

## Ascariasis, a review

Markus Schindler-Piontek<sup>1</sup>, Nitin Chaubal<sup>2</sup>, Sirine Dehmani<sup>3</sup>, Xin Wu Cui<sup>4</sup>, Yi Dong<sup>5</sup>, Malay Sharma<sup>6,7</sup>, Christoph F Dietrich<sup>3</sup>

<sup>1</sup>Emergency Department, University Medical Center Mannheim, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany, <sup>2</sup>Thane Ultrasound Centre, Thane, India, <sup>3</sup>Department Allgemeine Innere Medizin (DAIM), Kliniken Hirslanden, Beau Site, Salem und Permanence, Bern, Switzerland, <sup>4</sup>Department of Medical Ultrasound, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, <sup>5</sup>Department of Ultrasound, Zhongshan Hospital, Fudan University, Shanghai, China, <sup>6</sup>Jaypee Hospital Noida, India, <sup>7</sup>Jaswantra Speciality Hospital Meerut, India

### Abstract

Ascariasis no longer widespread within Europe and so experience in diagnosis and treatment is limited for many specialists. On the other hand, clinicians face increasing numbers of migrants from high prevalence countries and are therefore, challenged to update in this field of infectious diseases. Here we present imaging features and current knowledge of this infection.

**Keywords:** ascariasis; epidemiology; diagnosis; treatment; prevention

### Introduction

In Europe, ascariasis is no longer widespread; therefore doctors may have little or no experience with ascariasis case management. On the other hand, increasing numbers of immigrants from high prevalence countries challenge clinicians to remain updated in infectious diseases. Our working group has summarized the imaging features of parasitic diseases, including hydatid cysts [1-6], schistosomiasis [7,8], fascioliasis [9] and other important intestinal diseases reported rarely in Europe which may mimic parasitic diseases [10-14]. Here we present the current knowledge and imaging of ascaris infection including clinical features and hot topics in ascariasis.

### The parasite

Ascariasis is caused by infection with parasites of the genus *Ascaris* (*A.*). There are two species that can infect

humans; *A. lumbricoides* and *A. suum*. These nematodes are the longest roundworms to parasitize the human intestinal tract; the female ranging from 20-35 cm and the male 15-25 cm [15]. It is noteworthy that Ascariasis infection has been a worldwide plague of mankind for a very long time. *Ascaris* eggs have been identified in archeological coprolites in the Americas, Europe, Africa, the Middle East, and New Zealand, dating back more than 24,000 years [16,17].

#### *Ascaris lumbricoides* and *Ascaris suum*

*A. lumbricoides* and *A. suum* are genetically and morphologically very closely related species, with humans serving as the primary host to *A. lumbricoides* and pigs as the primary host to *A. suum*. Both the spp have a close affinity and there are documented infections of humans by *A. suum* and vice versa [15]. *A. suum* infects humans, possibly through two courses of the infection. Larvae may migrate uncoordinatedly through the host organs, potentially causing considerable damage (see visceral larva migrans below) or complete their natural reproductive cycle and develop into mature nematodes.

The complete developmental cycle of *A. suum* in humans was initially described by Takata 1951 in Japan, who purposely infected humans with *A. suum* ova and recorded the symptoms and prepatency time [18]. Understandably, this experiment has not been repeated, as the

