An overview of cercariae from the Egyptian inland water snails

Wael M. Lotfy1*, Lamiaa M. Lotfy2, Refaat M. Khalifa3

1Department of Community Health Nursing, Faculty of Nursing, Alexandria University, Matrouh Branch, Marsa Matrouh, Egypt
2Graphics Department, Faculty of Fine Arts, Alexandria University, Alexandria, Egypt
3Parasitology Department, Faculty of Medicine, Assiut University, Assiut, Egypt

ARTICLE INFO

Article history:
Received 1 Nov 2017
Received in revised form 10 Nov 2017
Accepted 15 Nov 2017
Available online 20 Nov 2017

Keywords:
Digenean
Larva
Mollusca
Mollusc
Trematoda
Trematode

ABSTRACT

The study on trematode larvae found in Egyptian molluscs was initiated by the pioneering work of Sonsino in 1892 and Looss in 1896. Since then tens of cercariae and some digenean life cycles have been reported in the country. Unfortunately, only fragmentary publications are available for identification of cercariae present in the country. In addition, some of such publications may not be accessible to some researchers, as they are either theses or published in old volumes of non-international journals. The present work was carried out with the aim of preserving our heritage through reviewing the different types of cercariae known from the Egyptian inland water snails. We provide a survey based on literature. Major types of cercariae known to exist in the country are covered. They are presented as regards description, development, taxa, importance and snail hosts. This review can be used as a field guide for identification of cercariae colonising the Egyptian inland water snails.

1. Introduction

In digenetic trematodes, cercariae represent a juvenile stage of the vertebrate-inhabiting adult worms. In addition, the name cercaria can be used properly in a generic sense for a species in which the adult stage is unknown, as is done with the term cysticercus and microfilaria among some cestodes and nematodes, respectively[1,2]. Generally, the cercaria has an oval or elongated body, flattened in the dorsoventral plane, and a tail. An oral sucker is localized subterminally at the anterior extremity of the body. There may be also a ventral sucker which is located in the middle or posterior part of the body. In addition, there are digestive and proctonephridial excretory systems, different types of glands, genital primordium and sensory organs (external sensory papillae and eyespots). Morphology of the tail varies considerably in the different species. It may be considerably shortened or completely lost. The range of variation in cercarial morphology is considerable, and most have specializations that enable them to survive a brief free-living existence and make themselves available to next host[2,3].

A classification system has been created by Lühe in 1909 for grouping of cercariae into several types based on their morphological variations[4]. In this system, salient morphological characteristics are used for grouping cercariae into various major groups, and each major cercarial group may be divided into sub-groups on the basis of minor morphological differences. In this classification, Lühe recognized five major groups: lophocercariae, gasterostome, monostome, amphistome and distome cercariae[4]. The classification of Lühe was modified and supplemented by many subsequent workers. Probably the most complete version of this classification is available in the review by Dawes in 1946[5]. Species identification based on morphology of cercariae is usually difficult and unreliable. However, by using detailed morphological criteria alone, identification of cercariae to the family level, and occasionally to the genus level is possible[1].

In Egypt, since the pioneering work of Sonsino in 1892 and Looss in 1896 on the role of molluscs as intermediate hosts of digenetic trematodes[6,7], only fragmentary publications are available for identification of cercariae present in the country. In addition, some of such publications may not be accessible to some researchers. This is because they are either theses or published in old volumes of non-international journals. The present work was carried out with the aim of preserving our heritage through reviewing the different types of cercariae known from the Egyptian inland water snails.
We provide a survey based on literature. Major types of cercariae known to exist in the country are covered. They are presented as regards description, development, taxa, importance and snail hosts. Nomenclature of the different snail species was done according to Lotfy and Lotfy in 2015[8].

2. Monostome cercariae

2.1. Description

This type of cercariae is characterized by the absence of both the ventral sucker and pharynx; and by the presence of a simple tail, two or three pigmented eye spots, a pair of adhesive organs at the posterior extremity of the body, two excretory canals in body uniting near the eyes, and dense cystogenous glands (Figure 1). They are divided into two subtypes: ephemera cercariae which generally have three eyespots (triocellate) and urbanensis cercariae which, in most cases, have two eyespots (diocellate). Noteworthy, cercaria urbanensis itself is a species with three eyespots[1,5].

2.2. Development

This type of cercariae develops in a redia, which in turn arises from a miracidium without the intervention of a sporocyst stage. Monostome cercariae are born in an immature stage which completes development and encysts in the open[1,5].

2.3. Taxa

These cercariae are produced by species of the families Notocotylidae Lühe, 1909; Pronocephalidae Looss, 1899; Mesometridae Poche, 1926; and Microscaphidiidae Looss, 1900. The family Notocotylidae colonises the digestive tract, commonly the caeca, of birds and mammals[9]. The family Pronocephalidae occurs primarily in the intestines of marine and aquatic reptiles with a few species occurring in marine fishes[10]. The family Mesometridae is a small family of five genera, currently comprising seven species from the digestive tract of marine teleost fishes[11]. The family Microscaphidiidae inhabits the digestive tracts of marine and freshwater chelonians and teleosts[12].

2.4. Importance

The monostomes have no medical or veterinary importance[1, 5, 13].

2.5. Snail hosts

Only cercariae of the ephemera subtype were reported from the country in eight snail species:

1. Bellamya unicolor (B. unicolor) snails were reported to be infected with an unidentified species of this subtype[14].
2. Biomphalaria alexandrina (B. alexandrina) snails were reported to be infected with an unidentified species of this subtype[14,15].
3. Bithynia goryi [most probably Gabbiiella senaariensis (G. senaariensis)] snails were reported to be infected with an unidentified species of this subtype[16,17].
4. Cleopatra bulimoides (C. bulimoides) snails were reported to be infected with unidentified species of this subtype[14,18].
5. G. senaariensis snails were reported to be infected with Catatropis indicus (Notocotylidae) cercariae[19].
6. Melanoides tuberculata (M. tuberculata) snails were reported to be infected with Paramonostomum aegyptiacum (Notocotylidae) cercariae[20]. In addition, snails of the same species were reported to be infected with unidentified species of ephemera subtype[7,14,21,22].
7. Planorbis planorbis (P. planorbis) snails were reported to be infected with an unidentified species of this subtype[14].
8. Potamides conicus (P. conicus) snails were reported to be infected with an unidentified species of this subtype[23].

