Mass vaccination and herd immunity: cattle and buffalo

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Summary
The design of effective programmes for emergency response to incursion of epizootic diseases of cattle, for exclusion of such diseases and for implementation of progressive control in enzootic situations leading to eventual virus elimination, is currently largely empirical. This needs to be remedied to provide more cost-effective use of vaccines and more effective control. At population level, protective effects of immunisation can extend well beyond the individual, influencing the dynamics of viral propagation within the whole population, non-vaccinated as well as vaccinated. This concept of herd immunity and application of the resulting epidemiological principles, combined with experience gained from disease control programmes such as the Global Rinderpest Eradication Programme has much to offer in designing effective science-based control programmes. This paper explores practical exploitation of the herd immunity principle by considering some of the factors which militate against mass vaccination achieving effective levels of herd immunity and, with these in mind, suggesting ways to optimise the efficiency of mass vaccination programmes.

Keywords
Cattle – Epizootic disease – Herd immunity – Vaccination.

Introduction

For centuries, even millennia, livestock keepers have conducted immunisation programmes, with some degree of success in protecting their livestock against the contagious diseases which periodically confounded the livestock production systems essential for their well-being. Examples include the use of infectious urine from calves and lesser kudus (*Tragelaphus imberbis*) infected with mild strains to immunise cattle against rinderpest in Ethiopia and eastern Africa, respectively (16); and the subcutaneous implantation of infected lung tissue to immunise cattle against contagious bovine pleuropneumonia. With the increasing availability of a broad spectrum of vaccines in the 20th Century there arose an understanding that the occurrence of disease epizootics needs to be matched by mass vaccination programmes, as if infectious disease epizootics result solely from a failure to vaccinate enough animals. The use of mass vaccination campaigns has come to be seen as virtually synonymous with infectious disease control, particularly in developing countries, even though some of the major gains in disease elimination were achieved in Europe and Asia by the stringent application of zoosanitary procedures, including culling, before vaccines became available; contagious bovine pleuropneumonia (CBPP) and rinderpest are notable examples. However, non-vaccine control methods call for a measure of self-discipline that may not always be forthcoming.

It is manifest that vaccines exert their protective effect primarily by inducing an immune response in the vaccinated animal, yet it has been observed that protective effects of immunisation can extend well beyond the individual, influencing the dynamics of viral propagation within the whole population, non-vaccinated as well as vaccinated. The resulting ‘herd immunity’ concept was explored in detail by mathematical modelling in seminal work of the 1980s (2, 3). The fundamental issue is that it is not necessary to immunise every individual within a population to be able to eliminate an infectious agent from, or prevent its entry into, that population; the level of herd immunity must simply be sufficient to reduce the susceptible sector of the population below a critical point of population density.

This paper sets out to explore the practical exploitation of the herd immunity principle by considering some of the factors which militate against mass vaccination achieving effective levels of herd immunity, and with these in mind suggesting means of optimising the efficacy of mass vaccination programmes.

The application of mass vaccination

In attempting to control disease, whether enzootic or epizootic, caused by an infectious agent we are essentially attempting to interrupt the sustained transmission chain from infected host to susceptible host. Logically we can do this by removing either the excretor or the recipient. This principle applies equally to the human and veterinary fields, although the methods of implementation often differ. In dealing with the excretor side of the relationship, old-fashioned fever hospitals were designed to limit the number of contacts available to an infected person; in modern medicine barrier nursing achieves the same result. In the farming world we cannot support such measures and we are prepared at times to destroy our virus excretors, together with many uninfected contacts, in order to break the chain; pictures of piles of burning cattle slaughtered in attempts to limit the excretion of foot and mouth disease-virus are etched on many minds. The emotive welfare issue is increasingly making slaughter-based control socially unacceptable, thus removing from the veterinary armament one of its most effective tools. Inevitably, greater reliance is being placed on the use of vaccines. An economic dimension is also evident as farming is about profitability, either to the individual or to the nation, and as slaughtering can incur massive costs which include the payment of compensation, it follows that a benefit–cost analysis must lie behind decisions made, not just emotive public debate.

