procedure without undue discomfort. In exceptional cases, requiring manipulation at the point of fracture, a brachial block is used.

X-ray control of reduction is desirable if available, but it has been found that reduction is usually complete after

FIG. 1.—Showing patient's position and apparatus required.

twenty minutes, and in the cases recorded check radiographs were deferred until the following day. It may be noted that the whole procedure can be carried out in the x-ray room without upsetting the routine of that department.

With the weights still in position some form of immobilization is applied. As a primary method the plaster slab is the most satisfactory, because, if necessary, this can be continued to an abduction shoulder spica or the limb be further immobilized on any of the many abduction frames. Fig. 2 shows the method of applying the slab.

FIG. 2.—Immobilization by plaster slab. Note the circular turns of plaster bandage carried well up into the axilla.

height at which the sling is tied. These restricted movements, along with active movements of the wrist and fingers, are begun early.

Post-reduction radiographs are taken as soon as is convenient, and if reduction is not satisfactory the weights can be reapplied without removing the plaster casing. So far I have found that once reduction is complete there is little tendency to redisplacement.

Illustrative Cases

Case 1.—A lance-corporal was admitted with a history of injury to the right arm sustained by a fall while engaged in physical training. Clinically he showed a gross angulation deformity of the mid-shaft of the right humerus, with shortening of one and a half inches. Dorsiflexion of the wrist was not possible. One attempt at reduction had been made before admission. Treatment was carried out by the method described. At eight weeks clinical union was sound, with steady improvement of the injury to the musculo-spiral nerve.

Case 2.—A soldier was admitted giving a history of injury to the left arm sustained in a motor-cycle accident. Clinically he showed a fracture of the mid-shaft of the left humerus, with the lower end of the upper fragment palpable anteriorly and with $3/4$ inch shortening. There was no evidence of musculo-spiral involvement. One attempt at reduction was made before admission and one in hospital by a colleague. Treatment was carried out by the method described, except that a brachial block was used. At seven weeks clinical union was sound, and a radiograph showed good callus formation.

Summary

A simple method for reducing fractures of the mid-shaft of the humerus is described. It is designed to secure accurate apposition of fragments, with minimum trauma to soft tissues. General anaesthesia is not necessary, and only in exceptional cases is a brachial block required. A minimum of apparatus is needed, that suggested being standard equipment of any hospital.

SNEEZING, AND DISINFECTION BY HYPOCHLORITES

BY

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While the photographic technique developed in America (Jennison, 1941) and recently used in this country (Bourdillon and Lidwell, 1941) has shown that many thousands of droplets are emitted during a vigorous sneeze, few quantitative studies of aerial infection from sneezes have been recorded. Winslow and Robinson in 1910 published a useful review of earlier work and described some quantitative tests of their own on the spray emitted in speaking and coughing, but the only quantitative data we have seen on sneezes are the observations of W. F. and M. W. Wells (1936), made with their air centrifuge. They showed that 50 sneezes from a group of subjects in an air-conditioned room sent up the count of " α streptococci" from 0 to 220 per cubic foot. The following notes describe a brief quantitative study of the number of bacteria-carrying particles given out during sneezing, of their rate of disappearance from the air in a closed room, and of the rate at which they are killed by a hand spray, using sodium hypochlorite.

Technique

A small room of 816 c.ft. capacity (11 ft. 6 in. by 7 ft. 6 in. by 9 ft. 3 in. high) contained a table, two wooden chairs, and heating-pipes. The floor and table were oiled to keep down dust, the door and window were kept shut so far as was possible, and the air in the room was circulated, partly by convection from the hot-water pipes, but chiefly by a 12-inch electric "table" fan pointing upwards at 45 degrees from one corner of the floor and running at about half-speed. The air was sampled through two glass tubes (diameter 1 inch) leading from points about 1 ft. 6 in. above the table through one of the walls

