Classical swine fever: new control and eradication methods*

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Summary: Economic losses and risks to productivity posed by classical swine fever (CSF) have increased in many countries together with pig population density and with increasingly intensive production systems. Greater efforts to control and eventually eradicate CSF have been prompted by the appearance of atypical forms of the disease, as well as by the recrudescence of infection in formerly disease-free countries. The spread of African swine fever (ASF) to formerly uninfected regions calls for vigilance and action against both diseases.

The virus of CSF is a member of the Pestivirus genus within the family Togaviridae. Identification of structural proteins has revealed minor differences among virus strains, as well as a relationship of this virus with the pestivirus of bovine viral diarrhoea (BVD).

Specific laboratory diagnostic methods have been developed which permit the rapid and reliable demonstration of virus in tissues, particularly the direct immunofluorescent (IF) antibody test and virus isolation in cell cultures. Specific antibodies against the virus can be detected in the blood serum of pigs by virus neutralization, the indirect IF and a series of other serological tests. These laboratory diagnostic tests are also effective in differentiating CSF from ASF and from other viral infections of the pig.

Experience with some of the more recently developed attenuated virus strains, such as the strains C (Chinese), LPC (China), GP (or GPE) and Thiverval has proved that these strains are safe for vaccinating pigs of any age, and are highly immunogenic.

Systematic application of modern attenuated virus vaccines has contributed to reducing losses caused by CSF. However, eradication still depends on the eventual application of well-known veterinary sanitary measures. It should be borne in mind that infected pigs and feeding pigs with improperly sterilized slaughterhouse and kitchen offal play the most important role in the spread of the virus. In the eradication phase of CSF control, vaccination should be restricted to emergency use or preferably banned altogether, to permit the systematic serological screening of slaughter pigs for antibodies against the virus.


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INTRODUCTION

The importance of new methods for the control and eradication of classical swine fever (CSF) can be estimated on the basis of country disease reports published in the monthly Bulletin of the O.I.E., and also from reports submitted by Member Countries on this technical item of the 52nd General Session. Solutions to the problems are contained in a rich selection of papers which have been published in the international literature. These sources have been used to compile this review.

Reports on this technical item have been received by the O.I.E. from a total of 46 countries of the four main geographical regions: Europe (19 countries), the Americas (11 countries), Asia, the Far East and Oceania (11 countries), and Africa (5 countries).

From these reports it seems to be clear that the importance of CSF is closely correlated with the size and distribution of the pig population as well as with the system of management practised in the reporting country. In a number of countries, including 7 reporting ones, mainly in the Near East region, there are practically no pigs. However, from all other regions gradual increase and concentration of pig populations has been reported. This trend has been connected with an increased risk of the spread of infectious diseases including CSF.

Fifteen out of the 39 countries in which pig production is of economic importance have reported to be free from CSF infection for various periods of time. But the majority of reporting countries, including most of those presently free from infection, admit that CSF constitutes one of the main hazards to pig production and to trade in pigs and pig products.

By screening the literature on the subject, including computerized data base searching, more than 800 papers and review articles on CSF have been made available. In selecting for a relatively short list of references, in addition to the most important priority aspects, preference has been given to more recent publications in world languages which are directly related to practical aspects of CSF control and eradication, rather than to those dealing with basic research on the virus, or immunological and pathological aspects of the disease. Only three country reports (by the Netherlands, Taiwan ROC and the U.S.S.R.) submitted to this General Session have been included with the list of references, because they contained original information not encountered in the published literature. Statements from many more country reports have been used in compiling the review, but no reference to anonymous reports has been made.

In preparing the review, the difficulty was faced to make available information useful for policy makers and diagnosticians from a wide range of countries in which not only the epidemiological situation of CSF, but also the possibilities to face the challenge are largely different. For instance, some endemically infected countries in South America have reported to have had
great difficulties in obtaining basic information on the occurrence of the disease. Some of them had estimated that more than 80% of outbreaks were not reported to the authorities. Therefore, priority has been given in these countries to intensified vaccination programmes rather than to applying sanitary measures which would have required a more developed infrastructure and more financial support from central funds than available. On the other end of the list of reporting countries are industrialized ones, which have intensive pig production and highly efficient veterinary services. These countries are either free from CSF infection, or they are carrying out short-term programmes for the eradication of the disease. In such countries no vaccines are used, or vaccination is limited to meet emergency situations under strictly controlled circumstances.

