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Since 1967 when the global programme of smallpox eradication began, the world-wide incidence has declined ~~sharply and, in 1969, reached the lowest yearly total ever recorded (fig. 1)~~ at a steady rate of between 35 and 40% per year, despite ~~far~~ better reporting in most countries. (1) The total of 53 000 cases recorded last year is the lowest ever reported to WHO. The total this year will be about 30 000 cases. The number of countries experiencing smallpox has also decreased - from 43 in 1967 to 20 in 1970. Despite considerable increases in air travel, outbreaks in ~~the non-endemic~~ European countries have been less frequent ~~(fig. 2)~~. (2) However, even a single imported case of smallpox can be cause for considerable concern as is presently the case in Copenhagen

Of particular interest this year was the recent outbreak in Meschede, Germany, in which it appears that airborne transmission of infection played an important role. ~~This outbreak was initially appraised by~~ I participated in the initial appraisal of this outbreak with Drs. Posch and Richter of the German Federal Republic. Subsequently, my colleague, Dr. Paul Wehrle investigated the problem in detail with German authorities.

Meschede, Federal Republic of Germany, 1970

On 31 December 1969, a 20-year-old German electrician flew to Dusseldorf from Karachi, West Pakistan, and then proceeded by train to his home in Meschede. He had never been successfully vaccinated.

On 10 January, he developed fever and on the following day was hospitalized in Meschede in an infectious disease isolation ward in a large general hospital. He was confined to a private room. Isolation precautions were observed from admission since typhoid fever was initially suspected, and he was known to be convalescing from hepatitis.

~~From 11 to 14 January, the patient felt well but remained strictly confined to his private room.~~ Toilet facilities were provided by an individual bedpan returned to his room after use. He had direct contact with only two nursing sisters but no ~~other~~ patients.

On 14 January, a rash was first noted and on 16 January, the diagnosis of smallpox was confirmed. Using special precautions, the patient was transferred to a recently constructed smallpox isolation hospital in nearby Wimbern. At the time of transfer on 16 January, he had extensive cutaneous and oral lesions and was coughing frequently. (SLIDE - 1)

For several days prior to the patient's admission, the entire hospital had been closed to visitors because of an outbreak of influenza in the community. After the diagnosis ~~of smallpox~~ was confirmed, the building ~~which housed the isolation ward~~ remained closed for several additional weeks. ~~All personnel~~

~~known to have had direct contact with the patient were immunized and isolated.~~ All ~~remaining~~ staff and ~~all~~ patients in the isolation unit as well as those on the upper floors of the building were ~~also~~ immunized and confined within the hospital building. Because of the advanced age and/or serious illnesses of many of the patients, it was decided to immunize many with an inactivated smallpox vaccine and/or vaccinia immune globulin (VIG). Some patients received live smallpox vaccine immediately while others received live vaccine a few days after (receiving) inactivated vaccine or VIG.

Transmission presumably occurred from 13 January, when the patient first developed his rash, until 16 January when he was removed to the Wimbern Hospital. (3) ~~That the index case was infectious as early as 13 January is confirmed by a single short interval of indirect exposure of case No. 8 on that one day only (table 1).~~ Seventeen persons experienced onsets of illness within the next incubation period ~~following the index patient's period of residence within the hospital (figure 3)~~. Fourteen were patients; two were nurses and one was a visitor. ~~The last~~ Finally, two cases occurred as a result of secondary spread within the hospital. Each was a patient who shared a room with an earlier case. Four of the 20 persons afflicted died.

~~Most patients and all but four had been vaccinated successfully in the past. However, most had not been revaccinated for 25 years or more.~~

The floor plan of the hospital building in which the outbreak occurred as well as the location of all cases is shown in the next slide. (SLIDE-2) ~~figure 4. The location of individual cases is indicated by numbers which correspond with those of table 1, where the other characteristics of these patients have been listed.~~

The building (itself) was constructed in 1932. Heating is provided by steam radiators located beneath the windows in each room, and ventilation is provided ~~for rooms and corridors~~ by opening the windows or doors.

The building is divided into four units. ~~These are~~ (1) R.1., the isolation unit on the ground floor; (2) R.3., the entire first floor; (3) R.5., the eastern half of the second floor which is used as a cloister for ailing nuns requiring hospital care; and (4) R.6., the remaining half of the second floor.