to a corridor. One tube led to a slit sampler for air-borne bacteria, of the type described recently (Bourdillon, Lidwell, and Thomas, 1941). In this instrument the air is sucked at a rate of 1 c.ft. per minute through a narrow slit on to the surface of nutrient agar (containing 10% of horse serum in these tests) in a slowly rotating Petri dish. The Petri dish is then withdrawn, and is incubated for eighteen to twenty hours at 37° C. before counting the colonies. Incubation was usually aerobic, but in a few tests anaerobic jars were used. The other glass tube led to a sampler for estimating the hypochlorite dispersed in the air, whether as gas or as solid particles. This sampler consisted of a glass absorption apparatus in which the gas was brought into intimate contact with a 0.1% solution of *o*-toluidine in normal aqueous hydrochloric acid. After sucking 1/2 or 1 c.ft. through the liquid the yellow colour produced was estimated photo-electrically. In some experiments Petri plates of 9 inches diameter containing serum agar were also exposed on the table at a distance of five feet from the man who sneezed.

Course of an Experiment

After leaving the room shut overnight to let dust settle, the sneezer and one experimenter entered the room and sat down with as little brisk movement as possible. With these precautions the number of bacteria-carrying particles found during the initial control period of each experiment was too small to influence the results appreciably. It was usually 2 or 3 per c.ft., but once was as high as 6. A control period of five minutes ensued, during which bacterial sampling of the air of the room was done from outside with the slit sampler, and sometimes also with Petri plates placed on the table. One experimenter then took snuff or the bromine compound mentioned in a previous paper (Bourdillon and Lidwell, 1941) and sneezed from two to five times in the course of one or two minutes. The fan was kept running from shortly before the sneezes until varying periods after them (one minute after in Curve A in the Chart, for the whole experiment in Curve C, and until after the hypochlorite spraying in the spray tests). One minute after the last sneeze samples of air were again taken, and sampling was continued at frequent intervals up to forty-five minutes from the sneeze. In tests in which hypochlorite was sprayed, sampling was continued as in the other tests, but spraying was also carried out between one and three minutes after the sneeze. An experimenter walked round the room with a hand spray spraying a 1% solution of sodium hypochlorite in water. In the later tests, including those recorded here, the hand spray used was of an improved type, baffled so as to deliver a fairly dry mist containing 8 to 9 c.cm. of the hypochlorite solution for each 100 strokes of the pump. We understand that the Ministry of Health proposes to issue sprays of this type for use in London shelters.

A. Control Tests without Hypochlorite

Table I shows the colony counts obtained in one of the control tests. In this test the subject sneezed four times in quick succession.

TABLE I

Counts from Slit Sampler		Counts on 9-inch Petri Dish	
Time	Count per c.ft.	Time	Count per min. exposed
Shortly before sneezes	2	6 to 1 min. before sneezes	0.2
1 min. after sneezes	492	1 " 2 min. after sneezes	220
3 " " "	440	2 " 3 " " "	215
5 " " "	342	5 " 6 " " "	153
8 " " "	288	10 " 15 " " "	82
10 " " "	196	15 " 20 " " "	45
15 " " "	157	20 " 25 " " "	35
20 " " "	89	30 " 35 " " "	14
25 " " "	51	45 " 50 " " "	3
30 " " "	30		
40 to 45 min. after sneezes	10		
45 " 50 " " "	8		

Five other tests were made similarly without hypochlorite spray, giving similar results, except that they average slightly lower initial counts and a slightly greater rate of fall.

TOTAL NUMBER OF INFECTIVE PARTICLES

On multiplying the number of colonies obtained from one cubic foot of air by the number of cubic feet (812) in the room, we find that the total number of bacteria-carrying droplets emitted in each sneeze of this experiment averaged not less than $490 \times 816 \div 4 = 99,960$. As this includes none of the larger droplets which fell below the level of the sneezer's head (3 ft. 6 in.) during the first minute after the sneeze, the true figures for total infected particles per sneeze must be considerably higher. The calculation assumes uniform mixing throughout the room within the first minute after the last sneeze. Evidence that such mixing was sensibly achieved (by the fan) is given by the uniform slope of the curves showing the fall in bacterial content after the second minute.