Dealing with the recipient side, mass vaccination is also the main tool applied, but with varying degrees of success, depending on the extent to which zoosanitary procedures are also implemented (e.g. movement management and quarantine). One scenario to look at is what might be termed the long, slow approach. This stems from the classic situation in which, at the outset, the weight of infection is so great that a slaughter policy (i) might not work, and (ii) would be too costly to contemplate. Vaccination is then utilised to gradually reduce the weight of infection until either eradication becomes an inevitable consequence, or a terminal slaughter policy becomes an economically attractive alternative. The eradication of FMD from post-war Europe is a vindication of this gradualist approach, and after 30 years' vaccination the way was opened for a declaration of freedom from infection. Success is also testimony to the existence of a public/private sector Veterinary Services alliance able to mount and sustain an efficient, systematic vaccination programme.

Vaccines are also used where insect vectors rule out the use of zoosanitary measures and where short campaigns are expected to be successful because of climatic constraints on vector activity. The limitation and eradication of bluetongue virus type 4 from western Turkey in 1979 and 1980 by two rounds of mass vaccination is a case in point. Vaccine has been less successfully applied to the recent upsurge of multi-serotype bluetongue virus infections in the Mediterranean basin and extending northwards from it. Climate change may be profoundly altering vector–virus–host interactions by extending the season of vector transmission and facilitating overwintering. Inevitably this will impact on vaccination strategies. It merits emphasis that in South Africa, where bluetongue is endemic, the sheep industry (which uses improved breeds) can only exist under a permanent bluetongue vaccine umbrella.

Factors influencing the effectiveness of mass vaccination programmes and optimising their efficiency

'Blitz' vaccination or 'immunosterilisation'

'Blitz' vaccination, whereby a whole population of animals is vaccinated within a very short space of time, can be dramatically successful. Applied to all cattle and buffalo in dairy colonies around Baghdad and the Southern and Central Governorates of Iraq in 1994, three campaigns over a three-month period totally eliminated rinderpest infection, which had persisted for several years despite more casual immunisation programmes. Similar results were achieved in northern Tanzania in 1997-1998, where intense mass vaccination, termed 'immunosterilisation' (22), rapidly eliminated an incursion of rinderpest into the Maasai steppe. Most recently, a single round of rinderpest vaccination of the herds belonging to the Murle and Jie peoples of southern Sudan eliminated the last reservoir of lineage 1 rinderpest virus in Africa (16). Intensive focal vaccination proved highly effective in eliminating an incursion of type A FMD into Albania in 1996 (8). In all these cases perhaps the decisive factor underpinning success was that these were highly risk-focused vaccination campaigns.

Vaccine quality assurance

It goes without saying that only fully efficacious vaccines should be used in vaccination programmes, yet, in order to attempt to spare the inadequate resources available for vaccination programmes to control serious diseases, it is not uncommon for developing countries to accept vaccines, knowingly or unwittingly, from suppliers who do not have a high reputation for sustaining quality. This highlights the need for independent quality assurance laboratories. The effect that the availability of such a laboratory can have has been very clearly demonstrated in the case of rinderpest, where the work of the Food and Agriculture Organization/Interafrican Bureau for Animal Resources Pan African Veterinary Vaccine Centre was accompanied by a doubling of the acceptability rate of vaccine batches to virtually 100% over five years (15, 23). When combined with the enforcement of internationally coordinated national regulations, which stated that only accredited vaccines should be used for the Pan African Rinderpest Control Programme, this service undoubtedly contributed to the success of rinderpest control programmes. This was so not only in Africa: it is now clear that the existence of an independent quality assurance laboratory was a decisive factor in elimination of rinderpest from Pakistan, where transfer of improved rinderpest vaccine production technology and quality assurance processes improved performance of control programmes there as from 1995; within five years rinderpest virus had been eliminated (16). Vaccination programmes benefited not only directly from the provision of quality-assured vaccines with ensured immunogenicity but also from the renewed faith of farmers in the protective effect of rinderpest vaccines. International and national efforts to bring about progressive control of FMD in Asia lack an independent quality assurance mechanism and this constrains acceptance of vaccine from local suppliers who might produce effective products but lack a means of demonstrating their efficacy.

Arguably the appropriateness of vaccines selected for use should be considered here. It is not uncommon for FMD vaccines not to be matched adequately to the antigenic determinants of the field strains addressed; in extreme cases they might not even be of the serotype required. Clearly, vaccination programmes using such vaccines will be compromised.