Food is prepared in the main hospital kitchen and supplied separately to each of the three floors. Individual dishes and eating utensils are kept on each of the ~~three~~ floors and are separate for each of the five unit kitchens. Linen is marked with identifying symbols for each floor and unit, and the linen from each of the four units is ~~disinfected and~~ washed separately in the hospital laundry.

A small service elevator connects three of the ward kitchens. This is used infrequently to transfer ~~bread or similar items~~ small items of food between R.1 and R.3. and is said not to have been used for the R.5 kitchen. The doors to this elevator ~~were observed to~~ closed tightly on each floor.

The appearance of 17 cases of smallpox on three floors of the hospital during the second generation of disease was quite unexpected. Three possible mechanisms of transmission were considered; (1) direct personal contact, (2) contamination of fomites with resultant indirect spread of infection, and (3) airborne spread.

Considerable efforts ~~Direct personal contact~~ were made to determine the extent of direct personal contact between the index case and others ~~The index case had no direct face-to-face or personal contact with any of the subsequent cases.~~ However, interviews with members of the hospital staff and ~~many of~~ the other patients all confirmed the statement of the index patient that he did not leave his room at any time following admission until his transfer on 16 January. At the time of transfer, he was encased in a protective plastic garment which was designed to prevent airborne as well as contact spread of infection. The doors to all other patients' rooms were closed and he was carried on a stretcher along the corridor of the isolation unit to a waiting ambulance.

Transmission by contamination of fomites, while difficult to exclude with absolute certainty, seemed most unlikely. None of the supplies, dishes or linen from R.1 was mixed with those of the upper floors. Also, linen from each room in the isolation unit was routinely placed in separate bags and disinfected prior to washing.

Nurses assigned to the isolation ward did not work on the other floors with the exception of a single night nurse who was responsible for patients throughout the building ~~with the exception of the~~ for patients in the cloister, R.5. This night nurse had at most very limited contact with the patient as he required minimal ~~if any~~ care ~~at night~~. ~~The physicians coming for patients in the infectious disease ward~~

An elderly priest who normally visited all patients, customarily served the building beginning with the second floor. ~~By so doing, he was able to ride up in the elevator in the main hospital building, cross to the isolation unit building and then walk downstairs visiting the patients on the second, first and ground floors in that order.~~ The room of the index patient was one of the last he visited.

The most reasonable explanation for the spread of smallpox appears to be the airborne route. In addition to the fact that no alternative mechanisms of transmission could be elicited, two incidents as well as the distribution of cases within the hospital support this hypothesis. The first incident relates to the circumstances of the exposure of patient No. 8. This patient visited the hospital only once on the evening of 13 January and remained in the building for 15 minutes. After entering the hospital by the front door, he located a physician and spoke briefly with him at the site designated "8". As the hospital was closed to visitors, he was not permitted to enter the patient care areas. He developed typical smallpox 11 days after.

The second incident relates to the circumstances of exposure of case 15 who was confined to the cloister on the third floor. This patient, one of the nursing sisters, had been hospitalized for many months with severe arthritis and did not leave her room for any purpose. No hospital personnel other than the nuns, the priest, and a physician caring for the nuns were permitted to enter this area. She developed smallpox on 31 January.

Finally, patient attack rates by floor within the hospital were essentially identical. Such uniform rates would seem most unlikely if transfer of infection had occurred by direct contact or through fomites or indirectly by hospital personnel.

Finally,) Patterns of air flow within the building were examined. ~~On the day selected for test, meteorological conditions were believed to be comparable to those of mid-January.~~ A smoke generating device was released in the room which had housed the index patient. The patterns of the air currents were approximately as shown in the slide ~~shaded portions of figure 2.~~ Within the building, dense smoke entered the corridor and those rooms adjacent to that of the index patient. The smoke then passed down the corridor, through a door normally kept ajar by means of a special device and then into the entrance hall. The visitor who contracted smallpox had waited in this entrance hall. After passing through

this entrance area, the smoke proceeded directly to the central stairwell which served effectively as a chimney. This open stairwell conducted the dense cloud of smoke to the first and second floor levels where it drifted into the corridors and adjacent rooms.

