Available online at www.sciencedirect.com
SCIENCE DIRECT®
Parasitology International 55 (2006) S247 – S252
www.elsevier.com/locate/parint

Control of hydatidosis

David Heath [a,*], Wen Yang [b], Tiaoying Li [b], Yongfu Xiao [b], Xingwang Chen [b], Yan Huang [b], Yun Yang [b], Qian Wang [b], Jiamin Qiu [b]

[a] *AgResearch, Wallaceville Animal Research Centre, PO Box 40063, Upper Hutt, 6007, New Zealand*
[b] *Sichuan Institute for Parasitic Diseases, Centres for Disease Control, Chengdu, 610041, China*

Available online 4 January 2006

Abstract

Control of hydatidosis is less effective without the support of dog-owners, and this support can only be obtained if the people have a clear understanding of the life-cycle of the hydatid parasite(s) and what risk factors contribute to human infections. Dissemination of this information is the biggest challenge for hydatid control. Participatory planning between dog-owners and community leaders should evaluate the possible control technologies, and should enable a choice of those aspects that suit the sociology and economic status of the particular community. Collection of baseline data is essential, as is on-going surveillance. Hydatid control should be mainly self-funded, which again requires the support of the dog-owner. A pilot hydatid control program for Tibetan herdsmen is described.

Keywords: *Echinococcus granulosus*; *Echinococcus multilocularis*; Control; Education; Participatory planning

1. Introduction

Echinococcus granulosus remains a persistent and re-emerging problem in countries of low economic output where resources for an intensive control program, that has been successful in rich countries, are not available. By an understanding of the transmission biology, including mathematical modelling, alternative and cost-effective means of control can be developed [1–7].

What drives hydatid control? A number of studies have conclude that cystic hydatid disease caused by *E. granulosus* can result in a 10% decrease in whole of life performance for infected animals (reduction in quality of meat, production of fibre, production of milk and in number of surviving offspring [17]). However, these figures are not well-known to third world farmers, and are probably insignificant in the face of pandemics of infectious disease and losses due to reproductive diseases, parasitism and starvation. Therefore all programs of hydatid control around the world have been driven by the zoonotic status of the parasite and concerns for human health [10,11]. Concern is proportional to the education status of the population and economic status of the farming community.

1.1. The Iceland example

Estimates at the time showed that 15–20% of the people were infected with hydatid [20,23]. This was a small community of 70,000 people. A pamphlet describing the life-cycle of hydatid and how to prevent infection, stressing prevention of dogs getting offal, was sent to every family. Hydatid education was continued in the schools. Once the government felt that the people wanted organised hydatid control, a law was made to register dogs and impose a tax. This was followed by a law to prevent feeding of offal, and later to prevent home-killing.

1.2. The New Zealand example

New Zealand had a relatively small number of reported cases (87 new cases reported a year) but post-mortems revealed an infection rate of 610/100,000. 80% of old sheep had hydatid cysts [10,19]. Education by the Departments of Agriculture and of Health prompted formation of voluntary farmer hydatid control committees. It was necessary to rely on the influence of education until such time as farmers were ready to accept an effective scheme that necessarily involved some degree of compulsion. A conference of farmers made it clear that the great majority of farmers were ready for effective measures and were willing to pay for them. This led to

* Corresponding author. Tel.: +64 4 5290374; fax: +64 4 5290380.
E-mail address: david.heath@agresearch.co.nz (D. Heath).

1383-5769/$ - see front matter
doi:10.1016/j.parint.2005.11.052

government legislation establishing the National Hydatids Council with representatives from farmers, pet dog owners, the Veterinary Association, local Government and Agriculture and Health from National government. The council was charged with devising measures for eradicating hydatid, for issuing information, instructions and advice, and for organising the monitoring of dog infections and livestock infections.

1.3. The Tasmanian example

Gemmell [10] was not convinced that a hydatid control program driven by the people was the best approach, even though he worked for much of his life in the New Zealand system. He quoted the Tasmanian program that was run by the Department of Agriculture [13,23]. Although hydatid control in Tasmania was administered by State Government, there were marked similarities in the social education leading to the setting up of the control programme. Without the heroic efforts of Dr Trevor Beard in publicising the hydatid problem in Tasmania, and the groundswell of public opinion that he generated, the Tasmanian program may not have begun. As it was, most of the country supported the program, including the legislation that was necessary for a few recalcitrant farmers.

