

Echinococcus oligarthrus Diesing, 1863, in Panama and a comparison with a recent human hydatid

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Although 12 or more species names have been proposed within the genus *Echinococcus*, recent reviewers (Verster, 1965; Abuladse, 1964; Rausch and Nelson, 1963) tend to recognize only *Echinococcus granulosus* Batsch, 1786, *E. multilocularis* Leuckart, 1863, and *E. oligarthrus* Diesing, 1863, as morphologically distinguishable species. Additionally, the name *E. patagonicus* Szidat, 1960, is still applied to material from Argentine foxes, but Rausch and Nelson (1963) believe it to be morphologically similar to *E. granulosus*. The name *E. cruzi* was applied by Brumpt and Joyeux (1924) to a hydatid found in a South American agouti (*Dasyprocta aguti* L.). Cameron (1926) considered this form to be the larval stage of *E. oligarthrus* and therefore a synonym, but experimental confirmation is still lacking, and the life-cycle of *E. oligarthrus* has not been demonstrated.

Of the recognized species only *E. oligarthrus* is known to utilize American Felidae as definitive hosts. The species was first found in a Brazilian puma in 1850. In 1863 Diesing described this material as new and designated it *Taenia oligarthra*. Lühe (1910) re-examined and redescribed Diesing's specimens and placed the species in the genus *Echinococcus*. Subsequently, Cameron (1926) redescribed *E. oligarthrus* on the basis of some specimens that he collected from a South American jaguarundi (*Felis yagouaroundi*) which had died in the London Zoological Gardens. According to Abuladse (1964) these are the only two collections of *E. oligarthrus* which have been reported. Recently Verster (1965) has presented a partial redescription based on four specimens taken from Cameron's material.

In the Republic of Panama no species of *Echinococcus* has been reported previously, but several cases of human hydatidosis have been seen in the local hospitals. All but one of these cases, however, are believed to have been *E. granulosus* of foreign origin. The one exception was the recently reported polycystic multilocular hepatic cyst found in a native Panamanian who claimed never to have been out of the Republic (Sousa and Lombardo Ayala, 1965).

Since the report of the first autochthonous human hydatid case in Panama, adult worms of *Echinococcus* have been found in two pumas and immature worms have been found in a jaguarundi. These specimens have been designated *E. oligarthrus*. Because of the paucity of information about the species and the variability shown in the present collection, a description of these specimens is given below.

MATERIALS AND METHODS

Source of Material

Two infected pumas (*F. concolor* L.) and one infected jaguarundi (*F. yagouaroundi*

Geoffroy) were obtained from a forested area north of Gatun Lake in central Panama. One puma was killed in the Canal Zone, while the other two cats came from the Republic just outside the Canal Zone. Two jaguars (*F. onca* L.) from the same area were negative, as were one tayra (*Tayra barbara* Goldman) and two coatis (*Nasua narica* L.). A domestic cat (*F. catus* L.) from the endemic area was also negative, and faecal floatations from three domestic hunting dogs (*Canis familiaris* L.) failed to show taeniid eggs. An ocelot (*F. pardalis* L.) from the south shore of Gatun Lake was also examined but was found to be negative. Faecal floatations were made from an additional puma which had been captured on the Bayano River in Darien province, but no taeniid eggs were seen.

One of the infected pumas had a massive infection estimated at 100,000 worms. The helminths were distributed throughout the small intestine and included many specimens thought to be less than one week old (fig. 26), as well as many egg-filled adults (fig. 27). The other puma had a light infection of adult worms; and the jaguarundi contained about 1,000 immature worms (figs. 2, 3 and 24) localized in the first 5 inches of the upper small intestine.

Human hydatid material from the cyst reported by Sousa and Lombardo Ayala (1965) was fed through a stomach-tube to a coati (*N. narica*); unfortunately this animal died nine days later from unknown causes, and about 30 growing *Echinococcus* scoleces were recovered (fig. 25).

Methods

Worms were washed from the gut with water, concentrated by sedimentation, and fixed in warm alcohol-formalin-acetic acid solution.

In order to study the large series of worms obtained it was necessary to use mass methods. Large numbers of worms were stained overnight in Mayer's carmalum. They were then transferred to a vial containing 50 per cent. alcohol, and a cotton cloth was tied over the mouth of the vial. The vial was inverted on a folded towel to remove the fluid and was placed in a container of 100 per cent. alcohol. The air was removed from the vial by pipette suction applied through the cloth. After ten minutes of dehydration, the alcohol was removed from the vial with a towel, and the vial was filled with methyl salicylate by immersion. The worms were stored in the methyl salicylate clearing agent, and were studied in groups on depression slides. Selected specimens were mounted in Canada balsam.