Vaccine formulation

Robustness of vaccines can significantly impact on the efficiency of vaccination programmes, especially in tropical developing countries. Ideally one requires a vaccine with enhanced thermostability to reduce dependence on cold chains. The thermostable rinderpest vaccine formulation used in pastoral areas of Africa is believed to have been an important factor in achieving success. The lack of thermostability after reconstitution, however, is probably one factor responsible for reducing the effectiveness of vaccine programmes; discarding vaccine within a working day rarely seems to be an acceptable procedure for vaccination teams or administrators.

Vaccination procedures

Provision of written standard operating procedures and training in their use is essential. It is common to detect serious malpractices when monitoring vaccination practice in the field, which result from inadequate training of vaccination staff. These include the use of uncooled boiled water for reconstituting rinderpest and CBPP vaccines; the use of water rather than saline to reconstitute rinderpest vaccine; the use of hot syringes to draw up vaccine; the use of incorrectly calibrated syringes; retaining reconstituted vaccine for much longer than its effective retention time; transporting vaccine at ambient temperatures or even in sun-heated cars from office refrigerator to field; and lack of cold chain during importation and from central storage to field units.

Many factors interact to reduce the immunising efficiency of vaccination programmes. Even a single effective round of vaccination can be expected to result in an overall immunity level of only 70%, with another round being necessary to achieve 90% (18, 22).

Vaccine delivery systems and the veterinarian–farmer interface

In the extensive pastoral context, such as prevails in much of Africa and Asia, disease control and eradication vaccination programmes are frequently implemented by standing armies of government animal health technicians. The results may be far from optimal for many reasons. One of these is a lack of appreciation of the needs of the livestock owners in terms of seasonal migrations and demands on their time for activities such as ploughing and harvesting of crops. A poor veterinarian–farmer interface can easily result in the poor timing of vaccination campaigns and inappropriate placement of vaccination teams. The result is poor performance and low herd immunity. Community-based approaches have been highly effective in correcting these problems in Africa and in accessing remote and even war-torn areas of countries (9).

Another much neglected resource is that of the private practitioner who can be activated through national veterinary associations and contracted to perform services for the animal health authorities. This can be one way to extend the time period of vaccine availability rather than running only strictly confined pulsed vaccination campaigns.

The participation of livestock in control programmes and campaigns is constrained in developing countries by government monopolies in terms of supplies, delivery systems and logistical arrangements. More flexible arrangements in which farmer, private sector veterinarian and trader organisations participate and contribute, even financially, are called for – an approach which has yielded dividends in FMD control in Latin America.

In developing countries, livestock owners, though possessing considerable knowledge of the diseases affecting their livestock, are often not sufficiently informed of the reasons why they are requested by government authorities to present their cattle for vaccination. For example, in Cambodia in the late 1990s FMD vaccination was discredited when buffalo later died from haemorrhagic septicaemia; their owners had not been made aware that their buffalo had been vaccinated specifically for FMD rather than generically for 'serious disease'. Subsequently they were reluctant to participate in FMD vaccination programmes, a reluctance contributed to by changing policies of cost recovery. In some years vaccines were given free of charge by non-governmental organisations (NGOs) replete with funds, and in other years other NGOs and government tried to implement a more realistic cost-sharing programme. Livestock owners did not object *per se* to paying for vaccination but were confused by changing policy; once accustomed to receiving vaccine free of charge, they were understandably reluctant to see why they should start paying. A consistent and area-coordinated policy is a clear prerequisite as is sincere dialogue with livestock owners which reflects reality.

In the traditional pastoralist area of the Afar region of Ethiopia, under the Joint Project 15 rinderpest control programme of the 1970s, teams used to attempt to vaccinate all cattle in a herd annually despite the fact that livestock owners were reluctant to vaccinate cattle over two years of age because they knew that they would be protected by earlier campaigns (and probably from field infection). In addition, attempting to restrain older cattle for vaccination in extreme conditions wasted enormous effort and alienated cattle owners. Insistence on vaccinating all cattle irrespective of age led to poor cooperation and a failed vaccination programme.

