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PATHOLOGY OF EXPERIMENTAL CYSTICERCUS BOVIS INFECTION IN THE REINDEER (RANGIFER TARANDUS LINNÉ, 1758)

K. BLAŽEK, V. S. KIRICHEK,* and J. SCHRAMLOVÁ

Institute of Parasitology, Czechoslovak Academy of Sciences, České Budějovice, and
*K. I. Skryabin All-Union Institute of Helminthology, Moscow

Abstract. In the present study, the tissue reaction of the brain, skeletal muscles and heart in experimental *C. bovis* infection of the reindeer is described. There is non-purulent cysticercal leptomeningites with formation of multinucleate symplasms in the cerebral meninges, and lymphocytic encephalitis in the superficial layers of the cerebral cortex. The tissue reaction around the morphologically differentiated cysticercus in the meningeal location is similar to that in muscle cysticercosis of cattle. In muscles and heart, larvae die very soon after infection and they are resorbed in the course of formation of fibroplastic granulation tissue around them. *C. bovis* reaches the infective stage in cerebral localization only. The authors suppose that this phenomenon is due to a certain degree of immunological tolerance in the brain.

It is generally known that cattle is the only specific intermediate host of the human tapeworm *Taenia saginata* (Goeze, 1782). It has been found, however, that some wild-living herbivorous animals from Africa can harbour the bladder worm of *T. saginata* — *C. bovis* — too, and that they become the source of taeniasis of the native inhabitants. *C. bovis* was found in zebu, cammel, and various species of antelopes (Graber 1959, 1974, Nelson et al. 1965, Sachs 1969). Spontaneous liver cysticercosis in sheep caused by this parasite was also recorded (Graber 1959). Recently, some other findings of *C. bovis* in wild-living ruminants of the family Bovidae were recorded from Africa: from a young Thomson's gazelle (*Gazella thomsoni*) artificially reared (Stevenson et al. 1981) and from a young wild topi (*Domaliscus korrigum*) (Stevenson et al. 1982). Searching for some additional intermediate hosts of *T. saginata*, Stevenson et al. (1982) carried out an experimental infection of a young wildbeest (*Connochaetes taurinus*) and young oryx (*Oryx gazella*) with the eggs of *T. saginata*. The wildbeest, one day old, the oryx of the age of 10 days, got 5 000 *T. saginata* eggs each. In the wildbeest, no cysticerci were found 11 weeks after infection, in the oryx 853 cysticerci were found 12 weeks after infection, most of them being viable. Two calves of *Bos indicus* were also infected in the same manner and in both of them, cysticercosis was detected after slaughter.

Spontaneous infection of other animals than cattle (*Bos taurus*) from other continents than from Africa has not been known until now. The establishment of the reindeer (*Rangifer tarandus*) as intermediate host of *T. saginata* in tundra regions of the far North of the USSR is surprising and important from the epidemiological point of view. It has been proved that in these animals, cysticerci finished their development only in the meninges of the brain and that they died very soon in skeletal muscles and heart. Man becomes infected eating raw brain of infected reindeer which custom is quite familiar in the native population of the tundra region (Kirichek et al. 1984).

In the present work the results of the investigation of the tissue reaction in the brain, skeletal muscles and heart in experimental cysticercosis of the reindeer are

recorded. No publications dealing with the tissue reaction in the brain cysticercosis (caused by *C. bovis*) have been available till now in spite of the fact that *C. bovis* has been found in the meninges of cattle as well (Joest 1921, Chroustová 1981), and that larval stages of some other species of cestodes have been relatively often found in the brain in the course of muscle cysticercosis of domestic and wildliving animals (Innes and Saunders 1962).

MATERIAL AND METHODS

For the purpose of this study, we examined by means of histological methods samples of the brain, skeletal muscles and heart from 5 reindeer which had been experimentally infected with eggs of the so-called "northern isolate" of *Taenia saginata* (Kirichek et al. 1984). Samples of the organs mentioned above from one uninfected reindeer and one calf were examined too. The reindeer were 6—7, the calf 1.5 months old. The infective dose rate was 5 000 *T. saginata* eggs for the reindeer, 10 000 eggs for the calf. The reindeer were slaughtered 25, 50, 59, 75 and 115 days, the calf 25 days after the infection. The tissue samples were fixed in 10 % formaline, and they were embedded in paraffin by means of usual methods. Serial paraffin sections were made and stained by hematoxylin-eosin, some of them by van Gieson's method and by Masson's trichrome stain.