Received 30.04.2021 Accepted 23.06.2021

Med Ultrason

2022, Vol. 24, No 3, 329-338

Corresponding author: Prof. Christoph F. Dietrich

Department Allgemeine Innere Medizin (DAIM),

Kliniken Hirslanden Beau Site,

Salem und Permanence, Bern, Switzerland

Phone: +41798347180

E-mail: c.f.dietrich@googlemail.com

risk of severely harmful and potentially deadly parasitosis caused by viscerally migrating *A. suum* larvae renders such endeavors unethical. There are difficulties in differentiating the adult worms [19] and even more the ova [20,21] of *A. suum* and *A. lumbricoides* and there has been a lack of studies in this field for decades. It is virtually impossible to distinguish the ova of the two species by morphology; though by electron microscopy, it becomes attainable albeit with difficulties. Advances in molecular biology have allowed more recent studies to further elucidate the subject. Zhou et al collected 258 ascariis nematodes; 137 parasites from 92 human hosts collected from the faeces of patients undergoing anti-helminthic treatment and 121 parasites from 82 pig hosts obtained from an abattoir. It was found that 14%, corresponding to 19 of the total 137 human derived parasites, were of pure-bred pig origin [22]. A similar study conducted two years earlier in Japan found 30%, corresponding to three of the total nine adult nematodes parasitizing the human intestines, to be of pig origin [23]. Despite documented cross infections in both directions, there is some evidence of a higher affinity of *A. lumbricoides* to its conventional host, than those of *A. suum* [21,22]. There are also indications that a significantly higher number of parasites may be needed in order to introduce a viable infection in the case of host infidelity, especially for *A. lumbricoides* to infect a porcine host [20,24]. Finally, *A. suum* and *A. lumbricoides* are able to interbreed creating hybrids [22,25,26]. The host infidelity, overwhelming genetic and macroscopic similarities, and the capacity to interbreed have led to debates regarding whether or not *A. lumbricoides* and *A. suum* can be considered separate species [22,27-31]. The most widely accepted definition of a species includes the ability of the members to procreate fertile offspring. Some studies, however suggest that hybrids of *A. suum* and *A. lumbricoides* have a considerably decreased fertility [25]. Further research is needed to clarify these issues.

#### **Endemic high prevalence areas**

An extraordinarily high prevalence is reported in both Kashmir, India [32,33] and Colombia, ranging from 25 to 90 percent [34]. Ascariasis prevalence is the highest in tropical countries where warm, wet climates favor transmission the whole year through. In dry areas, transmission predominantly occurs during the rainy months. Ascariasis occurs most commonly in areas of suboptimal sanitation practices, associated with faecal contamination of soil, water and food.

#### **Epidemiology of human *Ascaris suum***

Human infections with *A. suum* were considered to be rare and coincidental, albeit possible in principle. Nevertheless, pig husbandry and the use of pig faeces for

fertilizer have been associated with a growing number of human infections, particularly in temperate regions of developed countries. *A. suum* infections have been reported in Americas, Asia and Europe [22,27,28,31]. In high-income industrial countries, high sanitation standards for human waste disposal have diminished contact and consequently the number of human *A. lumbricoides* cases. Consequently, ascariasis infections contracted in these areas are more likely to be due to *A. suum* than due to *A. lumbricoides*. Further, as the two ascariis species are hard to differentiate, under-reporting of human *A. suum* cases is highly likely, particularly in endemic areas where pigs are raised [29,30].

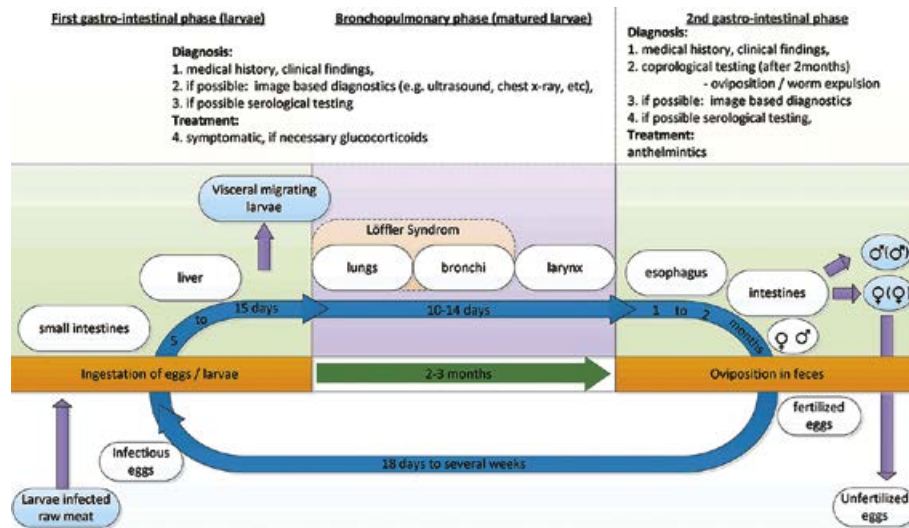
#### **Pathogenesis and pathophysiology**

Ascaris belong to the group of soil-transmitted helminthes (STH), the so-called geohelminths, which have common features in their natural reproduction cycle. Independent of any additional vector, transmission occurs solely *via* the release of infectious ova into the environment from the host faeces. This external soil bound stage, and the endo-parasitic stages, which can be considered two different phases, are independently vital for reproduction. Autoinfection is not possible in this genus. The number of adult worms in a diseased individual is solely dependent on the degree of oral exposure to ova, and so serves as a marker of ascariis prevalence in the patient's region. Prior infection does not confer protective immunity [35].

#### **Life cycle of *A. lumbricoides***

Ova passed in the stool of a previous host, are deposited in the soil and embryonate, becoming infective. The time for ova maturation into an infective state depends upon the surrounding temperature, varying from 10 days (environmental temperature of 30°C), to 55 days (at 16°C) [36]. Ova are very resistant to unfavorable climate conditions or disinfectants, and can remain viable for as long as 7-15 years [15,37].

