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POINTS IN QUESTION

EPIDEMIOLOGICAL AND TAXONOMIC QUESTIONS ON HUMAN TAENIIDS

Both Taeniasis and Cysticercosis are actually considered as progressive zoonosis (ARAMBULO, 1982). Recently, a third form of human taeniid, *Taenia asiatica* Eom et Rim, 1993 (=«Taiwan *Taenia*»; = «Asian Taenia»), has been described (EOM & RIM, 1993). The characteristics of this taeniid appear to be half-way between those of the other two well-known human species of the genus *Taenia* Linnaeus, 1758: *T. solium* Linnaeus, 1758 and *T. saginata* Goeze, 1782. The characteristics of these 3 species of human Taeniids are the following:

1) *Scolex morphology*: In *T. solium*, both in the adult and cysticercus (*Cysticercus cellulosae*) stages, there is a conspicuous apical rostellum armed with two hook rows. *T. saginata* has always been described as the unarmed human taeniid lacking rostellum and hooks at adult and larval (*C. bovis*) stages, a fact which was even used to erect, for this species, a different genus *Taeniarhynchus* Weinland, 1858 accepted in several reviews (WARDLE & MCLEOD, 1952; ABULADZE, 1964; SCHMIDT, 1986; MOVSESSIAN, 1989); however, other authors (VERSTER, 1967, 1969; RAUSCH, 1994) prefer to synonymize *Taeniarhynchus* with *Taenia* owing to some studies showing the existence of a rudimentary rostellum and temporary hook anlages in the early development of the cysticercus of *T. saginata* (SLAIS & MACHNICKA, 1976; ZDARSKA, 1976; KOSMINKOV, 1987; FAN, CHUNG, LIN & PAWLOWSKI, 1992). *T. asiatica* has been described as presenting a visible rostellum in both adult and cysticercus (*C. viscerotropica*) stages, but it appears always unarmed in the adult stage and bearing caducuous rudimentary hooks in the cysticercus (hook number is very variable, and completely unarmed cysticerci have been found) (FAN, 1988; EOM & RIM, 1993).
2) *Strobilum morphology*: The strobila of *T. solium* and *T. saginata* can be differentiated at the level of both sexually mature and gravid segments, uterine branch number allowing the differential etiological diagnosis of both taeniasis. The whole strobilum of *T. asiatica* appears to be undifferentiable from that of *T. saginata* (FAN, 1988; EOM & RIM, 1993), thus making a specific etiological diagnosis impossible if the scolex cannot be recovered.
3) *Way of leaving the host*: The gravid proglottids of *T. solium* leave the definitive host in groups of segments and passively, whereas in *T. saginata* and *T. asiatica* they do it singly and spontaneously (FAN, 1988).
4) *Cysticercus morphology*: Besides the character of the presence/absence of rostellum and hooks in the cysticercal scolex (*T. solium*: armed rostellum present; *T. saginata:* rostellum and hooks absent, but in very early development a rudimentary rostellum bearing rudimentary caducuous hooks; *T. asiatica*: visible rostellum armed or unarmed), the larval stages of human teaniids differ in size (large size in *T. solium*, intermediate size in *T. saginata*, and small size in *T. asiatica* –see FAN, 1988) and external wall characteristics (*T. solium*: with wartlike processes after PAWLOWSKI & SCHULTZ, 1972 and PAWLOWSKI, 1982; *T. saginata*: rugae after PAWLOWSKI & SCHULTZ, 1972, PAWLOWSKI, 1982 and EOM & RIM, 1993; *T. asiatica*: with wartlike processes after FAN, 1988 and EOM & RIM, 1993).
5) *Cysticercus development*: The development period of the cysticerci of *T. solium* in the intermediate host is shorter than in *T. saginata* (7-9 weeks and 10-12 weeks, respectively). This development appears to be much quicker in *T. asiatica* (only 4 weeks) (FAN, 1988).
6) *Intermediate hosts*: According to the data available in papers referring to natural and experimental infection studies, much remains to be done concerning the ecological-ethological and biochemical-physiological specificities of the cysticerci of the three human taeniid species. *T. solium* cysticerci are parasites preferentially of pig, but they have also been found in a long list of other mammal species (several species of monkeys, wild boars, bushbabies, bushpigs, camels, rabbits, hares, rock hyraxes, brown bears, dogs, cats, foxes, polecats, coatis, rats, mice, goat, sheep, horse and deer –see PAWLOWSKI, 1982; FAN, CHUNG & WU, 1994), although the identity of these cysticerci has not always been confirmed. The existence of varieties or subspecies has been suggested to explain the different hook sizes of *T. solium* cysticerci found in pigs, cats, baboons, dogs and man (PAWLOWSKI, 1982). The *T. saginata* cysticercus seems to have a more restricted intermediate host spectrum. The typical intermediate hosts are domestic Bovidae (*Bos* spp.). The *T. saginata* cysticerci recorded from reindeer, and the sporadic findings of unhooked cysticerci in llamas, proghorn, oryx and oribi antelopes, bushbucks, Dorcas and redfronted gazellas, wildebe-