RESULTS

In the reindeer, which were infected with the eggs of northern isolate of *T. saginata*, cysticercosis of skeletal muscles and internal organs (heart, liver, lungs) was established. All cysticerci in this localization were regressively changed. In skeletal muscles of the reindeer slaughtered at 25, 50 and 75 days after infection, 87, 113 at 15 nodular lesions were found. These nodules measured about 2—7×1.5—4.5 mm and 25 days p.i., but 1.4—1.7×0.8—1.2 mm only at 75 days p.i. In the reindeer slaughtered later (e.g. 115 days p.i.) no nodular lesions were found. In all these animals, however, 8—47 pieces of cysticerci were found at various sites of the cerebral meninges. They had a scolex and were quite viable. Cysticerci were present neither within brain tissue nor in the area of the spinal cord.

The histological investigation of the brain at 25 days p.i. revealed a slight inflammatory infiltration of the pia and arachnoid with lymphocytes, in lesser degree also with eosinophiles and plasmacytes. In some places of superficial layers of the cerebral cortex the wall of some vessels was infiltrated with lymphocytes.

At 50—115 days p.i., the pathological reaction of the meninges and brain at the sites where cysticerci were located was in principle the same in nature. The intensity of the reaction varied in individual cases, but the difference was not substantial. The cysticerci were located in the subarachnoid space. The pia-arachnoid was congested and edematous and sometimes slightly, sometimes more intensively infiltrated with lymphocytes and plasma cells (Plate I, Fig. 1, Plate III, Fig. 2). Eosinophiles appeared less often in the exudate. Very often, however, large multinucleate symplasms and giant cells of Langhans, cell type or of the type of foreign body giant cells could be found (Plate III, Fig. 1, Plate IV, Fig. 2). The arachnoid over the cysticerci was slightly thickened. In some cases, the meninges were neat and nearly without pathological changes. But, in the region around the opening of the spiral canal of the cysticercus, the tissue reaction of meninges was always graduated and had characteristic features of a granulomatous inflammation (Plate II, Fig. 1). The granulation tissue was formed by fibroblasts, large macrophages and multinucleate symplasms. Clusters of monocytes, lymphocytes and plasma cells occurred regularly in the granulation tissue, the number of eosinophiles, however, was rather low.

In heavy infection, the meninges were conspicuously edematous and they were

infiltrated with lymphocytes and eosinophiles. There were also macrophages with phagocytized erythrocytes. In these cases, the walls of some meningeal arteries in the vicinity of cysticerci got thicker and infiltrated with cells (Plate I, Fig. 1, Plate IV, Fig. 1). The intima of these vessels covered inside the lumen which became narrow and sometimes nearly closed. In superficial layers of the cortex of brain hemispheres, the wall of some vessels was infiltrated with lymphocytes. Foci of satellitosis and glia-nodules were also observed (Plate II, Fig. 1, Plate IV, Fig. 3.).

The cysticerci were morphologically differentiated, but mostly they had not fully invaginated scolex. The proliferating portion of the scolex, protruding above the surface of the bladder, was covered with conspicuously folded tegument of the spiral canal which continuously turned into the tegument of the bladder (Plate II, Fig. 1).

In the heart of the reindeer slaughtered at 25 days p.i., we found granulomas with central necrosis, made up of fibroblasts, histiocytes and large multinucleate cells. The granulation tissue of these granulomatous lesions was infiltrated with lymphocytes and scanty plasma cells and eosinophiles. Cysticerci were never found in these granulomas.

At 75 days post infection, the nodes were of the same character. Sometimes, shadow-like structures could be seen in the centre which underwent necrosis. These structures reminded parts of the bladder of a cysticercus which died at an early developmental stage. They were surrounded by great amount of eosinophiles and by clusters of giant cells. At the periphery of these nodules, hyperplastic lymphatic tissue could be found. The epicardium (endocardium, respectively) above the nodules situated closer to the surface of the heart was thicker and infiltrated with lymphocytes and plasma cells.