3. Gymnocephalous cercariae

3.1. Description

This type of cercariae is a form of the leptocercous cercariae which include also echinostome and stylet cercariae. The leptocercous type is characterized by a straight slender tail that is much narrower than the cercarial body (Figure 2). Also, the ventral sucker of leptocercous cercariae is situated on mid-ventral surface of the body[5]. The term “gymnocephalous” literally means “naked headed”; i.e. cercariae without ornamentation of body. The gymnocephalous cercariae are featured with having two almost equal suckers. Neither stylet nor spiny collar is present. Numerous cystogenous glands are present in the body[11].
3.3. Taxa

The gymnocephalous cercariae are produced by species of the family Fasciolidae (and some other families)[1].

3.4. Importance

Species of the family Fasciolidae have great veterinary importance[1].

3.5. Snail hosts

In Egypt, gymnocephalous cercariae are shed by nine species of freshwater snails:

1. B. alexandrina snails were reported to be infected with cercariae belonging to the genera Fasciola (Family Fasciolidae)[24,25], and Ribeiroia (Family Psilostomatidae)[26].
2. Bithynia sp. (most probably G. senaariensis) snails were reported to be naturally infected with an unidentified species of gymnocephalous cercariae[27].
3. C. bulimoides snails were reported to be naturally infected with cercariae belonging to the genus Philophthalmus (Family Philopthalmidae) [7,26,28-32]; Sphaeridiotrema szidati (Family Psilostomatidae) [33]; and unidentified gymnocephalous cercariae[31,34].
4. Galba truncatula snails were reported to be naturally infected with cercariae belonging to the genus Fasciola[25,35], and successful experimental infections with Fasciola hepatica (F. hepatica) and Fasciola gigantica (F. gigantica) were described[36-38].
5. Lanistes carinatus (L. carinatus) snails were reported to be naturally infected with unidentified species of gymnocephalous cercariae[16,39,40].
6. Lymnaea stagnalis (L. stagnalis) snails were reported to be naturally infected with cercariae belonging to the genus Fasciola[35].
7. M. tuberculata snails were reported to be naturally infected with unidentified species of gymnocephalous cercariae[18,27,31,34,41-43].
8. Pseudosuccinea columella (P. columella) snails were reported to be naturally infected with cercariae of F. gigantica[44-46].
9. Radix natalensis (R. natalensis) snails were reported to be naturally infected with cercariae belonging to the genus Fasciola[14,18,27,35,42,45,47-51]. Results of experimental infection confirmed the susceptibility of this snail species to be infected with F. gigantica[52] and F. hepatica[52,53]. It is worth mentioning that in 2008 Hussein and Khalifa reported failure to infect R. natalensis with F. hepatica[54]. In 2001, Lotfy et al. concluded that F. gigantica was better adapted to R. natalensis snails than F. hepatica. They added that although adult R. natalensis snails were refractory to experimental infection with F. hepatica, immature snails can be infected and the infection may proceed to maturity[52].

4. Echinostome cercariae

4.1. Description

This type belongs to the leptocercous cercariae[5]. The oral sucker without a stylet but is surrounded by a head collar which bears a row or two of collar spines around its margin, as in the adult forms of these parasites (Figure 3). The eyespots are absent. Numerous cystogenous glands are present in the body[1,5,13]. Some echinostome cercariae and especially those of the genus Echinostoma possess two types of glands, known as penetration and paraesophageal glands[55].

4.2. Development

The echinostome cercariae develop in rediae, and encyst in invertebrates (including snails) and/or vertebrates (including fishes and amphibians)[1,5,13].

4.3. Taxa

The echinostome cercariae are produced by species of the family Echinostomatidae which are intestinal parasites of fishes, reptiles, birds and mammals[1,5,13].

4.4. Importance

Some species of the family Echinostomatidae may have veterinary importance[1,5,13]. Echinostomes are antagonistic to the development of other trematodes in the same snail host[56-58]. Thus competing echinostome larvae might be used to control other trematodes[59]. It was suggested to use echinostomes in schistosomiasis endemic foci in Egypt to suppress the development of schistosomes[60]. Field studies confirmed that the prevalence of echinostome cercariae in any locality in Egypt is usually on the expense of Schistosoma cercariae[40].

4.5. Snail hosts

In Egypt, echinostome cercariae are shed by seven species of freshwater snails:
1. *B. alexandrina* snails were reported to be naturally infected with cercariae belonging to the genus *Echinoparyphium* [27]; *Echinostoma liei* [26, 61]; *Echinostoma revolutum* (Syn. *Echinoparyphium recurvatum*) [40]; *Nephrostomum ramosum* [63, 64]; and many unidentified species of echinostome cercariae [34, 40, 65-70]. Noteworthy, the species *Echinostoma liei* may be synonymous with *Echinostoma revolutum* [62].

2. *Bulinus truncatus* (*B. truncatus*) snails were reported to be naturally infected with cercariae of *Echinoparyphium bioccalerouxi* [27, 62]; *Echinoparyphium ralphaudyi* [71, 72]; *Echinostoma revolutum* [40]; *Echinostomum recurvatum* [6, 21, 26, 29-31, 40, 73-76] and many unidentified species of echinostome cercariae [34, 42, 60, 65, 66]. It is to be noted here that the species *Echinoparyphium bioccalerouxi* may be synonymous with *Echinostomum recurvatum* [27, 62].

3. *C. bulimoides* snails were reported to be naturally infected with unidentified species of echinostome cercariae [32].

4. *Haitia acuta* (*H. acuta*) snails were reported to be naturally infected with unidentified species of echinostome cercariae [42, 65].

5. *L. carinatus* snails were reported to be naturally infected with unidentified species of echinostome cercariae [31, 77].

6. *P. columella* snails were reported to be naturally infected with *Echinostoma caproni* and an unidentified species of echinostome cercariae [46].

7. *R. natalensis* snails were reported to be naturally infected with unidentified species of echinostome cercariae [48, 65].

5. **Stylet cercariae (Xiphidiocercariae)**

5.1. **Description**

This type of cercariae is a form of the leptocercous cercariae [5]. They are equipped with a stylet in the anterior margin of the oral sucker which is used in penetration of their next host. This type of cercariae is divided into four subtypes [1, 5, 13, 78]:

1) The ornatae cercariae (Figure 4) in which the tail is provided with a dorso-ventral finfold, the virgula organ is absent, and the ventral sucker is smaller than oral sucker.

