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The epidemiology of respiratory infection in an isolated Antarctic community

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INTRODUCTION

During 1965 and early 1966 a study in virus epidemiology was undertaken at Mawson, an Australian National Antarctic Research Expedition station. The aim of the study was to assess the incidence and aetiology of infection, particularly respiratory infection, in the station personnel.

Such a captive group, which has limited and known contacts, would seem to provide an excellent opportunity for an epidemiological study. Paul & Freese (1933) demonstrated the feasibility of conducting programmes in polar bacteriology, but virology under these conditions is more difficult. Because of the isolation and relatively small size of most establishments, virus culture is not possible, though specimens can be collected for later culture attempts. This is satisfactory for some of the more stable virus groups but infection with other viruses can be confirmed only by detecting changes in the antibody titre of serial serum samples.

Two virology programmes had been attempted in Antarctica before 1965. Sladen & Goldsmith (1960) were engaged on 'Operation Snuffles' during the summer of 1958–9. This included studies on fifty-six volunteers from the 232 men on the icebreaker U.S.S. *Staten Island,* who gave monthly blood specimens for antibody assay. Each man had a total of fifteen throat swabs taken for virus culture before entering and after leaving ports of call on the voyage and whilst in Antarctica. Less than 50% of the total ship's complement complained of upper respiratory tract symptoms after leaving these ports of call. In addition, serum specimens were collected from the entire complement of the U.S.S. *Staten Island* at the beginning of the voyage and before returning to America, a period of approximately 6 months. Blood and throat swabs were also collected from personnel at two Antarctic stations; Hallett which was semi-isolated and Wilkes which had been completely isolated for 1 year. The Wilkes party reported some minor symptoms after contact with M.V. *Magga Dan,* which had arrived a few days before U.S.S. *Staten Island.* Neither party had epidemics of colds or sore throats after boarding the U.S.S. *Staten Island.* A final unpublished phase of this study was the collection of similar specimens from wintering parties at McMurdo Sound. All

specimens were sent to Dr R. M. Chanock, who tested the sera for the presence of antibodies to a number of respiratory viruses, not including rhinoviruses. No evidence of infection was shown with the viral antigens tested (R. M. Chanock, personal communication). Following this a systematic study of serum from members of the South African National Antarctic Expeditions was carried out during 1961 and 1962 to detect virus antibody in monthly serum specimens. This survey did not show any evidence of new virus infection during this expedition (J. H. S. Gear, personal communication).

METHODS AND MATERIALS

Logistics

Mawson (latitude 67° 36′ S, longitude 62° 53′ E) is approximately 3600 miles and 10 days' sailing from Melbourne. Budd (1964) fully discusses the living conditions and the type of work performed at this Station. The party under study arrived at the station early in January, 1965. Their ship left the Mawson area with the 1964 party aboard 4 weeks later. The twenty-seven new personnel remained isolated from then until January 1966, when there was a brief visit by a small party of Russian airmen who had already spent more than 1 month in Antarctica. The final relief took place in February and the 1965 party arrived back in Hobart in March 1966. The relief party had been at sea and at Wilkes for approximately 1 month before reaching Mawson.

Clinical data and specimen collection

The medical history of each subject was recorded from December 1964 until March 1966. Further inquiries were made by questionnaire in June 1966. Throat swabs were taken and kept in 2 ml. of virus transport medium at −70° C. (Equal parts of Hanks's balanced salt solution and Parker 199 medium with penicillin 100 units, streptomycin 100 μg., neomycin 20 μg. and amphotericin B 5 μg. in each bottle.) Nose swabs were collected with cotton-tipped applicator sticks moistened with the same medium and were also stored at −70° C. Specimens of faeces 5–10 g. in weight were collected by the men and placed in sterile 1 oz. screw-capped bottles for storage at −70° C. Serum preparation from clotted blood samples proved unsatisfactory because of unexplained haemolysis in many of the specimens; consequently, plasma was prepared from citrated blood. This proved suitable for antibody assay and gave similar results to serum samples collected from the same subject. Specimens were stored in mechanical refrigerators until the virological tests at the Institute of Medical and Veterinary Science (I.M.V.S.) were completed. Blood smears were prepared from all blood specimens and leucocyte counts were performed on those samples collected at Mawson.