New hosts contract ascariasis by consuming water or food contaminated with embryonated ova. Ingested ova hatch in the small intestine within four days and release larvae that migrate through the mucosa of the caecum and proximal colon. Subsequently, the larvae penetrate the intestinal wall and migrate *via* the blood stream or lymphatics to the liver and *via* the right heart to the lungs. Upon arrival, the larvae mature inside the alveoli over 10 to 14 days, ascend the bronchial tree up to the trachea, and are swallowed. Back in the intestine, larvae mature into adult worms inside the lumen of the small intestine (table I). The majority of adult worms is found in the jejunum; although they may be detected anywhere in the gastrointestinal tract and occasionally migrate to ectopic sites, including the bile duct, esophagus or into the oro-



**Fig 1.** Life cycle of *A. lumbricoides*. The life cycle is divided into four parts; three inside the host (first GI passage, tracheobronchial passage and second GI passage) and one environmental developmental cycle of the fertilized eggs. Approximate time intervals, in blue arrows, are derived from animal studies and clinical findings.

pharynx. This behavior, sometimes called “erratic ascariasis”, is stimulated by stress to nematodes, including sub-therapeutic anthelmintic doses, anesthesia or severe illnesses, particularly when accompanied by high fever [38]. Additionally, ascaris tend to enter fistulas seeking food during daylong fasting. This is why one may see more biliary migration during the month of Ramadan in Islamic countries [39].

Adult worms begin to lay eggs around 2 months post-inoculation [18,24,36]. When both female and male worms are present in the intestine, each female worm produces approximately 200,000 fertilized eggs per day. If only female worms are present, infertile eggs are produced that do not develop into the infectious stage. If there are only male parasites no eggs are formed. Adult *Ascaris lumbricoides* nematodes have a lifespan of 6 to 18 (up to 24) months and are finally passed in the stool [36], whereas most *A. suum* parasites die within 23 weeks [40]. In highly endemic areas, burdens of several hundred worms per individual may be observed. There are case reports of more than 2,000 adult worms in individual children [41]. The number of eggs produced per female worm tends to decrease as the worm burden increases. As most parasitic infections are associated with similar predisposing factors, co-infection with other parasites is very common [42] (fig 1).

**Atypical means of contracting ascariasis**

In addition to the standard means of contracting ascariasis, by ingesting ova-contaminated food, several alternative routes deserve consideration. Consumption of undercooked or raw liver and lungs, from animals infected with the early larval stage of ascariasis infection,

seems to be able to infect other hosts [43]. This is of local relevance as eating raw or undercooked pork organs have significance in local cuisine [31]. Rarely maternal-fetal transmission *via* trans placental migration of larvae has been reported [44]. Although the placenta is not usually a target for larvae, in the visceral larva migrans syndrome (VLM) this is a rare mode of transmission.

**Differences between *Ascaris lumbricoides* and *A. suum* during their developmental cycle**

Though closely related, the two species parasitizing humans seem to show distinctive behavior and different pre-patency periods in humans. As there is currently no reliable method of detecting the migrating routes of ascaris larvae outside necropsy, there are no dependable data of the specific route of intestine/liver passage in humans. The migratory behavior of *A. lumbricoides* larvae [45] was initially thought to be identical to that of *A. suum* larvae in pigs as there has been no contradicting data. Results from animal studies of *A. suum* propose that the parasite, even though found in the small intestines, do penetrate the mucosa of the upper colon and caecum [46]. The transition and penetration of *A. suum* larvae in its host occurs very fast. After 5-7 hours post-inoculation larvae can be detected in the mucosa of the caecum. The maximal larvae load (larvae/g mucosa) occurs at 6-12h. After 24h all intestinal larvae have already passed through the mucosa and cannot be detected there anymore [46].

Larvae first appear in the liver after 6 hours, with a peak at 4 days after inoculation [47]. This temporal delay in the pre-hepatic migratory movement of *A. suum* larvae has yet to be elucidated. Furthermore, it questions

Table I. Transition of *A. suum* in pig host and post-inoculation.

Transition of <i>A. suum</i> in pig host	Post-inoculation (days)	References
Intestine to liver	6 hrs – 4 up to 10 days	[46]
Liver to lung	6-8	[15]
Lungs to oropharynx	8-10	[24]
Second arrival to small intestine	9-15	[46]

Table II. Patency periods of ascariasis.