The smoke from the index patient's room also passed out from the partially opened window as a thin layer and proceeded directly up the exterior surface of the building. Upon opening windows in the rooms above, ~~that housing the index patient,~~ smoke ~~readily~~ immediately entered these rooms. This pattern of smoke flow into the upper windows appeared to be caused by convection currents generated by the radiators located below these windows. It is interesting to note that the pattern of air flow coincided remarkably with the distribution of cases within the hospital.

Extensive studies in both endemic and non-endemic countries have indicated the need for close ~~and often prolonged~~ personal contact if transmission of infection is to occur. Only infrequently have cases been reported in which the individual has not had direct or "face-to-face" contact with an earlier case. Whether or not in these isolated instances airborne transmission over considerable distances may have occurred has always been uncertain.

One previous and little known episode, however, is of interest. In an outbreak in Kreis Monschau, Germany, in 1961, a second generation case was the source of infection for 19 additional cases, only 9 of whom had face-to-face contact with the patient. In this outbreak, ~~The patient~~, a 9 year old girl, was admitted to the hospital with severe confluent disease, an ulcerative pharyngitis and a continual barking cough. Although the ward to which she was admitted had been cleared of ~~other~~ patients, a number ~~of patients~~ remained in a neighbouring ward at the end of a common corridor until the following day ~~when they were transferred or discharged~~. In due course, ten persons developed smallpox: seven patients in the adjacent ward, two members of the staff of the adjoining ward and the carpenter who had worked to erect a wooden partition in the corridor. None of these persons had direct face-to-face contact with the source case. Infection appeared to have spread by air over a considerable distance along the common corridor through which air currents flowed from the isolation unit to the neighbouring ward.

The Meschede outbreak very likely resulted from an unusual combination of at least three important factors. It is noted that the patient had a densely confluent rash with severe bronchitis and cough. As described by Rao and his colleagues, patients with more serious disease are much more effective transmitters of infection than those with a mild or modified illness. This is attributed to the fact that such patients are likely to have a greater number of lesions on the mucus membranes and thus shed larger quantities of virus into the saliva and subsequently into the air. Virus dissemination was undoubtedly accentuated by coughing. The virus particles expelled during coughing undoubtedly survived in the air for unusually long periods of time as the relative humidity in the hospital was very low. Experimental studies ~~(Harper, 1961)~~ have shown that vaccinia virus will survive for ~~long~~ for longer periods when the relative humidity is low. Finally, the hospital itself was of a design which inadvertently ~~appeared to~~ favoured the production of ~~relatively~~ strong air currents when the building was heated ~~during periods of low environmental temperature~~. This factor favoured dissemination of virus particles throughout the building while the low relative humidity favoured virus survival.

In the Kreis Monschau outbreak similar features were noted, specifically, a source case with extensive rash and cough, transmission during a period of low relative humidity and a hospital structure ~~favouring the occurrence of air currents~~ which permitted rapid transfer of variola virus from one area to another.

Should outbreaks of smallpox occur in Europe in the future, the possibility of similar occurrences should be kept in mind ~~and appropriate control measures taken.~~

Acknowledgement

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AIRBORNE TRANSMISSION OF SMALLPOX

A RECENT OUTBREAK IN MESCHEDE, GERMANY[1]