Compromised immune responsiveness to vaccines

For a number of reasons it is not safe to assume that animals given an appropriate course of an efficacious vaccine will be rendered immune. Immune competence is an increasingly important issue that can be compromised by a number of factors. Just as in poultry where it is widely recognised that immune responses are severely compromised by a plethora of physiological, genetic, infectious and toxic agencies in industrialised production systems (5), similar factors might now be compromising immune responses of cattle in feedlots (Fig. 1) and dairy farming systems and swine in intensive fattening units (20, 21). This is not occurring just in developed countries; highly stressful industrialised production systems are on the rise in developing countries as well. In Pakistan, for example, the mixed buffalo and cattle dairy colonies around Karachi, where throughput exceeds 500,000 lactating cows per year, combine high density with poor hygiene, climatic stress and extensive use of bovine growth hormone. One result is a high prevalence of pneumonic pasteurellosis (not typical haemorrhagic septicaemia) which is not controlled by vaccines that are normally reliable (1). In comparison with the poultry industry, little is known of intensive cattle production systems in this respect, but the reduction of immune competence which accompanies selection for production traits could well be an important factor in disease occurrence in cattle production systems in future (5).

A related issue is that industrial-type intensive production systems developed for the production of milk in the Kingdom of Saudi Arabia, combined with an increasing exposure to a multiplicity of FMD virus serotypes, have created a situation where it no longer seems possible to achieve exclusion of FMD by vaccination (26).

Even in extensive production systems, such as the transhumant cattle systems of sub-Saharan Africa, immunosuppression can play a significant role in reducing the efficiency of vaccination programmes. For example, chronic trypanosomosis has been shown experimentally to suppress the immune response of cattle to bacterial and viral vaccines (6, 19). Although the extent to which this impacts at field level has not been defined, it is more than a hypothetical possibility. Chronic trypanosomosis is prevalent in sub-Saharan Africa and, at least in certain localities, a significant proportion of cattle could be expected to be immunosuppressed for this reason – possibly another factor contributing to poor performance of vaccination campaigns. Elsewhere in Asia, prevalent, but largely unrecognised, *Trypanosoma evansi* infections of buffalo and cattle might exert the same effect. Malnutrition, if only seasonal, must also surely contribute to sub-optimal response to vaccines.

Fig. 1
A cattle feedlot for imported cattle in the Philippines (1994)

Maternally derived antibodies can significantly reduce the efficacy of control by mass vaccination. In the case of rinderpest, where such antibodies persist for up to a year, annual vaccination programmes leave a significant proportion of calves vaccinated under one year of age vulnerable to infection for up to a year. Conversely, the absence of colostrum feeding and, therefore, the lack of protection by maternal antibodies, rendered Holstein calves from dairy units entering feedlots in the Kingdom of Saudi Arabia in the early 1990s highly susceptible to rinderpest virus infection, temporarily enzootic at that time. A sustained transmission chain, which showed signs of persisting, was established within contiguous fattening units. Withholding colostrum completely, whatever other detrimental effects resulted, enabled vaccination in the first week of life to render calves immune by 10 days of age when moved to the new premises. The transmission chain was broken and rinderpest was eliminated.

Dangers associated with mass vaccination

Apart from the dangers associated with sub-optimal population immunity aiding viral persistence, as discussed elsewhere, the actual process of mounting a vaccination programme carries with it inherent dangers. There are many reasons why vaccination should be used only when there is no other choice; these include:

a) Vaccines can be a source of adventitious agents and their use can have serious effects. Rinderpest vaccines have been known to be contaminated with virulent rinderpest virus and FMD virus, and CBPP vaccines have contained virulent *Mycoplasma mycoides*. Although usually not documented for commercial reasons, examples abound.

b) Used without a full understanding of epidemiology, attenuated vaccines can have serious and unexpected effects. One of the best examples is that of bovine virus diarrhoea (BVD) virus vaccines in cattle, where so-called attenuated vaccines actually contain 'normal' BVD virus. While causing no observable effects in calves, as is normal for BVD virus, when injected into pregnant cattle this virus can cause the full panoply of fetopathic effects (14).

c) The use of live virus vaccines is attended by risk because they may retain the capacity to cause the disease they are designed to prevent, as documented for live attenuated FMD vaccines in Latin America in the 1970s (13) or they can revert to virulence. This was almost certainly the cause of rinderpest outbreaks in the vaccination buffer zone that was maintained along the borders of Russia until a decade ago (16).

d) The process of assembling large numbers of cattle at vaccination points, as commonly occurs in developing countries, provides an opportunity for transmission of an agent should it be present within the population. Foot and mouth disease, and indeed rinderpest itself, have occasionally been spread in this way during rinderpest vaccination programmes.

e) Attending and investigating veterinarians, traditional healers and vaccinators can and do spread infectious agents by moving from farm to farm. There are many descriptions of such events in pigs and poultry but far fewer in cattle, although anaplasmosis and enzootic bovine leucosis are well-known examples of this phenomenon.