Curve A in the Chart shows the counts given by the slit sampler in this experiment. It is interesting to note that the points as plotted on a logarithmic scale lie on a

Chart showing numbers of bacteria-carrying particles before and after sneezing: Curves A, B, and C without spraying (Curve B gives the mean values for six such tests); Curves D and E with hypochlorite spray. The numbers greater than 5 per c.ft. are plotted logarithmically, but in order to save space the numbers below 5 (under the dotted line) are plotted arithmetically. The vertical arrow points to the period of spraying.

straight line. This is what would be expected from particles of uniform small size, with a rate of fall slower than the velocity of the convection currents in the room concerned.

DURATION OF SUSPENSION OF PARTICLES

The numbers of particles remaining suspended as long as forty minutes after the sneezes are higher than most people would expect. Thus the figure of 10 per c.ft. at forty-two minutes shows that there were still 8,000 bacteria-carrying particles in the room. Line B in the Chart gives the average values for the six control tests without hypochlorite. This line shows that half an hour after the sneezes there were on the average 20 bacteria-carrying particles per c.ft.—i.e., over 16,000 in the room. It thus seems probable that the danger of infection from a sneeze may last at least half an hour in a closed room.

EQUIVALENT VENTILATION RATES

When discussing impurities in the air it is useful to adopt the practice, employed by ventilation engineers, of expressing the rate of removal of the impurities in terms of the amount of pure air which would have to be introduced in order to remove the impurities at the rate observed. The amount of pure air needed for this is usually stated in "turnovers per hour"—i.e., in the number of times per hour that a volume of fresh air equal to the volume of the room is introduced. Expressed in these terms, the rate of removal of the sneeze droplets in our tests was equivalent on the average to 6.4 turnovers per hour, and ranged from 5 to 9 in the different control

tests. Such a variation in the rate of fall is to be expected as the result of the varying size of droplets, caused by different rates of expiration and different degrees of closure of the lips and teeth in the various sneezes. Curve C is that of a sneeze having a rather higher rate of fall, equivalent to 7.8 turnovers per hour.

B. Tests with Hypochlorite Spray

Table II shows the results recorded by the slit sampler in two tests in which a hand spray of hypochlorite was used. In each test the subject sneezed four times. Only the slit sampler results are given in this case.

TABLE II

Time	Experiment I	Experiment II
	Count per c.ft.	Count per c.ft.
Shortly before sneezes ..	5	6
1 to 2 mins. after sneezes ..	1 213 (20 strokes of spray pump given at 2 to 2½ mins. after sneezes)	616 (30 strokes of pump at 2 to 2½ mins.)
2 to 2½ " " " " ..	128	424
2½ to 3 " " " " ..	64	168
3 to 4 " " " " ..	40	38
4 " 5 " " " " " ..	16	11
5 " 6 " " " " " ..	7	9
7 " 12 " " " " " ..	2.5	3
Rel. humidity, 66%; dry-bulb temp., 65° F. Max. apparent concentration of HClO observed just after spraying: 1 vol. per 7 million vols. air (0.00035 mg. per litre). Ventilation turnover giving equal rate of disappearance of particles, 67 per hr.		
R.h. 75%; dry-bulb, 65° F. Max. apparent HClO: 1 vol. in 10 millions (0.00024 mg. per litre). V.t. = 130 per hr.		

These results are also shown in the Chart as Curves D and E. In each case the kill is very rapid. The faster rate of kill in Experiment II may possibly be related to the higher humidity.

