

# Update Le point

Articles in the Update series give a concise, authoritative, and up-to-date survey of the present position in the selected fields, covering many different aspects of the biomedical sciences and public health. Most of the articles are written, by invitation, by acknowledged experts on the subject.

Les articles de la rubrique Le point fournissent un bilan concis et fiable de la situation actuelle dans les domaines considérés, couvrant de nombreux aspects des sciences biomédicales et de la santé publique. La plupart de ces articles auront donc été rédigés sur demande par les spécialistes les plus autorisés.

## Control of echinococcosis/hydatidosis: present status of worldwide progress\*

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*Progress in national and provincial control programmes directed against Echinococcus granulosus is reviewed. The results show that this parasite, because of the low basic reproductive rate in its domestic life-cycle, is unstable and is amenable to control or eradication by currently available methods. The difference between control and eradication is defined and some suggestions for extension of control are discussed.*

Over the last three decades major advances in biomedical technology and international cooperation have stimulated a variety of global and regional campaigns to improve human health. These campaigns include programmes for controlling echinococcosis/hydatidosis caused by *Echinococcus granulosus*, one of the etiological agents of hydatid disease in man. A control programme is defined here as the active implementation of specific measures, with appropriate legislation, by a disease control authority to limit the incidence of the disease. The term eradication is defined as the purposeful reduction of a specific disease's incidence to the point of continued absence of transmission within a specified area by means of a time-limited campaign (1). The difference between eradication and control is important because once eradication has been achieved, the costly burden of control can be discontinued (1).

Whatever the approach to the control of echinococcosis, the multiplicity of interacting factors that determine the dynamics of the disease should be recognized (Fig. 1).

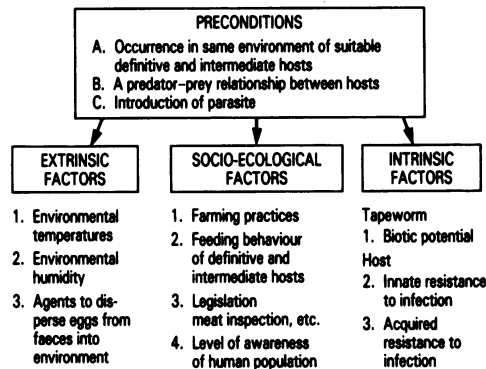


Fig. 1. Factors determining the epidemiology of *Echinococcus granulosus* in its domestic life-cycle.

\* A French translation of this article will appear in a later issue of the *Bulletin*.

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Most of the parameters involved in a control programme have been described in detail in the *Guidelines for surveillance, prevention and control of echinococcosis/hydatidosis*.<sup>a</sup> The present article reviews progress in the application of *E. granulosus* control measures and suggests ways in which this might be accelerated.

## GENERAL EPIDEMIOLOGICAL CONCEPTS

### Stability

A stable population at equilibrium can often withstand perturbations, such as might be encountered in a control programme. Parasite populations that are intrinsically stable are therefore more difficult to control than less stable ones. *E. granulosus* in its domestic life-cycle has been shown by field trials, as well as provincial and national control programmes, to be of low stability and to be readily responsive to control (2-4).

### Basic reproductive rate

The basic reproductive rate ( $R_0$ ) is central to an understanding of the epidemiology of control. It is defined as the average number of offspring produced throughout the lifetime of a mature parasite, which themselves reach reproductive maturity, in the absence of density-dependent constraints on parasite establishment, survival or reproduction (5). The rate  $R_0 = 1$  defines a transmission threshold below which the parasite population is unable to maintain itself. The objective of control is, therefore, to reduce  $R_0$  to below 1 and maintain it at that level until transmission has ceased. It has now been established that the basic reproductive rate of *E. granulosus* in its domestic life-cycle is usually low (4, 6).

### Hyperendemic, endemic and extinction states

Echinococcosis can be regarded as hyperendemic when it is regulated by a density-dependent constraint in the form of acquired immunity and superinfection does not take place ( $R_0 > 1$ ). It can be regarded as endemic when the infection pressure is so low that this constraint seldom operates and superinfection can occur ( $R_0 \geq 1$ ). This type of regulation was referred to as type 1 by Bradley (7); such systems are inherently unstable (7) and proceed towards extinction when  $R_0 < 1$  (4). If this status is maintained by a control programme, *E. granulosus* will be eradicated.

## PROGRESS IN CONTROL

Longitudinal prevalence data on echinococcosis in aged sheep are available for six different national (or provincial) control programmes (Fig. 2). All programmes showed a marked reduction in prevalence over time, thereby indicating that  $R_0$  was reduced to and maintained below one. Thus, each programme caused the parasite population to decline towards extinction.