ests, giraffes and lemurs, need experimental confirmation (PAWLOWSKI, 1982). It is worth mentioning that the pig has been found to be a good laboratory intermediate host for *T. saginata* strains from Etiopia, Madagascar and Poland (FAN, CHUNG, LIN & PAWLOWSKI, 1992). *T. asiatica* cysticerci are known to infect pigs and wild boar in nature (FAN, 1988; EOM & RIM, 1993). Experimentally, pigs, cattle, goats and monkeys have been successfully infected (FAN, 1988; FAN, CHUNG, LIN & WU, 1990a; EOM & RIM, 1993).

7) *Location in the intermediate host*: The cysticerci of *T. solium* may invade all porcine tissues, and show no clear preference for specific muscles or organs (FAN, CHUNG & WU, 1994). *T. saginata* cysticerci have been reported in muscle, brain and liver (FAN, 1988). *T. asiatica* cysticerci are usually found in the porcine liver (FAN, 1988; FAN, CHUNG, LIN & WU, 1990a; EOM, RIM & GEERTS, 1992), though extrahepatic locations have been demonstrated experimentally (omentum, lungs and serosa) (EOM, RIM & GEERTS, 1992).
8) *In vitro egg hatching*: *In vitro* hatching figures differed critically between *T. saginata* and *T. asiatica* eggs when studied in compared experiments. *T. asiatica* eggs appeared to be very fragile, so that selection of fully matured eggs was critical for *in vitro* hatching, contrarily to *T. saginata*, in which it appeared to be easy. Moreover, the shape of embryophore blocks of *T. asiatica* through the in vitro hatching process appeared to differ from that of *T. saginata* (ITO, FAN, CHUNG & SUZUKI, 1994).
9) *Immunology*: From the immunological point of view *T. asiatica* appears to be closely related to *T. solium*: when performing an immunoblot assay (EITB), with a specificity of 100% for human and pig *T. solium* cysticercosis, a cross-reaction occurs when employing specific pathogen-free (SPF) pigs parasitised with *T. asiatica* but not when employing serum from patients infected with *T. saginata* (PILCHER *et al.*, 1991). Recently, additional immunological differences have been established between *T. saginata* and *T. asiatica*: rats injected with non-viable oncospheres of *T. asiatica* showed statistically significant resistance to challenge infection with eggs of *T. taeniaeformis*, whereas those injected with non-viable oncospheres of *T. saginata* showed no resistance (ITO, FAN, CHUNG & SUZUKI, 1994).
10) *Molecular biology*: Comparative studies carried out with DNA isolated from *T. asiatica, T. solium, T. saginata* and 7 other taeniid species using restriction endonuclease digestion of genomic DNA and Southern blot analysis using ^{32}P-labeled total cestode RNA and cloned ribosomal RNA gene fragments as probes, have provided justification for distinguishing Taiwan *Taenia* under its own name, and not merely as a variant of *T. saginata* (ZARLENGA, MCMANUS, FAN & CROSS, 1991). A genetic yardstick approach was used to determine whether *T. asiatica* should most appropriately be considered as a distinct species or as a subspecies, strain or variant of *T. saginata*: the PCR-RFLP approaches proved useful for rapid and unambiguous discrimination of *T. asiatica* from *T. solium* and *T. saginata*, whereas the mitochondrial and nuclear sequence comparisons indicate that *T. asiatica* is much more closely related to *T. saginata* than recognized taeniid species are to each other. These results suggested to the authors the appropriateness of taxonomically designating *T. asiatica* as a subspecies or strain of *T. saginata* rather than as a different species (BOWLES & MCMANUS, 1994; MC MANUS & BOWLES, 1994).
