Diagnosing Ancient Diphyllobothriasis from Chinchorro Mummies

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Diphyllobothrium pacificum *has been reported as a human parasite from coprolites and skeletons in Peru and Chile. Our analysis of Chinchorro mummies from Chile provides the oldest evidence of* D. pacificum *directly associated with human mummies. These mummies date between 4,000 and 5,000 years ago. The basis for our diagnosis is presented. We find that the size of the eggs in the mummies is smaller than other discoveries of* D. pacificum. *We suggest that this is due to the peculiar circumstances of preservation of parasite eggs within mummies and the release of immature eggs into the intestinal tract as the tapeworms decompose after the death of the host. This information is important to consider when making diagnoses from mummies.*

Key words: *Diphyllobothrium pacificum* - archaeoparasitology - mummy

In 1989, operculated eggs consistent with species of *Diphyllobothrium* were found in intestinal contents of Chinchorro mummies from Chile (Reinhard & Aufderheide 1990). Since that time, this find has been cited in the literature repeatedly (Arriaza 1995, 1998, Aufderheide & Rodriquez-Martin 1998). However, the diagnostic criteria of the 1991 presentation were never formerly published. This is a significant deficiency because eggs of some *Diphyllobothrium* species of can be distinguished to species level based on egg size. We are taking the opportunity to correct this oversight. We reexamined the microscope slides from the 1989 study and measured 114 eggs from three mummies. The measurements and observations are reported below.

Previous evidence of Diphyllobothrium pacificum - One basic question in archaeoparasitology relates to the accuracy of diagnosis from ancient remains. The eggs of *D. pacificum* are operculated eggs that can resemble a variety of other cestodes such as *Spirometra mansoni* and trematodes such as those of *Nanophyetus* species. Also, prehistoric dietary practices could have resulted in consumption of eggs from parasites not infective to human. Sometimes prehistoric humans ate small animals entire, including the intestinal tracts (Reinhard 1990). Therefore, it is important to define the diagnostic criteria for parasite identification from eggs. This is especially true for oval, operculated eggs which can come from many species of parasite.

Baer (1969) described the normal life cycle of *D. pacificum* in sea lions from the coast of Peru and documented infections of humans (Baer et al. 1967). Human infections were also documented in Chile (Atias & Cattan 1976). Normally, the parasite cycles between marine fish and sea lions. The fish serve as intermediate hosts and the sea lions as definitive hosts. Humans become infected by eating poorly prepared fish with living cysts. Humans can not become infected by eating sea lion meat or viscera. Baer et al. (1967) noted that it was likely that prehistoric populations in coastal Peru were infected. Baer's prediction was actually verified before Baer had documented infections among modern Peruvians. Callen and Cameron (1960) had examined several coprolites from Huaca Prieta, Peru, including coprolites from the intestinal cavity of a burial dating to approximately 2,500 B.C. *Diphyllobothrium* eggs were found in the coprolites from the burial and clearly demonstrated prehistoric human infection.

More evidence of prehistoric diphyllobothriasis from South America was later discovered. Patrucco et al. (1983) found eggs in one of 52 coprolites from the coastal site of Los Gavilanes in North-Central Peru. The coprolite containing the eggs comes from a stratum dated to 2,700-2,850 BC. In addition, other coprolites from the site contained eggs of pinworm (*Enterobius vermicularis*), giant roundworm (*Ascaris lumbricoides*), and whipworm (*Trichuris trichiura*). Ferreira et al. (1984) reported finding *D. pacificum* eggs in four of 26 coprolites from the site of Tiliviche in Northern Chile. Occupational levels at the site date from 4,110 - 1,950 BC, and the site itself lies 40 km from the Pacific coast at an altitude 950 m. The importance of these finds is that they demonstrate that *D. pacificum* infection had a distribution that extended from the coast inland. This indicates that trade in infected fish reached inland or that inland peoples migrated to the coast to fish as reviewed by Reinhard (1992). This was the first report of this parasite from the Chinchorro Cultural Period.

MATERIALS AND METHODS

The coprolites were recovered during the dissections of mummies at the Museo Arqueológico San Miguel de Azapa near Arica, Chile. The coprolites were provided by Dr Arthur Aufderheide, School of Medicine, University of Minnesota, Deluth and Bernardo Arriaza, Department of Sociology and Anthropology, University of Nevada, Las Vegas.

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Received 26 August 2002
Accepted 25 November 2002

The coprolites were rehydrated in 0.5% trisodium phosphate for 48 h and then screened through a 300 µm mesh. The microscopic remains, including parasite eggs, were concentrated by centrifugation. Microscope preparations were made and examined at 400X with a Jenaval microscope. The eggs were measured with an ocular micrometer.