What seems to be common to all affected or interested countries, is the need for an intensified application of up-to-date methods for the diagnosis of CSF, considering also differential diagnosis from other pig diseases, especially African swine fever. Achieving and maintaining freedom from infection will eventually depend on the consequent application of veterinary sanitary measures, including the immediate slaughter of affected and in-contact pigs combined with movement control in the area. Regular serological screening of the herds should prevent against the spread of virus strains of low virulence, which can result in typical outbreaks of the disease under certain epidemiological circumstances.

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Classical swine fever (CSF), known also as European swine fever and hog cholera, has been responsible for heavy losses to the pig industry ever since its first appearance in Iowa, U.S.A., in 1833, and the subsequent spread of the infection to Europe in 1862 and the rest of the world.

During the past decade, since CSF was discussed by the 5th Conference of the O.I.E. Regional Commission for Europe in Prague, in 1971 (see Bull. Off. int. Epiz., 1971, 75, 519-687), significant contributions have been made to the effective control of the disease, and new problems have been encountered, among them the following:

— Properties of CSF virus and details of the pathogenesis of various clinical forms of the disease have been clarified.

— New laboratory techniques have been developed and applied to routine diagnosis of the disease.

— Improved attenuated virus vaccines have been tested both in laboratory tests and by mass application in the field.

— In regions in which African swine fever (ASF) infection appeared, governments were urged to deal more seriously with CSF because of difficulties of differential diagnosis.
— Economic losses due to CSF in countries with valuable pig stocks encouraged not only control measures but also eradication schemes.

— In some countries which had achieved or were close to complete eradication of CSF, new foci of the disease appeared, or difficulties were encountered in liquidating foci of atypical and subclinical forms of the disease.

Cost-benefit calculations carried out by modern statistical methods have amply justified the expenditure required by both governments and pig owners to control CSF by the most effective vaccination and sanitary measures (26, 43). It is also evident that the ultimate eradication of infection not only avoids economic losses in pigs and productivity, but opens new possibilities for international trade in live pigs and pig products.

This review is concerned with recent knowledge on various aspects of CSF which have direct bearing on control and eradication of the disease. Results of basic research on the virus and the pathology of the disease will be mentioned only briefly. No details on the technical aspects of laboratory tests, disinfection and sanitary measures will be discussed. Emphasis will be given to new aspects of the disease syndrome as well as the role of new diagnostic methods and vaccines in controlling the disease and in achieving the ultimate goal of eradicating the infection from a country or region. In quoting from a wealth of literature, preference has been given to more recent publications rather than to priority aspects. For more detailed information on the subject excellent reviews are available (24, 46, 47, 66).

AETIOLOGY

1. Morphological and chemical properties of the virus.

Recent research has provided details about the virion of CSF virus (33). The virus particles are spherical with a diameter of 40-50 nm. The viral envelope or peplon bears surface projections 6-8 nm long. The virion contains infectious RNA. At least three structural proteins have been identified, two of which are glycoproteins of the envelope. The envelope also contains lipids and carbohydrates. Based on these properties of the virion, the virus is classified as a member of the genus *Pestivirus* of the family *Togaviridae* (50). One other member of the *Pestivirus* genus is the agent of bovine virus diarrhoea (BVD) which causes also border disease in sheep. It shares common antigens with CSF virus (46).

Resistance to thermal inactivation of CSF virus strains constitutes a genetic marker. After heating to 56°C for 30 minutes, highly virulent, attenuated and avirulent strains of the virus undergo a decrease of infectivity of 1.6, 2.7 and 4.0 log_{10} ID_{50}, respectively (4). Stability of CSF virus is best in the slightly alkaline range, but it is sensitive to low pH values.
2. Biological properties of the virus.

No major antigenic types have been encountered with CSF virus, but minor differences have been described by several authors. Aynaud et al. (1974) suggested two subgroups: subgroup I contains the virulent Alfort strain, the « C » (Chinese) and the Thiverval vaccine strains, while subgroup II comprises the American 331 strain and several isolates from chronic CSF (5).

Various degrees of antigenic relationship have been revealed between strains of CSF and BVD virus (49, 56), and this will be considered in the serological diagnosis of the disease, to be discussed below.