To facilitate hook-counting, specimens were mounted in an upright position so that an end-on view could be obtained (figs. 28 and 29). For this purpose plastic pin-hole grids were devised. These were made by punching 12 small holes in 1-cm.-square pieces of plastic with a sharpened dissecting needle. Scoleces were taken individually from the clearing agent on the tip of a dissecting needle and were inserted in the holes in the plastic squares. The filled grids were mounted in balsam under a cover-glass. Because of the small size of the worms, it was necessary to load the grids under a dissecting microscope.

Drawings of scoleces and adult worms were made with a micro-projector, while hook-drawings were made with the aid of a camera lucida.

General measurements of the strobila and reproductive structures were made with an ocular micrometer. In the case of hook measurements, however, it was found that accurate

reproducible results could not be obtained in this way. Each hook was drawn by camera lucida, and a drawing of a stage micrometer, made to the same scale, was used to make the measurements. Only hooks seen in profile were drawn, and 1-4 hooks per scolex were used. A total of 50 hooks in each category was measured. Verster (1965) found that a total of 50 hooks gave a statistically valid sample.

A considerable amount of confusion exists in the literature about methods of measuring cestode hooks. Meggitt (1927) proposed an elaborate system for measuring hymenolepid hooks. This involved lines projected from the hooks and mathematical ratios of the dimensions, but it has not been adopted by subsequent workers. Skinker (1935) correctly pointed out that hook measurements given in the literature were not comparable, since no one scheme for measuring hooks had been generally accepted. She presented her own method, but applied two different schemes in the same paper. For the genus *Echinococcus*, several different systems have been used (Sweatman and Williams, 1963; Verster, 1965). Cameron (1926) gave only the hook lengths of *E. oligarthrus*, and no range of sizes was given.

We consider that in spite of the considerable variation in the hooks of *Echinococcus* certain points of reference can be distinguished. Abstract concepts and the measuring of lines projected from the hook should be avoided. The method used in the present paper is shown in fig. 20, where A-C equals length, B-D equals width (obtained by projecting a line through the centre of the guard), C-E equals blade length, and E-F equals handle length. Hook measurements are given in microns (μ) while other measurements are given in millimetres (mm.). The mean and standard deviation are given in parentheses after the range of measurements.

DESCRIPTION OF THE PARASITE

Five thousand specimens of the parasite were studied. The adult worms, described below, were taken from *F. concolor* (see table).

Strobila

Twenty specimens were measured.

The entire adult worm consists of a scolex followed by three segments (fig. 5). The first segment is immature. The second segment contains mature reproductive structures (fig. 6). The terminal segment is gravid and contains about 50-300 eggs. The genital pores alternate irregularly.

The total length of gravid adults is from 2.2 to 2.9 mm. (2.52 ± 0.18). The greatest width is at the middle of the terminal segment and is from 0.29 to 0.41 mm. (0.36 ± 0.03).

Scolex

Hook counts were made of 50 specimens; and hook measurements of 50 large and 50 small hooks.

The scolex is typical of the genus. It has a rostellum armed with two rows of hooks and four suckers. The rostellum is about 0.1 to 0.12 mm. in diameter, and the suckers are from 0.06 to 0.09 mm. in diameter. The suckers are followed by an unsegmented neck region of variable length. The hooks are variable in shape and size even on a single

specimen. The hook number also shows a wide range of variation. The total number of hooks is from 26 to 40 (34.7 ± 2.85). The large hooks of the anterior row have the following dimensions: length, 43.60μ (52.5 ± 3.56); width, 18.26μ (21.1 ± 1.82); blade length, 29.34μ (31.4 ± 1.31); and handle length, 11.30μ (21.6 ± 3.03). The dimensions of the small posterior hooks are: length, 28.45μ (39.1 ± 4.57); width, 11.18μ (15.2 ± 1.45); blade length, 21.30μ (26.6 ± 1.94); and handle length, 5.20μ (12.8 ± 3.80).

