Foot-and-mouth disease: an introduction

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Summary: The clinical and economic severity of this disease is exacerbated by its extraordinary ability to spread. These properties led European countries to launch, at the beginning of this century, programmes for research and cooperation for efficient control of the disease.

Vaccines produced after the Second World War did not always produce the results hoped for, and this was because considerable variation existed among field strains of the virus from different parts of the world.

Reference is made to two outbreaks, in 1962 and 1964, in which there was a threat of exotic strains of aphthovirus spreading to Europe. Recently developed techniques of chemical synthesis and genetic intervention have a part to play in improving vaccines of the future.


To understand why foot-and-mouth disease for so long has occupied an outstanding place in the veterinary research effort, we have to look back at the development of the animal disease situation in Europe from the middle of the nineteenth century. Foot-and-mouth disease was then only one of the major plagues of livestock. Rinderpest, pleuropneumonia and tuberculosis were more serious factors in the economic loss from disease and, although there were serious outbreaks of foot-and-mouth disease, for example, in England in 1839, 1870 and 1880, the disease was generally overshadowed by the others present until they were brought under control by the end of the century.

What were the features of foot-and-mouth disease that exercised the veterinary authorities so much? In observing a single case, the dramatic initial signs: salivation, lameness, fever and vesiculation, are short-lasting, with relatively rapid recovery. Looking further at the herd situation, however, the effects soon appear more serious. In the dairy herd, the acute phase brings total loss of milk yield, abortions and death in young calves. Recovery in the adult is accompanied by secondary mastitis and many animals will never recover their normal productivity. Beef herds will suffer similar losses, though adult beef animals may escape the more serious sequelae. In pigs, abortion and deaths in young stock and mastitis in sows are the most serious features.

This catalogue of trouble is exacerbated by what is undoubtedly the outstanding characteristic of foot-and-mouth disease, its extraordinary capability for spread. With the short incubation period, this led to the disease appearing almost simultaneously over large areas and the effects of the loss of meat and milk were therefore felt all the more severely. Another problem was the apparent failure of the development of

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immunity and the possibility of re-infection after a fairly short interval, not explained until the 1920's brought recognition of the type difference.

A product of the situation was extensive veterinary political activity. There has been a steady sequence of investigating committees of one sort and another since the 1880's, both in Europe and the UK. The records of the earlier ones can be recommended as delightful reading and perhaps as a warning to anyone pontificating as an expert witness. Research was beginning. The classic work of Loeffler and Frosch established the viral etiology of the disease and dealt in a way far ahead of the authors' time with questions such as the extreme rapidity of virus multiplication, the small amount of virus necessary to initiate infection and the detection of neutralising antibody.

From 1900 onwards the general concern began to have an effect. Work on foot-and-mouth disease obviously needed more than a corner of an established laboratory, in view of the high risk of spread of the infective agent. The first specialist institute was set up at Insel Riems in Germany in 1909, implanting the idea that isolation and an island site were synonymous. Pirbright and Lindholm in Denmark followed in 1925. International cooperation, both on research and on field control methods, began slowly but gathered impetus in the 1920's. It is an indication of the importance that the disease had gained that the first specialist commission within the Office International des Epizooties was on foot-and-mouth disease and that it is still in being after more than fifty years.

In the UK it was realised from the start that the most effective method of control in Britain was eradication by slaughter and disinfection. With import control, the number of new outbreaks was generally small and for periods of up to six years around 1900 the country would remain free of the disease, but the major outbreaks in 1911 and the early 1920's led to the establishment of the Foot-and-Mouth Disease Research Committee and the beginning of scientific work at Pirbright in early 1925.

The activities of the Department of Agriculture and the new research station were more successful in limiting spread of the disease than in reducing importation of virus. The field staff made great efforts to encourage farmers in early reporting of suspicious signs and to obtain their acceptance of the draconian measures for stamping out infection. From the laboratory came information on virus persistence outside the animal, methods of spread and the efficiency of disinfectants and other aspects of importance in field control.