In the skeletal musculature, granulomas without cysticerci (alike at in he heart), but also with them could be discovered at 25 days post infection. The cysticerci had the appearance of a bladder with a small cavity and with a cellular cone at one pole, without any invagination (Plate V, Fig. 1).The opposite pole had sometimes a tail-like shape (Plate V, Fig. 2). The centre of granulomas was necrotic. The necrotic masses were stratified and sometimes they contained erythrocytes. They were surrounded by spindle-shaped giant cells. In the granulation tissue, consisting of histiocytes, fibroblasts and collagen, also plasmacytes, lymphocytes and giant multinucleate cells were present. In the case that the cysticercus was inside the nodule, it was surrounded by a great amount of eosinophiles, and the granulation tissue was infiltrated with eosinophiles too.

At 75 days p.i., granulomas formed by fibroblasts, histiocytes and new-formed capillaries were found in the skeletal muscles. Such granulomas use to be found in infections with migrating larval stages of helminths. (Plate VI, Figs. 3 and 4) In the centre of granulomas, necrotic masses and eosinophiles were observed. In the necrotic area of some nodules, shadow remnants of structures suggesting parts of a disintegrated bladder wall of a very young cysticercus were seen. (Plate VI, Figs. 1 and 2). They were surrounded by eosinophiles. Deposits of calcium salts could be revealed in the centre of some granulomas and in small nodules made up of lymphocytes.

Additionally, we examined samples of skeletal muscles of the calf, infected with the eggs of *T. saginata* of northern isolate. We wanted to know what difference — if any — would occur between pathological lesions in specific and nonspecific intermediate hosts. In the calf too, nodular lesions without cysticercus were found at 25 days after infection. Their centre was built by macrophages, polymorphonuclear neutrophilic leucocytes, eosinophiles and by amorphous mass. But, nodules with cysticercus were also present. In this case there was a distinct invagination in the cellular cone at one pole of the bladder, and the tegument of the bladder was folded.

The nodular lesion around the cysticercus was composed of the following zones: the centre of the nodule with macrophages and leucocytes; the intermediate zone made up of fibroplastic vascularized granulation tissue; the outer layer consisting of circularly arranged fibrotic tissue and of hyperplastic lymphatic tissue at the periphery.

DISCUSSION

All nonspecific intermediate hosts of the human tapeworm *T. saginata*, which have been known to harbour infective stages of *C. bovis*, belong to the family Bovidae (Graber 1959, 1974, Stevenson et al. 1981, 1982). However, there are animals in this family which are rather resisting to the infection with the eggs of this tapeworm. In these animals, cysticerci die very soon also if the infection was successful (Boczoń et al. 1974, Kozakiewicz 1977, Geerts et al. 1981, Blažek et Schramlová 1983). It is assumed that in the musculature of sheep., e.g., *C. bovis* never reaches the infective stage (Geerts et al. 1981). In this animals species, cysticerci could be found more often in parenchymatous organs than in muscles (Blažek et Schramlová 1983), and we cannot exclude the possibility that cysticerci could be able to grow to the infective stage just in these organs.

Detailed investigations in the tundra region of the Far North of the USSR and experiments in animals proved that reindeer could be infected with *T. saginata* eggs and that the cysticerci developed to the infective stage in these ruminants in cerebral localization only (Kirichek et al. 1984, Kirichek 1985). This finding is very important from the epidemiological point of view. This is the matter of partial adaptation of *T. saginata* to the new nospecific intermediate host, the only one which belongs to the other family (Cervidae) than both the specific and the other nonspecific intermediate hosts. It is evident from the original reports (Kirichek et al. 1984) and from the present study of pathological reaction that in skeletal muscles and in the heart of the reindeer the cysticercus develops slowly and dies at an early developmental stage. The granulomatous reaction around the dead cysticercus becomes weak rather soon and remnants of the pathological lesions disappear within three months after infection (Kirichek et al. 1984). Causes involved in the early death of the cysticercus seem to be the same (or similar) as those mentioned in our earlier paper concerning the tissue reaction in *C. bovis* infection of sheep and goats (Blažek et Schramlová 1983).