TABLE
Showing the measurements of 20 specimens of *E. oligarthrus*

Structure	Range	Mean	Standard deviation
Strobila			
Total length	2.20-2.93 mm.	2.52 mm.	± 0.18
Total width	0.29-0.41 mm.	0.36 mm.	± 0.03
Gravid proglottid			
Length	1.15-1.65 mm.	1.37 mm.	± 0.15
Width	0.29-0.41 mm.	0.36 mm.	± 0.03
Distance from anterior end to genital pore...	0.53-0.66 mm.	0.59 mm.	± 0.015
Mature proglottid			
Length	0.38-0.67 mm.	0.57 mm.	± 0.066
Width	0.19-0.33 mm.	0.26 mm.	± 0.038
Distance from anterior end to genital pore...	0.13-0.24 mm.	0.19 mm.	± 0.029
Cirrus sac			
Length	0.09-0.14 mm.	0.11 mm.	± 0.016
Width	0.041-0.055 mm.	0.05 mm.	± 0.0036
Large hooks			
Length	43-60 μ	52.5 μ	± 3.56
Width	18-26 μ	21.1 μ	± 1.82
Blade	29-34 μ	31.4 μ	± 1.31
Handle	11-30 μ	21.6 μ	± 3.03
Small hooks			
Length	28-45 μ	39.1 μ	± 4.57
Width	11-18 μ	15.2 μ	± 1.45
Blade	21-30 μ	26.6 μ	± 1.94
Handle	5-20 μ	12.8 μ	± 3.80

Immature Proglottid

The immature first segment is nearly square and is 0.13-0.24 mm. in width and 0.11-0.24 mm. in length. Reproductive system Anlagen can usually be seen in the centre of the proglottid.

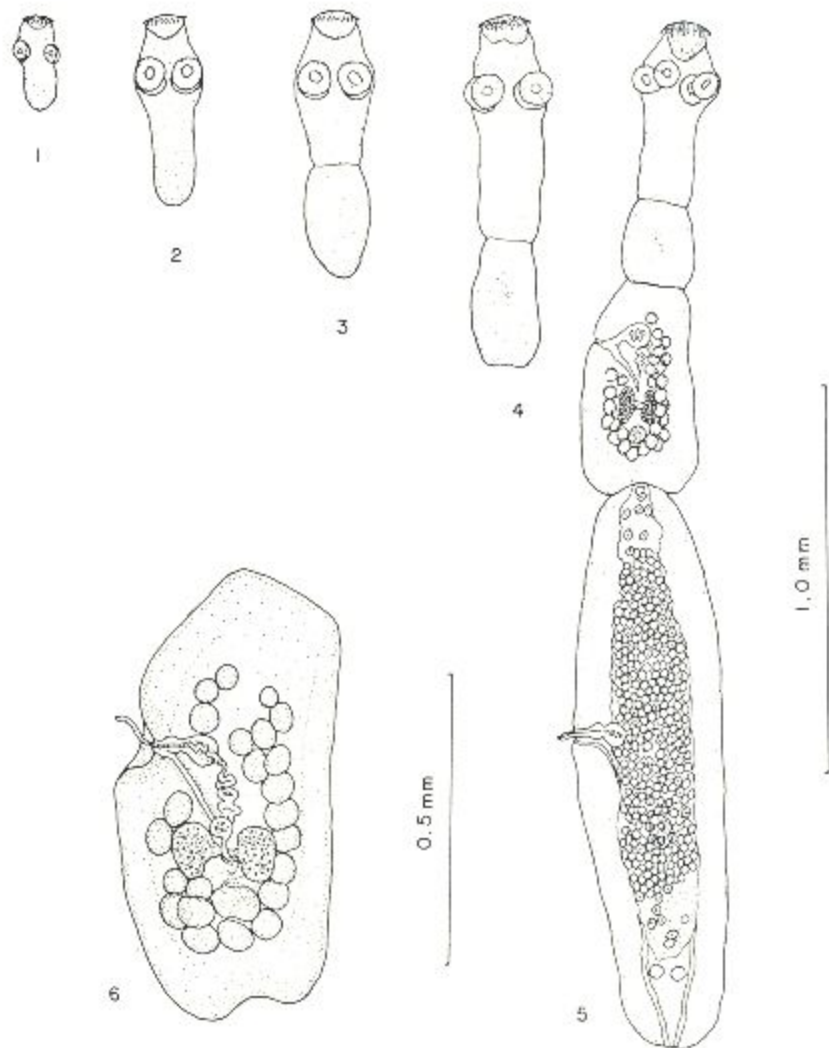
Mature Proglottid

Twenty specimens were measured; testes counts were made of 50 specimens.

The mature segment is longer than it is wide (fig. 6). Its total length varies from 0.38 to 0.67 mm. (0.57 ± 0.066), and the width from 0.19 to 0.33 mm. (0.26 ± 0.038). The genital pore is situated 0.13 to 0.24 mm. (0.19 ± 0.029) from the anterior end, or at an average of 33 per cent. of the length of the proglottid.