3. Virus culture.

The virus can be propagated in cultures of mammalian cells, especially those of porcine origin. Both primary cell cultures and established cell lines support virus multiplication. CSF virus strains usually cause no cytopathic effect when grown in cell culture. Some strains described to be cytopathic have proved to be contaminated with other viruses (10), or they exerted such an effect only under certain strictly controlled circumstances (23). Therefore, virus multiplication in cell culture has to be demonstrated indirectly, for instance by the immunofluorescent (IF) antibody test (36, 51). An infectivity test based on the enumeration of fluorescent plaques in monolayers of PK 15 cells is also used (71).

4. Host range.

The domestic pig and its wild ancestor, the wild boar (Sus scrofa ferus), are the only species naturally susceptible to infection with CSF virus. However, the virus can be adapted to grow in other species such as rabbits and guinea pigs, and passage in these species results in attenuation of the virulence of virus strains used for vaccine production.

DIVERSITY OF CLINICAL AND PATHOLOGICAL FEATURES

Especially in countries with intensive systems of pig production, in which effective measures for the control and eventual eradication of CSF are practised, the clinical and pathological definition of the disease has been altered to include, in addition to the usual acute form of the disease, chronic and atypical, often very « mild » syndromes. This circumstance has raised difficulties in diagnosis and consequently in the eradication of CSF from several countries (9, 16, 37).

1. Typical infection.

Typical infection caused by fully virulent virus in susceptible pigs of any age is an acute or peracute febrile disease. Pigs infected orally develop fever
(41°C) after an incubation period of 2 to 4 days, followed by lymphopenia, anorexia, hyperaemia or haemorrhages in the skin, conjunctivitis, nasal discharge, and sometimes diarrhoea with blood in the faeces. Posterior paralysis and convulsions may also develop. Mortality can exceed 60% and often most of the affected pigs die within 2 weeks. The pathological lesions of typical CSF are due to generalized vasculitis and destruction of lymphocytes. The lesions consist of widespread bleeding below the serous and into mucous membranes, thrombosis, splenic infarction and intestinal ulceration. Lymph nodes are loaded with erythrocytes. Histologically, encephalitis may be present in most pigs, except those which have died from peracute disease (22, 66).

2. Chronic forms.

They are characterized by an early acute phase, followed by a period of partial recovery and finally relapse and death of the animal (53). This form of the disease is connected with persistent viraemia and impaired immune responsiveness of the host, with deposition of immune complexes in the kidney and other organs (20). In chronic forms of CSF, fibrinous lesions («boutons») with concentric design are present in the colon and caecum, and foci of haemorrhagic, fibrinous pneumonia in the lung. Lymph nodes are depleted of lymphocytes and germinal follicles. Glomerulonephritis with hyaline change is indicative of an immunopathological process.

3. Atypical forms.

Atypical (or «mild») forms are mostly limited to restricted areas or individual herds. The clinical disease affects mainly young pigs, with fever, anorexia and retarded growth. Some pigs develop posterior paralysis and convulsions. In some outbreaks most of the pigs survive the infection without overt clinical symptoms. The pathological findings may be scanty with only some haemorrhages on the surface of the kidney, in the mucosa of the bladder and rectum. However, such smouldering infections can suddenly change into acute outbreaks, when fully susceptible young pigs come into contact with it (9, 46).

If susceptible pregnant sows are infected with CSF virus strains of low virulence, intrauterine infection of the fetuses can occur without clinical involvement of the virus carrier sow. Transplacental transmission of CSF virus was first observed in sows inoculated when pregnant with vaccines containing insufficiently attenuated virus strains. The same process has been observed after natural infection of sows with virus strains of low virulence. The consequence of such an infection might be abortion, stillbirth, mummification, and perinatal death. Piglets born alive after intrauterine infection are often weak and affected with congenital tremor, splayleg and reduced vitality (13, 15, 30, 77).

Experiments have shown that the outcome of transplacental infection of pig fetuses with virus of low virulence depends on the stage of pregnancy at
the time of infection of the sow (31, 77). Most piglets born of sows infected during pregnancy are immunotolerant. They do not produce antibodies and remain permanent carriers of CSF virus (54, 58, 72). Not even antibodies acquired from the colostrum are demonstrable in such piglets, because they become bound to permanently carried virus. Viraemia due to congenital infection can persist for the entire life of a pig. It has been shown that immune tolerance and persistent viraemia will develop in fetuses infected before the 70th day of gestation (28), but it has also been observed in piglets infected in utero after the onset of immune competence (73). There are differences in the fetal pathogenicity of virus strains of low virulence not only according to the stage of pregnancy at infection, but also among the litters of individual sows and between litter mates (8, 18).