It seems that the larva does not develop fast enough in the incompatible environment because of some degree of nutritional deficiency and that it is not able to adopt some substances from the foreign host and transform them for its own benefit. Then it is recognized as "foreign" and destroyed by immunological attack of the host. In the meninges of the brain, however, the larva reaches the infective stage. In spite of the fact that the basic immunological reactions are realized in the brain too (Hašek et al. 1977), it is assumed that the immunity in the brain appears later or that it is less effective than in other organs (Lodin et al. 1977). It is known that the presence of immunocompetent cells is considerably reduced in this location. The phenomenon of the second set reaction, however, can be demonstrated very well in the brain (Lodin et al. 1977). We believe that the larvae of *T. saginata* can reach the infective stage in the brain because they got into a locality where they are sheltered (to some degree) from the immunological response of the host's organism. According to our own opinion it is not the matter of the very adaptation of *T. saginata* to the new intermediate host. In the intermediate hosts of some other species of tapeworms (*T. solium*, *T. hyaenae*), the cysticerci develop to the infective stage

in the brain, but in other organs and muscles, they do it as well (Innes and Saunders 1962). It is also known that in some cases cysticerci (*C. cellulosae* in pigs e.g.) can be found in great amounts in the brain, while in skeletal muscles of the same animal, they are only few (Mirovich 1927). In these cases, however, the intermediate host specificity of the tapeworm is not strong or the larvae develop in specific intermediate host.

The tissue reaction evoked in meninges of the reindeer around the morphologically differentiated cysticercus shows all characteristic features of the reaction in muscles of cattle. The occurrence of large symplasmas in the vicinity of the alive cysticercus is very conspicuous. The presence of cysticerci in the brain meninges is associated with a nonpurulent meningoencephalitis, sometimes only with an admixture of eosinophiles. In the case of accumulation of several cysticerci in one place, inflammatory reaction of the wall of some meningeal arteries occurred, even in the late phase of infection. The pathological changes in the brain tissue and in the meninges enlighten on the nervous symptoms observed in some experimentally infected reindeer: disturbance of gait coordination, walking in circles, reeling, holding the head to one side (Kirichek et al. 1984).

The scolex of the cysticerci which were localized in meninges was often not fully invaginated, not even in the late phase of infection. This phenomenon cannot be considered a sign of slower development of the larvae; it is probably caused by the influence of the special localization.

If the tissue reaction and the morphology of larvae from the nodular lesions in muscles in reindeer and cattle are compared, it is evident that larvae developing in the reindeer are delayed in their development (or even damaged), while the stage of development of the larva from cattle accords with the duration of infection. Findings of nodules without cysticercus or with remnants of the bladder in the musculature of cattle, support the knowledge that cattle too is rather resisting to the infection with the eggs of the northern isolate of *T. saginata* (Kirichek et al. 1984).

ПАТОЛОГИЯ ЭКСПЕРИМЕНТАЛЬНОГО ЗАРАЖЕНИЯ СЕВЕРНОГО ОЛЕНЯ (*RANGIFER TARANDUS* LINNÉ, 1758) ЦИСТИЦЕРКОМ *CYSTICERCUS BOVIS*

К. Блажек, В. С. Кириček и Я. Шрамлова

Резюме. Описана реакция ткани в мозге, скелетных мышцах и в сердце северного оленя, зараженного цистицерком *C. bovis*. В мозге встречается негнойный цистицерковый лептоменингит с образованием многоядерных симплазм и в поверхностных частях коры головного мозга — негнойный (лимфоцитарный) энцефалит. Реакция вокруг морфологически дифференцированного цистицерка одинакова как у мышечного цистицеркоза крупного рогатого скота. В мышцах и сердце цистицерки скоро погибают и резорбируются. Вокруг них образуется фибропластическая грануляционная ткань. Только те цистицерки, которые локализованы в мозге, развиваются до инфекционной стадии. Авторы полагают, что это причинено определенной степенью иммунологической толерантности в мозге.

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K. B., Parasitologický ústav ČSAV,
Flemingovo nám. 2, Praha 6
ČSSR