11) *Capacity to produce human cysticercosis*: The larval stage of *T. solium* produces human cysticercosis when the cysticerci develop in the subcutaneous tissues, heart, skeletal muscle, brain and eyes. The question as to whether man can be an intermediate host for *T. saginata* has not been satisfactorily answered (PAWLOWSKI & SCHULTZ, 1972; PAWLOWSKI, 1982). There is no doubt that cysticerci with hookless scolices have been found in the human body: in some cases they have been numerous; in others they were accompanying intestinal *T. saginata* infection (PAWLOWSKI & SCHULTZ, 1972; TORRES, 1989; ZHU *et al.*, 1989). Although the phenomenon appears to be very rare, the question remains open, and emphasis has been placed on the importance of careful morphological examination of cysticerci removed from human patients (PAWLOWSKI & SCHULTZ, 1972; PAWLOWSKI, 1982). Concerning *T. asiatica*, the true capacity of this taeniid to produce human cysticercosis remains unknown. Two different opinions have been expressed concerning *T. asiatica* cysticercosis in man. ITO (1992) is of the opinion that human cysticercosis in the Asian-Pacific regions, where infection by the *T. asiatica* adult stage is well known, is caused by the ingestion of eggs of this species. Contrarily, BOWLES & MCMANUS (1994) and MCMANUS & BOWLES (1994), based on molecular data which suggest that *T. asiatica* is closer to *T. saginata* than to *T. solium*, are of the opinion that *T. asiatica* is unlikely to be an important cause of human cysticercosis.
12) *Geographical distribution*: *T. solium* and *T. saginata* are known to be present throughout the world. According to studies of recent years, *T. asiatica* seems to be confined to the Asian-Pacific regions. It has been detected in Taiwan (HUANG, 1967; CHAO & FAN, 1986; CHAO, WONG & FAN, 1988: FAN, 1988), Indonesia (FAN, LIN, KOSMAN & KOSIN, 1989), Thailand (FAN, CHUNG, LIN & WU, 1990b) and Korea (FAN *et al.*, 1989; EOM & RIM, 1993). This taeniid may also be present in the Phillipines, where a «*T. saginata*-like species» has been reported (pigs harbouring armed cysticerci, *T. saginata* adults present in humans, cattle presenting no *C. bovis*)

(ARAMBULO, CABRERA & TONGSON, 1976; CABRERA & ARAMBULO, 1977). Furthermore, *Taenia* isolates with a genotypic identity corresponding to *T. asiatica* have been recorded in China and Malaysia (BOWLES & MCMANUS, 1994).

The specific differences between *T. asiatica* and *T. solium* appear to be clear, whereas this is not the case with *T. saginata*, which *T. asiatica* seems to be closer to. Despite the similarities between the latter two, differences are more numerous and taxonomically important enough to consider the «Asian *Taenia*» as an independent entity (see Table 1). However, these similarities and differences are the bases of different authors' opinions concerning the appropriate taxonomic status to be given to this form, whether a specific or a subspecies/strain level. Morphological and biological evidence supports a species level for *T. asiatica*, whereas molecular data suggest a subspecies or strain level for it within *T. saginata* (BOWLES & MCMANUS, 1994; MCMANUS & BOWLES, 1994). Thus, both possibilities can be accepted, depending on the importance given to one or another aspect. But from a pragmatic point of view, that is, from the points of view of epidemiology and health, it would be more useful to consider it as a distinct species, as accepted in similar taxonomic problems known in other uniparental parasite organisms of medical importance such as among the genera *Giardia, Entamoeba* or *Toxoplasma* (TIBAYRENC, 1993).