Research has clarified the role of humoral and cellular immune responses to CSF virus infection (19, 59, 61, 74, 75, 76). The significance of immunopathological processes in the pathogenesis of atypical forms of CSF has been demonstrated (32, 62).

**DIAGNOSIS**

In view of wide variation in clinical symptoms and pathological lesions caused by virus strains of different virulence in pigs of different age groups, reliable diagnosis is dependent on the application of a wide range of diagnostic methods. These include field epidemiological and clinical observations, gross and histopathological investigations as well as various specific laboratory tests to demonstrate viral antigen in tissue sections, to isolate and identify the virus, and to reveal specific antibodies in the blood serum of pigs.

Trained personnel and facilities to apply a reasonable choice of sophisticated laboratory tests is vital for effective control and eventual eradication of CSF in a country.

1. **Pathology.**
   
   In spite of the fact that lesions caused by CSF virus strains differing in virulence are often not pathognomonic, both gross pathology and histopathology continue to be an integral part of CSF diagnosis. However, it should preferably be linked to specific tests to demonstrate viral antigen in tissues (12, 13, 70).

2. **Demonstration of viral antigen and infective virus.**
   
   From numerous laboratory tests developed for this purpose, only those will be mentioned which have actual or potential practical application in routine diagnostic laboratories. Many others are valuable tools in the hands of research workers (24).
(a) The immunofluorescent (IF) antibody test is a rapid and reliable test for demonstrating viral antigen in tissues of diseased pigs. This test is widely used in the specific diagnosis of viral diseases. Since its first application to CSF in the 1960’s (36, 51), the direct IF test applied to frozen sections of tonsils and other organs has become the most widely used laboratory test for direct demonstration of CSF antigen in the body of suspect animals.

Tonsils are the first organ to become positive in infected pigs. Sections of ileum, spleen and kidneys give positive results in this descending order. However, in subacute and chronic cases of the disease, the distal part of the ileum is often the only specimen to show fluorescence (68).

Both false-positive and false-negative reactions occur with the direct IF test, though false-positive reactions are very rare, and occur in pigs infected with bovine virus diarrhoea (BVD) pestivirus, antigenically related to CSF virus. False-negative results are more frequent. Specimens from pigs which have died from peracute disease might be negative, because at least one week has to pass before viral antigen can be demonstrated in tissues by the IF test. Specimens from pigs infected with virus of low virulence or pigs partly immune due to previous vaccination may give less distinct IF reactions (9). Pigs vaccinated with live virus vaccines may give positive IF tests for about two weeks after vaccination.

If, instead of cryostat sections, smears of tissues are used for the IF test, non-specific bright fluorescence both in the cytoplasm and in the nucleus of tissue cells can render interpretation of the test uncertain (24).

In Romania, direct IF testing of bone marrow smears of suspect pig carcasses has been found useful for the differentiation of pigs infected with pathogenic virus from pigs vaccinated with live virus vaccines. This test has been found positive only in pigs infected with pathogenic virus, but it remained consequently negative with samples from pigs vaccinated with either lapinized C strain or a cell-culture attenuated vaccine (Celvivac).

(b) The agar-gel precipitation (AGP) test with antigen from the pancreas of diseased pigs (48, 55) was one of the first specific laboratory tests to be used for routine diagnosis. However, due to doubts about its sensitivity, it has been replaced by the more reliable IF test.

(c) Virus isolation in cell culture using the direct IF test to reveal virus growth is the most reliable proof of the presence of virus in tissues. Virus isolation can also reveal small quantities of virus, and is therefore slightly more sensitive for detecting virus in tissues than the IF test applied to frozen sections. Spleen is the best organ as inoculum for isolation tests. The efficacy of the test has been reported to be 89% compared with swine inoculation tests in 324 field cases (52). For virus isolation, PK 15 cells are widely used, but swine buffy coat cells may be slightly more sensitive than permanent cell lines to small quantities of virus.
(d) Enhancement of the cytopathic effect of Newcastle disease virus is used as a routine diagnostic test mainly in Japan, where it was originally developed (38, 39). It is specific and reliable, but more time-consuming than the direct IF test.