2) The virgulate cercariae (Figure 5) in which the tail is without dorso-ventral finfold, a bilobed or pyriform virgula organ (contains mucoid secretions) is present in the region of the oral sucker, and the ventral sucker is smaller than the oral sucker.

3) The ubiquita cercariae (Figure 6) in which the tail is without dorso-ventral finfold, the virgula organ is absent, and the ventral sucker is vestigial or absent.

4) The armatae cercariae (Figure 7) in which the tail is without dorso-ventral finfold, the virgula organ is absent, and the oral and ventral suckers are of equal size or the ventral sucker is larger than the oral sucker.

However, Nasir in 1972 reviewed the classification of stylet cercariae, and commented that none of the different characters used have significant taxonomic value and that of the stylet cercariae should be left without subdivisions [79].

5.2. **Development**

They develop in sporocysts, and encyst in invertebrates, amphibians and reptiles. Sometimes they may encyst in sporocysts of other trematodes [1, 5, 13].
5.3. **Taxa**

The ornatae subtype is produced by the families Haematoloechidae and Macrodorididae. Haematoloechids are lung parasites of amphibians. Macrodorids are intestinal parasites of fishes and amphibians. The virgulate subtype is produced by species of the families Allassogonoporidae (Gyrabascidae), Lechitohendridae and Pleurogenidae. Allassogonoporidae are parasitised by bats and rodents (and experimentally in carnivores). Lechitohendridi are parasitised by bats, and occasionally birds. Pleurogenids are parasitised by amphibians and mammals. The ubiquita cercariae are produced by trematodes of the families Microphallidae and Eumegacetidae. Microphallids are intestinal parasites of most vertebrate classes, but mainly birds. Eumegacetidae are bird parasites. The armatae subtype is produced by species of the families Auristomidae, Cephalonogimidae, Haplotmetridae (Plagiorchiidae), Ochetosomatidae (Reniferidae), and Telorchidae. Auristomids are intestinal parasites of North American, European and African turtles. Cephalonogimids are parasitised by the gastro-intestinal tract of fishes, amphibians and reptiles. Haplotmetrids are intestinal parasites in all groups of vertebrates. Ochetosomatids are parasitised in Neartic and Neotropical snakes. Telorchids are intestinal parasites of reptiles and amphibians[1,5,13,78,80].

5.4. **Importance**

They have no medical or veterinary importance[1,5,13].

5.5. **Snail hosts**

In Egypt, different studies revealed the presence of different species of stylet cercariae in 12 species of freshwater snails:

1. *B. unicolor* snails were reported to be naturally infected with cercariae belonging to the genus *Eumegacete* (Family *Eumegactidaceae*)[81], and unidentified species of stylet cercariae[14,49,50,82].

2. *B. alexandrina* snails were reported to be naturally infected with cercariae of *Lepoderma ramlanum* (Family Plagiorchiidae)[83], and unidentified species of *stylet cercariae*[14,49,50].

3. *Bithynia* sp. (most probably *G. senaariensis*) snails were reported to be naturally infected with unidentified species of *stylet cercariae*[27].

4. *B. truncatus* snails were reported to be naturally infected with cercariae of *Lepoderma ramlanum*[15,21,72,76,83,84], and unidentified species of *stylet cercariae*[7,14,26,27,29-32,34,40,42,49,50,60,83,85-87].

5. *C. bulimoideas* snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14,15,21,26,29-32,34,40,49,50,82,83,86,88].

6. *H. acuta* snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14,49,50].

7. *L. carinatus* snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14-16,27,31,32,34,39,40,77,82,83,89].

8. *L. stagnalis* were reported to be naturally infected with an unidentified species of *stylet cercariae*[44].

9. *M. tuberculata* snails were reported to be naturally infected with cercariae that belong to the genus *Eumegacete*[81], *Lechitohendrium granulosum* (Family *Lechitohendridiidae*)[90,91], *Lechitohendrium pyramidum* (Family *Lechitohendridiidae*)[26,92], and unidentified species of *stylet cercariae*[14,15,21,22,26,31,32,34,40,41,43,49,50,83,89,90,93,94].

10. *Planorbella duryi* (*Helisoma duryi*) snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14].

11. *P. planorbis* snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14,49,50].

12. *R. natalensis* snails were reported to be naturally infected with unidentified species of *stylet cercariae*[14,15,27,30,31,34,44,48-51,83,86,95-97].

6. **Paramphistomoid cercariae**

6.1. **Description**

Paramphistomoid (syn. Paramphistome, and Amphistome) cercariae are amongst the largest known freshwater cercariae. They are featured with having a prominent body, a large ventral sucker that is situated at the posterior end of the body, a small unbranched tail, and globular masses of highly refractive material which fill the main excretory canals (Figure 8). The cercariae are present near the anterior end of the body[5]. This type of cercariae can be assigned to three subtypes: (1) Cercaria pigmentata which is pigmented and with anastomosed mediolateral branches of the ascending main excretory tubes, and usually without pharyngeal appendages; (2) Cercaria diplocotylea which is without pigmentation and mediolateral branches, usually with pharyngeal appendages, main excretory tubes either straight or convoluted; and (3) Cercaria intermedia which is with antero- and posterolateral diverticula of the main excretory tubes, with or without pigmentation, and with pharyngeal appendages[98].

6.2. **Development**

They develop in rediae, and are born in a relatively immature stage which complete development in the snail host tissues. They usually encyst on objects in water or in the skin of tadpoles[5,98].

6.3. **Taxa**

Paramphistomoid cercariae are relatively a homogenous group and all belong to the adults of the superfamily Paramphistomoidea. The majority of paramphistomoids are intestinal parasites. They are found in fishes, amphibians, reptiles, birds (one genus) and mammals, including man. They are more common in fresh- and brackish-water fishes than in marine fishes[99].

6.4. **Importance**

Paramphistomes of the pigmentata subtype are intestinal parasites of mammals, especially ruminants. Some species of them have great veterinary importance. Species of the diplocotylea and intermedia subtypes have no medical or veterinary importance[5,98].