1.4. The Argentina example

Gemmell also quoted the hydatid control programs set up in Southern Provinces of Argentina by Ministries of Agriculture and Ministries of Health (Neuquen, Rio Negro, Chubut and Tierra del Fuego) [11]. He felt that the structure of these Government-administered programs was correct. Nevertheless, in these Provinces over many years of control the prevalence of hydatid has reached a lower plateau, but the parasite has not been eradicated. Clearly, the fight remains between Government and the farmers, with not all the farmers sufficiently educated or committed to play their part.

1.5. The Chile example

A good example exists in the 12th region of Chile, where hard work by the Government veterinary department has reduced the hydatid prevalence in sheep on the big estancias to a very low level [18]. However, no further progress toward eradication can be made because they do not have jurisdiction of town dogs in Punta Arenas. Many Punta Arenas citizens travel to the Argentine Provinces during the summer, with their packs of working dogs, and unwittingly bring back fresh hydatid infections each year.

1.6. Control of E. multilocularis

In those regions where *E. multilocularis* is a problem, control again needs to rely heavily on education of the public about the life-cycle of the parasite and how to avoid infection. This disease, referred to as the "second cancer", could easily be controlled by committed dog owners. The disease is spread to humans in most cases from dogs in the hyperendemic regions of China. The removal of unwanted dogs, assisted by relaxing of religious taboos about dogs, and the regular anthelmintic treatment of wanted dogs, together with increased personal hygiene, would be very successful provided all members of a community followed the procedures. The danger of a visit from an untreated dog could be reduced by peer pressure, without the need to involve Government. Because *E. multilocularis* is endemic in these areas, maintained by a sylvatic cycle through foxes and rodents, surveillance would be most appropriate for domestic dogs using a specific coproantigen test. Ownership of dogs is associated with increased prevalence of *E. granulosus* and *E. multilocularis* in humans, implying that treatment and control of domestic dogs could play a major role in decreasing the risk of infection in the Tibetan populations of Qinghai Province, PR China [5,21].

1.7. The sylvatic cycle for E. multilocularis

Technology for eradication of *E. multilocularis* has not yet been developed. Clearly, if all carnivorous hosts could be regularly treated with an anthelmintic, after several years eradication might be achieved [15,16]. However, this technology is in its infancy. It may become important if human infections begin to appear in Europe, caused by urban infected foxes and raccoon dogs.

1.8. The sylvatic cycle for E. granulosus

Populations of *E. granulosus*-infected wild-life both in Australia and Africa act as important reservoirs in perpetuating the transmission of *E. granulosus* to both domestic animals and humans. In Australia, *E. granulosus*-infected wild-life are infiltrating urban areas and represent a potentially important new public health problem [8]. A similar situation exists for *E. multilocularis* in Europe and Japan [9].

1.9. The importance of community structure

Decisions on control methodology need to take into account the social structure of the community. For instance, in many provinces of China a government regulation with an adequate funding structure would be transmitted through cadres at County, District, Township and Village level, and would be enforced by the village veterinarians and the police. However, such a structure is not easily accepted by the minority races, and a structure with much greater sensitivity, proposed by local ethnic leaders, is more likely to be successful. Who then, are the local leaders? These are well-defined in the Uygur, Mongol, Kazakh and Kyrgiz people of Western China but overall leadership is not so clear among the Tibetans, most of whom are Buddhists. The Tibetan people have become accustomed during the past 500 years to being led by the Lamas. Local leaders promoted by the Chinese have seldom the same respect and power as do the Lamas, but under the present structure the local Tibetan appointees are expected to be the arms of Government.

2. The three phases of hydatid control

Hydatid Control is divided into 3 phases—Planning, Attack and Consolidation [10,15,24]. Planning involves a sociological survey and establishment of age/incidence baselines for worms in dogs and other carnivores, and cysts in grazing animals and humans. Determining the genotype of human infections and which genera of grazing animals are involved in transmission [22] is now recognised as an important first step. Planning should involve dog-owners as well as Government leaders (Participatory Planning) and systems for financial support should be agreed by all participants.

The Attack phase involves a range of procedures agreed during the Planning phase [10]. These may include: education about hydatid disease and its control [12]; removal of unwanted dogs; regular treatment of dogs with praziquantel; preventing dogs getting access to uncooked organs of animal species involved in transmission; changing the animal husbandry practices to limit the hydatid life-cycle; use of the vaccine against *E. granulosus* for the domestic animals mainly involved in transmission of hydatids (usually sheep and goats but not always) [14].