3. Detection of specific antibodies.

A number of serological tests have been developed to demonstrate antibodies in the blood serum of pigs.

(a) The virus neutralization (VN) test in tissue culture has proved to be more specific than any other serological test for diagnostic use in CSF. The test is conducted with a constant amount of virus and varying serum dilutions, and any virus not neutralized in the cell cultures is detected by the direct IF test (17, 21). The peroxidase linked assay has also proved suitable for rendering the reaction visible (68).

The VN test is especially useful in detecting chronic, atypical and subclinical infections. The diagnostic significance of the test is inconclusive if applied to sick and vaccinated pigs.

Due to the antigenic relationship between the CSF and BVD viruses, false-positive reactions to the VN test could be a consequence of infection of the pig with BVD virus (49, 56). The occurrence of BVD infection in breeding sows varies in different countries. A comparative VN test with CSF and BVD viruses has been adopted as an official test in control and eradication programmes for CSF in the European Communities (68). It is advisable to test all sera with CSF titres between 1:5 and 1:40 against BVD virus as well (9, 34, 46).

(b) The indirect immunofluorescent antibody test is carried out with dilutions of serum from pigs, added to cell cultures infected with CSF virus and then treated with fluorescein-labelled anti-pig globulin. It is suitable for screening purposes, but its specificity is inferior to that of the VN test, because it cannot distinguish between antibodies against CSF and BVD viruses (60).

(c) Among more recently developed serological tests, immuno-electrophoresis is less sensitive than the VN test and gives cross reactions with BVD antibodies, but it has proved useful in screening large numbers of serum samples (67).

(d) The enzyme-linked immunosorbent assay (ELISA) for detecting CSF antibodies has given results comparable to the VN test. But cross reactions with antibodies to BVD virus were recorded (65).

4. The animal inoculation test.

This biological test is still the most reliable method of revealing small quantities of CSF virus, and to differentiate it from ASF. However this test is
expensive, time-consuming and requires isolation facilities for proper and safe performance. When adequate expertise and facilities are available to perform specific laboratory tests for the diagnosis of CSF and ASF, there is little need for animal inoculation. To perform this test, pigs susceptible and immune to CSF are inoculated with the suspect material, mostly spleen tissue. In the case of CSF infection, only the susceptible pigs will become infected, but in the case of ASF, pigs will contract the disease whether susceptible or immune to CSF. Should all inoculated pigs remain healthy, they are challenged with virulent CSF virus 3-4 weeks after inoculation to reveal the possible presence of CSF virus of low virulence in the inoculum, which does not cause disease, but might immunize infected pigs. Even this test can miss the rare degraded virus which has lost not only virulence but also immunogenicity.

Rabbit inoculation is used to differentiate between lapinized and field strains of CSF virus. Lapinized strains, in contrast to field isolates of the virus, cause a febrile reaction in rabbits. Both field and lapinized strains of CSF virus induce resistance in rabbits against subsequent challenge with lapinized virus.

**EPIDEMIOLOGY**

It is very difficult or impossible to establish accurately the actual geographical distribution of CSF infection at a certain time. With the exception of some countries with a favourable geographical location and prolonged freedom from the infection, information published periodically in the monthly Bulletin of the O.I.E. and compiled in the F.A.O.-W.H.O.-O.I.E. Animal Health Yearbook is not equally valid for all reporting countries at the date of publication. One reason for errors is inadequacy of disease reporting, particularly in countries with extensive systems of pig farming. But experience has shown that outbreaks of CSF can appear suddenly in countries in which disease control is primarily based on vaccination, and which import live pigs and pig products from countries not completely free from the disease.

**Spread of the virus.**

The infected pig and its products are the most important source of infection with CSF virus.

*Movement of pigs,* often through markets and dealers, is probably most frequently responsible for the spread of CSF. This has been proved indirectly by observations in several countries that a drastic ban on animal movement, for instance because of an outbreak of foot and mouth disease, has resulted in a sharp reduction in the number of CSF outbreaks (63).