Virus isolation procedures

Virus isolation was attempted using a range of cell-culture systems at temperatures and hydrogen ion concentrations considered optimal for the growth of virus

groups implicated in upper respiratory tract infection. The cell systems are detailed below:

(i) Primary monkey kidney (PMK) cell cultures were supplied as cell suspensions from *Maccacus cynomolgous* monkeys by Commonwealth Serum Laboratories (C.S.L.), Melbourne.

(ii) The HEp-2 cell line (Toolan, 1954) used in this study was originally received from C.S.L. and has been maintained at the I.M.V.S. for a number of years.

(iii) Two strains of human foetal diploid cells were used. The first was a foetal lung strain (HFDL) supplied by C.S.L. and had been shown to support the growth of some rhinoviruses. The second was the WI-38 strain kindly supplied by Dr L. Hayflick of the Wistar Institute, Philadelphia. The culture methods used for these strains were those described by L. Hayflick (personal communication).

The maintenance media for the cell monolayers are outlined in Table 1. In addition, all media contained 2 % foetal calf serum, 100 units of penicillin/ml. and 100 μg. streptomycin/ml. Leibovitz medium number 15 was used to maintain cultures inoculated with specimens from the final four collections of the study and all of the human foetal diploid cultures.

Table 1. *Composition of maintenance media used for cell culture and incubation temperatures used in this study*

Inoculum	Cell culture and incubation temperature		Formula*	Sodium bicarbonate (ml. of 4·4 % solution)	Sodium hydroxide (ml. of N solution)
Nose and throat	HEp-2	37° C.	Eagle's MEM in Earle's BSS	2·8	—
	HEp-2	37° C.	Leibovitz 15	—	0·15
	PMK	33° C.	Eagle's MEM in Earle's BSS	1·9	—
	PMK	33° C.	Leibovitz 15	—	—
	HFDL and WI-38	33° C.	Leibovitz 15	—	—
Faeces	PMK	37° C.	Eagle's MEM in Earle's BSS	2·8	—
	PMK	37° C.	Leibovitz 15	—	0·15

* GIBCO dehydrated media used throughout, see Grand Island Biological Co., New York, *Price and Reference Manual*, 1966.

Because of the large number of nose and throat swabs collected in this survey, the complementary samples were pooled in the laboratory and processed as one specimen in HEp-2, PMK, HFDL and WI-38 cell cultures which were subsequently scanned for cytopathic changes. Specimens were maintained in HEp-2 cell cultures for 28 days which entailed passaging the culture, after three cycles of rapid freezing and thawing at 14 days. The PMK cell cultures were tested for haemadsorption (Chanock & Johnston, 1964) 14 days after inoculation to detect the presence of

myxoviruses. Haemadsorption tests were similarly performed on the human foetal diploid cell strains 21 days after inoculation.

The specimens of faeces were suspended in Eagle's medium plus 2% foetal calf serum and inoculated into PMK cell cultures and maintained for 21 days. When toxicity resulted in early cell degeneration a further passage was performed.

Serology

The standardized straight-line technique of complement fixation test was employed to detect antibodies against influenza A and B, mumps, adeno-virus, Herpes simplex and ornithosis. The method has been described by Bradstreet & Taylor (1962).

RESULTS

Clinical data

There were thirteen men who complained of symptoms of upper respiratory tract infection within 2 weeks of leaving Melbourne. These cases were mild while on the ship, but several of these men developed a cough once they began working at the station. The clinical course of these colds ranged from 1 to 2 weeks and were the only cases recorded until January 1966. No infective diseases were observed during the period of isolation. It was not uncommon, however, to have a sore, dry throat on waking in the morning, presumably a result of breathing the warm, dry air of the sleeping huts. This discomfort would disappear after a few hours. This phenomenon was noted at other Antarctic stations (K. E. Hicks, personal communication) and has also been observed in the Canadian Arctic (Schmidt, 1963).

The Mawson geophysicist (J.E.H.) worked with a Russian field party from 3–9 January 1966, during which time he had some rhinorrhoea and transient dry throat. He returned to Mawson and suffered from mild abdominal pain and loose, but not more frequent, bowel motions from 11 to 13 January. Ten days later many of the party had diarrhoea and some abdominal colic, apparently related to the eating of mutton that had been frozen and thawed several times. During the afternoon and evening of 26 January four men, including J.E.H., were engaged in hosing down the station area with seawater pumped from beneath the harbour ice. While manœuvring the canvas hose their hands and patches of clothing not covered by rubber over-garments became damp and cold, but subjectively they did not feel any greater cold discomfort than they had experienced during the previous year. Thirty-six hours later, three (including J.E.H.) of these four men noted the onset of sore throat, mild rhinorrhoea and muscle aches. The sore throats persisted for 1 week.