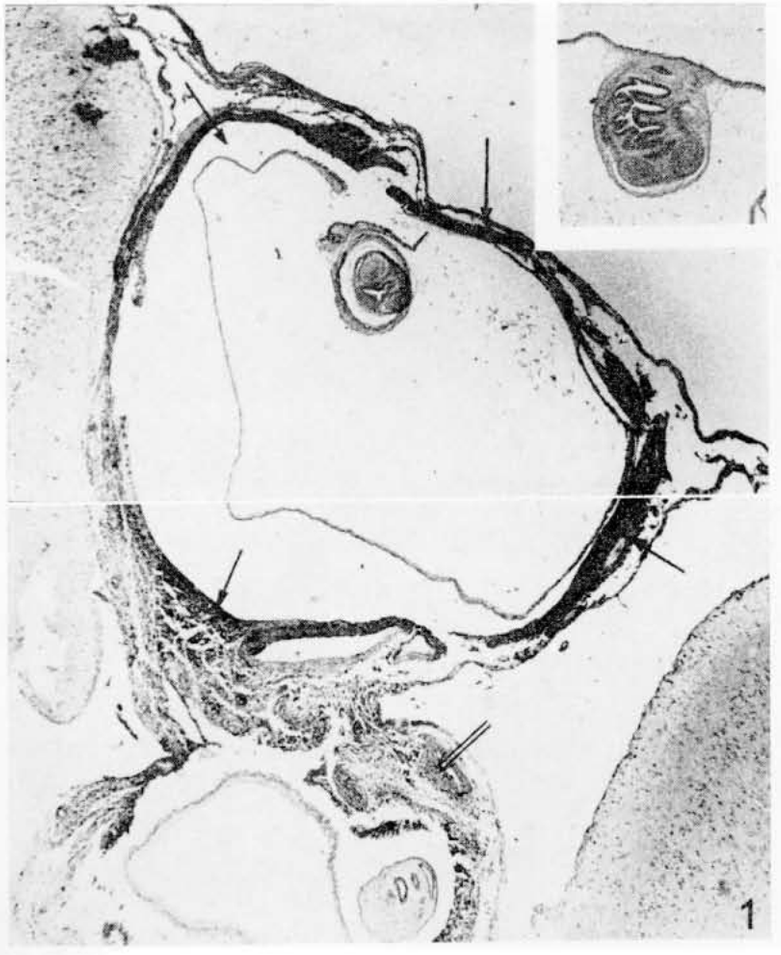


Fig. 1. Two cysticerci (*C. bovis*) in the arachnoid space of the cerebral meninges. The meninges around the cysticercus (arrows) and the wall of some meningeal arteries (double arrow) show signs of rather strong inflammatory reaction (HE, 70×).
Inset. Detail of the invaginated scolex of morphologically differentiated cysticercus from meninges. The scolex has no hooks. (HE, 100×).

