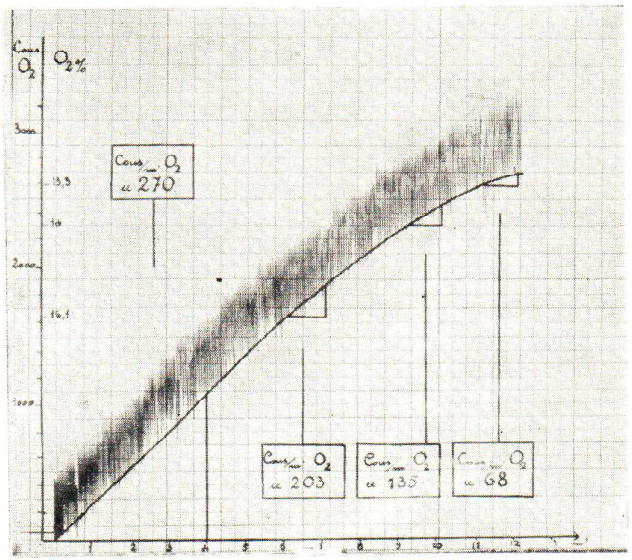

Fig. 3. Spirometric tracing of a silicotic, having a disability of 75%
Sl. 3. Spirometrijska krivulja silikotičara, koji je 75% nesposoban

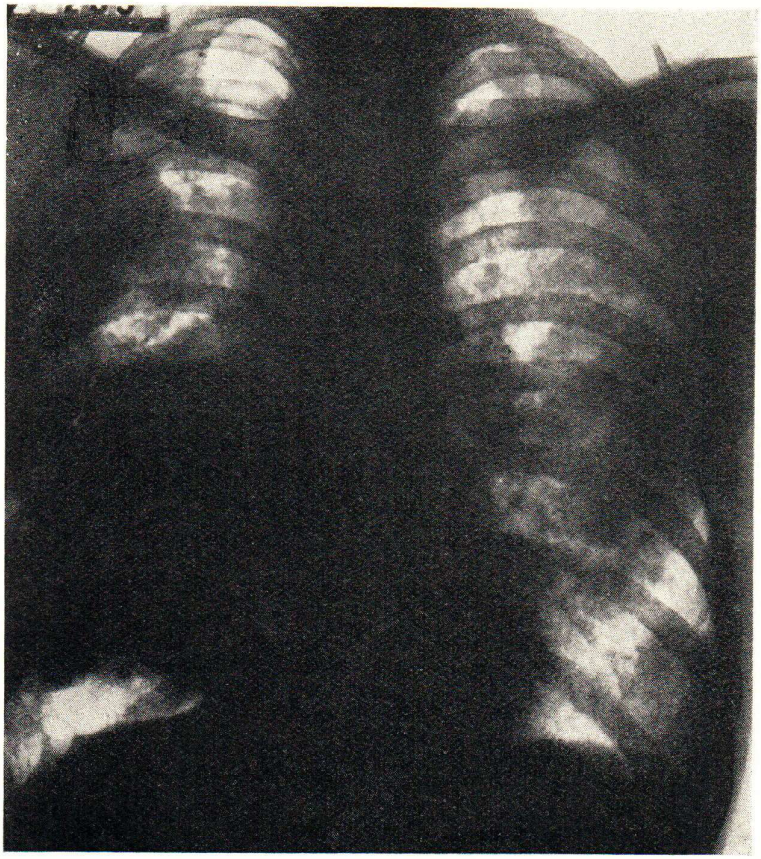

Fig. 4. Roentgenogram of the chest of the silicotic whose tracing is shown at fig. 3
Sl. 4. Rentgenogram grudnog koša silikotičara, kojeg je spirometrijska krivulja prikazana na sl. 3

estimating the impairment in respiratory function, we have established by empirical way the following table in which, for the sake of simplicity, we refer directly to disability:

Values for the estimation of disability, according to the Parmeggiani and Sassi method

Reduction % in consumption of O_2	Partial tension of O_2 in the apparatus				
25	12,7	13,5	14,5	16	17
50	10,9	12	13,3	14,5	16
75	9,2	10,8	12,5	13,5	14,5
Disability in %	0	25	50	75	100

With the increase in the number of cases examined, we are working out a nomogram which will allow the immediate reading of the degree of disability in function of the three standard values of the reduction in the consumption of oxygen.

Our test takes from ten to twenty minutes, and with the aid of the calibration curve and of the nomogram, gives the final result in less than five minutes, without requiring any difficult operation. It is so easy that it can be entrusted to a nurse or to a laboratory technician.