Differences	Similitudes
Scolex morphology	Strobilum morphology
Cysticercus morphology	Way of leaving host
Cysticercus development	Mitochondrial COI/nuclear rDNA 28S sequences
Nature of intermediate host	
Preferent location of cysticerci	
Immunology	
PCR-RFLP approaches	
In vitro egg hatching	

Table 1. - Differences and similitudes between *T. saginata* and *T. asiatica*.

Despite their genetic closeness, it would be helpful to separate *T. asiatica* from *T. saginata*, or, in other words, not to confound it with *T. saginata*, for several reasons:

A) Prophylactic measures differ substantially between both parasites, owing to the different main source of human infection (cattle for *T. saginata* and pig for *T. asiatica*). *T. saginata* is too well-known (the relationship of this taeniid with cattle is known outside the pure scientific circle) and the consideration of *asiatica* as a subspecies or strain of *T. saginata* would easily give rise to errors in activities carried out by health professionals, who do not usually take taxonomic questions into account.

B) Similar considerations can be made concerning epidemiological studies and application of control measures to be undertaken by health professionals who are not parasitology specialists.

C) The possibility that *T. asiatica* can cause human cysticercosis has not yet been disproved and, consequently, cannot be rejected for the moment. The biological, epidemiological and pathological characteristics coded by the small genetic differences detected in given *T. saginata* and *T. solium* isolates are unknown (BOWLES & MCMANUS, 1994) and the same can be concluded concerning the genetic differences between *T. saginata* and *T. asiatica*. Whereas genetic similarities with *T. saginata* support *T. asiatica* not being able to cause human cysticercosis (BOWLES & MCMANUS, 1994; MCMANUS & BOWLES, 1994), immunological similarities with *T. solium* suggest the contrary, as already pointed out by other authors (ITO, 1992).

D) If *asiatica* is maintained as a subspecies or strain of *T. saginata*, a geographical problem will always exist, because: a) subspecies and strain levels are typically used for taxonomic units confined to given areas; b) the proposed name *asiatica* already suggests such a geographic delimitation (but, due to the rules of nomenclature, this cannot be changed, and moreover it may even have been well chosen from the scientific point of view). If *asiatica* is raised to species level, the discovery of a third taeniid parasitizing humans can more easily encourage studies in other parts of the world to determine the species present in the different regions. Such studies, unfortunately, are not carried out as often as we would like. Human taeniids are simply diagnosed as *Taenia* sp. because eggs are found in stools or because expelled gravid proglottids are not properly identified. In fact, there is no reason why a parasite whose intermediate and definitive hosts are cosmopolitan and whose eggs appear to be very resistant to environmental conditions (LAWS, 1968) cannot have a more extensive geographical distribution than that known today for *T. asiatica*.

E) The last reason concerns a number of controversial epidemiological situations, related to the sole presence of *T. solium* and *T. saginata*. Thus, in many parts of the world discrepancies exist between the incidence of human or pig cysticercosis and the incidence of adult *T. solium* infection in man. This has even created the opinion that *T. solium* infection may not be as rare as generally assumed (VERSTER, 1967).

In America, and particularly in Mexico, where cysticercosis constitutes an important public health problem (FLISSER, PLANCARTE & CORREA, 1991), few cases of *T. solium* are reported, in comparison with the cases of cysticercosis. It seems that for every case of *T. solium* there are 14 cases of *T. saginata* parasitation (14 *T. saginata*-like adults!) (MAZZOTTI, 1944; SALAZAR-SCHETTINO, DE HARO-ARTEAGA,

RUIZ-HERNANDEZ & LOBO-MARTINEZ, 1984). This clear epidemiological situation has even led to the suggestion that cysticercosis might spread without an intervening adult stage (SALAZAR-SCHETTINO, DE HARO-ARTEAGA, RUIZ-HERNANDEZ & LOBO-MARTINEZ, 1984).