It should be mentioned that in some regions wild boars might be a source of CSF virus infection for domestic pigs (37).
The carrier pig plays an important role in the epidemiology of CSF mainly in countries in which progress in eradicating the disease has been accompanied by the appearance of atypical and subclinical forms of the infection, caused by virus strains of low virulence (15, 16, 46). Some of these strains only harm fetuses, as a result of intrauterine infection (7). Congenitally infected pigs can harbour the virus for life, and they can transmit the virus by contact (58). It has also been postulated that foci of such infection can initiate outbreaks of typical swine fever (9, 45).

Swill feeding is another important factor in spreading CSF virus mainly in endemically infected countries, or when slaughterhouse and kitchen offal is fed to pigs without proper heat treatment.

There are numerous ways in which the virus can be spread by animate and inanimate vectors. The virus can be transmitted mechanically by contaminated clothing (mainly footwear), by various animal species such as dogs, birds and arthropods, as well as by all kinds of fomites, including transport vehicles, crates and various utensils.

**DISEASE CONTROL**

Various methods can be applied for the control and eventual eradication of CSF in individual countries. No set of measures is equally successful in every country and under all circumstances. However, currently available prophylactic and sanitary measures make it possible for any country to control and eradicate the infection if properly applied.

In deciding on a strategy for disease control in a particular country or part of it, the following circumstances should be considered:

— the economic value of the pig stock in respect of home consumption and export potential;
— the size, structure and types of management of pig holdings;
— the prevalence and the character of CSF infection;
— the state of development of animal health services, including diagnostic laboratory facilities;
— availability of government and other funds to support a national disease programme.

In order to reduce and eventually eliminate losses caused by CSF, the application of vaccination and sanitary measures can be considered.

**VACCINES AND VACCINATION**

1. **Type of vaccines.**

The formerly applied serum and virus method was not only expensive, but it involved the application of virulent virus, thereby creating foci of infection.
Of the inactivated vaccines, crystal violet vaccine has attained the broadest application. However, protection conveyed by this vaccine develops slowly, and the degree and duration of immunity is unsatisfactory. Therefore, carriers of the virus are created when vaccinated pigs are exposed to infection with virulent virus.

Because of their greater potency, preference is now given to attenuated virus vaccines.

Some of the early vaccine strains, attenuated by passage in rabbits (lapinization) such as the Rovac (Koprowski) and the SFA (Hudson) strains, proved to be too virulent, often causing untoward reactions in vaccinated pigs. In sows vaccinated during pregnancy, the vaccine virus caused intrauterine infection of the fetuses, which interfered with their development (25).

In the past 10 to 15 years attenuated virus strains have become available which differ markedly from those formerly used (69).

Generally speaking, two types of modern attenuated virus vaccines against CSF have met the high requirements of safety and immunogenicity when applied in the field. One group is the lapinized strains which have undergone several hundred rabbit passages more than the earlier strains. The other group of virus strains is referred to as cold mutants, because they are virus clones in which low virulence is genetically correlated with preferential growth at 28 to 30°C instead of at normal body temperature.

At present most experience has accumulated with the following four attenuated virus strains: the C (Chinese) and the LPC (China) lapinized strains, the GP (or GPE) guinea pig cell-culture adapted and the Thiverval cold mutant strains.

The widest distribution has been achieved by the C strain of virus since its introduction to Europe from the People's Republic of China (11, 14). From Europe its use has spread to many parts of the world. In respect of the LPC, the GP and the Thiverval strains, most experience has been gained in their country of origin, which is Taiwan, Japan and France, respectively (1, 3, 44, 64).

The above-mentioned four attenuated virus strains are innocuous for pigs of all ages. They are genetically stable. No increase in virulence has occurred in several back passages to pigs. Strains C and Thiverval also proved safe when tested on pigs immunosuppressed by prednisolone treatment (2, 3, 27, 42, 64). However, there are certain differences between these strains in their multiplication in vaccinated pigs as well as in the duration of viraemia and excretion of the vaccine virus. Neither the C nor the LPC strains are excreted to a significant extent by vaccinated pigs, but half of the pigs vaccinated with the GP strain excrete virus for ten days after vaccination, in amounts sufficient to immunize in-contact pigs (64).

These four virus strains are also distinguished by a high level of immunogenicity. Vaccinated pigs resist challenge 5 days after vaccination, or even
earlier. The duration of immunity in pigs vaccinated with the C strain has been estimated to last for the whole economic life of the pig, and in sows for at least four pregnancies (9, 64).