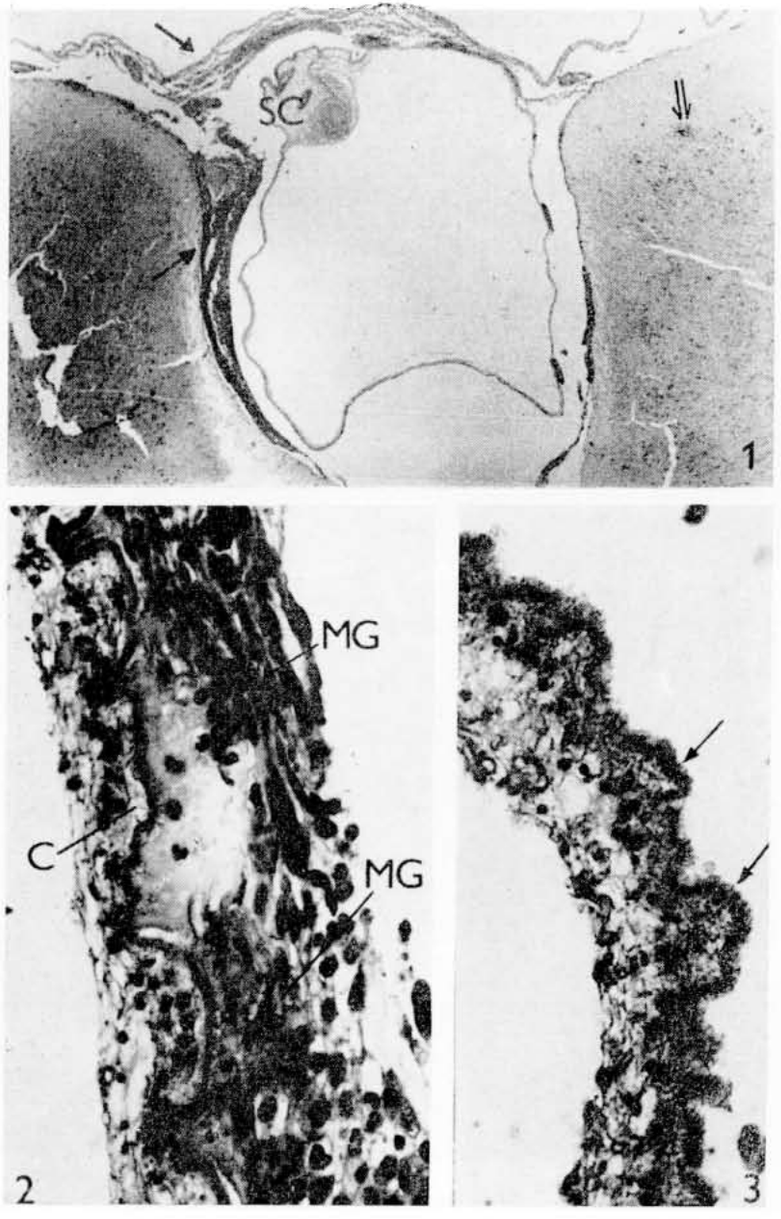
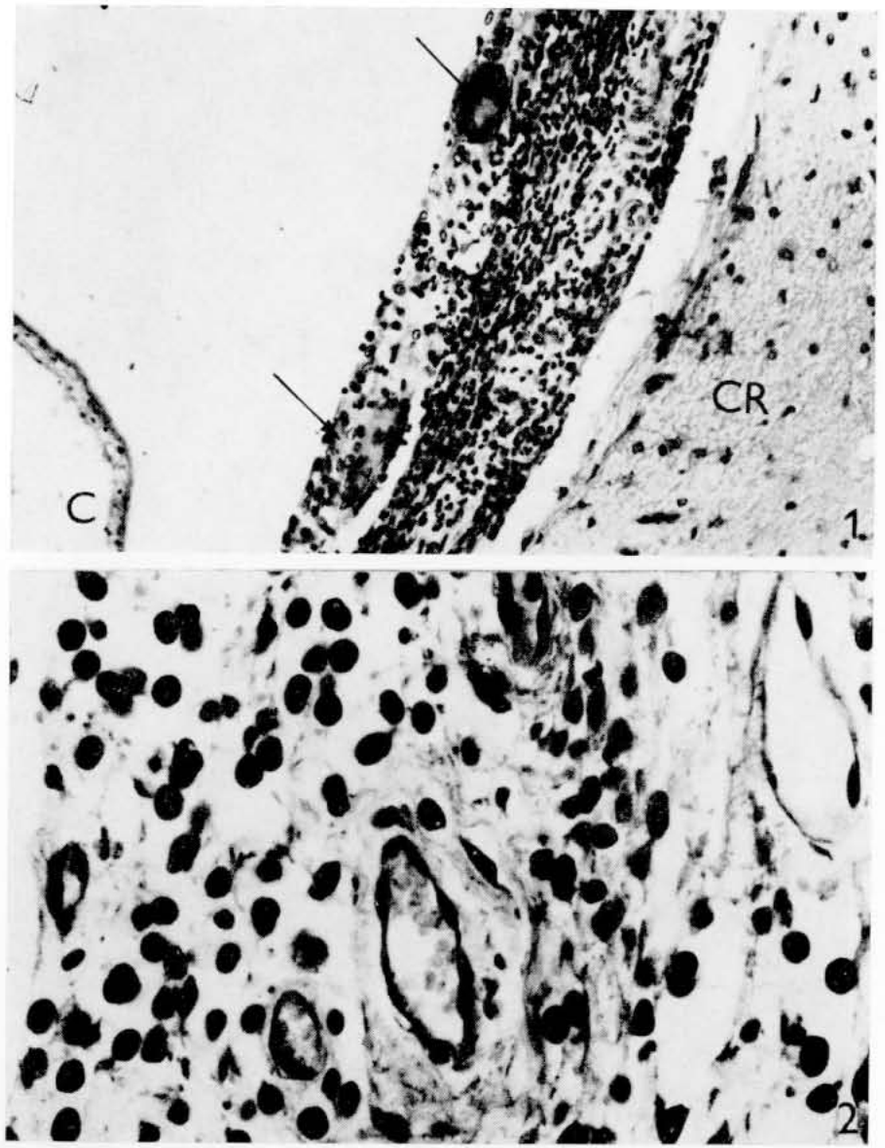