The Attack phase must be accompanied by annual surveillance of progress. (Annual age/incidence of new human infections (a suggestion for areas where most children go to school is to conduct annual ultrasound surveys of all 12-year-old children), annual coproantigen survey of dog faeces, annual accumulation of statistics of *E. granulosus* infections (infective and non-infective) in slaughtered livestock, annual census of livestock, changes in status of Knowledge, Attitude and Practice with regard to hydatid disease). Annual feed-back of rate of progress to the dog-owner is very important.

The Consolidation phase can only occur when an acceptable level of control has been achieved. The most cost-effective control measures for maintaining this level of control are then used. Surveillance must still take place.

3. How has a Sichuan pilot program for hydatid control among Tibetan herdsmen fitted the above criteria?

This is an ongoing joint program between the Chinese and New Zealand governments. It was proposed by the Sichuan Institute for Parasitic Diseases, instituted by the New Zealand Agency for International Development nzaid and administered by their agency (Landcare Research New Zealand Limited). The program was reviewed and approved by the Beijing Ministry of Foreign Technology and Economic Cooperation, their Provincial (Sichuan) and Prefectural (Ganzi) counterparts, and the veterinary and human health administrators of Ganzi County.

Human Echinococcosis (both *E. granulosus* and *E. multilocularis*) is a major health hazard in Western Sichuan. Ultrasound scanning has revealed that 12% of some populations are infected. Several factors contribute to the life cycles: For *E. multilocularis*, overgrazed pastures are suitable for rodents to multiply, and rodents are food for dogs. Most households keep guard dogs. There are also large numbers of unwanted dogs. The cause of human hydatid is not generally understood by the affected people.

3.1. Planning

3.1.1. A sociological survey

This was conducted to elucidate the social structure and the life-style patterns of the people. It included descriptions of 1) the profile of project area, 2) the physical conditions of the project area, 3) the social conditions and infrastructure, 4) the farming system: rangeland and stock management, 5) health and knowledge about hydatid disease, 6) dogs and rodents, 7) the livelihood system, 8) gender analysis, 9) constraints and opportunities for development. The recommendations from the survey pointed out that under current conditions the closed environment and a poorly educated population would limit the implementation of hydatid control mechanisms and their impact. In the project design, health education is very important, but it was felt that this by itself would not be enough to change the attitude and behaviour of the people. They should be involved in monitoring and evaluation. The beneficiaries of the project, and especially the poor and women and children should be involved in all assessments and evaluation. Therefore monitoring and evaluation is not only a means to ensure sound project implementation, but it allows the people to take the project as their own.

3.1.2. Baseline of age/incidence of human infections

This was carried out using ultrasound scanning of livers, and a blood test to differentiate *E. granulosus* from *E. multilocularis*.

3.1.3. Baseline of dog infections

Unwanted dogs were necropsied where possible. A 6-monthly coproantigen sample was taken from 20 households in each village. There were 29 villages with an average of 100 households per village.

3.1.4. Baseline of E. granulosus in yaks

At the beginning of the program 100 four-year old yaks were necropsied in the study area, and 50 mature yaks were inspected at the local abbatoir. No cysts were found that contained protoscoleces, although we have recently found cysts with protoscoleces in very old yaks.

3.1.5. Baseline age/incidence in sheep and goats

Organs were inspected from sheep and goats aged 6 months to 5 years, and from 12–14 year old animals.

3.1.6. Determining the genotype involved in transmission

Human cysts and those from yaks, sheep and goats were all genotyped as the G1 sheep strain. Some fertile infective cysts were found in yaks, and it was concluded that yaks were an important contributor to maintaining the *E. granulosus* but not the *E. multilocularis* life cycle [22]. Old sheep and goats contained large fertile *E. granulosus* cysts.

3.1.7. Participatory planning

This was not possible because of geographic isolation of the people, the fact that most were illiterate, communication via radio was poor or non-existent, and very few children attended school. Communication through village leaders was difficult, and after 6 years of the project, only 40% of people understood the hydatid life-cycle. In retrospect, the project should not have moved to the attack phase until the people fully understood the life-cycle and the interventions that were available to them.