The ovary and vitelline gland are similar to those of the other species in the genus and vary in shape and position.

The spherical testes are 0.02-0.06 mm. in diameter and 15-46 (28.8 ± 4.46) in number. They surround the female reproductive structures posteriorly. From 3 to 14 (8.9 ± 2.1) testes are situated anterior to the genital pore. The pear-shaped cirrus sac is 0.041-0.055 mm. (0.05 ± 0.004) wide and 0.09-0.14 mm. (0.11 ± 0.016) long. The cirrus sac is variable in position but usually projects into the proglottid either transversely or directed posteriorly.



FIGS. 1-6. Showing the growth of *E. oligarthus*. 1, Immature scoleces about one week old from *F. concolor*. 2 and 3, Immature scoleces about two or three weeks old from *F. yagouaroundi*. 4, Maturing specimen about four weeks old from *F. concolor*. 5, Fully mature specimen from *F. concolor*. 6, Detailed structure of mature proglottid.

Gravid Proglottid

The gravid proglottid is much longer than it is wide (figs. 5 and 27). It measures 1.15-1.65 mm. in length (1.37 ± 0.15) and 0.29-0.41 mm. in width (0.36 ± 0.03). The genital pore is situated slightly pre-equatorially or at a distance of 0.53-0.66 mm. (0.59 ± 0.015) from the anterior end of the proglottid. This distance represents an average of 42.2 per cent. of the length of the proglottid. The gravid saccular uterus extends through most of the proglottid and contains 50-300 eggs which measure 30-39 μ in diameter. The embryonic membrane of the eggs (i.e., the shell) measures about 2-4 μ in thickness. The hooklets of the oncosphere measure about 9 μ in length. The uterus extends to the anterior end of the proglottid, and after the latter has been shed from the strobila, the uterine wall ruptures at that point to release the eggs. The cirrus and cirrus sac, vagina, vitelline gland, and a few testes usually remain in the gravid proglottid.

DIAGNOSIS

Echinococcus oligarthrus Diesing, 1863

Cestodes of American felids, varying in length up to 3.0 mm., with three segments. Hooks, 26-40 in number, large row 43-60 μ in length, posterior row 28-45 μ in length. Genital pore well anterior to middle in both mature and gravid proglottids. Testes 15-46 in number, 3-14 anterior to the genital pore. Cirrus sac transverse or tilted posteriorly. Uterus without lateral branches.

The definitive hosts are *F. concolor* L. (puma) and *F. yagouaroundi* Geoffroy (jaguarundi). Additional definitive-host names which appear in the literature but which are erroneous include: *F. tigrina* (Yamaguti, 1959); *F. jaguarundi* (jaguar) (Wardle and McLeod, 1952); jaguar (Cameron, 1926); and puma (*F. puma*) (Smyth and Smyth, 1964).

The intermediate hosts are unknown. The following intermediate-host names appear in the literature: *Dasyprocta agouti* in Cameron (1926) and in Rausch and Nelson (1963); *Myocastor* sp. in Rausch (1953) and Smyth and Smyth (1964); and *Microcavia australis* (?) in Smyth and Smyth (1964). Since the life-cycle of *E. oligarthrus* has not been described, however, the assignment of intermediate hosts is entirely speculative.

The geographical distribution of *E. oligarthrus* includes Brazil and Panama.

Smyth and Smyth (1964) cite Rausch (1953) who gave the distribution as Central and South America, but Rausch and Nelson (1963) stated that *E. oligarthrus* is known only from South America. Sweetman and Williams (1963) stated that the species has been seen in Central and South America. We have not been able to find any previous record of the species in Central America.

DISCUSSION

Although our present material differs somewhat from the published descriptions of *E. oligarthrus* (Cameron, 1926; Verster, 1965), there can be no doubt that it is conspecific. Comparable features are the small size, the segment number, the large size of the hooks, the hook morphology, the position of the genital pore, and the hosts. The distribution of the testes is also comparable, although Rausch and Nelson (1963) stated that the testes

of *E. oligarthrus* are in the 'Posterior half of segment'. This is obviously an error and may derive from Cameron (1926) who said 'They are not present, however, in the anterior portion'. Cameron's plate, in the same paper, plainly shows eight testes anterior to the genital pore, and Verster (1965) found seven or eight testes anterior to the genital pore in specimens from the same collection.