Parasite / Host	Pre-patency period (days)	References
<i>A. suum</i> in pig	40-62	[24]
<i>A. suum</i> in human	24-29 (few outliers up to 73)	[18,24]
<i>A. lumbricoides</i> in human	67-76	[18,24]

whether the current model of *A. lumbricoides* penetrating the upper intestinal mucosa is accurate or otherwise. Additionally, as early as 1934 Roberts [48] described delays of *A. suum* larvae proceeding to the lungs, being still detectable in the liver until day 10-15 [15]. It seems that *Ascaris suum* has a faster transition time from the intestines to liver and on to the lung. This results in a shorter pre-patency period, on average shorter even than for the same transition in the conventional host [21]. Furthermore, the *A. suum* parasite has a shorter life span in humans than *A. lumbricoides*. The periods found in the literature are summarized in Table II.

### Clinical symptoms

Many infected individuals are asymptomatic or experience non-specific symptoms, however poorly recognized sequelae include problems in school or work performance, malnutrition and growth impairment in children [49-52]. When they occur, clinical symptoms are classified into acute (early) and chronic disease. Symptoms of acute ascariasis result from the irritating effects of larvae migrating, particularly through the lungs, and the immunological response. Chronic ascariasis may clinically manifest as nutritional depletion (often compounding malnutrition present in highly endemic areas), or by direct irritation and mechanical obstruction induced by the large adult worms.

#### Early symptoms

The early manifestations of ascariasis result in part from physical irritation of larvae passing through tissues, as well as from an immune-mediated reaction against the larvae. During the first infection, physical damage to the tissues and capillaries appears to be the main cause of symptoms initially. Animal models suggest that the allergic reaction begins to contribute to symptoms after about one week [53]. Re-infection or super-infection is

additionally associated with a higher incidence of a type 1 hypersensitivity reaction, involving considerable pulmonary eosinophilic infiltrates and marked peripheral eosinophilia [54].

#### Complications of the early phase of infection

During the early stage, characterized by larvae migration, complications are mainly due to the host immune reaction, as well as larvae migrating to ectopic locations [55-57]. The immune reaction in most cases is mild and self-limiting, but severe and even fatal cases have been reported, mostly due to respiratory failure [38,58,59]. A heavy parasite load is postulated to be a potential risk factor for asthma in children [60].

#### Migrating larvae versus visceral larva migrans (VLM)

Visceral larva migrans (VLM) was originally defined by Beaver et al 1952 [61] for erratic zoonotic hookworm infections in humans, due to *Toxocara spp.* Later studies concluded that erratic migratory paths of *A. suum* (to the brain, spinal-cord, kidneys, uterus, or even popliteal vessels etc.) [55-57], should be added to the VLM definition. The opponents of this notion point out that in many cases *A. suum* can mature and propagate in humans without showing erratic visceral larvae migration, thereby excluding the species as a dead-and-end / incidental host. Proponents state that the clinical and laboratory findings of the *A. suum* erratic visceral migration of larvae resemble those of a classical VLM syndrome and therefore should be included [62-66].

#### Chronic (late) ascariasis

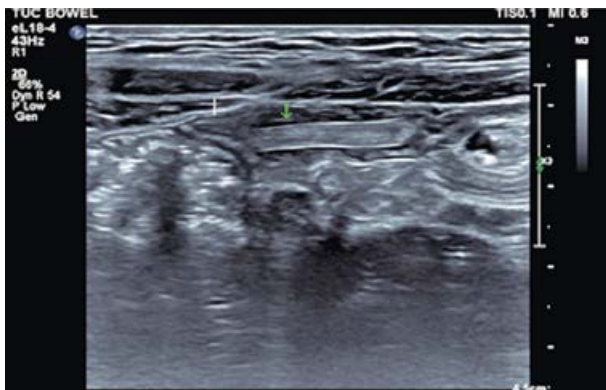
Symptoms of chronic ascariasis (starting from six to eight weeks after egg ingestion until 18 months post infection) are induced by the adult worms. The symptoms are non-specific and may consist of abdominal discomfort, anorexia, nausea, vomiting, diarrhea and weight loss. The patient may notice large adult worms passed in the stool.

**Complications of chronic ascariasis**

Complications are usually due to mechanical organ obstruction from a single adult worm (hepato-biliary and pancreatic obstruction) or from large numbers of adult worms (intestinal obstruction). Of those, intestinal obstruction is the most common complication (38 - 87 %) [67,68].