3.1.8. Provision of adequate finances

The pilot project is a joint project between New Zealand and China. New Zealand paid for equipment, vehicles, surgery and drugs, and technology transfer. China paid for running costs and people who did the work. After the first year, when people had not been paid for their work, the project faltered until money was finally allocated several years later. In retrospect, the attack phase should not have commenced until finances were in place. There should also have been a move to sustainability by promoting self-funding of aspects of the program, such as regular treatment of dogs with an anthelmintic.

3.2. The Attack phase

3.2.1. Education

Education of the Lamas, the dog-owners and their children about hydatid control. This was only partly achieved during the 5 years of the program. We should have followed the Iceland example, and delivered a pamphlet to every household describing the hydatid life-cycles and how to avoid human infection. Because a high proportion of the people are illiterate, and very few children go to school, the pamphlet would have to be self-explanatory through pictures. By the end of the 5 years a laminated A4 colour page containing cartoons about the life-cycles and how to avoid infection, together with Tibetan and Chinese text, had been distributed to most households (Fig. 1).

3.2.2. Removal of unwanted dogs

There are 6000 wanted dogs and between 1000 and 2000 unwanted dogs in the study area. We have made no progress in convincing the Lamas to declare unwanted dogs a danger to the people, and for the Lamas to give permission to kill unwanted dogs. The Buddhist religion forbids the shedding of blood from a living thing. Our use of an effective and humane poison to remove unwanted dogs has met with much resistance.

3.2.3. Regular treatment of dogs with praziquantel

An attempt in the first year to give praziquantel every 2 months was not successful. Veterinarians could not travel through the winter snow, and during the summer people were too widely dispersed. We settled on 2 treatments each year-one in April before the snow melted and people left for the summer pastures, and the other in October after the National holiday, when people had returned to their winter quarters but the snow did not prevent travel. Nevertheless, a survey of Knowledge, Attitude and Practice revealed that up to 25% of dog-owners did not trust the pills, and were throwing them away.

Fig. 1. An A4 laminated colour cartoon intended to be distributed to every household.
Ganzi Community Health and Hydatid Disease Control
How to prevent hydatid disease
Transmission of hydatid disease

1. The dog carries the worm. Worm eggs are found in water and soil. Eggs stick to the fur of the dog.
2. When sheep or cattle drink water or eat grass that has been contaminated by the eggs, the hydatid disease will grow in the liver or lung. This is the larval stage.
3. After killing sheep or cattle people like to feed their dogs with those uncooked lungs and livers. Then the worm can grow in the intestine of the dog. This is called the adult stage. The worm is called the hydatid tapeworm.
4. When people are playing with dogs the eggs can stick on their hands. If they don't wash their hands before eating the egg will infect the human.
5. This is the route of how the dog transmits the disease to humans.
6. In order to keep healthy, prevent hydatid disease. So when you are feeding dogs, don't forget to eliminate the parasite at the same time. You can mix the praziquantel pill with the dog food, and feed it to them. Meanwhile, kill the unwanted dogs.
7. Don't feed the dog with raw liver or lungs. You can cook them and then feed the dog.
8. Don't play with dogs often. Before eating you must wash your hands. Don't let the dog into your house.
9. Check your body often in order to discover this disease as early as possible. When you discover the disease, please take the medicine. The doctor will prescribe Albendazole.

3.2.4. Preventing access by dogs to uncooked organs of livestock

Up to this time there is no indication that any attempt is being made to boil livers and lungs of sheep and goats before feeding to dogs. Deaths in the winter due to parasitism and starvation generally result in the skin being taken, and the rest of the animal discarded to provide dog and bird food.