The number of testes of *E. oligarthrus* (based on 50 specimens) was found to be 15-46 (average 29); 90 per cent. of the specimens had 20-40 testes. The number of testes thus appears to overlap those of *E. multilocularis* (range 17-31, average 22) and *E. granulosus* (range 32-65, average 56) as given by Rausch and Nelson (1963). The average number of testes for *E. oligarthrus* falls between the averages for the other two species.

The testes distribution may be of greater taxonomic significance than is the testes number. Various investigators have noted the number of testes anterior to the genital pore in species of *Echinococcus*. Szidat (1960, 1963) stated that the number of testes anterior to the genital pore was 0-5 for *E. multilocularis*, 9-23 for *E. granulosus*, and 5-8 for *E. patagonicus*. He thought, therefore, that *E. patagonicus* came between the other two species in this respect. It appears, however, that Szidat counted only those testes anterior to the cirrus sac on the poral side of the proglottid. His plate shows at least 14 testes anterior to the level of the genital pore, which falls well within the range of *E. granulosus* for this character. In our collection, the number of testes anterior to the genital pore was found to be 3-14 (average 8.9). It will be noted that this range falls between those of the other two species but overlaps both.

The assumption that the immature worms from the jaguarundi are *E. oligarthrus* is supported by the following points: the hook number (see graph); the blade morphology (figs. 8 and 31); the anterior position of the genital pore (suggested by the cirrus sac primordium seen in a few specimens); and the host species. Also, the jaguarundi was obtained from within a mile of the locality where one puma was shot, and no other species of *Echinococcus* is known to occur there.

The value of hook numbers for differentiating between the species of *Echinococcus* is somewhat in doubt. Rausch (1953) was of opinion that the number of rostellar hooks is so variable that it is worthless as a specific character of the genus. Lubinsky (1960), on the other hand, showed statistically significant differences in hook numbers between populations of *E. granulosus* and *E. multilocularis*. He pointed out, however, that in order to use hook counts for taxonomic purposes a considerable number of scoleces should be counted and the data should be statistically evaluated. Lubinsky found that 93.2 per cent. of *E. multilocularis* scoleces had 20-32 (average 28) hooks, while 91.2 per cent. of *E. granulosus* scoleces had 28-40 (average 32).

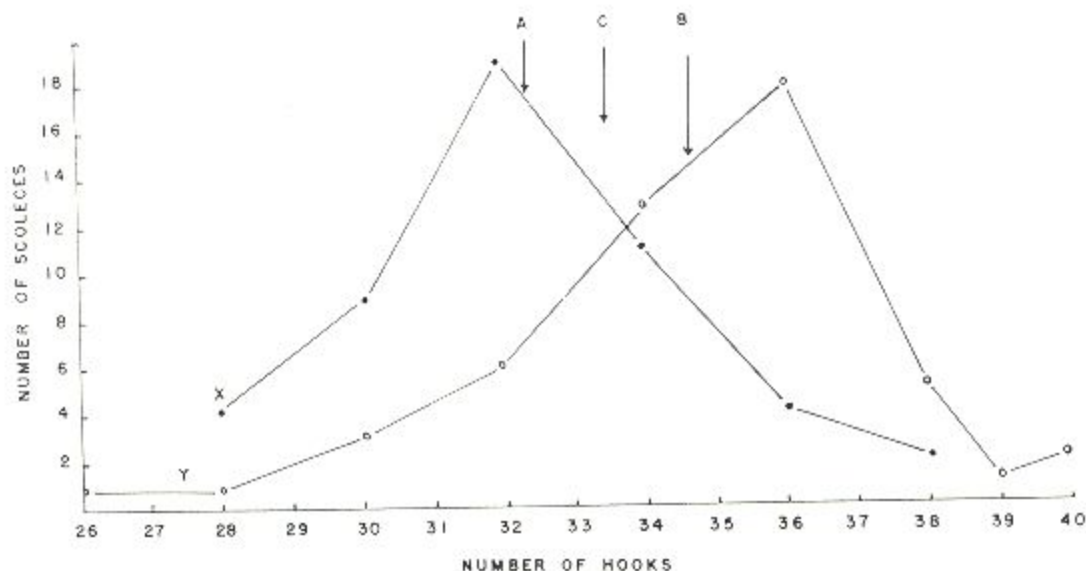
In the material from the puma, a hook count of 50 scoleces ranged from 26 to 40 (34.7 ± 2.85). The range for 74 per cent. of this sample was 32-36. A count of 50 scoleces from the jaguarundi ranged from 28 to 38 (32.4 ± 2.5) with 70 per cent. between 32 and 36. A count of 20 nine-day-old specimens of human origin recovered from a coati ranged from 30 to 38 (33.4), with 75 per cent. having 32-36 hooks.