This method investigates the more important dysfunction of silicosis, is objective, and independent of the subject's will to collaborate, perhaps more so than any other method known up to now. It can be performed on any patient, even in the more seriously disabled, because it requires no effort, not even that of standing, and takes place without his knowledge. The physiological variations in the test correspond to the wide field of errors depending on technical factors and on the physical characteristics of the apparatus; if we value working capacity in percentages, it gives an approximate result within plus or minus 5%. The apparatus is very simple and inexpensive, even without comparing its cost with that of the equipment necessary to obtain by other methods results of the same order of accuracy in the estimation of disability of silicotics.

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O NOVOJ METODI OCJENJIVANJA RESPIRATORNE FUNKCIJE KOD SILIKOTIČARA

Prosuđivanje respiratorne funkcije i nesposobnosti silikotičara i radnika izvrgnutih prašini zasad je problem, koji se može riješiti samo primjenom složenih fizioloških metoda, koje lako podliježu griješkama i koje iziskuju upotrebu vrlo skupih aparata (kao na pr. Knippingova, Rossierova, Margarijina i Pelnarova metoda). Ove se metode ne mogu u praksi upotrebiti izvan fizioloških laboratorija.

Testovi, koji se najčešće upotrebljavaju (vitalni kapacitet, hotimična apnoja, maksimalni kapacitet disanja, pneumotakografija i t. d.) ograničavaju se samo na ispitivanje mehanike disanja, t. j. na ispitivanje funkcija, koje su sporedne i nespecifične što se tiče izmjene plinova u plućima, prijenosa kisika i ugljičnog dioksida i unutarnje respiracije. Neki su autori smatrali, da mogu izbjeći tom prigovoru povećavajući broj testova, t. j. podvrgavajući pacijenta seriji testova i stvarajući zaključak na bazi općeg toka testova; no na taj način ne samo da unutarnji proces respiratorne funkcije nije ispitan, nego i samo vladanje pacijenata od testa do testa čini zaključke još težima. Pri procjenjivanju nesposobnosti to stanje ima za posljedicu raznolikost mišljenja, koja se ne podudaraju i koja su subjektivna, a procjenama nedostaje elemenat razmjera; mjerenje oštećenja u procentima je sasvim proizvoljno.

Mi smo postavili sebi zadatak, da izradimo metodu za procjenu respiratorne funkcije, koja 1) ne iziskuje skupocjenu aparaturu, 2) koja se može brzo i – prije svega – lako primijeniti i 3) daje precizne rezultate, koji se mogu brojčano izraziti za liječničko-pravne svrhe. U tu svrhu mjerimo pritisak kisika, koji nalazimo u času izvjesnog smanjenja njegove potrošnje, kad, u respiracionom aparatu zatvorenog sistema, ispitanik udiše mješavinu kisika, kojega se koncentracija sve više snizuje; tim mjerilom ispitujemo efikasnost izmjene plinova na nivou alveolarne membrane i nije nam potrebno, da pacijent izvodi vježbe. U tom pravcu naša se metoda razlikuje od već spomenutih metoda Knippinga, Pelnara, Margarije, Rossiera i t. d.

Ovu smo metodu već prikazali na medicinsko-znanstvenom sastanku o silikozi u Bohumu (18.–20. oktobra 1951.). U međuvremenu stekli smo još veće iskustvo i dosad ispitali oko 100 slučajeva. U velikom broju tih slučajeva mogli smo kontrolirati naše rezultate prema onima, koji su dobiveni Margarijinom metodom, koja se općenito upotrebljava u Fiziološkom laboratoriju naše klinike, pomoću pokretnog saga. Naši nas rezultati toliko ohrabruju, da objavljujemo postupak, koji smo izradili.

Služimo se običnim Benediktovim aparatom, kojega ukupni kapacitet povisujemo na 30 l pomoću rezervoara od 18 l montiranog na cijev za udisanje iz zvona neposredno iza rezervoara s natronskim vapnom. Povećavanje kapaciteta aparata donosi niz prednosti: 1) smanjuje se veličina pogreške uzrokovane eventualnom naknadnom promjenom volumena pacijentovih pluća u toku eksperimenta; 2) smanjuje se veličina pogreške uzrokovane raznom veličinom mrtvog prostora kod raznih ispitanika; 3) smanjuju se sve pogreške, koje mogu imati utjecaja na mjerenje volumena respiratorne mješavine (promjene u volumenu gumenih cijevi, promjene u volumenu natronskog vapna, nepotpuno punjenje aparata kod početka eksperimenta i t. d.); 4) promjene u volumenu respiratorne mješavine uzrokovane povećanjem temperature, koje izaziva

disanje u vrijeme pokusa, smanjene su toliko, da više nije potrebno uzeti ih u obzir pri interpretaciji rezultata; 5) konačno, trajanje testa je otprilike utrostručeno, i zato test više odgovara fiziološkim uvjetima, vrijednosti su točnije, a krivulja se mnogo lakše čita.