It should be mentioned that a potential risk with every live virus vaccine is the possibility of spreading contaminant viruses not revealed by routine innocuity tests. This risk can be reduced by propagating the attenuated virus strain in the body of species other than pigs, or in cell cultures derived from such species, as it is usually done with CSF vaccines (3).

The ideal CSF vaccine has yet to be produced. It should contain the immunizing antigen as a subunit protein extracted from the virus, or preferably produced by genetic engineering or by chemical synthesis.

2. Application of vaccines.

In a number of countries systematic vaccination has been applied not only to reduce economic losses caused by the disease, but also to reduce the number of outbreaks to a level at which eradication of infection by sanitary measures alone is feasible (69).

Vaccination of sows with modern attenuated virus vaccines has proved useful in controlling foci of subclinical infection caused by virus strains of low virulence (6). However, concern has been expressed over the risk of inadequately immunized pigs becoming infected with a virulent strain of virus, which could then be transmitted both within the uterus and horizontally (9, 69).

Another problem with the field application of attenuated virus vaccines against CSF is that maternal antibodies in the blood of piglets born of immune sows can interfere with the immune response to vaccination. Therefore it has been suggested that vaccination of piglets born to immune sows be delayed until 6 to 8 weeks. If due to an emergency, colostrally protected piglets are vaccinated at an earlier age, booster injection of the vaccine 3 to 6 months later should provide for lasting immunity (40, 41).

An important observation was made by Lee and Lin (1984) concerning the application of the LPC vaccine strain to newborn piglets. More than 200,000 piglets born to immune sows were vaccinated at birth and allowed to suck colostrum immediately thereafter. Precolostrally vaccinated piglets acquired solid and lasting immunity. The level of VN antibodies reached peak levels at 6 months and protection lasted for two years or longer. This vaccination scheme proved especially useful when applied to endemically infected, large breeding herds (44).

In a country-wide vaccination scheme applied in Korea, the major cause for vaccine failure has been attributed to the presence of maternal antibodies in the serum of young pigs at the time of vaccination. To overcome this problem, new-born piglets in endemically infected herds have been vaccinated
precolostrally. The conspicuous success of this vaccination scheme supports favourable experience with precolostral vaccination reported by Lee and Lin (44).

It should be mentioned that mass vaccination of pigs by the aerogenic route has been attempted with varying results during the past two decades (24). More recently, satisfactory immunity has been reported in groups of pigs treated for 30 min. with an aerosol of cell-culture propagated strain C virus. Success was dependent on a high concentration of virus vaporized to standard droplet size in rooms provided with regulated temperature and humidity (29, 35).

According to reports submitted to the 52nd General Session of the O.I.E., 1984, by the veterinary authorities of 46 countries from 4 regions, vaccination is encouraged as the most important measure to prevent CSF in Yugoslavia, Sri Lanka, Thailand, Colombia, Ecuador and Paraguay.

National vaccination schemes have been carried out or attempted in Japan, Taiwan, Argentina and Cuba.

Designated zones of a country are vaccinated for limited periods of time as a part of a national eradication scheme in Belgium, Czechoslovakia, Greece, Italy, U.S.S.R., Brazil, Chile and Mexico.

In some countries, the use of vaccines against CSF is generally prohibited, but in an emergency the vaccination of pigs may be ordered within a designated area, e.g. in Bulgaria, France, Hungary, the Netherlands, Norway and Switzerland.

No vaccination against CSF is allowed in Austria, Denmark, Great Britain, Ireland, New Zealand, Canada and U.S.A.

Most authors and most veterinary authorities of the reporting countries agreed on the need to prohibit vaccination against CSF at a certain stage of the control programme, if eradication of infection is the ultimate aim. The main reason of banning vaccines is to enable serological screening tests to be applied to slaughter pigs in order to detect subclinically infected herds. In countries running an official eradication programme, vaccination is restricted gradually on a territorial basis, with concomitant application of strict sanitary measures to eradicate foci of infection and to prevent reintroduction of the disease agent into areas already cleared. In areas of a country in which an eradication programme has been initiated, it is advisable to identify vaccinated pigs by ear tags or tattooing, and to register them (68).