The design and assessment of vaccination programmes

Some epidemiological principles relating to vaccination

Seminal work by Anderson and May (2, 3, 4) initiated development of a body of knowledge relating mathematical theory and field epidemiological information, in the process creating a set of powerful tools for use in designing and evaluating disease control and eradication programmes. Describing the dynamics of infectious diseases in vaccinated populations greatly increases our understanding of how vaccine influences the epidemiology of infectious disease (25).

Theory, borne out in practice, points to the importance of the optimal age for vaccination to achieve eradication (after the loss of maternally derived protection but before the natural acquisition of infection) and the proportion of animals needing to be vaccinated to achieve elimination (the vaccination threshold for exclusion). Such critical points can be calculated by reference to the age at first infection, the proportion of susceptibles remaining in the population at equilibrium, the seropositivity rate at equilibrium, the birth rate, life expectancy, duration of maternally derived immunity and the reproductive rate of the agent (4).

The twin concepts of 'invasion' and 'exclusion' thresholds are crucial to understanding the likely performance of vaccination programmes and the meaning of seromonitoring results. For successful elimination or exclusion of a contagious microbe from a population it is necessary that the sum of all actions taken, including vaccination, should force the effective reproductive rate of the agent below unity; the disease will then die out and be unable to invade again if herd immunity is maintained. Thus, an understanding of the basic reproductive number, R_0, and the effective reproductive number, R_e, derived from it, is critical from both theoretical and practical perspectives. The basic reproduction number is the number of secondary infections resulting from a primary case introduced into a totally susceptible population (4) and is a feature of both the infectious agent and the host population in which transmission is occurring. However, it must be understood that most considerations assume homogeneously-mixing populations and that 'Susceptible–Infected–Recovered' (SIR) models generally assume that each infected individual interacts with an infinite set of other individuals, ignoring the discrete nature of populations in which the few individuals infected rapidly use up all neighbouring susceptibles, thus reducing the value of R_e. This in turn leads to underestimation of the vaccination threshold needed to eradicate a disease.

In the case of sedentary farming systems overall populations are fragmented into holdings which may each contain one or more of a number of species of differing susceptibility to a particular virus. The rinderpest eradication programme was contributed to, at least in its early days, by vaccination campaigns in extensive pastoral herds, yet even these cannot be considered truly to represent one or more homogeneously-mixing populations, for they too are fragmented by discontinuities of population distribution, the ethnic relationships (and antagonisms) of the livestock owners, and by geographical features such as mountain ranges. The varying transmission rates between groups are influenced by annual migrations and grouping/regrouping of animals.

Practical and logistical issues

Homogeneously-mixing models are sufficiently accurate to be of practical use but, for the reasons given above, it is essential to have good quantitative measurements for both the global dynamics and the local behaviour of a disease (7). To succeed, vaccination programmes must include a high proportion of the population but must also achieve uniform coverage, because pockets of susceptible individuals can allow a disease to persist or re-invade (7).

The level of vaccination which needs to be attained to achieve elimination of an infectious agent from a population is often stated didactically, yet rarely is the selected figure determined by science. For rinderpest the level is variously quoted to be from 70% to 90%, usually at the higher end. However, this belies evidence that rinderpest was eliminated from areas such as West Africa when herd immunity levels rarely exceeded 60%. Modelling studies (10) have started to provide a deeper understanding of the interaction between herd immunity and the force of infection exerted by strains of differing virulence. With less virulent strains herd immunity of 50% or so might be sufficient to bring about elimination, whereas virulent strains require far higher seroprevalence levels. This perhaps goes some way to explaining how rinderpest was eliminated from West Africa with relative ease on two occasions, when one understands that the virus west of Nigeria was derived from the Mauritania/Mali focus of rinderpest, which was relatively mild (16).

Another important consideration is for how long immunity must be maintained for elimination to be achieved. For a short-lived infection with a pathogen which does not persist in the environment or an alternative host, and for which there is no reactivatable latent stage, once a suitably high level of herd immunity is achieved, assured by seromonitoring and revaccination if required, the pathogen should very quickly be eliminated and vaccination be withdrawn. It is essential that a statistically significant measure of the immunity induced, usually achieved by serological testing, be included in the assessment of vaccination campaign performance.