With the exception of New Zealand where the elected National Hydatids Council, constituted by an Act of Parliament, delegates its authority to local control authorities,

<sup>a</sup> ECKERT, J. ET AL. *Guidelines for surveillance, prevention and control of echinococcosis/hydatidosis*. Unpublished WHO document, VPH 81/28, 1981.

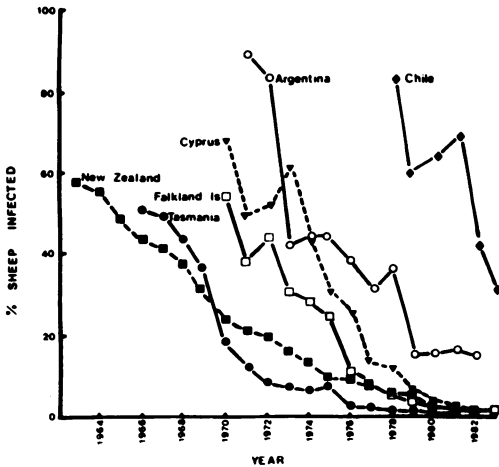


Fig. 2. Changes in prevalence of *Echinococcus granulosus* in aged sheep during control programmes in New Zealand, Tasmania, Cyprus, Falkland Islands (Malvinas), Argentina (Neuquén), and Chile (Region XII). (Reproduced, with permission, from reference 3)

the programmes in the other countries were carried out through established animal or human health agencies as the controlling authority.

### Programmes primarily using arecoline surveillance

The control programmes in New Zealand, Tasmania, Cyprus and Argentina (province of Neuquén) have all relied on administration of arecoline to dogs for surveillance and on educational campaigns. In New Zealand a laboratory test was used for the educational programme, and more recently a 6-weekly dog-dosing programme with praziquantel was adopted. In all other campaigns a field test using arecoline directly identified the infected dogs. In Tasmania quarantine of infected dogs and more recently infected sheep flocks has been undertaken. In Cyprus the dog population was reduced drastically, thereby eliminating the habitat for the adult tapeworm.

On the other hand, in Argentina (Neuquén) dogs detected by arecoline have been treated with praziquantel.

The rate of decline of echinococcosis in Cyprus was much greater than in either New Zealand or Tasmania. In Argentina (Neuquén) there have been periods of sharp decline followed by periods of plateau when, it seems, the parasite population returned to endemic status ( $R_0 \geq 1$ ).

### Programmes primarily using a drug treatment schedule

In both Chile (Region XII) and the Falkland Islands (Malvinas), 6-weekly drug treatment programmes with praziquantel have been applied and in each case the initial decline in the prevalence was rapid. The rate was similar to that in Cyprus, but was achieved without a dog destruction policy. These results suggest that a non-discriminatory dog-dosing programme with an effective drug, if applied from the start to the dog population at risk, can maintain  $R_0$  at a much lower level than an arecoline-based programme, unless the latter involves a drastic reduction in the dog population.

### Experiences gained from ongoing control programmes

When interest in the control of echinococcosis developed in the late 1950s in New Zealand and subsequently in Tasmania, very little was known of the methods required to introduce and sustain a formal control programme or to predict its likely outcome. Following the introduction of these methods and several other programmes, it has become possible to study the events that led to control and the effects of the strategies adopted. The measures applied are summarized in Table 1.

Several important factors responsible for success have been identified. Despite marked socio-ecological variations, in all cases a strong educational programme, adapted to meet the requirements of each community, assisted in gaining support for the introduction of

Table 1. Control measures directed towards prevention of infection and reduction of *Echinococcus granulosus*<sup>a</sup>

Disposal of offal:	Meat inspection Education Legislation Improvement of existing or erection of new slaughtering facilities Burning or burial of offal Sterilization of offal
Control of dogs:	Registration of dogs (collar/tattoo) Banning of dogs from infected areas
Reduction of dog population:	Mass killing Testing and selective killing
Reduction of tapeworm population:	Testing and penalties <sup>b</sup> Mass drug treatments

<sup>a</sup> Based on reference *B* and that given in footnote *a* on page 334.