A comparison of Lubinsky's data with the present material shows that all three of our

samples have hook-count ranges which are higher than that of *E. multilocularis*. Although the hook-count ranges of the present samples are comparable to those of *E. granulosus*, the means are higher. Hook counts may, therefore, be of use as an additional character in differentiating *E. oligarthrus* from *E. multilocularis*.

It should be noted that abnormal oncotaxy was occasionally seen in the present collection. One of the scoleces from the puma which was counted had 39 hooks owing to the duplication of a small second-row hook. Since this phenomenon seemed to be rare in the material, no special study was made of it.

On the basis of available evidence, it seems probable that the human hydatid material from Panama is also *E. oligarthrus*. The following observations support this contention. The human hydatid hooks are larger than any previously reported ($39.9\text{--}43.7\mu$ according to Sousa and Lombardo Ayala, 1965), and *E. oligarthrus* has larger hooks than other known species. The hook number is comparable with the mean, and it falls between the means for the puma and jaguarundi material (see the graph). The hook morphology is quite

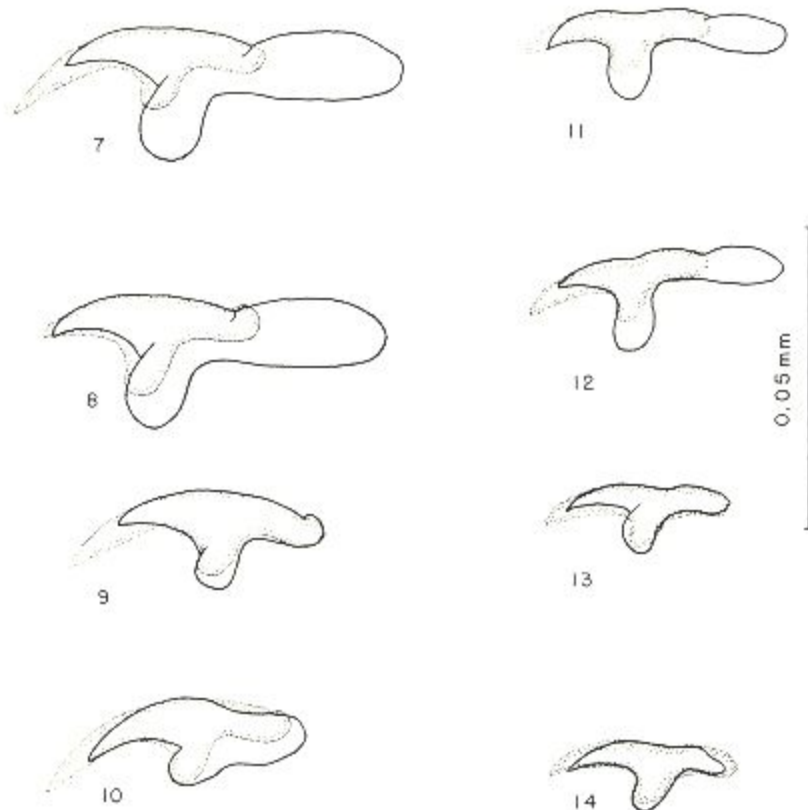


Graph showing the frequency distribution curves of hook counts of *E. oligarthrus*; x-curve = 50 scoleces from the jaguarundi; y-curve = 50 scoleces from the puma; A and B = mean points; and C = the mean of 20 scoleces of human origin recovered from a coati.

similar with respect to the dorsal curvature, the blade width, the angle between blade and guard, and the angle between handle and guard (figs. 7, 9 and 11-14). The fact that the blade point of the human hydatid hook is longer could be the result of its deriving from an abnormal intermediate host. The hook morphology of the Panamanian hydatid material is not comparable to typical *E. granulosus* hooks (fig. 10). The human hydatid was multilocular, but *E. multilocularis* is known only from northern and arctic regions. Szidat (1960, 1963) has postulated the existence, in South America, of a species of *Echinococcus* other than *granulosus* to account for certain multilocular human hydatids