6.5. **Snail hosts**

Several species of paramphistomoid cercariae were reported from four species of freshwater snails in Egypt:

1. *B. alexandrina* snails were reported to be naturally infected
with paramphistomoid cercariae which may be *Paramphistomum microbothrium* (*P. microbothrium*) (syn. *Calicophoron microbothrium*)[67,68,100].

2. *Bulinus forskalii* (*B. forskalii*) snails were reported to be naturally infected with *P. microbothrium*[6,101]. *Gastrodiscus aegyptiacus* (*G. aegyptiacus*) a parasite of equines and pigs, was reported from Egypt[7,102,103], *B. forskalii* has been reported as a snail host of *G. aegyptiacus* in other countries[104-107].

3. *B. truncatus* snails were reported to be naturally infected with *P. microbothrium*[6,15,72,101]. Infection with *Paramphistomum cervi* cercariae were reported by some authors[76,108,109], but these reports are doubtful because the presence of the species *Paramphistomum cervi* in Egypt is doubtful[95,110-112]. Many authors reported unidentified species of paramphistomoid cercariae from *B. truncatus* snails[21,26,29-31,34,40,42,49,50,60,95].

4. *C. bulimoides* snails were reported to be naturally infected with *Gastrodiscus aegyptiacus*[7]. The ability of the parasite to infect the snail was denied by several authors[107,113]. However, it was reported that *G. aegyptiacus* succeeded to infect *Cleopatra* sp. under experimental conditions in Zimbabwe[114]. Cercariae belonging to the genus *Megalodiscus* were isolated from the snail *C. bulimoides*[26,31]. Many authors reported unidentified species of paramphistomoid cercariae from *C. bulimoides* snails[21,26,34,42,88].

7. Furcocercous cercariae

7.1. Description

This type of cercaria is mainly characterised by a forked tail into which the body is not retractable. Some of the furcocercous cercariae may bear a pair of pigmented eyespots or may have a pharynx. The forked-tail may be either brevifurcate or longifurcate. Brevifurcate forked-tail is that in which the length of each of the furcal ramus is less than half the length of the main tail stem. Longifurcate forked-tail is that in which the furcal ramus is more than half the length of the main tail stem. The furcocercous type of cercariae is divided into five main subtypes[1,115]:

1) The lophocercous aphyryngeate cercariae (Figure 9): This subtype is featured with the presence of a brevifurcate tail, absence of the pharynx, the oral sucker is absent, the ventral sucker is vestigial or absent, and the eyespots are absent. Some species have a fin extending the full length of the body dorsal side. The penetration gland cells are of one type. The body is in the resting position above the tail.

2) The brevifurcate aphyryngeate monostome cercariae (Figure 10): This subtype is featured with the presence of a brevifurcate tail, absence of the pharynx, the oral sucker is present but the ventral sucker is absent. The penetration gland cells are of one type. The eyespots are sometimes present. The body finfold is present. The body is in the resting position below the tail.

3) The brevifurcate aphyryngeate distome cercariae (Figure 11): This subtype is featured with the presence of a brevifurcate tail, absence of the pharynx, and the presence of the oral and ventral suckers. Furcal finfolds and eyespots are sometimes present. The penetration gland cells are of two types.

4) The longifurcate pharyngeate monostome (Vivax) cercariae (Figure 12): This subtype is featured with the presence of a longifurcate tail, the presence of the pharynx, the presence of the oral sucker, but ventral sucker vestigial or absent. The penetration gland cells are of one type. The body finfold is absent but the furcal finfolds are sometimes present. The excretory pores are located at tips of furcae. The caudal bodies in tail-stem are absent.

---

Figure 9. Lophocercous aphyryngeate cercaria.
Figure 10. Brevifurcate aphyryngeate monostome cercaria.
Figure 11. Brevifurcate aphyryngeate distome cercaria.
Figure 12. Longifurcate pharyngeate monostome (Vivax) cercaria.
5) The longifurcate pharyngeate distome (Holostome or Strigid) cercariae (Figure 13): This subtype is featured with the presence of a longifurcate tail, the presence of the pharynx, and the oral and ventral suckers. The penetration gland cells are of one type. The body and furcal finfolds are absent. The excretory pores are located on sides of the furcae. Caudal bodies are present in the tail-stem.

Figure 13. Longifurcate pharyngeate distome (Holostome or Strigid) cercaria.

7.2. Development

Some genera develop in sporocysts and others in rediae. The cercariae may actively penetrate the definitive host without prior encystment (blood flukes) or they may encyst in vertebrates. The lophocercous apharyngeate type develops in sporocysts, and does not encyst but actively penetrates the definitive host. The brevifurcate apharyngeate monostome type develops in rediae and encysts in fishes. The brevifurcate apharyngeate distome type develops in sporocysts, and penetrates the definitive host directly. The longifurcate pharyngeate monostome type develops in sporocysts, and encysts in fishes. The longifurcate pharyngeate distome type develop in sporocysts and encysts in snails, tadpoles, reptiles and fishes[1,115].

7.3. Taxa

The lophocercous apharyngeate type is produced by species of the family Sanguinicolidae (blood parasites of fishes). The brevifurcate apharyngeate monostome type is produced by species of the family Clinostomatidae which are parasites in the mouth and oesophagus of birds. The brevifurcate apharyngeate distome type is produced by species of the families Spirochiidae which are blood parasites of reptiles and Schistosomatidae which are blood parasites of birds and mammals[1,115].

7.4. Importance

Some species of the family Sanguinicolidae may have some veterinary importance. Species of the family Schistosomatidae have great medical and veterinary importance. The brevifurcate apharyngeate monostome, the longifurcate pharyngeate distome type, and the longifurcate pharyngeate monostome type have no medical or veterinary importance[1,115].