<sup>b</sup> Such as quarantine of infected dogs and fining of owners.

control measures. Of considerable importance was the need for surveys in the planning phase; this was not always appreciated and baseline data were not obtained in many cases. One of the simplest ways to determine the feasibility of echinococcosis control in any region is to obtain data on the number of larvae in the intermediate animal hosts at different ages (Fig 3). Provided that the infection pressure has remained constant during the life of the animals, a linearly increasing age-intensity curve indicates that acquired immunity has not operated; the parasite is therefore endemic. If the curve is convex, then acquired immunity has operated and the parasite is hyperendemic. Confirmation that immunity has been acquired can be obtained by a controlled experiment. If the parasite is endemic, it is often feasible to introduce a control measure that reduces  $R_0$  to below one, and thereby drives the parasite population towards extinction. A far greater control effort is required to achieve this if the parasite is hyperendemic (4).

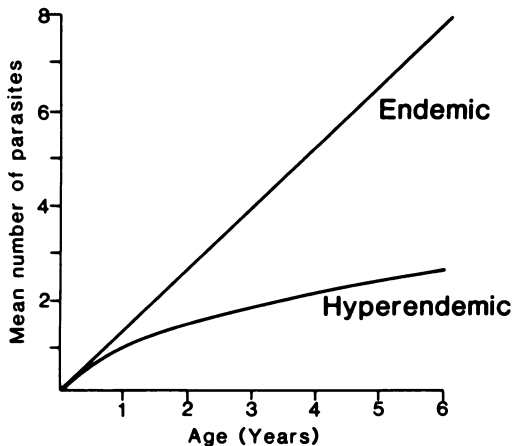


Fig. 3. An illustration of age-intensity curves in hyperendemic and endemic states. Scales are for indication only, but approximate those found for *Echinococcus granulosus* (endemic) and *Taenia hydatigena* (hyperendemic) in New Zealand in 1958.

Yekutieli (1) described four phases in the implementation of an eradication programme against infectious diseases. These are the preparatory, attack, consolidation, and maintenance of eradication phases. The duration of the first three phases depends on the biological and epidemiological characteristics of the disease. Although no two programmes have followed identical courses, this general concept can be used to describe the main events that have been observed in echinococcosis control and eradication.

In the preparatory phase, the main activities have involved selecting and training the staff, setting up surveillance and dog registration programmes, developing the logistic foundations such as transport and drug supplies, and finally introducing effective slaughter and offal disposal facilities. This phase was usually completed within one or two years. The attack phase, which includes

further upgrading of slaughter facilities, commenced with the introduction of the primary control measure aimed at destabilizing the parasite. Owing to delays in transmission, this phase appears to last more than 20 years in the case of arecoline-based surveillance and less than this when a non-discriminatory dog-dosing programme is applied. If reliable vaccines and/or larvicides were available, the duration of the attack phase could be reduced considerably.

During the consolidation phase, which is being approached by several programmes (Fig. 2), the remaining reservoirs are focal. The main aim in this phase is to strengthen surveillance and to identify and eliminate isolated pockets of infection. If the goal is eradication, the programme must be maintained until transmission has ceased. The maintenance of eradication phase, which has not yet been reached in any programme, involves permanent vigilance to prevent reintroduction of the parasite and will have to be carried out by the established animal health service. As pointed out by Yekutieli (1), the special control services can then be disbanded.

### Permanent control or eradication

Any reduction in  $R_0$  is helpful because it may reduce transmission of *E. granulosus* to man, but unless  $R_0$  is reduced and maintained at below 1, eradication will not be achieved. These two goals, namely prevention of transmission to man and eradication of the parasite, are therefore not the same.

Roberts et al. (4) have pointed out that owing to delays in transmission, it takes time for eradication to be achieved after  $R_0$  has been reduced to below 1. Long before this occurs, transmission to man will have virtually ceased. This point has now been reached in the Tasmanian and New Zealand campaigns. The decision has then to be made whether to remove control altogether, to retain it at a reduced level of activity, or to attempt eradication.

These three control options have to be evaluated on technical, epidemiological and socioeconomic grounds. So far, in all cases, the control programmes have reduced the parasite from a hyperendemic ( $R_0 > 1$ ) or endemic ( $R_0 \approx 1$ ) to extinction ( $R_0 < 1$ ) status. If the decision is made to remove control measures before transmission has ceased, the parasite may revert to an endemic or even hyperendemic status. Removal of all controls, therefore, cannot be considered to be an effective option.