RESULTS

The eggs ranged in length from 22.5 µm to 57.5 µm and in width from 17.5 µm to 53.75 µm. The average eggs dimensions are presented in the Table. Baer (1967) stated, "The eggs (*D. pacificum*) are thick-shelled, operculated, measuring 40-60 µm in length and 36-40 µm in diameter; they are thus considerably smaller than those of *D. latum* with which they cannot be confused". The size of *D. latum* eggs is 58-76 µm in length and 40-51 µm in diameter. Therefore, the eggs from the Chinchorro mummies are more consistent with *D. pacificum* that *D. latum* and a diagnosis of *D. pacificum* is appropriate.

It must be noted that the eggs from the mummies are in the lower end of the range of *D. pacificum* eggs from modern infections and ancient infections. In their analysis of parasite eggs from Tiliviche, Chile, Ferreira et al. (1984) report *Diphyllobothrium* eggs of 53.63 ± 2.82 µm and 39.42 ± 5.64 µm. The smallest eggs from the mummies are much smaller than the modern size range of *D. pacificum*.

TABLE

Average measurements of *Diphyllobothrium* eggs from three mummies

Mummy	Eggs measured	Average length	Average width
4	88	41 µm	36 µm
5	15	38 µm	32 µm
25	4	45 µm	31 µm

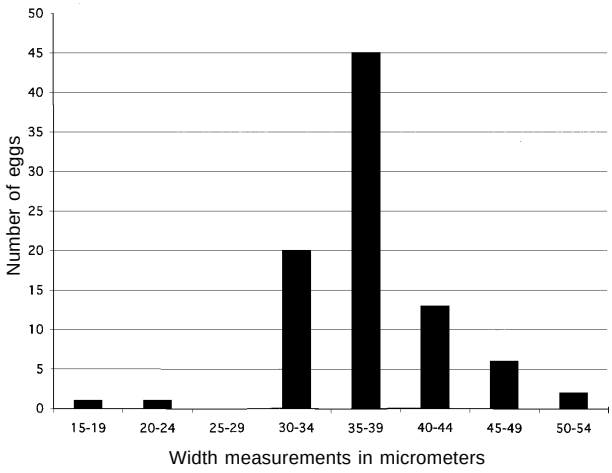

Fig. 1: *Diphyllobothrium* eggs in Chinchorro mummies, Peru; width measurements

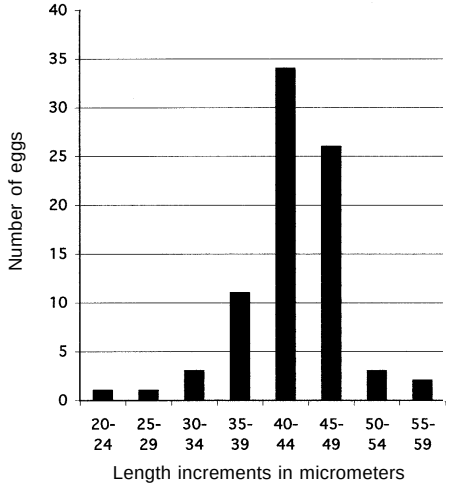

Fig. 2: *Diphyllobothrium* eggs in Chinchorro mummies, Peru; length measurements

DISCUSSION

The small size of the *D. pacificum* eggs from the Chinchorro mummies is noteworthy and begs explanation. The distribution of egg sizes is presented in Figs 1-2. As can be seen, the distribution approximates a normal curved. There is no indication of bimodality and therefore it is likely that only one species produced the eggs. An explanation for the small size can be found by considering the context of the coprolites and eggs dissemination.

Diphyllobothrium species are anapolytic tapeworms that lay eggs through the genital pores of the proglottids. The eggs become incorporated in the feces as the eggs mix with undigested food and products of digestion. Therefore, in coprolites found not associated with mummies, the diphyllobothriid eggs are fully mature. Therefore, the size of diphyllobothriid in coprolites should be consistent with modern specimens as found by Ferreira et al. (1984).

When the host organism dies, tapeworms within the body decompose. Therefore, it is possible that the eggs found in coprolites within mummies were released in an immature state from decomposed proglottids. In examination of the eggs from the Chinchorro mummies, it was very common for the eggs to be collapsed. No eggs were embryonated. We suspect that the eggs were immature and were released into the intestinal tracts of the mummies as the tapeworms decomposed after the host died. This would account for the smaller size of the eggs which are deformed.

This is the first time that egg size difference has been noted between mummy context and other prehistoric and modern specimens. We believe that this size difference results from the unique preservation conditions within a corpse that would result in the mixing of immature and mature eggs from helminth parasites. In future mummy studies, this aspect of preservation must be considered when making diagnoses.

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