Reports on the combination of vaccines against CSF and other infectious diseases of pigs, such as swine erysipelas and Aujeszky's disease, have not been included with the review. More information seems to be required before a well documented vaccination schedule can be proposed for combined vaccinations.
SANITARY OR VETERINARY REGULATORY MEASURES

There are only a few major pig-producing countries which have not had to resort to vaccination. However, it is also true that eradication of infection and maintenance of a disease-free status can hardly be achieved by vaccination alone (9, 46, 66, 78).

Sanitary or veterinary regulatory measures applied to control CSF are basically the same as those enforced against other contagious diseases of pigs. The most important measures are as follows:

(i) Disposal of diseased and in-contact pigs and preferably stamping out all susceptible pigs involved in an outbreak. For economic reasons and depending on the number of pigs involved in an outbreak, the meat of clinically healthy pigs may be processed for heat-treated products. However, in such cases special attention should be paid to the safe processing of slaughter offal and to sterilizing abattoir effluent.

(ii) Cleaning and disinfection of the premises, vehicles and all objects which could have been contaminated by infected pigs and their products.

(iii) Restriction of movement of pigs into, within and around an outbreak to prevent spread of the virus.

(iv) Prohibition of pig markets, shows and other gatherings within a larger protective zone around an outbreak. The extent of such protective zones should be determined according to local circumstances of pig density and traffic.

(v) Prohibition of feeding swill to pigs unless safely sterilized in a plant under official supervision. This measure should preferably be extended to whole countries and enforced irrespective of the occurrence of CSF, because it prevents the spread of other dangerous diseases, such as FMD, ASF and swine vesicular disease.

(vi) In countries in which eradication of CSF is not immediately practicable, vaccination of all pigs before movement (unless for immediate slaughter) provides support for sanitary measures to prevent spread of the disease.

(vii) In countries not completely free from CSF, special problems arise for protecting large pig production units from infection. In view of the need to protect such units from other contagious diseases as well, provision should be made to divide such plants into functionally separate sections, which can be operated as isolated units all the time, or at least in emergencies.

(viii) In disease-free countries or countries likely to reach this goal in the near future, the identification of individual pigs and registration of all pig movements greatly contribute to the effectiveness of sanitary measures. The presently available ear tags and tattooing do not seem to be fully satisfactory for broader application.

(ix) In countries free from CSF it is important to endeavour to trace the source of an outbreak in order to prevent spread of virus from the same source by pigs in the incubation period, or by other means.
Success in achieving and maintaining freedom from CSF in a country is largely dependent on the occurrence of the infection in neighbouring countries, and in those from which pigs and pig products are imported. Therefore, efforts should be made to harmonize control and eradication measures among countries of a region.

Prompt reporting to neighbouring countries and to international Organizations of an outbreak, and the measures taken to meet the emergency, will promote the alertness of other countries at risk.

Appendix

52nd GENERAL SESSION OF THE O.I.E.
RESOLUTION No. XI
CLASSICAL SWINE FEVER (CSF) : NEW CONTROL AND ERADICATION METHODS

CONSIDERING
the economic value of pig herds in many countries and the devastating losses which can be caused by CSF and that, ideally, this disease should be eradicated from any country in which it occurs;

RECOGNISING
the aim of eradication and the fact that several countries have successfully completed eradication programmes based on existing diagnostic methods,

THE COMMITTEE
RECOMMENDS
1. That the central veterinary authority of the country concerned should assess the prevalence and distribution of CSF infected herds and prepare a formal programme of eradication.

2. Where any country cannot undertake a full programme of eradication, that the disease should be brought under control by an officially directed programme of vaccination using vaccines of acceptable standards of safety and potency.

3. That the methods for achieving eradication, control or prophylaxis and the criteria for determining freedom from CSF should conform with the recommendations of the O.I.E. International Zoo-sanitary Code.

4. That laboratory facilities, specifically for standardised diagnosis of CSF, should be made available.
5. That studies of viral nucleic acid and proteins should be advanced with a view to:
   (a) identifying variant virus strains; and
   (b) selecting the most suitable strains for serum-neutralisation testing for both diagnosis and differentiation from BVD antibodies.

6. That immunological research should be focussed on elucidating the particular problems of:
   (a) vaccination of the progeny of immune sows; and
   (b) virus persistence in partially immune swine.

(Adopted by the International Committee of the O.I.E. on 25 May 1984.)

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REFERENCES