7.5. Snail hosts

Several species of furcocercous cercariae were reported from 10 species of freshwater snails in Egypt:

1. *B. unicolor* snails were reported to be naturally infected with unidentified species of furcocercous cercariae[14].
2. *B. alexandrina* snails were reported to be naturally infected with *Apharyngostrigea ibis*[64,116], (maybe) *Bilharziella polonica* (*B. polonica*)[117], *Schistosoma mansoni*[14,27,31,32,42,64,67,68,70,87,117-119], and unidentified species of furcocercous cercariae[15,21,31,32,40,64,67,68,87,117,120].
3. *Atyopsis sp.* (most probably *G. senaariensis*) snails were reported to be naturally infected with unidentified species of furcocercous cercariae[117].
4. *B. forskalii* snails were reported to be naturally infected with an unidentified species of (schistosome) furcocercous cercariae[109,121].
5. *B. truncatus* snails were reported to be naturally infected with *Cynodiplostomum azimi*[15,72,122], *Schistosoma haematobium* cercariae[27,32,34,40,60,76,85,87,109,118,123], and unidentified species of furcocercous cercariae[21,26,31,34,40,60,76,85,95,109,124].
6. *C. bulimoides* snails were reported to be naturally infected with cercariae of the genus *Cardicola*[26,31,32], and *Prohemistomum vivax*[6,15,16,125,126], and unidentified species of furcocercous cercariae[14,18,26,31,32,40,88,89,120,127,128].
7. *Gyraulus ehrenbergi* snails were reported to be naturally infected with cercariae similar to those of *B. polonica*[117].
8. *M. tuberculata* snails were reported to be naturally infected with furcocercous cercariae similar to those of *B. polonica*[117].
9. *P. planorbis* snails were reported to be naturally infected with unidentified species of furcocercous cercariae[14].
10. *R. natalensis* snails were reported to be naturally infected with unidentified species of furcocercous cercariae[31,42].

8. Opisthorchioid cercariae

8.1. Description

This type of cercariae has unforked tail with well-developed
dorso-ventral finfolds (Figure 14). The ventral sucker is vestigial or absent, eyespots are present, adhesive organs at posterior end of the body are absent, and cystogenous glands in body are few in number\[1,5,13\]. The opisthorchioid cercariae are subdivided into two subtypes; parapleurolophocercous and pleurolophocercous cercariae. Some authors do believe that parapleurolophocercous and pleurolophocercous cercariae are synonymous which is not correct[15]. The tail of the pleurolophocercous cercaria is provided with only dorso-ventral finfolds. When the tail shows additional lateral finfolds, the cercaria is called parapleurolophocercous[131,132].

8.2. Development

They develop in rediae mostly in prosobranch snails and encyst in fishes and amphibians. Adult flukes of most species are parasitic in the liver, bile-ducts and gall-bladder of birds and mammals, with some species found in the digestive tracts of reptiles and teleosts[1,5,13,80].

8.3. Taxa

Generally, opisthorchioid cercariae are produced by species in the superfamily Opisthorchioidea. The families Cryptogonimidae and Opisthorchiidae produce pleurolophocercous cercariae. Parapleurolophocercous and pleurolophocercous cercariae have been reported for the family Heterophyidae[1,5,13,80].

8.4. Importance

Some species of the families Heterophyidae and Opisthorchiidae have great medical importance e.g. Heterophyes heterophyes (H. heterophyes) (Family Heterophyidae), and Clonorchis sinensis, Opisthorchis viverrini and Opisthorchis felineus (Family Opisthorchiidae)[1,5,13,133].

8.5. Snail hosts

In Egypt, known cercariae of this group are shed from four species of inland water snails:

1. P. conicus snails were reported to be naturally infected with cercariae of Heterophyes aequalis, Heterophyes dispar and H. heterophyes[134-138]. Also, this snail was reported to act as the intermediate host of Stictodora sawakinensis[136-138] and unidentified species of the genus Stictodora (Family Heterophyidae) [23,139-141],

2. C. bulimoides snails were reported to be infected with cercariae of the genus Centrocestus (Family Heterophyidae)[26,31,40], Haplorchoides cahirinus (Family Heterophyidae)[26,142], and several unidentified species of this type of cercariae[31,88].

3. M. tuberculata snails were reported to be naturally infected with cercariae of Centrocestus aswanensis (Family Heterophyidae)[143], Centrocestus unequiorchalis[144,145], Haplorchis pumilio (H. pumilio) (Family Heterophyidae)[16,26,40,89,90,146-151], and Haplorchis yokogawai[26,149,152]. It is worth mentioning that in addition to H. pumilio and Haplorchis yokogawai, other two species Haplorchis pleurolophocerca and Haplorchis taichui were reported from Egypt. M. tuberculata may be the snail host of these species[153]. M. tuberculata snails were reported to be naturally infected with cercariae of Pygidopsis genata[6,7,154], Stellantchasmus falcatus (Heterophyidae)[155], and cercariae belonging to the genus Stictodora[26,29,30,149,156]. Also, this snail was reported to act as the intermediate host of several unidentified species of opisthorchioid cercariae[15,21,22,31,41,157]. Noteworthy, it was mentioned in some literature that H. heterophyes is transmitted by this snail[158]. However, this information is doubtful and needs to be confirmed by some studies.

4. R. natalensis snails were reported to be infected with opisthorchioid cercariae[16], which were identified as H. pumilio[151]. Except for this report opisthorchioid cercariae are known only from prosobranch snails[78].

9. Cystophorous cercariae

9.1. Description

The tail of this type of cercariae is large (Figure 15), and has a chamber (caudal cyst), at the anterior end, into which the cercarial body may withdraw[78,159].

9.2. Development

This type of cercariae develop in rediae (rarely daughter-sporocysts). The metacercariae are found in aquatic organisms. The definitive hosts acquire the infection by feeding[80,160].

9.3. Taxa

They are produced by trematodes in the families Gorgoderidae and Hemiuridae, and possibly other families[27,78,159].
9.4. Importance

Gorgoderids are parasites of amphibians, fishes and reptiles. Many species inhabit the urinary bladder of their hosts but, more rarely, other locations, such as the swim-bladder, coelom (elasmobranchs), gall-bladder or intestine, are utilized[80]. Hemiurids are usually parasitic in gut or associated organs of fishes, occasionally amphibians, rarely reptiles[160].

9.5. Snail hosts

There is only one report describing the presence of an unidentified species of cystophorous cercariae in B. alexandrina[27].

10. Unknown rare types

In addition to the above mentioned Egyptian types of cercariae, there are some strange rare forms well documented in the literature[90,161,162]. Such forms could not be assigned to any of the known types.