With regard to the question of permanent control at a reduced level of activity, it is known that parasites such as *E. granulosus* with a low production and infectivity of eggs in its dog/sheep life-cycle, are not much affected by slight breakdowns in control after they have reached extinction status. Thus, removing some controls and retaining others on a cost-effective basis should not lead to a return to a hyperendemic state when the risk of transmission has become unlikely. It seems that the main requirement, if permanent control is adopted as the policy, is to ensure that the level of transmission remains so low that human hydatid disease will not recur. At this level, continuing with non-discriminatory dog-dosing or arecoline surveillance achieves little and they could be reduced or removed altogether. Permanent control can be achieved most economically in the consolidation phase by maintaining surveillance and taking local action when breakdowns are identified.

With respect to eradication, Yekutieli (1) considered that there are six pre-conditions for the successful implementation of an eradication programme. These are: (i) absence of adverse factors of human and animal ecology; (ii) adequate administrative, operational and financial resources; (iii) availability of effective tools for breaking transmission; (iv) favourable epidemiological features of the disease; (v) socioeconomic importance of the disease; and (vi) specific reasons for preferring eradication to control. A weakness in any one of these pre-conditions may preclude success.

All six pre-conditions can be fulfilled on islands because the reintroduction of the parasite can be prevented by vigilance. Eradication cannot readily be achieved with echinococcosis on a state-wide or continental basis if the first pre-condition given above cannot be met. This is because reintroductions of the parasite from untreated endemic zones could lead to a resurgence of the parasite. This means the programme in the control zone would remain permanently in the consolidation phase. Thus, if measures cannot be applied to prevent the continuous reintroduction of the parasite during the consolidation phase, then the situation is one for permanent control and not eradication.

## FUTURE PROGRAMMES

The encouraging results from all six control programmes discussed demonstrate that *E. granulosus* is not a stable parasite in its domestic life-cycle. Once a control programme has been introduced, there is a reduction in the prevalence of human hydatid disease in all age groups and the benefits to the community soon become evident (9). Hence, future programmes should be based on, in order of priority: (a) implementation of adequate baseline surveys; (b) development of effective control programme structures; (c) development of surveillance; (d) development of strict dog registration systems; and (e) introduction of comprehensive but cost-effective (for human health) dog-dosing programmes. These can only be achieved by high standards of appropriate training in the many facets of epidemiology.

### Contributions by international agencies

There can be little doubt that the meetings held on research and control since 1966 by FAO, WHO, and more recently UNEP have had a profound effect in establishing the concepts of sound structure, planning and implementation of effective control practices against echinococcosis. This is particularly evident from some of the programmes in Latin America. These have closely followed the recommendations set out at the FAO/WHO inter-regional seminar for the control of hydatidosis held in Buenos Aires in 1970 and followed by the PAHO/WHO seminar on hydatid control held at the Pan American Zoonoses Centre, Ramos Mejía, Argentina, in 1975. Indeed, the continued close liaison between that Centre and the countries of the region in training and in supporting the surveillance of human hydatid disease, as well as in expanding knowledge on the epidemiology of echinococcosis, provides an excellent example of international and regional collaboration.

The recent establishment of the UNDP/WHO Mediterranean Zoonoses Control Centre (MZCC) provides a further example of the value of such collaboration. The recent MZCC workshop on planning and management of national programmes for the control and elimination of echinococcosis/hydatidosis, held in Athens in 1983, and on design and management of pilot projects for echinococcosis/hydatidosis control, held in Cairo in 1985, which followed similar lines of participation to that of the PAHO/WHO seminar in 1975, permitted a thorough review of the progress in the development of projected control programmes in the Mediterranean region.

The joint FAO/UNEP/WHO consultation on field control of taeniasis and echinococcosis held in Nairobi in 1976 was followed a year later by the setting up of a Hydatid Research Unit by the Kenyan government and the African Medical and Research Foundation. Many donors have contributed funds to assist studies on the complex epidemiological problems of this parasite among the nomadic peoples of northern Kenya.

This programme culminated with the development in 1984 of a pilot control project in north-west Turkana (10). The proposed development of a WHO Zoonoses Centre in Kenya<sup>b</sup> could be invaluable in providing training and other support facilities, taking into account the special epidemiological and socio-ecological conditions found with echinococcosis in many African countries.

Undoubtedly the WHO guidelines for surveillance, prevention and control of echinococcosis/hydatidosis<sup>c</sup> will continue to be the parent document for the formulation of national programmes. The key to further expansion in worldwide research and control may well depend on the extension of these valuable international seminars, training programmes and workshops on an inter-regional basis.

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<sup>b</sup> MANN, I. *Environmental control of echinococcosis and hydatidosis in Turkana district of Kenya as a model for developing countries*. Paper presented at the XIth International Congress for Tropical Medicine and Malaria, Calgary, 16-27 September 1984.

<sup>c</sup> See footnote a on page 334.