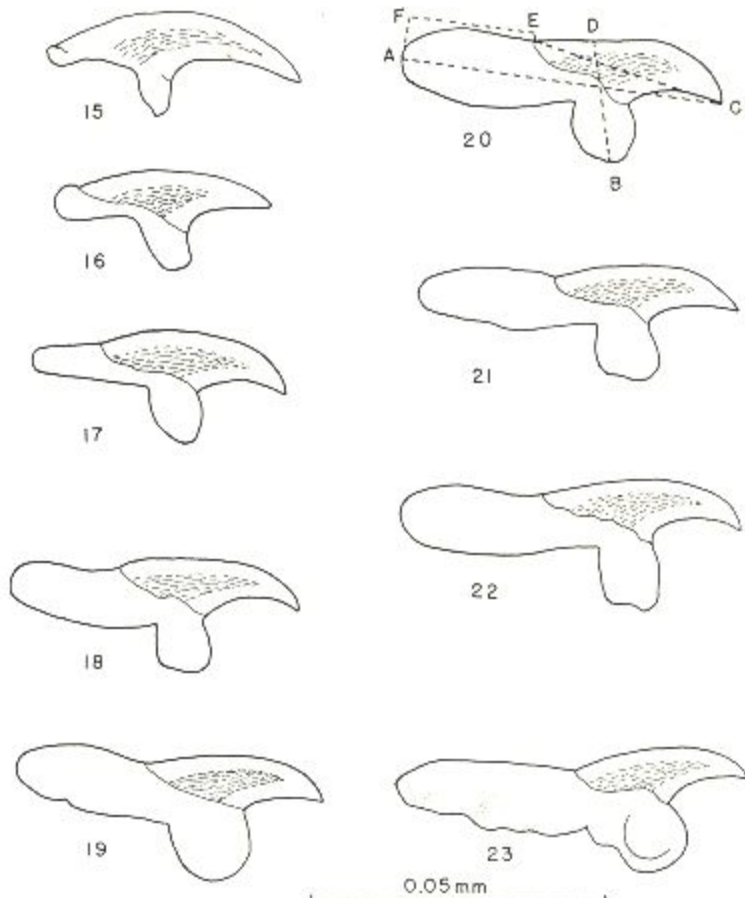
seen there. *E. patagonicus* Szidat, 1960, is morphologically similar to *E. granulosis*, according to Rausch and Nelson (1963), while the present studies indicate that *E. oligarthrus* is more closely related to *E. multilocularis*. This opinion was also expressed by Verster (1965). There seems to be no logical reason for postulating the existence of an undescribed species of *Echinococcus* in Panama.

It was indicated by Sousa and Lombardo Ayala (1965) that the Panamanian human hydatid resembled *E. multilocularis* in some respects and *E. granulosis* in others, but that it presented some characteristics (i.e., large hooks) that suggested a parasite different to those two



FIGS. 7-14. Showing large hook morphology. 7, Hook from mature puma specimen with hook from nine-day-old human specimen superimposed (stippled drawing). 8, Hook from mature puma specimen with hook from immature jaguarundi specimen superimposed. 9, Hook from immature jaguarundi specimen with hook from nine-day-old human specimen superimposed. 10, Hook from adult *E. granulosis* with hook from nine-day-old human material superimposed. 11-14, Small hooks from adult puma specimens with small hook from nine-day human material superimposed.

species and probably indigenous to the American tropics. They further suggested that the polycystic multilocular human hydatidosis of the Panama-Colombia area might be due to the same species of parasite. The fact that the Panamanian patient had spent some 30 years in jungle areas of Darien province where wild felids abound is additional supporting evidence. He is known to have enjoyed hunting, and no doubt came in contact with wild



FIGS. 15-23. Showing the morphological variation in large hooks. 15, Hook from Panamanian human hydatid. 16, Immature specimen from jaguarundi. 17-23, Mature specimens from puma. 20, Method of measuring hooks.

felids. Furthermore, *E. granulosis* has not been reported in Darien or elsewhere in Panama.