3.2.5. Vaccinating sheep and goats against E. granulosus

The highly-efficient Eg95 vaccine [14], if administered correctly, should prevent the acquisition of *E. granulosus* cysts by grazing livestock. Less numbers of cysts will be found in old animals, and young animals should remain virtually free of cysts. In the time it takes for old stock to be replaced, a population of livestock free of hydatid cysts should be generated. In this pilot program we first determined by genotyping and by necropsies that sheep and goats were mainly responsible for yak and human infections, and therefore decided to only vaccinate sheep and goats. To demonstrate the power of this new tool, sheep and goats in 2 townships were vaccinated, and those in the other two townships were not vaccinated. The comparison of the effect of vaccination can only be made after old sheep and goats have all died of old-age, which might be 15 years from the start of vaccination. The difficulty of vaccinating all sheep and goats in Tibetan herding environments was not initially appreciated. The animals are usually tethered at night but go out to graze each day. Calling a flock of animals in from the hill, and then tethering them, can take 1–2 h, so not many flocks can be vaccinated in one day. To prime and boost animals, two vaccinations should initially be given, one month apart. The immunity stimulated will last for 12 months. A third vaccination given 6–12 months after the second stimulates a high and long-lasting immunity. Boosting may then not be needed for 3–4 years, but annual boosting in the Autumn is recommended. We monitored the success of the vaccinations by taking blood samples at random and checking the level of anti-Eg95 antibody. Only some flocks showed correct antibody levels. Others had very little or no antibody, indicating that the animals had only received one or no vaccinations. This was supported by a KAP survey where flock-owners indicated that (a) the veterinarian had not visited them, or (b) they did not trust the vaccine because many of their vaccinated animals died later in the winter. Although we showed that these deaths were due to acute parasitism combined with starvation, the flock-owners blamed the vaccine. The vaccine was being provided free of charge in this pilot program, but future hydatid control should have the benefit of the vaccine evaluated by the people, and they should pay for it if they decide to use it to rapidly reduce the risk of human *E. granulosus* infection. On no occasion could the veterinarians fit in 2 vaccinations in the autumn or spring, so the second and third vaccinations were given 6–12 months apart. Because hydatid was not hyperendemic in the environment, taking 6–12 months to stimulate protective immunity was acceptable.

3.2.6. Changing animal husbandry practices to limit the number of old animals

Sometimes whole flocks of sheep or goats are sold to visiting buyers, but usually very few animals are sold or killed for eating. The flock/herd structure includes 50% males, and many old females that are past breeding age. The few lambs or kids or baby yaks that are born each year balance the number of old animals that die of natural causes. It is these old animals that carry the infectious hydatid cysts which maintain the life cycle of *E. granulosus*.

3.2.7. Monitoring changes in age/incidence of new human infections

We attempted to do this by offering a second ultra-sound scanning of the population after 4–5 years, but very few people had come to be scanned at the beginning of the program (about 10% of the 9000 population), and very few came at the second round of scanning. Clearly a manageable cross-section of the population should volunteer to be scanned regularly (say every 5 years) to monitor progress in reduction of new human infections.

3.2.8. Monitoring statistics of E. granulosus in slaughtered livestock

Unfortunately, very few sheep and goats are sold, and none for slaughter at the local abbatoir, so this information cannot be collected. The only data comes from necropsies of animals purchased by us and from yaks killed at the Ganzi Yak killing house.

3.2.9. Monitoring changes in numbers of infected dogs using coproantigen

This technology is very useful if carried out correctly. Initially it was decided to collect a faecal sample from 1 dog in each of 20 households in each of the 29 villages. The veterinarians were trained well, and produced good samples supported by notebooks describing each dog and the animals owned by the household. After some years the veterinarians had all been replaced, and the new people in some cases collected all the samples for a village from one household. It is important to train the vets before every sampling period, and to instill into them pride in doing their work correctly. Coproantigen results should also be fed back to each village veterinarian to maintain their interest in the job, and their dedication to do it correctly.

3.2.10. Annual analysis of changes in knowledge, attitude and practice

Surveys need to be very carefully designed so as not to lead the person being surveyed. These surveys have been particularly useful, especially if they are conducted in the Tibetan language. Chinese enumerators have had to write down what their Tibetan interpreter tells them, without having any idea of the truth of his/her words. Nevertheless the surveys have pointed out the lack of knowledge of the hydatid life cycle and hence the distrust of pills for the dog or vaccine for the sheep and goats.

4. Conclusion

The above example of the pit-falls encountered in setting up a pilot hydatid control program demonstrates the importance of the dog-owner's understanding of the hydatid life-cycles and of "owning" a control program by then being asked to contribute to planning and the finding of necessary funds. Diagnosis of human infections and their appropriate treatment should remain the concern of Government Health Authorities.

References

[1] Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. Paris: World Organisation for Animal Health; 2001.

[2] Torgerson PR, Budke CM. Echinococcosis—an international public health challenge. Res Vet Sci 2003;74:191–202.

[3] Budke CM, 2004. Echinococcosis on the Tibetan Plateau. Inaugural dissertation for Doctor of Philosophy, University of Basel. p. 151.