U.S.-Scottish Conference on Infectious Disease

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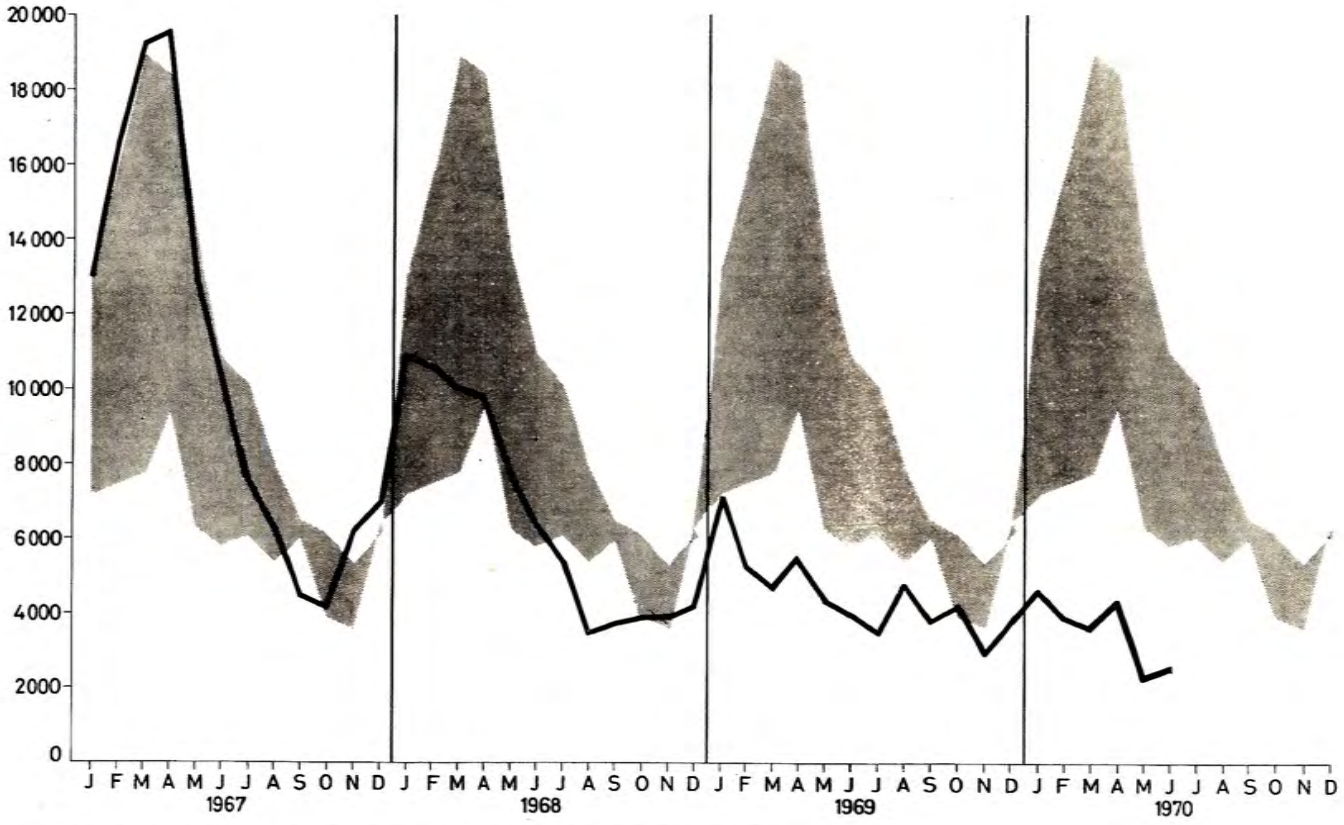
FIG. 1 WORLDWIDE SMALLPOX INCIDENCE, 1967 - 1970



The grey area represents the range between the highest and lowest incidence reported during the five-year period 1962 - 1966

Fig. 2 Introductions of Smallpox into Europe, 1961 - 1970.