The relief ship arrived on 3 February and during the changeover and on the return voyage six other men had similar respiratory symptoms, but all the cases were mild. No fever was noted, clinical examination of the fauces and pharynx showed nothing abnormal, and cough when present was irritative and not productive.

By questionnaire it was found that seventeen men, including five who had

infections during the relief and on the return voyage, developed upper respiratory tract infection of moderate severity on returning to Australia. Twelve of them developed symptoms within a fortnight of disembarkation, and symptoms lasted from 7 to 14 days.

Virus isolation and serology

All attempts at virus isolation using the systems detailed above from the throat, nose and faeces specimens were unrewarding. There were no diagnostic rises in antibody titre to any of the antigens tested. The scattering of the men on their return unfortunately precluded the collection of further specimens.

Leucocyte studies

The total leucocyte counts done through the year remained relatively constant for each man, as did the differential white blood cell percentages. In some instances, marked increases in the ratio of polymorphonuclear leucocytes to lymphocytes occurred during the voyages but they correlated poorly with symptoms. Total white blood counts could not be performed while at sea so the significance of these changes is unknown.

DISCUSSION

The clinical findings in the 1965 Mawson party were consistent with the observations made during previous and subsequent expeditions. The 'burning out' of respiratory infection (Tyrrell, 1965) began when the party, drawn from all over Australia, sailed south in a small ship, living four or five to a cabin. This wave of infection continued for a week or so after arrival at the station, during which time the men spent long hours in strenuous outdoor activity in temperatures around freezing point and with wind speeds up to 60 knots. It is understandable that the men who landed with colds should have had an exacerbation of symptoms at this time. Seven of the 1966 Mawson party similarly had upper respiratory symptoms during their voyage to Wilkes (J. Hudson, personal communication) and many of the 1966 Macquarie Island party developed moderate to severe colds once they had reached the Island (D. Edwards, personal communication). Two of the latter party were confined to bed because of an accompanying fever. Taylor (1960) and Hedblom (1961) also noted moderately severe upper respiratory tract infections in newcomers to American stations in Antarctica.

Once established at Mawson, the 1965 party did not report any more colds for almost a year. This observation is in keeping with the experience of other expeditions on which adequate records have been kept (Wilson, 1965). This phenomenon appears to be a function of the size of the community and its isolation. A population of about 500, as in the Spitzbergen study by Paul & Freeze (1933), is near to a critical size for the perpetuation of colds throughout the year. Most Antarctic populations do not number over thirty during the winter, thus there are a limited number of subjects susceptible to any virus pool left in such a group after the first few weeks. Though it is conceivable that some virus groups capable of prolonged colonization of various organs (such as adenoviruses and enteroviruses) may remain, the men's physical isolation ensures that new viruses will not be introduced.

Much interest has centred around the epidemics of respiratory tract infections that have been seen to devastate some isolated communities when they are contacted by outsiders (Andrewes, 1965). We believe a distinction should be drawn, however, between naturally isolated peoples and the personnel of modern polar expeditions. Examples of the former group include the Eskimos with their history of explosive outbreaks of infectious diseases such as poliomyelitis (Reinhard & Gibson, 1960) and influenza (Reinhard, 1962; Philip & Lackman, 1962). Heyerdahl (1958) also describes a wave of respiratory infection known locally as a 'coconga' which affects the Easter Islanders following visits by a ship. Similar outbreaks of respiratory tract infection afflicted the islanders of Tristan da Cunha when visited by ships which had recently left larger centres of civilisation (Woolley, 1963). There are even groups of aboriginals in Australia at present who have had little contact with outsiders, and with their relatively inexperienced immunological status, can be decimated with a viral disease such as measles (Tooth & Lewis, 1963). Virus diseases in this type of community with its limited experience of infection have high morbidity and mortality rates. This susceptibility contrasts with that seen among personnel on polar expeditions even though they are isolated for a period of 12 months or more. There are a number of relevant observations that have been made in Antarctica in the last 10 years. Taylor (1960), the Medical Officer at McMurdo Sound during 1956, records that on the relief of his party, some colds were experienced, but were mild in comparison with those suffered by the relieving party. Siple (1960) spent the winter of 1957 at the South Pole Station and records an unusually severe epidemic of upper and lower respiratory tract infection both in his party and in the crew of the aircraft which visited them in late October. It would appear, though, that this was a special situation and that the airmen were actually infected with Asian influenza, which was epidemic at the time. This would explain a high rate of infection in the wintering-over party and the severity of the symptoms. This specific instance cannot be taken, then, as the typical reaction of a modern Antarctic community on breaking isolation. Records were kept at McMurdo Sound of the number of upper respiratory tract infections amongst the 1959 wintering-over party and the incoming relief personnel (Hedblom, 1961). Again, one notes the relatively few infections suffered by the wintering-over party whilst still in Antarctica: 16 cases among approximately 80 men, as compared with 134 cases among approximately 170 of the newcomers.