Herd immunity generated to a level below the critical exclusion threshold can actually perpetuate the circulation of infection by creating a partially immune population in which either the virus exists in a cryptic fashion, or in which its destructive effects are so limited as to be tolerated by the farmers and hence by politicians – provided no one looks at what it is costing. Rinderpest was perpetuated in India for over 30 years by such a system and similar factors have operated in the Somali ecosystem for 15 years or more (10).

When starting on the progressive control of an epizootic disease it is often difficult to discern relationships between outbreaks and to distinguish reservoirs of infection (i.e. areas of true endemicity) from epidemic indicator areas. It is at this stage that mass vaccination is most valuable. Vaccination over a two- to three-year period can suppress infection to a point where such epidemiological discrimination becomes possible once vaccine is withdrawn. Unless this is done, enabling the use of vaccine to be focused in the light of epidemiological understanding, the tendency is for unfocused mass vaccination programmes to become institutionalised and fail to do more than just suppress disease. Even this outcome may suffer as campaigns lose drive and effectiveness with time. Using mass vaccination in this way is an expensive process that can easily consume a large proportion of the recurrent budget for Veterinary Services in a developing country; we experienced this many times during the eradication phase of the Global Rinderpest Eradication Programme. Arguably one of the major benefits of rinderpest eradication has been the freeing up of resources which were previously tied up in rinderpest control by vaccination.

Often the trick is to recognise when the job has been completed and devise methods of disengaging from the campaigns. Many countries in Africa and Asia continued to vaccinate for decades after rinderpest was eliminated. It seems that it is a lot easier to commence vaccination than to stop, and that 'vaccine addiction' may be a disease in its own right. The temptation to find another disease to which the mass vaccination approach can be applied uncritically must be resisted; CBPP is an example in post-rinderpest sub-Saharan Africa.

Mass vaccination need not, and indeed should not, be conceived as just area-wide, pulsed, 'blanket' vaccination whereby all cattle and/or buffalo in a population are repeatedly vaccinated, usually annually. Focusing vaccination can greatly increase the impact of control programmes, whether that focusing is directed by addressing age cohorts, geographically defined discrete sub-populations, demographic groupings or other factors. Focusing can simplify vaccination programme logistics and reduce costs. Most importantly, directing vaccination to points where transmission is occurring significantly enhances effectiveness of control. Mathematical models (12) have suggested that eradication can be achieved with fewer overall vaccination doses if they are distributed primarily to high contact-rate groups rather than distributed uniformly to the overall population.

A different example of focusing vaccination to good effect is that of the very successful containment of FMD of the SAT serotypes within the wildlife reservoir in the east of South Africa by maintaining, over many years, a surrounding vaccination buffer zone in cattle maintained on fenced ranches (24).

Conclusion

As Anderson and May (3) noted: 'The development of a safe, effective and cheap vaccine [...] is only a first step (albeit an essential one) towards community-wide control.' Undeniably, consideration of issues relating to vaccine quality is of great importance, yet, leaving aside cost issues, this needs to be balanced by the use of sound epidemiological principles and lessons learnt from field experience to ensure the efficacy of vaccination programmes.

Many lessons can be learnt from an analysis of experience gained in rinderpest control and eradication (16, 23). The following points can be stressed:

– where mass vaccination is to be used, the more intensively it is applied, the more rapidly it achieves the objective desired;

– vaccination campaigns require seromonitoring as an integral component to provide quality assurance of vaccination efficacy and so that the results are used to generate remedial action; results must be available within two months at most if they are to provide a basis for action;

– eradication programmes require careful management and work best when they are conceptualised within time-bound frameworks and managers are permitted to take risks;

– eradication programmes require clear initial objectives and clear exit strategies;

– eradication programmes should be designed around an understanding of the epidemiology of the pathogen involved; in India the epidemiology of rinderpest in small ruminants was not well understood and elucidating the role of peste des petits ruminants was an added difficulty.

Almost invariably the current approach to disease control is empirical, with vaccination programmes being embarked on without consideration of the epidemiological basis; this needs to be remedied to provide more cost-effective use of vaccines and more effective control. Stochastic mathematical modelling has started to demonstrate how this approach can be of value in the veterinary field with rinderpest and CBPP (10, 11, 17) but much remains to be done. Mass vaccination programmes need to be planned, monitored and managed. Modelling can provide quantitative criteria with which the performance of vaccination programmes can be judged, whether in terms of preventing the introduction of an agent and the likelihood of generating a fresh epizootic, or progress of a control programme leading towards elimination of an infection. To do this, surveillance systems need to be tuned to provide the data required and combined with livestock population and performance data to provide the analytical basis essential for science-based decision making in infectious disease control and monitoring the progress of interventions.