In the old USSR, the existence of a strain variation of *C. bovis* was reported for the first time (ABULADZE, GIL'DENBLAT & BUSLAEVA, 1977). Subsequently, in western Siberia, and due to the increasing prevalence of *T. saginata* in humans, it was suggested that reindeer might be the intermediate host for this species (particularly as cattle do not constitute part of the diet in this region). However, *C. bovis* has not been found in reindeer, and consequently the identity of this *Taenia* remains in question (SERDYUKOV, 1979; MOZGOVOI, KOVAL'CHUK, GOSTEEV & SHAKHMATOVA, 1979).

In Spain, 9 cases of *T. saginata* are reported for every 1 of *T. solium* (SAIZ-MORENO, 1976). Surprisingly, the finding of *C. bovis* in cattle is exceptional, while the confiscation percentages due to swine cysticercosis are present in all provincial statistics in the country, reaching 2.3% in some instances (SAIZ-MORENO, 1976).

In Africa, and specifically in Nigeria (BELINO, 1975; SCHILLHORN VAN VEEN, 1979), Kenya (GINSBERG & GRIEVE, 1959) and Sudan (EL SADIK, 1979), there is a *T. saginata* strain whose cysticerci are found in the liver of cattle (BUCK, LAMBERTIN & BELONA, 1935). This strain was already related to those present in Taiwan and in the Phillipines. The presence of rudimentary hooks in the cysticerci may have obviously been overlooked, but it appears evident that the potential development of this African taeniid in alternative hosts remains to be studied (WOUTERS, BRANDT & GEERTS, 1987).

All these so far unexplained situations in different parts of the world could be related to two facts: a) the possibility that *T. asiatica* has a more extended geographical range than is now suspected, that is, not limited to Far East Asian boundaries (What could have impeded such a taeniid form using cosmopolitan intermediate and definitive hosts to colonize a larger geographical area?); b) the existence of other human taeniid forms (*T. asiatica*-like intermediate forms between *T. saginata* and *T. solium*) in other parts of the world.

It is evident that a general encouragement is today needed to obtain new data on these questions, and the appearance of a third taeniid species in the world arena can stimulate, worldwide, the beginning of more accurate scolex studies of adult and cysticercus stages both in human and pig infections respectively. Human taeniid adults usually remain unidentified at species level, as already noted, and cysticerci found in pig are usually directly ascribed to *T. solium* without scolex confirmation, simply taking specificity into account (*T. solium*/pig and *T. saginata*/cattle). Furthermore, one has to take into account that the cysticercus parasitised sites in pigs could depend upon the geographical region involved, animal race, host age, etc., as known in *C. bovis* (KERNEY, 1970); in other words, the possibility that the larval stage of *T. asiatica* could exhibit extrahepatic tropism outside the Asian regional context cannot *a priori* be discounted. The coexistence of high prevalences of swine cysticercosis and low prevalences of *T. solium* adult infection in man could be related to the presence of *T. asiatica* in given regions or *T. asiatica*-like taeniid form(s) in other areas. It should be remembered that the larval stage of *T. asiatica* usually presents hooks (FAN, 1988; EOM & RIM, 1993) (how many veterinarians, carrying out their daily activities, undertake hook measurements of the cysticercus scolex if the presence of hooks is verified?) and cross-reacts with a 100% specific immunodiagnostic assay for *T. solium* (PILCHER *et al.*, 1991); thus, the possibility that a number of cases of human cysticercosis immunologically diagnosed in different parts of the world may in fact be caused by *T. asiatica* or *T. asiatica*-like forms.

Undoubtedly, much remains to be done on human taeniids worldwide. Thus, any new elements which can encourage further studies at all levels in different parts of the world cannot be neglected. We must try to extend the atmosphere created in the Far East, thanks to the appearance of a third human teaniid, to other areas and encourage studies at all levels, beginning with serious morphoanatomical studies of the parasites following standardized methodologies (see MAS-COMA & GALAN-PUCHADES, 1991 for an example proposed for other Cyclophyllideans). Maintaining *T. asiatica* as a third human species, instead as a subspecies or strain of *T. saginata*, would clearly benefit such an aim.

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