This final phase of the period of isolation for the 1965 Mawson personnel was complicated by the contact with the Russian aircrew, which lasted approximately 12 hr., and by the presence of one member of the party (J.E.H.) who had been with a larger Russian party for 6 days. His description of his upper respiratory symptoms during this time was suggestive but not conclusive of infection, and his abdominal symptoms on returning to Mawson were of uncertain origin and significance. More definite, however, is the fact that three men, including J.E.H., developed some upper respiratory tract symptoms 18 days after the Russian contact and within 36 hr. of an episode of chilling which lasted from 3 to 4 hr. It can be postulated that a virus was seeded into the Mawson population directly by the

visitors or indirectly by J. E. H. and that the later apparent infections were examples of virus activation (Andrewes, 1965) in men who were engaged in a cold job for some hours. There was no evidence of cross-infection from these men to the other personnel. Another factor which may have played a part was a general climatic change with a significant temperature drop (Holland, Spicer & Wilson, 1961; Sutton, 1963) which occurred at this time. This would suggest that if virus activation is a reality, it is dependent on a number of environmental factors, and may explain the difficulty experienced in inducing activation of infection in volunteer experiments.

Three of the second series of infections were reported 3–5 days following the arrival of the relief ship and the rest were at weekly intervals after that. This series of cases as observed by one of us (A.S.C) fell into the doubtful mild cold and mild cold classes described by Tyrrell (1965) and can be taken as evidence of infection (Roden, 1958). Resistance to infection and modification of an infection is related to the possession of protective antibody against the challenging virus. It was interesting to note that the low levels of complement-fixing antibody present at the beginning of the expedition did not drop significantly during the year of isolation. McLean (1919), Adams & Stanmeyer (1960) and Sladen (1965) report that the bacterial flora of the mouth and pharynx decreases during a year in Antarctica. Ritchie (1958) has suggested that colds are prolonged by the secondary bacterial infection of virus-damaged tissues. It is tempting to suggest that the mildness of some of the colds experienced by men who have wintered in Antarctica could be explained by the relatively low-grade secondary infections by their depleted pharyngeal flora. There was, however, no apparent diminution of pharyngeal flora seen in this Mawson group in a separate bacteriological study, though quantitative methods were not used.

These observations suggest that there is a reduced susceptibility to colds in many wintering-over parties while still on the ice, though exceptions have been recorded. Wilson (1965) quotes an experience recounted by Dr Goldsmith concerning members of a wintering party from Halley Bay, many of whom caught severe colds on boarding their relief ship. Several days later, however, these men, still suffering from their colds, came into contact with another wintering party from Shackelton Base, none of whom caught colds. A similar situation was noted at Macquarie Island when the 1965 party there failed to contract respiratory infection despite the presence of the currently infected 1966 relief expedition (D. Edwards, personal communication). It is possible that the relief parties challenged the respective wintering-over parties with viruses to which the latter were immune. This, however, must be a moderately uncommon situation in view of the multiplicity of rhinovirus serotypes now recognized. The work of Hemmes, Winkler & Kool (1960) and Buckland & Tyrrell (1962) may have a bearing on virus survival and spread under Antarctic conditions where the relative humidity in the heated living huts remains from 15 % to 30 %, favouring the survival of influenza, parainfluenza and respiratory syncytial virus, but limiting the effective transmission of other virus groups. If this is a factor, one may expect an inverse effect at a sub-Antarctic station such as Macquarie Island where a constant high humidity pre-

vails, possibly encouraging the survival of the ether-stable viruses such as the adenovirus group and the picornaviruses.