The coincidence of periods of high levels of disease on the continent especially in Germany, Holland, Belgium and France, with peaks of new outbreaks in Britain, often in East Anglia and south-east England, was noted but wind-borne infection was discounted because of the failure to demonstrate transfer of infection experimentally over more than a few metres. Much time and effort was spent on migrant birds and the unfortunate starling. Imported meat from South America was the other potential source of virus. Experimental evidence for survival of virus in bone marrow under the conditions of shipping of carcasses was obtained at Pirbright. This work was extended by Henderson and myself during the war and more emphasis placed on the risk from offal and from pork. Subsequently, greater restriction of these imports did appear to reduce the number of new outbreaks attributable to the meat trade.
Foot-and-mouth disease continued to be a major problem during and after the war. In Britain, in spite of wartime difficulties — for example, the need to bury carcasses instead of burning — the field control methods were maintained with limited salvage of in-contact animals. At Pirbright, research was directed at measures that might have to be taken, should the disease spread beyond the point at which control by slaughter was practicable. Had there been an outbreak of the proportions of the 1967 series, this might have been the case. The most practical alternative was a vaccination programme. Vaccines were at that time in their infancy. Waldmann and his co-workers had prepared successful vaccines from vesicular material from bovine tongue lesions and Graub and Saxer had suggested another source of virus for inactivation, the blood collected from infected cattle at the peak of the disease. At Pirbright, for several reasons the decision was made to investigate the blood vaccine, which had crystal violet added as a bacteriostat. It is a notable paradox that the studies on this vaccine, which never came to be used in the field, produced the greatest steps forward in foot-and-mouth disease research for two decades, leading Henderson to develop his method of titration of virus on the bovine tongue to establish methods for the estimation of vaccine potency, and to the consideration of statistical evaluation of innocuity tests.

Work at this time also led to the serological methods which replaced cross-immunity experiments in animals for the typing and strain-differentiation of virus. Just after the war, too, the development of the unweaned mouse as an experimental host transformed the approach to laboratory work. One of the great strengths of the Institute continued to be the facilities for studies of the virus in the natural hosts and these facilities were continually improved, notably by the expansion of 1952-56. Tests on vaccines of different types and strains brought to light the enormous variability of the virus and the newer methods made possible more precise studies on variation in virulence and species adaptation of strains. The possibility of study of these phenomena at the molecular level now exists and must be rewarding.

So far, the emphasis has been on the disease in Europe. In other continents the epidemiological picture was sometimes widely different. Infection was not always followed by the severe spreading disease so much dreaded in Europe. In South America in the 1920’s and 1930’s there would seem to have been major waves of the disease from time to time but more usually a low level of mild infection. The disease most frequently became apparent after the movement and collection of cattle either from breeding to fattening areas or on collection at slaughterhouses.

In Asian countries, low insidious infection seems to have been most common with occasional crises when the disease appeared among imported animals in stock improvement programmes or in specialised dairy units. In India and South-East Asian countries, disease was seen in buffalo, sometimes mild but occasionally severe, with crippling lameness in draught animals.

Pirbright did, at quite an early stage, develop an interest in the problem in African countries. From 1931 onwards, strains of virus were received from Rhodesia, Bechuanaland and Kenya. Difficulties in cross-immunity tests led to their being classified as "atypical" but the strains were stored and, when further strains were received in 1948 and later the whole question was re-investigated, the existence of the three African (SAT) types was established. The occurrence and distribution of these types poses a most interesting question in what might be called viral archeology. Their separate existence as the only representatives of the foot-and-mouth
disease virus south of the equator, as far as records exist, gives rise to much speculation, especially since homology experiments seem to confirm their separation from the O, A and C groups.