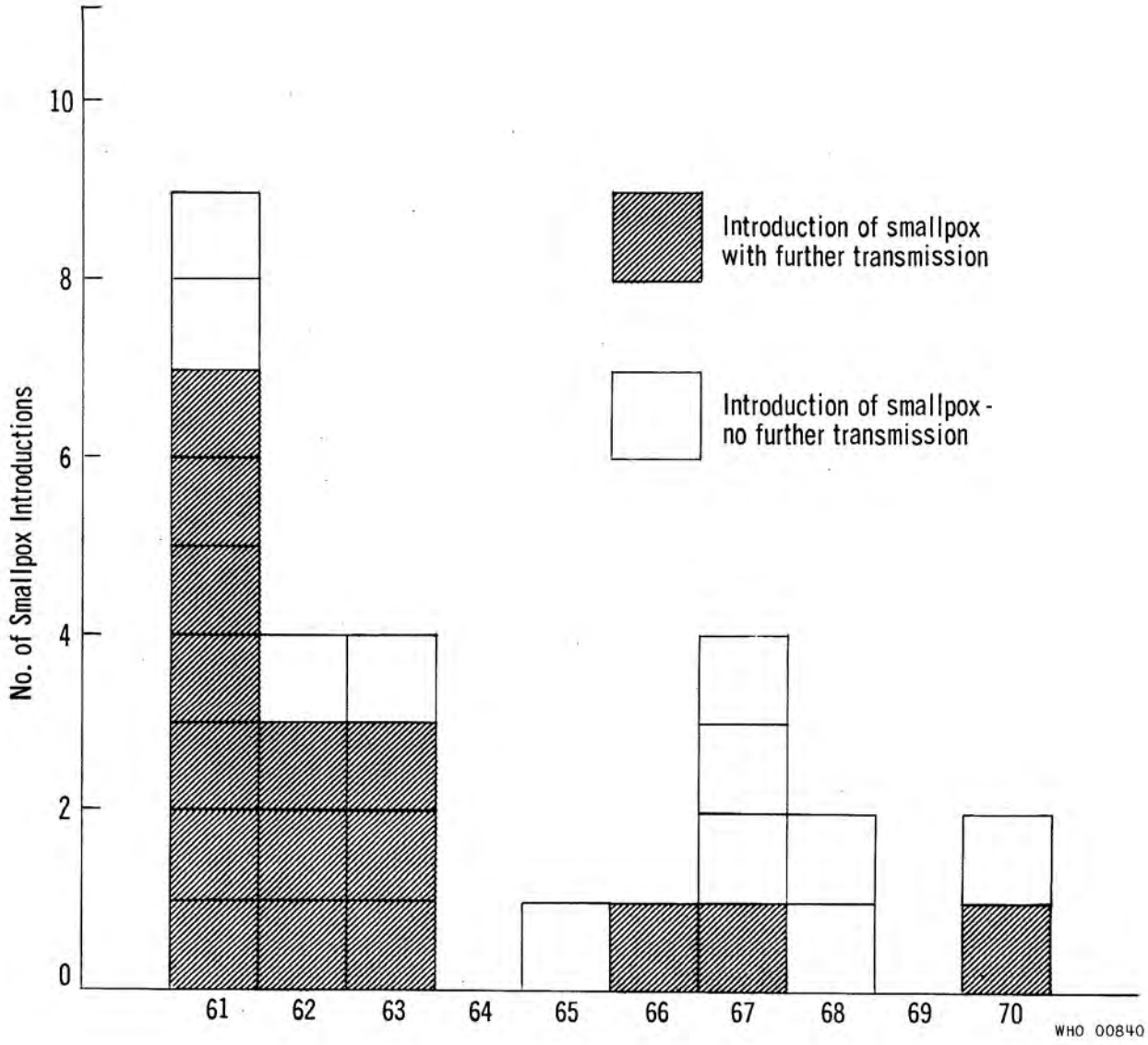


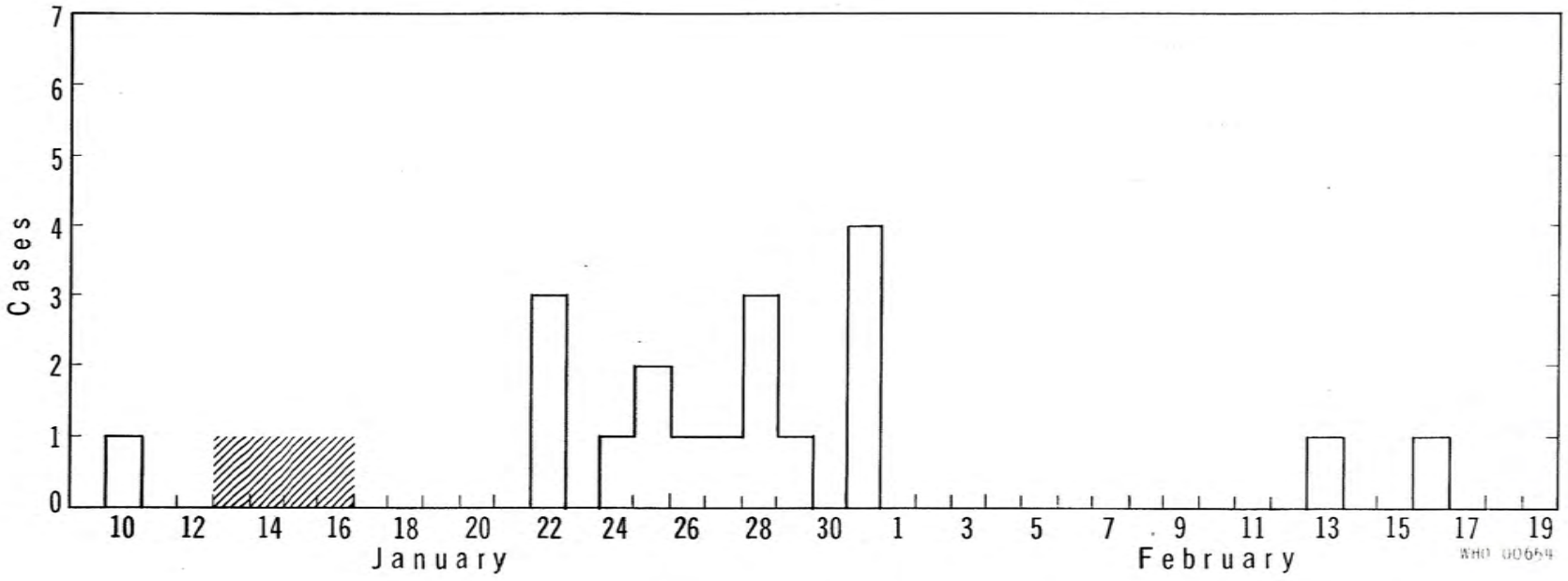
Table 1

CASES OF SMALLPOX, MESCHEDE, GERMANY, BY AGE, SEX, ONSET DATE AND IMMUNIZATION STATUS

Case No.	Age	Sex	Onset		Outcome	Past vaccination		Recent vaccination			Comment
			Fever	Rash		Vacc. Scar	Most recent Vacc. (Year)	Killed vacc.	VIG[1]	Live Vacc.	
1	20	M	10/1	14/1		No	1969	-	-	-	Index patient
2	5	F	23/1	25/1		No	-	16/1	16/1	-	Patient - R1
3	17	F	22/1	25/1	Death	No	-	16/1	25/1	17/1	Nurse - R6
4	21	F	25/1	28/1		No	-	16/1	25/1	22/1	Nurse - R3
5	57	M	22/1	26/1		Yes	1968	-	22/1	19/1	Patient - R6
6	50	F	25/1	29/1		Yes	1932	19/1	19/1	19/1	Patient - R1
7	56	M	26/1	29/1		Yes	1942	17/1	18/1	-	Patient - R3
8	42	M	24/1	26/1		Yes	1946	-	-	-	Visitor
9	79	M	27/1	29/1	Death	Yes	1903 (?)	16/1	18/1	-	Patient - R3
