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FACTORS INVOLVED IN TRANSMISSION OF SMALLPOX  
AND DURATION OF IMMUNITY

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FACTORS IN TRANSMISSION

Source of virus

The ultimate source of the smallpox virus is human and is derived from the acute case. No long-term human carriers exist. Although virus is present in large quantities in the scab material the virus from the respiratory tract is by far the most important from the epidemiological point of view. The patient is infectious from the onset of the acute viraemia. Virus is liberated over a period of time depending on the type of attack. In some types the build-up of virus makes many patients appear to be most infectious about the third day, which generally coincides with the appearance of the rash. Respiratory virus may be present on the skin, clothing and bedding and the patient is infectious long before the maturation of vesicles, and discharge of scabs.

The most likely source of infection is contact with a patient in the pre-eruptive and early eruptive phase of the disease. The mode of infection may be direct droplet transmission or may be by resuspension of droplet dust from clothing and bedding.

The corpse may be infectious from body fluids or from dust on the clothing or shroud. Pathologists, post-mortem technicians and undertakers may be infected from this source, sometimes having a normal attack of smallpox but occasionally variola inoculata from pricking the finger. Laboratory technicians and laboratory cleaners have also been infected from specimens or glassware.

Personal clothing and bedding contaminated with respiratory virus from the initial phase is highly infectious and gives rise to infection in those handling bedding in the family, chamber-maids in hotels and laundry workers both in hospitals and elsewhere. Food does not appear to give rise to transmission. Flies are attracted to the secretions on the skin of the smallpox patient - and infection could be conveyed mechanically to the mouth or eyes of small children, particularly in tropical countries.

#### Aerial spread

The possibility of spread of variola major virus from smallpox hospitals by air currents for distances of the order of half a mile has been seriously considered on many occasions over the last fifty years. Variola minor virus does not appear to have been incriminated under these conditions.

Although bacteria have been shown to be capable of being blown along hospital corridors, and rather mysterious patterns of secondary cases of smallpox in hospitals may be due to this method of spread, it is always impossible to eliminate the probability of spread by persons or fomites rather than air currents.

Aerosols of vaccinia (and presumably variola) virus are stable for many hours in small containers but there is much practical difference between this and the air between a smallpox ward and a house half a mile away.

The hospital with early cases (with respiratory virus), not the convalescent hospital with much scab material, appears to cause trouble. The possibility of infection by missed cases in the community, imperfect disinfection of clothing or irregular contact between the sick and healthy can never be completely excluded.

To the question is it absolutely impossible for a virus to be blown a distance of a quarter of a mile and infect someone, the answer I think must be no, but to the question is this likely to cause the pattern of infection seen around a hospital, the answer is always no.

#### Type of case

The infectivity of different types of case varies considerably. Apart from having virus in the respiratory tract on the day of infection, a passive carrier state, the patient is not infectious during the incubation period. In the more severe types, the patient is very infectious but because of the severity of the

illness is likely to be immobile. The intermediate cases types 4, 5 and 6 are infectious for at least five or six days but the milder types, including the abortive and sine eruptione, may only be infectious for a few hours, and if this occurs at night the patient is likely to miss infecting any contacts, even those living in the same house.

#### Type of virus

All strains of variola major appear to be of equal infectivity but variola minor seems to lack the epidemic potential of variola major. A larger proportion of sub-clinical cases occurs.

### EXTRINSIC FACTORS IN TRANSMISSION

#### Mobility

In the more severe forms of smallpox the patient is confined to bed; maximum weight of infection is therefore on the other members of the family, particularly those involved in nursing. In the milder types of smallpox, particularly in variola minor, the patient may remain ambulant after the initial pyrexial attack. Due to variation in the amount of respiratory virus, its presence on clothing, etc., persons infected may be few or many in an unpredictable manner.

#### Family size and composition

The larger the family the greater the chance of rapid multiplication of cases. A high proportion of young adults increases the chance of community spread. Multiple cases in families do not occur as frequently as is sometimes supposed. This is particularly true of variola minor.

#### Occupation

Respiratory virus appears to die out fairly rapidly. Clothing removed from the patient in the initial and early eruptive phase which is clean is the greatest danger when handled by members of the family, by laundry sorters, or by persons selling old clothes immediately they are removed from the patient's home. Although scab material could be present in clothing or rags there is no conclusive evidence that this is the source of infection if the rags have been stored for any time.