11. Conclusion

Cercariae were described in the literature from 18 species of inland water snails (eight prosobranchs and 10 pulmonates) from Egypt. B. unicolor snails were reported to be infected with monostome, stylet and furcocercous cercariae. B. alexandrina snails were reported to be infected with monostome, gyrocochanothecarian, echinostome, stylet, paramphistomoid, furcocercous and cystophorous cercariae. Bithynia sp. (most probably G. senaariensis) snails were reported to be infected with monostome, gyrocochanothecarian, echinostome, stylet and furcocercous cercariae. B. forskali snails were reported to be infected with paramphistomoid and furcocercous cercariae. B. truncatus snails were reported to be infected with echinostome, stylet, paramphistomoid and furcocercous cercariae. C. bulmoides snails were reported to be infected with monostome, gyrocochanothecarian, echinostome, stylet, paramphistomoid, furcocercous, and opisthorchioid cercariae. G. senaariensis snails were reported to be infected with monostome cercariae. Galba truncatula snails were reported to be infected with gyrocochanothecarian cercariae. Gyraulus ehrenbergi snails were reported to be infected with furcocercous cercariae. H. acuta snails were reported to be infected with echinostome and stylet cercariae. L. carinatus snails were reported to be infected with gyrocochanothecarian, echinostome and stylet cercariae. L. stagnalis snails were reported to be infected with gyrocochanothecarian and stylet cercariae. M. tuberculata snails were reported to be infected with monostome, gyrocochanothecarian, stylet, furcocercous and opisthorchioid cercariae. Planorbella duryi snails were reported to be infected with stylet cercariae. P. planorbis snails were reported to be infected with monostome and gyrocochanothecarian cercariae. P. conicus snails were reported to be infected with monostome and opisthorchioid cercariae. P. columella snails were reported to be infected with gyrocochanothecarian and echinostome cercariae. R. natalensis snails were reported to be infected with gyrocochanothecarian, echinostome, stylet, furcocercous and opisthorchioid cercariae.

Freshwater pulmonates seem to be better hosts for trematode larvae compared to prosobranchs, because of their explorative behaviour and great tolerance to water and oxygen deficit[163,164].

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

The authors would like to gratefully acknowledge with many thanks the support of Prof. Hoda F. Farag (Medical Research Institute, Alexandria University), Prof. Karam I. Ashmawy (Faculty of Veterinary Medicine, Alexandria University), Prof. Faiza M. El-Assal (Faculty of Science, Cairo University), Prof. Saad A. Noor El-Din (Faculty of Science, Tanta University), Dr. Shawky M. Aboel-Hadid (Faculty of Veterinary Medicine, Beni Suef University). The authors acknowledge, also, colleagues whose work has been cited in compiling this review.

References

[1] Frandsen F, Christensen NO. An introductory guide to the identification of cercariae from African freshwater snails with special reference to cercariae of trematode species of medical and veterinary importance. Acta Trop 1984; 41(2): 181-202.
[2] Schmidt GD, Roberts LS. Trematoda: form, function, and classification of digeneans. Foundations of parasitology. 8th ed. Dubuque: Mcgraw-Hill Higher Education; 2009, p. 219-45.
[3] Galaktionov KV, Dobrovolskij A. The biology and evolution of trematodes: an essay on the biology, morphology, life cycles, transmissions, and evolution of digenetic trematodes. Dordrecht: Springer; 2003.
[4] Luhe M. Parasitische Plattwürmer. I: Trematodes. Jena: Verlag von Gustav Fischer; 1909.
[5] Dawes B. The Trematoda, with special reference to British and other European forms. Cambridge: Cambridge University Press; 1946.
[6] Sinoso P. [Studies on the parasites of freshwater molluscs in the vicinity of Cairo in Egypt]. In: Festschrift zum siebenzigsten Geburtstage R. Leuckarts. Leipzig, Germany; Wilhelm Engelmann; 1892. Italian.
[7] Looss A. [A research on the parasitic fauna of Egypt]. Mém Inst Égypt 1896; 3: 1-252. French.
[8] Lotfy WM, Lotfy LM. Synopsis of the Egyptian freshwater snail fauna. Folia Malacol 2015; 23(1): 19-40.
[9] Barton DP, Blair D. Family Notocotylidae Lüh, 1909. In: Jones A, Bray RA, Gibson GI, editors. Keys to the Trematoda. Vol. 2. New York: CABI Publishing and the Natural History Museum; 2005, p. 383-96.
[10] Blair D. Family Pronocephalidae Looss, 1899. In: Jones A, Bray RA, Gibson GI, editors. Keys to the Trematoda. Vol. 2. New York: CABI Publishing and the Natural History Museum; 2005, p. 361-80.
[11] Jones A, Blair D. Family Mesometridae Poche, 1926. In: Jones A, Bray RA, Gibson GI, editors. Keys to the Trematoda. Vol. 2. New York: CABI Publishing and the Natural History Museum; 2005, p. 213-9.
[12] Blair D. Family Microscaphidiidae Looss, 1900. In: Jones A, Bray RA, Gibson GI, editors. Keys to the Trematoda. Vol. 2. New York: CABI Publishing and the Natural History Museum; 2005, p. 193-211.
[13] Olsen OW. Animal parasites: their life cycles and ecology. 3rd ed.
Kafr El-Sheikh Governorate with special reference to species infecting humans. *Vet Med J* 1997; 45: 187-209.

[50] El-Bahy MM, Mahgoub MMA, Taher EE. Contributions on human fascioliasis and its snail intermediate host in Nile Delta, Egypt. *Int J Basic Appl Sci* 2014; 3(3): 172-9.

[51] Hussein AA, Califa RMA, Mas-Coma S. Trematode larval stages infecting *Radix natans* (Gastropoda: Lymnaeidae) in Qena Governorate, Egypt, with special reference to fascioliid cercariae. *Rev Iber Parasitol* 2006; 66(1-4): 69-74.

[52] Lotfy WM, El-Morshed NY, Abou El-Hoda M, Hussein AN, Khalifa RM. Experimental infections with *Dar Y*, Djuikwo TF, Vignoles P, Dreyfuss G, Rondelaud D. *Joe LK, Basch PF, Umathevy T. Antagonism between two species of* Echinostomatidae (Trematoda).

[53] Dar Y, Djuikwo TF, Vignoles P, Dreyfuss G, Rondelaud D. *Radix natans* (Gastropoda: Lymnaeidae), a potential intermediate host of Fasciola hepatica in Egypt. *Parasitology 2010*; 17(3): 251-6.