[4] Jenkins DJ. Hydatid control in Australia: where it began, what we have achieved and where to from here. Int J Parasitol 2005;35:733–40.

[5] Schantz PM, Wang H, Qiu J, Liu FJ, Saito E, Emshoff E, et al. Echinococcosis on the Tibetan plateau: prevalence and risk factors for cystic and alveolar echinococcosis in Tibetan populations in Qinghai Province, China. Parasitology 2003;127:S109–20.

[6] Torgerson PR, Heath DD. Transmission dynamics and control options for *Echinococcus granulosus*. Parasitology 2003;127:S143–58.

[7] Craig PS, Rogan MT, Campos-Ponce M. Echinococcosis: disease, detection and transmission. Parasitology 2003;127:S5–20.

[8] Jenkins DJ, Macpherson CNL. Transmission ecology of *Echinococcus* in wild-life in Australia and Africa. Parasitology 2003;127:S63–72.

[9] Ito A, Romig T, Takahashi K. Perspective on control options for *Echinococcus multilocularis* with particular reference to Japan. Parasitology 2003;127:S159–72.

[10] Gemmell MA, Roberts MG, Beard TC, Campano Diaz S, Lawson JR, Nonnemaker JM. Control of *Echinococcus granulosus*. In: Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. Paris: World Organisation for Animal Health, 2001. p. 195–203.

[11] Economedes P, Larrieu EJ, Orlando D. Evolution of programmes for control of *Echinococcus granulosus* (examples). In: Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. Paris: World Organisation for Animal Health; 2001. p. 204–9.

[12] Parodi P, Mantovani A, Seimenis A. Public health education and training in control programmes. In: Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE manual on echinococcosis in humans and animals: a public health problem of global concern. World Paris: Organisation for Animal Health; 2001. p. 219–25.

[13] Thompson RCA. Hydatidosis: eradication within insular systems: Tasmania. Int Arch Hydatid 1999;33:34–8.

[14] Heath DD, Jensen O, Lightowlers MW. Progress in control of hydatidosis using vaccination — a review of formulation and delivery of the vaccine and recommendations for practical use in control programmes. Act Trop 2003;85:133–43.

[15] Shaikenov BSh. Control of echinococcosis. In: Torgerson P, Shaikenov B, editors. Echinococcosis in central Asia: problems and solutions. Zurich: Dauir; 2004. p. 119–24.

[16] Kamiya M, Nonaka N, Sumiya G, Oku Y. Effective countermeasures against alveolar echinococcosis in red fox population of Hokkaido, Japan. In: Torgerson P, Shaikenov B, editors. Echinococcosis in central Asia: problems and solutions. Zurich: Dauir; 2004. p. 273–82.

[17] Battelli G. Evaluation of the economic costs of Echinococcosis. Int Arch Hidatid 1997;32:33–7.

[18] Campano Diaz S. Control of echinococcosis in the 10th, 11th and 12th regions of Chile. Int Arch Hidatid 1997;32:64–9.

[19] Maclean FS. Hydatid disease in New Zealand. Wellington: Standard Press; 1963.

[20] Thomson GA. Hydatid eradication in Iceland. Bulletin 15 of national hydatids council. Wellington: Standard Press; 1965.

[21] Budke CM, Qiu J, Craig PS, Torgerson PR. Modeling the transmission of *Echinococcus granulosus* and *Echinococcus multilocularis* in dogs for a high endemic region of the Tibetan plateau. Int J Parasitol 2005;35:163–70.

[22] Heath DD, Zhang LH, McManus DP. Short report: inadequacy of yaks as hosts for the sheep dog strain of *Echinococcus granulosus* or for *E. multilocularis*. Am J Trop Med Hyg 2005;72:289–90.

[23] Beard TC, Bramble AJ. Middleton M.J. Eradication in our lifetime; a log book of the Tasmanian hydatid control programs, 1962–1996. Department of Primary Industry, Water and Environment, GPO Box 192, Hobart, Tasmania; 2001.

[24] Gemmell MA, Roberts MG, Beard TC, Campano Diaz S, Lawson JR, Nonnemaker JM. Formulating effective and cost-effective policies in the planning phase for permanent control of *Echinococcus granulosus*. In: Eckert J, Gemmell MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE manual on echinococcus in humans and animals: a public health problem of global concern. Paris: World Organisation for Animal Health, 2001. p. 209–19.