An aspect of variability observed to advantage in Africa is the variation in species susceptibility. The interplay of virus in cattle and zebu seems to play a part in the confused epidemiological picture. Although insignificant lesions followed some attempts to infect zebu with cattle virus, on other occasions fairly severe disease was observed and, in African countries as elsewhere, severe waves of infection are seen. Wild species of ungulates also play a part, the best documented account being in relation to the Cape buffalo, in which the virus may persist in a herd from generation to generation without clinical signs. The carrier state, with virus recoverable from the pharynx, offers great possibility for the emergence of new variants demonstrated in both cattle and buffalo. The continuing variability of the virus in so many characteristics, together with the range of hosts, suggests that in some regions of Africa there has been achieved the nearest approach to an equilibrium between host and parasite, a balance disturbed only by animal movement or human intervention.

From the point of view of countries where foot-and-mouth disease is not present or where it is well under control, Africa, Asia and some South American countries constitute a reservoir of infection. Britain and the other European countries are still at risk, especially from "exotic" strains of virus against which vaccines currently used in Europe would not protect. The extensions of the African type, SAT 1, in 1962 through Bahrain, the countries of the Middle East to Turkey and the USSR, and of A22 in the same area in 1964-65, illustrate the problem (see Figs. 1 and 2). While the maintenance of protective buffer zones where animals are vaccinated against the new strain is most valuable, the risk can only be countered in the long term by import control and by a gradual pushing back of the limits of infected areas. Unfortunately, this involves control of disease in areas where political as well as epidemiological factors militate against satisfactory programmes. Bearing in mind also the reservoir of infection in wild host animals, it would be a rash prophet who would predict the possibility of eradication of foot-and-mouth disease in the foreseeable future.

Perhaps this statement underestimates the possibility of a completely new approach to vaccination or chemotherapy. Some 25 years ago, the initial success of the modified live strain vaccine programme gave grounds for optimism. Is there perhaps a future for a genetically engineered vaccine of this kind? Other possibilities may stem from the preparation of synthetic antigens or the incorporation of the code for the immunising antigen in the genome of another virus. Given a vaccine as effective as vaccinia in man or rinderpest in animals, covering the wide antigenic spectrum of foot-and-mouth disease, there is no doubt that some of the administrative problems would fade and we might see the disease controlled in some of those areas which look most refractory.

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FIG. 1
Spread of FMD type SAT 1 through the Middle East in 1962
FIG. 2
Spread of FMD type \( A_{22} \) through the Middle East in 1964-65
LA FIÈVRE APHTEUSE : INTRODUCTION. — J.B. Brooksby.

Résumé : La gravité clinique et économique de la fièvre aphteuse chez les bovins a été exacerbée par l’extraordinaire capacité de propagation du virus. Ceci a conduit les pays européens, dès le début du siècle, à lancer des programmes de recherche et de coopération pour lutter efficacement contre la maladie.

Les vaccins anti-aphteux mis au point après la Seconde Guerre mondiale n’ont pas toujours donné les résultats escomptés en raison de la grande variabilité des souches virales isolées sur le terrain dans les différentes régions du monde.

L’auteur rappelle, par l’exemple de deux épizooties survenues en 1962 et 1964, que des souches exotiques du virus aphteux menacent toujours l’Europe. Il estime que, dans l’avenir, la conception des vaccins pourra être améliorée grâce aux techniques de synthèse chimique et de génie génétique.


FIEBRE AFTOSA : INTRODUCCIÓN. — J.B. Brooksby.

Resumen : Se ha incrementado la gravedad clínica y económica de la fiebre aftosa en los vacunos debido a la extraordinaria capacidad de propagación del virus, lo que ha conducido a los países europeos, desde comienzos del siglo, a promover programas de investigación para luchar eficazmente contra la enfermedad.

Las vacunas antiaftosas elaboradas después de la Segunda Contienda mundial no siempre dieron los resultados esperados, debido a la gran variabilidad de las cepas víricas aisladas en el campo, en las distintas regiones del mundo.

Recuerda el autor con el ejemplo de dos brotes ocurridos en 1962 y 1964, que Europa sigue estando amenazada por cepas exóticas del virus aftoso. Estima que, en el futuro, podrá mejorarse la concepción de las vacunas gracias a las técnicas de síntesis química y de ingeniería genética.