We made fifteen tests in all, giving similar rapid kills of sneeze particles. It is interesting to calculate the number of bacteria-carrying particles which would be inhaled by persons who remained in a room after a series of four sneezes under the conditions shown in the Chart. Assuming a respiratory volume of 1/3 c.ft. per min. (=9.52 litres/min.) integration shows that in the case of the average unsprayed sneezes represented by Curve B about 1,200 bacteria-carrying particles would be inhaled during the thirty or forty minutes following the sneezes. In the instances in which hypochlorite was sprayed, only about 80 particles would be inhaled—i.e., about 1/15 of the number when no spray was used. Calculation shows that if after an event such as a sneeze the particles in the air are removed by any process, in one instance at a rate equivalent to a ventilation turnover of x per hour and in another instance at a rate of y turnovers per hour, then the total particles inhaled in the two cases will be in the ratio y/x . In the cases just quoted the equivalent turnover averages 98 for the hypochlorite action and 6.4 for the die-away of the control sneezes without spray. This ratio 6.4/98 is close to the 1/15 calculated above.

Limitations of Hypochlorite Sprays

While in the above-quoted fifteen instances the sneeze particles have been quickly killed by the hypochlorite, it must be remembered that this process is subject to serious limitations by various factors which are not yet wholly understood. The following restrictions have come to our notice as yet:

1. Many of the dry organisms found in dust are not quickly killed by the hypochlorite in the concentrations used. In our tests the spray has appeared to kill all the oral and nasal organisms, and some, but not all, of the dust organisms present before the sneezes.

2. As shown by Baker and Twort (1941) hypochlorite sprays become ineffective, or much less effective, when the air is very dry. We are not sure of the practical lower limit of humidity for effective killing. It is certainly below 60% at 70° F.

3. The rate of die-away of hypochlorite sprays is usually rapid, especially in crowded places.

4. Hypochlorous acid gas reacts rapidly with the vapour of most volatile organic compounds, especially phenols and cresols. Hence it is important to avoid the vaporization or spraying of these substances in any closed space in which disinfection by hypochlorite sprays is proposed. We have on two occasions failed to secure a sufficient concentration of hypochlorite owing to the use of cresol vapour in the room some days previously.

Discussion

The danger of infection from oral or nasal spray droplets is a matter of varying opinions. Thus Winslow and Robinson (1910) describe the "mouth spray" as "a fairly coarse rain which quickly settles downward," and conclude that "aerial infection of any sort is a minor factor in the spread of zymotic disease." Gordon (1906), on the other hand, after extensive studies, considers infection by oral droplets of great importance. Complete proof of their importance is unlikely until methods for the isolation and estimation of the viruses have advanced much beyond their present stage of development. But even now strong evidence of the importance of droplet infection is given by the facts that diseases of the upper respiratory tract are highly infectious and that these infections are transmitted by air-borne organisms. Our own tests quoted above give similar rates of fall of particles to those observed by Koeniger (1900) and quoted by Winslow and Robinson. But it seems hardly justifiable to describe as "a fairly coarse rain" particles of which 20% remain suspended for fifteen minutes and 4% for thirty minutes. We would rather emphasize the large number of infective particles which are emitted in sneezing, and the surprisingly long time before the number suspended becomes negligible.

Summary

Tests in a closed room have shown that an average vigorous sneeze causes the emission of about 100,000 bacteria-carrying particles of a size small enough to remain in the air for more than one minute. Of these about 4% will usually remain suspended in still air for as long as thirty minutes.

All or almost all the bacteria thus emitted can be killed in three to four minutes by a spray of 1% sodium hypochlorite solution in a concentration of 2.1 c.cm. per 1,000 c.ft. of air.

Certain unfavourable conditions exist, such as low relative humidity or high content of organic matter in the air, which may hinder the action of hypochlorite sprays.

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The committee for the Strickland Goodall Memorial Lecture in Cardiology consists of the Master of the Society of Apothecaries, Sir Stanley Woodwark; Sir Hugh Lett, Bt.; Sir Thomas Lewis, nominated by the President of the Royal Society; the President of the Royal College of Physicians, Sir Charles Wilson; and Dr. Geoffrey Bourne, nominated by the President of the Royal Society of Medicine. It has appointed Dr. William Evans, physician in charge of the cardiac department of the London Hospital, to deliver the third lecture, in June, 1942. The subject chosen is "Triple Rhythm," and the lecture will be given at Apothecaries' Hall, Blackfriars Lane, Queen Victoria Street. E.C.4.