Fig. 1. Cysticercus laying in the meninges. The tissue reaction appears mainly in the vicinity of the opening of the spiral canal on the bladder surface (arrows). In other parts of the periphery of the cyst, the inflammatory reaction becomes weaker. The scolex of the cysticercus (SC) is not fully invaginated and rises above the bladder wall. Glial nodules are dispersed (scattered) throughout the cerebral cortex (double arrow). (HE, 65×). **Fig. 2.** Detailed view of the contact zone between bladder of the cysticercus (C) and inflammatory changed meninges (MG). (HE, 320×). **Fig. 3.** The surface of the bladder wall is folded and equipped with microtriches (arrows) (HE, 320×).



ig. 1. The meningitis is often associated with formation of multinucleate giant cells (arrows) lso in the vicinity of viable cysticercus. (HE, 130×). **Fig. 2.** The cellular infiltration of congested, nd edematous meninges is made up mainly of lymphocytes and other types of mononuclear ells. (HE, 450×).

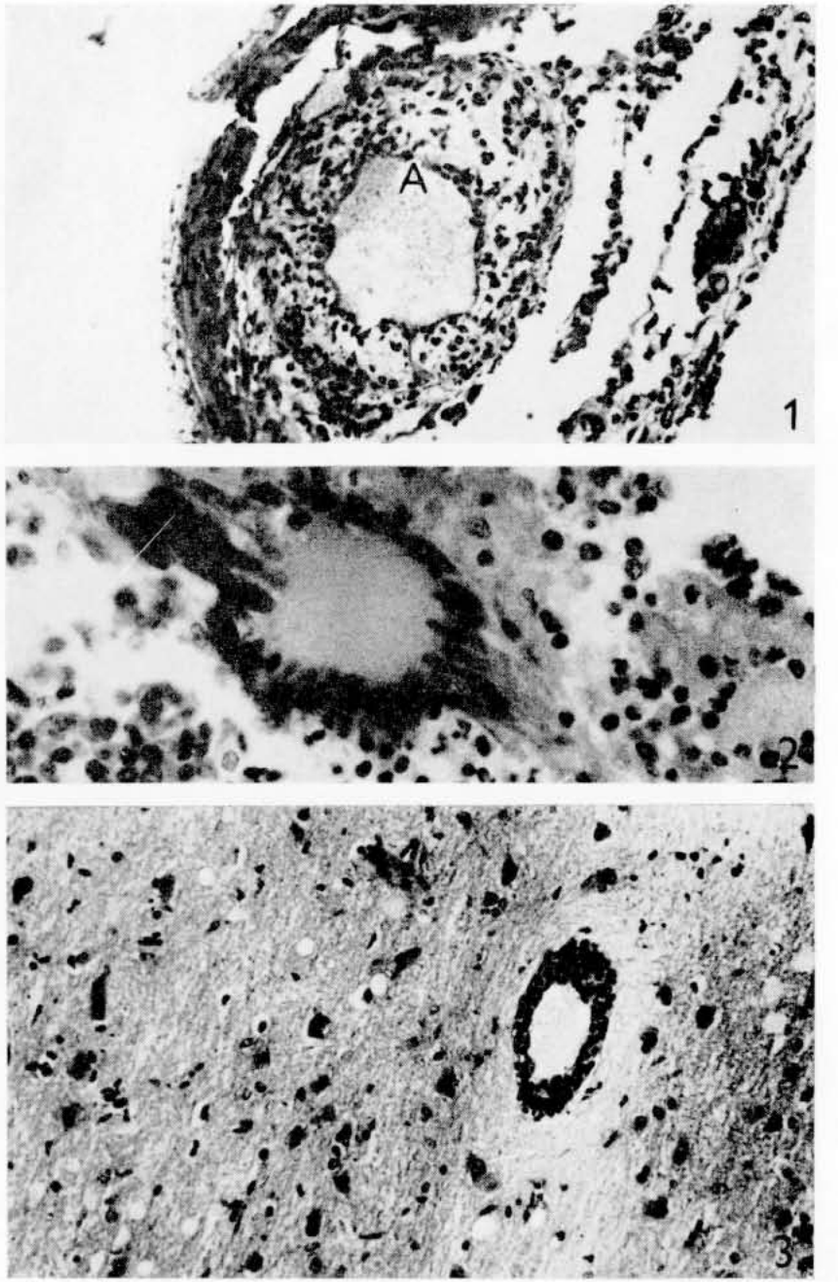


Fig. 1. During a heavy infection of meninges with *C. bovis*, the walls of some meningeal arteries (A) show signs of inflammation. (HE, 150×). **Fig. 2.** Detailed view of a multinucleate giant cell in *C. bovis* infection of meninges. (HE, 350×). **Fig. 3.** In the superficial layers of the cerebral cortex, the walls of some vessels are infiltrated with lymphocytes. (HE, 150×).