[54] Hussein AN, Khalifa RM. Experimental infections with *Fasciola* in snails, mice and rabbits. *Parasitol Res* 2008; 107(6): 1165-70.

[55] Fried B, Graczyk TK. *Echinostomes as experimental models for biological research*. Netherlands: Springer Science+Business Media Dordrecht; 2000.

[56] Joe LK, Basch PF, Umathey T. Antagonism between two species of larval trematodes on the snail. *Nature 1965*; 260(982): 422-3.

[57] Joe LK, Umathey T. Studies on Echinostomatidae (Trematoda) in Malaya. XII. Antagonism between two species of echinostome trematodes in the same lymnaeid snail. *J Parasitol 1966*; 52(3): 454-7.

[58] Lie KJ, Basch PF, Hoffman MA. Antagonism between *Parophocotyle segregatum* and *Echinostoma barbouri* in the snail *Biomphalaria straminea*. *J Parasitol 1967*; 53: 1205-9.

[59] Lie KJ, Basch PF, Heyneman D, Beck AJ, Audy JR. Implications for trematode control of interspecific larval antagonism within snail hosts. *Trans R Soc Trop Med Hyg 1968*; 62(3): 299-319.

[60] Chu KY, Dawood IK, Nabi HA. Seasonal abundance of trematode cercariae in *Bulinus truncatus* in a small focus of schistosomiasis in the Nile Delta. *Bull World Health Organ 1972*; 47(3): 420-2.

[61] Jeyarasasingum U, Heyneman D, Lim H, Mansour N. Life cycle of a new echinostome from Egypt, *Echinostoma liyi* sp. nov. (Trematoda: Echinostomatidae). *Parasitology 1972*; 65(2): 203-22.

[62] Rysavy B, Ergens R, Groschaft J, Moravec F, Yousif F, El Hassan AA. Preliminary report on the possibility of utilizing competition of larval schistosomes and other larval trematodes in the intermediate hosts for the biological control of schistosomiasis. *Folia Parasitol (Praha) 1973*; 20(4): 293-6.

[63] Abdel-Azim M. XII. On the life-history of *Nephotrematostomum ramosum* Sonsino, 1895. An Echinostome parasite from Ardeola ibis ibis (buff-backed heron). *Ann Mag Nat Hist 1934*; 14(79): 154-7.

[64] El-Gindy MS. Larval trematodes found in planorbid snails in Egypt (U.A.R.). *J Egypt Med Assoc 1961*; 44: 382-93.

[65] Abdel-Ghani AF. The role played by some vectors from field in transmission of echinostomes in Egypt. *J Egypt Med Vet Assoc 1974*; 34(3/4): 249-65.

[66] Fayek AS, Nada MS. On *Echinostoma* species from Sharkia Governorate. *J Egypt Vet Med Assoc* 1985; 45(1): 293-301.

[67] Allam AFM. A study on the trematode parasites in *Biomphalaria alexandrina* [dissertation]. Alexandria: High Institute of Public Health, Alexandria University; 1988.

[68] Abou Bassa LM, Salem A, Allam AF, Loutfy NF, Bassioni HK. Study on the morphology and identification of the various trematode infections detected in *Biomphalaria alexandrina* in the vicinity of Alexandria. *J Med Res Inst 1989*; 10(2): 1-17.

[69] Mandour A, Khalifa R, El-Saied M, Saad AI. *Cercaria aswani* sp. nov. recovered from *Biomphalaria alexandrina* inhabiting the River Nile in front of the High Dam. *Assia Vet Med J* 1991; 26(51): 161-8.

[70] Hussein AA, Rabie SA. *Schistosoma mansoni* and trematode larval stages in *Biomphalaria alexandrina* in Qena Governorate, Egypt. *J Egypt Ger Soc Zool 2007*; 53(1): 1-15.

[71] Lie KJ, Heyneman D, Jeyarasasingum U, Mansour N, Lee HF, Lee H, et al. The life cycle of *Echinoperpyium ralhaupe* sp. n. (Trematoda: Echinostomatidae). *J Parasitol 1975*; 61(1): 59-65.

[72] Mansour NS, Soliman GN, El-Assal FM. Some cercariae liberated from *Bulinus truncatus* snails intermediate host of *Schistosoma haematobium* in Egypt. *Bull Fac Sci Cairo Univ 1977*; 50: 99-118.

[73] Khalil M, Abaza MS. A new trematode parasite of the rat, *Echinostoma aegyptiacata*, nov.sp. *Rep Pub Health Lab Cairo 1924*; 6: 187-9.

[74] Abdel-Azim M. On the identification and life history of *Echinostoma revurcuratum* von Linstow, 1873. *Ann Trop Med Parasitol 1930*; 24: 189-92.

[75] Kurtz RE. Development of the cercariae of *Echinoperpyium revcurvatum* (Linstow, 1873) Luhe, 1909, with emphasis on excretory system. *Thyap Commenor 1953*; 149-58.

[76] El-Gindy MS, Rushdi MS, editors. The variability in morphology and anatomy of the bulinid snails in Egypt, with special reference to their transmission of *Schistosoma haematobium*. Ciba Foundation Symposium on Bilharziasis March 18-22, 1962; Cairo, Egypt: J. & A. Churchill Ltd.

[77] El-Bahy MM. Parasitological aspects of *Lanistes carinatus* (Olivier, 1804, Cyclostoma) snails and their role in transmission of parasitic diseases to animal and man. *Assiat Vet Med J 1998*; 38(76): 282-306.

[78] Schell SC. *Handbook of trematodes of North America north of Mexico*. Moscow; University Press of Idaho; 1985.

[79] Nasir P. Some aspects of xiphidiocercarial classification. *Zool An*; 1972; 189(5/6): 382-92.

[80] Bray RA, Gibson DI, Jones A. *Keys to the Trematoda*. Vol. 3. New York: CABI Publishing and the Natural History Museum; 2008.

[81] Sakla AA, Khalifa R. Studies on cercariae from *Melania tuberculata* snail in Assiat Governorate. 1. On a cercaria belonging to *Eumegacetes sp.* *Assiat Vet Med J 1983*; 10(20): 67-72.