10	89	M	28/1	30/1		Yes	-	21/1	21/1	-	Patient - R6
11	90	M	28/1	30/1		Yes	1892 (?)	16/1	18/1	-	Patient - R3
12	59	M	28/1	31/1		Yes	1930	17/1	-	22/1	Patient - R6
13	73	M	31/1	1/2		Yes	1909	17/1	18/1	30/1	Patient - R6
14	59	F	29/1	2/2		Yes	1930	-	-	17/11	Nurse - R6
15	65	F	31/1	2/2		Yes	1917	17/1	30/1	-	Patient-R5
16	69	F	31/1	2/2		Yes	1902	16/1	18/1	-	Patient - R1
17	60	M	31/1	4/2	Death	Yes	1917	17/1	-	30/1	Patient - R3
18	21	M	22/1	None		Yes	1961	-	-	17/1	Patient - R3
19	74	M	13/2	15/2		Yes	1907 (?)	17/1, 29/1	18/1	-	Patient contact - case 17
20	81	F	16/2	17/2	Death	Yes	1901 (?)	17/1	17/1	-	Patient contact - case 15

[1] Vaccinia immune globulin

FIG. 3 DATE OF ONSET OF SMALLPOX CASES - MESCHEDE HOSPITAL, 1970



Presumed infectious period of index case while at Meschede Hospital

Fig. 4 **Meschede Hospital — Hôpital de Meschede**