The important occupations are the doctor and the nurse who have neglected vaccination. The undertaker, health inspector and other members of the hospital staffs have also been infected. Raw cotton has been suspected as a source of infection in many outbreaks in Lancashire, but it seems probable that in some, if not all, outbreaks the arrival of cargoes of cotton coincided with the arrival of crews of ships from overseas ports where smallpox was present.

#### Dangerous situations

In countries with good free hospital services and early acute admissions, undiagnosed smallpox may be admitted and give rise to secondary cases in fellow patients

#### PUBLIC HEALTH FACTORS IN TRANSMISSION

##### Early diagnosis

Early diagnosis is very important in preventing spread of smallpox in a community. This is related to the efficiency and the availability of medical care, particularly the absence of a financial barrier. If the diagnosis is missed and the patient kept at home the family will be exposed to considerable risk of infection. If the patient is admitted to hospital and misdiagnosed there is considerable risk of infection of other patients, nursing staff, visitors and others. The ready admission to general hospitals unprepared for handling infectious cases is a hazard of the present age.

##### Isolation of contacts

The most important single factor in preventing the spread of smallpox is the rapid build-up of a ring of immunes around each focus of infection rather than indiscriminate vaccination. Vaccination should be done using triple-insertion technique and repeated on about the fourth day if there is no evidence that it is going to take. Inevitably some may be vaccinated too many times but it is better to do this on the few who constitute the ring. The size may vary from a few persons or houses around the family to a small community if the social customs suggest that this is advisable.

### Ambulant mild cases

Ambulant mild cases are particularly likely to occur amongst adolescents and fairly severe but ambulant cases may occur amongst tramps and other itinerants. In a modern society persons engaged in transport industries, notably seamen, road transport workers, and airmen are likely to have mild and missed attacks and so take infection from one place to another.

### Incubation period

The incubation period of variola major is surprisingly constant at 12-13 days to the onset of fever.

In variola minor the incubation period appears to be the same. Due to the trivial amount of eruption patients may mis-state the day of onset suggesting a longer incubation period which is not strictly accurate. In both types patients often have contact with their source of infection for two or three days or more so that it is always difficult to be absolutely certain.

### Exceptions

In some cases of variola major the incubation period appears to be between eight and ten days. In many concurrent vaccination has been performed and it seems possible that the initial pyrexial attack may be due to this and even the appearance of some of the lesions may be vaccinal rather than variolous, particularly when the attack is very mild. A shorter incubation occasionally occurs in very severe cases where any other possible source of infection can be ruled out, but this is often not as certain as might appear at first sight. In smallpox pulmonary allergy a virus pneumonia-like condition occurs in immune contacts and the incubation period is only eight days but these cases are not infectious. It is still good public health policy to regard the incubation period to the onset of fever as 12 days and the quarantine period of 16 days a reasonable safeguard.

#### IMMUNITY FOLLOWING SMALLPOX

The immunity following an attack of variola major is about 10 times that from primary vaccination. It would seem that in most people this will give lifelong immunity. There are exceptions, those who lose their immunity more quickly and therefore become susceptible to attack again. Second attack rates would appear to be about one in a thousand but depend very much on the age of the population at risk. Second attacks are either malignant and frequently fatal or exceedingly mild and abortive. The over-all case mortality is about 25 per cent. - but this would be affected by the difficulties of diagnosis. The milder cases are probably misdiagnosed because of the patient's history. Variola minor is most unlikely to occur after an attack of variola major but the reverse can occur. Variola minor probably confers little more immunity than a primary vaccination against an attack of variola major. It probably protects against a second attack of variola minor to the same degree as the variola major does to itself.

#### IMMUNITY FOLLOWING VACCINATION

In a non-endemic area single-insertion primary vaccination within one year reduces the chance of an attack to 1/1000th of that in the unvaccinated, within three years to 1/200th, within 10 years to 1/8th, within 20 years to 1/2, and has little if any effect in preventing infection after 20 years. In variola minor it is exceptional to get any clinical case within five years of a successful vaccination - the chance of clinical attack within 10 years is about 1/2000th of that of the unvaccinated. Thereafter it diminishes but some degree of immunity appears to be present for 30 years. I would suggest 1/80th at 20 years, 1/40th at 30 years, and 1/15th at 40 years, diminishing further with time. Whether vesicular revaccination boosts immunity to the same extent as primary vaccination appears less certain and many revaccinations give less stimulus than this.