The final phase of the present study began when the men reached Australia. More than half of the group had definite upper respiratory tract infections within 2 weeks of disembarkation. Subjective assessment only is available for these cases, but save for one or two, these infections were not more debilitating than the colds usually experienced by the subjects. This is a significant finding and it is interesting to note that there were many more definite infections at this time than were noted in Antarctica on breaking isolation and that the infections suffered in Antarctica conferred no significant protection against contracting infection on return to Australia. Though this type of information has not been obtained previously, it is of great significance in this type of study and we suggest that further surveys be conducted. As it is almost impossible to do it by personal interrogation and examination, questionnaire appears to be the only method of obtaining the data.

In summary, the sequence of events during an Antarctic expedition may be tabulated as follows:

(i) The party assembles and boards a ship. This crowding enables spread of infection to occur if there are virus excreters in the group, as colds are usually experienced on the voyage.

(ii) These colds may burn out if the voyage is long (over 1 month); but usually, on arrival in Antarctica and with much greater exposure to cold, infections continue to appear. Activation of latent infections is conceivable during this period and there is symptomatic worsening of existing colds.

(iii) When this wave of infection has ceased, upper respiratory tract infections are absent for the remainder of the period of isolation.

(iv) Mixing with the relief expedition usually results in some cases of respiratory infection in the wintering-over party while still in Antarctic regions, but these infections are notably mild and spread of infection is apparently not highly effective.

(v) Within a short period of returning to normal community life, colds of moderate severity, involving the majority of the personnel, can be expected. In some situations as yet undefined, these infections may occur while still in Antarctica.

Unfortunately, the several attempts to define the aetiological agents responsible for colds in Antarctica by serological and isolation studies have been unsuccessful. In spite of this, these Antarctic groups with their months of freedom from upper respiratory tract infection do provide excellent opportunities for basic epidemiological study. Surveys similar to those reported above should be continued, laying stress on a complete clinical coverage before, during and after the Antarctic sojourn. Careful specimen collection should be attempted during the relief period to try to establish which virus groups can cause colds under Antarctic and sub-Antarctic conditions. We believe that experimental inoculation of volunteers in these groups, using easily traced viruses, would yield valuable results. The general moral and ethical issues involved in the conduct of volunteer experiments have been discussed by Jackson *et al.* (1963) and their conclusions remain

valid for these isolated groups in view of the fact that the clinical manifestations of infection by most common cold viruses are mild.

One does not find difficulty in obtaining volunteers on these expeditions to take part in unpleasant procedures if the reasons are adequately explained and they feel that their participation is appreciated and will provide useful information. These groups would be ideal for the studies in the fields of virus persistence, antibody response to infection and resistance to serial reinfection by the same or different virus strain. Transmission experiments could also be attempted, for at a station such as Mawson there are numerous buildings which could be used, each with a thermostatically controlled heating system and stable relative humidity. Because there are trained weather observers at these stations, accurate recording of macro- and micro-meterological data does not present a problem. Medical laboratory facilities are adequate to allow simple haematological data such as white blood cell counts and erythrocyte sedimentation rate to be collected as described by Cate, Couch & Johnson (1964) for rhinovirus infections, before, during and after experiments.

SUMMARY

The results of a combined clinical and laboratory study of respiratory infections among members of an Australian Antarctic expedition are presented. Virus isolation and serological methods were employed, but the aetiological agent or agents responsible for respiratory infections in this group were not revealed.

The clinical findings were correlated with published and unpublished studies on comparable communities, and the following broad pattern of the epidemiology of respiratory tract infections in such groups has emerged. The assembly on board ship of a party from widely separated areas often leads to infections after embarkation. On long voyages these infections may burn out, but frequently new cases are still appearing when the party arrives in Antarctica. Symptoms in sufferers at this time become more severe, suggesting that the sudden environmental change from the warmth of an air-conditioned ship to the harsher Antarctic conditions may influence the course of the respiratory infections. With isolation established in Antarctica, further cases rarely appear. On exposure to the relief party, however, infections can be expected, and it is noted that morbidity is usually low and symptoms are mild, indicating an apparent heightened resistance to infection in the acclimatized party while still on the ice.

This study has further shown that most of these men, on returning to urban societies, contracted moderately severe upper respiratory tract infections in contrast to their apparent resistance when under Antarctic conditions.

The suitability of these groups for experimental study, including the inoculation of volunteers, was discussed and suggestions were made for future work.

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