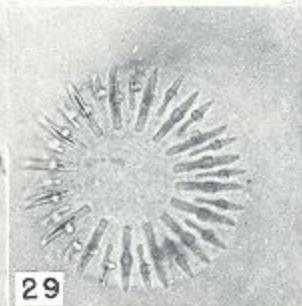
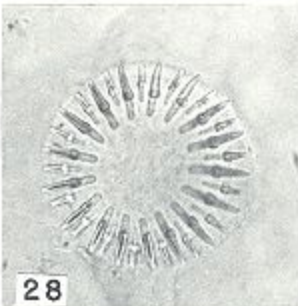
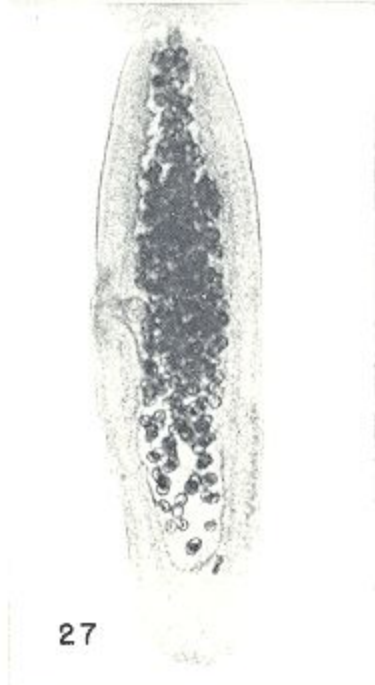
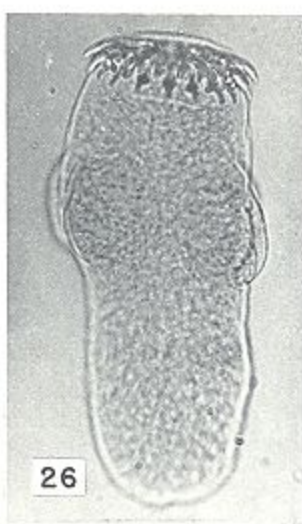
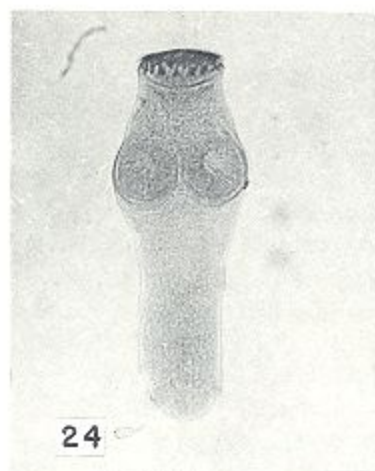
Present evidence indicates that *E. oligarthrus* is a valid species morphologically intermediate between *E. granulosis* and *E. multilocularis*, but with larger hooks than either.

E. oligarthrus differs from *E. granulosis* in the following respects. It is smaller in size, has fewer segments and larger hooks with longer handles. It has more anteriorly situated

EXPLANATION OF PLATE IX

E. oligarthrus

- FIG. 24. Immature specimen about three weeks old from a jaguarundi. ($\times 100$)
 FIG. 25. Immature specimen of human origin recovered from a coat at nine days. ($\times 100$)
 FIG. 26. Young immature specimen from a puma. ($\times 240$)
 FIG. 27. Gravid proglottid showing saccular uterus. ($\times 55$)
 FIGS. 28 and 29. End views of scoleces from a jaguarundi, showing hook counts of 34 and 32. ($\times 240$)
 FIG. 30. Large hooks from mature puma specimen. ($\times 810$)
 FIG. 31. Hooks from immature jaguarundi specimen. ($\times 650$)



genital pores, fewer testes, a non-branching uterus and eggs with thinner embryonic membranes. It differs also in its felid hosts.

E. oligarthrus is distinct from *E. multilocularis* in having larger hooks of a different shape, a larger number of hooks, fewer segments (three in *oligarthus*; 3-5 in *multilocularis*), a larger total number of testes and more testes anterior to the genital pore. Additionally, since *E. oligarthrus* utilizes tropical felids as definitive hosts, while *E. multilocularis* matures in arctic foxes and dogs, the two species would seem to be both ecologically and geographically isolated from each other.

Available evidence leads to the following conclusions. *E. oligarthrus* is a valid species occurring in tropical American felids. The species morphologically lies between *E. granulatus* and *E. multilocularis*, but is more like the latter. *E. oligarthrus* has considerably larger hooks than the other species, as well as other distinguishing characteristics. The species occurs in Panama and Brazil, and may be expected to occur in other tropical American regions. *E. oligarthrus* can be expected to be infective to man since it is morphologically intermediate between two species that do infect man. A recent polycystic multilocular human hydatid probably represented *E. oligarthrus*.

SUMMARY

1. Collections of *Echinococcus* were made in Panama from two pumas (*Felis concolor*) and one jaguarundi (*F. yagouaroundi*).
2. This material was identified as *Echinococcus oligarthrus* Diesing, 1863, and a redescription of the species is presented.
3. *E. oligarthrus* is recognized as a valid species which morphologically lies between *E. granulatus* and *E. multilocularis*.
4. Evidence is presented which suggests that a recently reported autochthonous multilocular human hydatid in Panama was probably *E. oligarthrus*.

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