[82] Yousif F, Ibrahim A. Four new xiphidiocercariae from freshwater prosobranches in *Egypt. J Egypt Soc Parasitol 1979*; 9(2): 411-9.

[83] Wanas MQ, Abou-Senna FM, El-Deen A, Al-Shareef AMF. Studies on larval digenetic trematodes of xiphidiocercariae from some Egyptian fresh water snails. *J Egypt Soc Parasitol 1993*; 23(3): 829-50.

[84] Abdel-Azim M. On the life history of *Lepodirnna ramalianum* Looss, 1896, and its development from a xiphidiocercaria. *J Parasitol 1935*; 21(5): 365-8.

[85] Mansoon-Bahr P, Fairley NH. Observations on bilharziasis amongst the Egyptian expeditonary force. *Parasitology 1920*; 12(1): 33-71.

[86] Saad AI, Khalifa R, Maher N. Studies on some freshwater cercariae from Aswan - Egypt; part 2. J *Egypt Ger Soc Zool* 1997; 23(3): 121-38.

[87] Aboelhadid SM, Thabet M, El-Basal D, Taha R. Digeneric larvae in schistosome snails from El Fayoum, Egypt with detection of *Schistosoma mansoni* in the snail by PCR. *J Parasit Dis 2014*; doi: 10.1007/s12639-014-0567-7.
Looss A. [Further comments on the names of the distomid genera I have suggested]. Zool Anz 1900; 23: 601-8. German.

Khalifa R. Studies on cercariae from fresh water snails in Assiut Governorate. 1. Cercaria stefanskii sp. nov., a vivax cercaria from Cleopatra cyclostomoides, with a redescription of Cercaria vivax Sonsino, 1892. J Egypt Soc Parasitol 1975; 4-5: 139-46.

Fahmy MAM, Mandour AM, Arafah MS, Omran LAM. Lotfy WM. Chontananarth T, Wongsawad C. Epidemiology of cercarial stage of Kuntz RE. Experimental studies on the biology of Khalil M. The life history of the human trematode parasite Taraschewski H, Paperna I. Trematode infections in Taraschewski H. Investigations on the prevalence of Looss, 1902 in Egypt. Mar Ecol Prog Ser Saad AIA. Life cycle of Helminthologia 1997; 34(2): 113-7.

Khalil M. The life history of a heterophyid parasite in Egypt. C R Cong Int Méd Trop Hyg 1932; 4: 137-47.

Khalifa R, El-Naffar MK, Arafah MS. Studies on heterophyid cercariae from Assiut Province, Egypt. 1. Notes on the life cycle of Haplorchis pumilio Looss, with discussion on previous described species. Acta Parasitol Pol 1977; 25(3): 25-38.

Al-Shareef AMF. Biological studies on some larval helminths associated with some fresh and brackish water snails in Egypt [dissertation]. Cairo: Faculty of Science, Al-Azhar University; 1988.

Khalila R, El-Nazer M, Sayed FG, Monib ME, Hassan AA. Studies on parapleurophocercous cercariae from Melanipara tuberculata in Assiut, Egypt J Med Sci 1994; 15(2): 573-83.

Saad AIA, Abed GH. Studies on the life cycle of Haplorchis pumilio (Looss, 1896) Looss, 1899 with morphological redescription of larval and adult stages. J Egypt Soc Parasitol 1995; 25(3): 795-806.

Noor El-Din SA, El-Sheikh H, Taima AA. Redescription of reida and cercaria of Haplorchis pumilio (Digenea: Heterophyidae) from Melanipara tuberculata and Radix natalensis snails collected from El-Beheira Governorate; Egypt. Proceedings of the 5th International Conference of Biological Sciences (Zoology) 2008: 197-203.

Fahmy MAM, Khalila R, Makhlouf LM. Studies on heterohedy cercariae from Assiut Province. 2. The life cycle of Haplorchis yokogawai Katsuta, 1936 Trematoda: Heterophyidae. Assiut Vet Med J 1986; 16(31): 119-32.

Chai JY. 2. Intestinal Flukes. In: Murrell KD, Fried B, editors. World class parasites: food-borne parasitic zoonoses: fish and plant-borne parasites. New York: Springer; 2007.p. 53-115.

Youssef MM, Mansour NS, Hammouda NH, Awadalla HN, Khalifa R, Boulos LM. Studies on some developmental stages in the life cycle of Pygidioptosis genata Looss, 1907 (Trematoda: Heterophyidae) from Egypt. J Egypt Soc Parasitol 1987; 17(2): 463-74.

Boulos LM, Abu Samra LM. Studies on some of the developmental stages in the life cycle of Stellantchasmus falcatus (Trematoda: Heterophyidae) in Egypt. J Egypt Soc Parasitol 1985; 15(2): 397-402.

Gabr NS. A study on a heterohedy cercaria belonging to genus Stictodora: El-Minia Governorate. EL-Minia Med Bull 1991; 2(2): 26-34.

Mansour NS, Soliman GN, El-Assal FM. A heterophyid cercaria from Melanipara tuberculata from Egypt. Bull Fac Sci Cairo Univ 1978; 51(1): 13-21.

Pinto HA, de Melo AL. A checklist of trematodes (Platyhelminthes) transmitted by Melanoides tuberculata (Mollusca: Thiaridae). Zootaxa 2011; 2799: 15-28.

Dawes B. The Trematoda with special reference to British and other European forms. Cambridge: Cambridge University Press; 1946.

Gibson DL, Jones A, Bray RA. Keys to the Trematoda. Vol. 1. New York: CABi Publishing and the Natural History Museum; 2002.

Demian ES, Yousif F, Rifaa MA. Contributions to the study of the larval trematodes found in the brackish-water snail Pireneula conica. Bull Zool Soc Egypt 1963; 18: 31-41.

Yousif F: A huge-tailed cercaria from the brackish-water snail Pireneula conica (Blainville). Bull Zool Soc Egypt 1968-1969: 22: 8-11.

Marshall DJ, McQuaid CD. Metabolic rate depression in a marine pulmonate snail: pre-adaptation for a terrestrial existence? Oecologia 1991; 88: 274-6.

Cichy A, Faltytynova A, Bikowska E. Cercariae (Trematoda, Digenea) in European freshwater snails – a checklist of records from over one hundred years. Folia Malacol 2011; 19(3): 165-89.