Alternatives to vaccination should always be the first resort but, undoubtedly, mass vaccination is, and will continue to be, one of the main tools used for emergency and progressive control of epizootic diseases. However, peculiarities of the immune responses of livestock under different physiological and intercurrent disease states, combined with the epidemiological intricacies of different infectious agents and differences in the composition and efficacy of vaccines, mean that the effective application of vaccines is not as simple and straightforward a matter as we would perhaps wish. Mass vaccination programmes must be designed while respecting epidemiological principles and managed effectively with a defined time-bound objective and an exit strategy in place. They must be energetically implemented with assured funding. Unless budgets are available from the outset and adaptive project management is ensured, campaigns should not be started.

In an early review article on the modelling approach to designing disease control programmes (3) a telling statement was made: 'Many difficulties surround the attainment of sufficient levels of herd immunity to eradicate common infections in developed and developing countries. Theory can define the level of vaccination coverage required for elimination, but success in practice depends on economic and motivational issues.' Cost assessments and likely benefits can be calculated but community motivation requires enlightened professional management and active community involvement.

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La vaccination de masse et l'immunité de troupeau : bovins et buffles

P.L. Roeder & W.P. Taylor

Résumé

De nos jours, les programmes efficaces visant à préparer une réaction d'urgence en cas d'incursion épizootique chez les bovins, à éliminer ces maladies et à mettre en œuvre des mesures progressives de contrôle en cas d'enzootie pour tenter d'éliminer le virus causal sont conçus de manière essentiellement empirique. Il convient d'y remédier afin d'améliorer le rapport coût-efficacité de la vaccination et d'assurer une prophylaxie plus efficace. Au niveau des populations, les effets protecteurs de l'immunisation ne se limitent pas aux individus mais jouent sur la dynamique de la propagation virale au sein de la population globale (sujets vaccinés et non vaccinés). Le concept d'immunité de troupeau et l'application des principes épidémiologiques qui en résultent, associés à l'expérience acquise grâce aux programmes de prophylaxie tels que le Programme mondial d'éradication de la peste bovine (GREP) offrent d'intéressantes perspectives pour concevoir des programmes de prophylaxie efficaces et fondés scientifiquement. Les auteurs examinent les possibilités pratiques du principe d'immunité de troupeau en élucidant un certain nombre d'arguments parmi ceux qui mettent en cause la capacité de la vaccination de masse d'atteindre des taux acceptables d'immunité de troupeau ; en s'appuyant sur ces observations, ils avancent des propositions visant à améliorer l'efficacité des programmes de vaccination de masse.

Mots-clés
Bovin – Épizootie – Immunité de troupeau – Vaccination.

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Vacunación masiva e inmunización de los rebaños de vacunos y búfalos

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Resumen
La preparación de programas eficaces para luchar en situaciones de emergencia contra brotes masivos de enfermedades epizoóticas, para eliminar esas enfermedades y para instaurar un control progresivo que conduzca a la posterior eliminación de los virus causantes de episodios enzoóticos, que actualmente es muy empírica, debe corregirse a fin de rentabilizar la utilización de las vacunas y mejorar el control de las infecciones. En las poblaciones animales, el efecto protector de la vacunación puede extenderse mucho más allá de cada animal individual e influenciar la dinámica de propagación de los virus en todo el rebaño, esté o no vacunado. Esta noción de la inmunización de los rebaños y la aplicación de los principios epidemiológicos consiguientes, sumados a la experiencia adquirida con programas de lucha contra enfermedades, como el Programa Mundial de Erradicación de la Peste Bovina (PMEPB), pueden ser de gran utilidad para preparar programas de control eficientes basados en datos científicos. En este artículo los autores analizan el aprovechamiento práctico del principio de la inmunización de los rebaños mediante el examen de algunos de los factores que se oponen a la vacunación masiva para lograr niveles de inmunidad satisfactorios y, teniendo en cuenta esos factores, proponen medidas para que los programas de vacunación de rebaños alcancen la mayor eficiencia posible.

Palabras clave
Epizootia – Ganado – Inmunidad de los rebaños – Vacunación.

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