Koncentraciju kisika u aparatu ustanovljujemo jednostavnim volumetrijskim procesom. Pluća zajedno s uklopljenim spirometrom sadržavaju mješavinu dušika i kisika, u kojoj dušik ostaje nepromijenjen, dok kisika biva sve manje i manje. Zato se procenat koncentracije kisika u svako doba može izraziti formulom:

$$O_2\% = \frac{v_i - v_c}{V_i - v_c} \cdot 100$$

gdje je v_i = volumen kisika u aparatu na početku eksperimenta, v_c = volumen do tog časa utrošenog kisika, a V_i = ukupni volumen aparata pri početku eksperimenta. Da bismo postigli što veću točnost u procjeni koncentracije kisika, što ga ispitanik udiše, uzimamo u obzir i volumene kisika i dušika u pacijentovim plućima u početku eksperimenta; osim toga usvojili smo krivulju baždarenja zasnovanu na primjeni navedene formule i tu smo krivulju nekoliko puta prekontrolirali Haldanovim aparatom.

Ispitanik diše u zatvorenom sistemu našeg aparata, koji se puni zrakom na početku pokusa. Parcijalni pritisak kisika u udisanoj mješavini postepeno se smanjuje. Potrošak kisika u određenom momentu postaje manji: najprije neznatno, a kasnije sve više i više. To smanjivanje potrošnje nalazimo kod većeg ili manjeg pritiska kisika, već prema efikasnosti respiratornih izmjena na nivou alveolarne membrane. Zatim ustanovljujemo, kojem pritisku kisika odgovaraju smanjenja u minutnoj potrošnji kisika. t. j. smanjenja od 25%, 50% i 75% u poređenju s početnom prosječnom potrošnjom registriranom u prve 3–4 minute testa. Mi, dakako, ne ispitujemo pacijente, koji, dok miruju, pokazuju pri udisanju zraka manju potrošnju kisika, jer su takvi pacijenti očito već 100% nesposobni.

Pokazali smo, da kod normalnih ispitanika 25%-no smanjenje potrošnje kisika nastaje kod parcijalnog pritiska kisika od 12,7% ± 0,38%, 50%-no kod parcijalnog pritiska kisika od 10,9% ± 0,46%, a 75%-no kod parcijalnog pritiska kisika od 9,2% ± 0,44%. Za procjenu oštećenja respiratorne funkcije sastavili smo prema iskustvu ovu tabelu, u kojoj se, zbog jednostavnosti, osvrćemo izravno na nesposobnost:

Vrijednosti za ocjenu nesposobnosti prema metodi Parmeggianija i Sassija

Smanjenje potrošnje O_2 u %	Parcijalni pritisak O_2 u aparatu				
25	12,7	13,5	14,5	16	17
50	10,9	12	13,3	14,5	16
75	9,2	10,8	12,5	13,5	14,5
Nesposobnost u %	0	25	50	75	100

Kako se povećava broj ispitanih slučajeva, izrađujemo nomogram, koji će omogućiti neposredno očitavanje stupnja nesposobnosti funkcije triju standardnih vrijednosti smanjivanja potrošnje kisika.

Naš test traje 10–20 minuta i s pomoću baždarne krivulje i nomograma daje konačni rezultat u manje od 5 minuta, bez ikakvog teškog postupka. Tako je lagan, da se može povjeriti medicinskoj sestri ili laboratorijskom tehničaru.

Ovom metodom ispituju se važnije disfunkcije silikoze. Ona je objektivna i ne zavisi od ispitanikove volje da surađuje – možda više nego ijedna druga dosad poznata metoda. Može se izvesti na svakom pacijentu, čak i na ozbiljnije onesposobljenima, jer ne traži nikakav napor, čak ni stajanje, i jer se izvodi bez pacijentova znanja. Fiziološke varijacije u testu odgovaraju širokom području griješaka, koje zavise od tehničkih faktora i fizičkih karakteristika aparata. Ako mjerimo radnu sposobnost u procentima, daje aparat aproksimativni rezultat unutar ± 5%. Aparat je vrlo jednostavan i jeftin, čak i ako se ne uspoređuje njegova cijena s aparaturom, koja je potrebna, da bi se po drugim metodama dobili rezultati jednake preciznosti pri procjenjivanju nesposobnosti silikotičara.

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