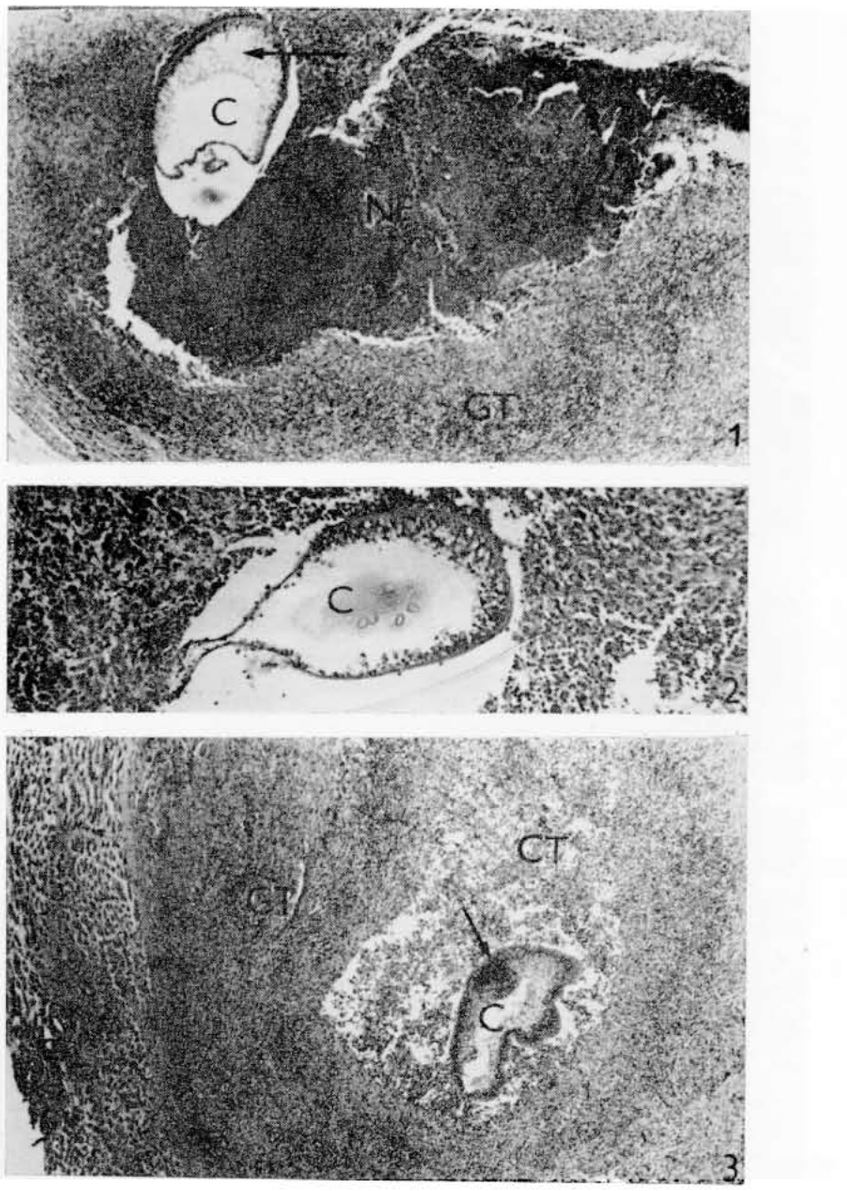


Fig. 1. At 25 days p.i., the focal lesion due to *C. bovis* infection of sceletal muscles of the reindeer, has the character of a nodule with necrotic centre (NE). The nodule is formed by fibroplastic granulation tissue (GT). The larva (C) has the form of the bladder with a cellular cone at one pole without invagination (arrow) (HE, 90×). **Fig. 2.** Cysticercus (C) inside a nodule in the skeletal musculature of reindeer. One pole of the bladder is tail-like elongated. (HE, 135×). **Fig. 3.** Nodule with the cysticercus (C) of the northern isolate from the skeletal muscle of the calf; 25 days p.i. The nodule is formed by granulation tissue (GT). In the centre of the nodule, there are macrophages and leucocytes. The cellular cone at one pole of the bladder has a shallow invagination (arrow) (HE, 90×).