**Intestinal obstruction**

The detection of one single adult worm in small or large bowel is an accidental event (fig 2). Intestinal obstruction is associated with an estimated burden of >60 intestinal worms [68]. Most obstructions due to ascariasis, up to 90%, occur in children 1-5 years old. Volvulus, intussusceptions (fig 3) and intestinal perforation have been described (fig 4) In the setting of heavy ascariasis, adult worms can obstruct the bowel lumen leading to acute intestinal obstruction [69] (fig 5). In one meta-analysis, intestinal obstruction accounted for 38 to 87 percent of all complications of ascariasis [70].



**Fig 2.** The ultrasound image shows an intra-intestinal adult Ascaris worm in a patient presenting with non-specific symptoms. As a method for detection of single ascaris parasites, ultrasound is not well established and such findings are in most cases accidental results.



**Fig 4.** In the fluoroscopic image of an endoscopic retrograde cholangiography (ERC) the ascaris parasite can be indirectly detected as long-thin shaped shadow/lesion by means of radio contrast agent and be removed during the same session.

Obstruction occurs most commonly at the ileocaecal valve, though migrating adult worms can also obstruct the appendix precipitating appendicitis. Symptoms of intestinal obstruction associated with ascariasis include colicky abdominal pain, vomiting, and constipation. Emesis may contain worms. In some cases, an abdominal mass that changes in size and location may be appreciated on serial physical examinations [71].

**Hepato-biliary symptoms**

Migration of adult ascaris worms into the biliary tree can cause biliary colic, biliary strictures, a calculous cholecystitis, ascending cholangitis, obstructive jaundice, liver abscesses or bile duct perforation with peritonitis [72-77]. Retained worm fragments can serve as a nidus for biliary stones. Trans-abdominal US is better first imaging method to visualize the parasite (fig 6-9).



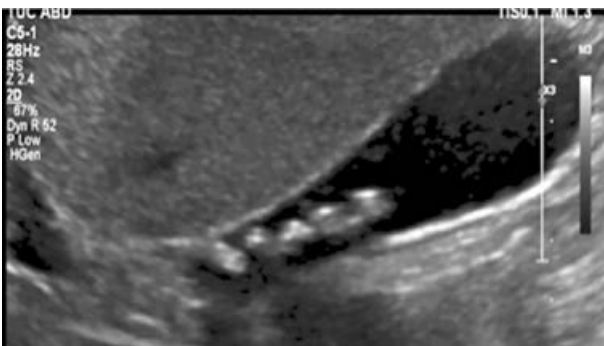
**Fig 3.** The ultrasound image below shows an Ascaris worm after migrating into the common bile duct (CBD) causing extra-hepatic cholestasis. This condition is in need of an endoscopic retrograde cholangiography intervention as it might otherwise progress to a complicated course (e.g. cholangitis)



**Fig 5.** A young patient presenting with severe abdominal pain. In the ultrasound exam a “target sign” as a pathognomonic indicator for an intussusception could be detected. In the center of the target sign can an ascaris worm be discovered.



**Fig 6.** The ultrasound image below shows an ascaris parasite perforating the intestinal wall (first picture) and free in the peritoneal cavity (second picture). Such intestinal perforation can lead to bacterial superinfections and to an acute abdomen.



**Fig 8.** The ultrasound image below shows an *Ascaris* infestation of the gall bladder without signs of an acute cholecystitis.

### ***Pancreatic symptoms***

Adult worms may also obstruct the pancreatic duct, leading to pancreatitis. Acute and chronic pancreatitis have been described [78,79], though pancreatic duct ascariasis is a rare entity. In a study of 500 patients with hepato-biliary and pancreatic disease due to *A. lumbricoides* infection, only seven had pancreatic ascariasis [78]. However due to its high prevalence, ascariasis has been associated with up to one-third of biliary and pancreatic diseases in India [75]. Another study including 300 Syrian patients with biliary or pancreatic ascariasis noted ascending cholangitis, acute pancreatitis, and obstructive jaundice in 16%, 4% and 1% of cases, respectively [61].

### **Diagnosis**

#### ***Early ascariasis***

##### ***Stool examination***

Stool examination is not useful in the early stages, since ova are only produced by mature female worms after 24 days (for prepatency period of *A. suum* in humans). Diagnosis in the early stage therefore relies on clinical



**Fig 7.** The ultrasound image below shows a typical B-Mode picture of an intestinal obstruction by multiple parasites, which is one of the most common complication of ascariasis. Severe parasite infestation can lead to an obstructive ileus and consecutive the necessity of a surgical intervention.



**Fig 9.** Ascariasis infestation of the left liver lobe.

suspicion, peripheral eosinophilia and symptoms related to larvae migration. Diagnosis is usually achieved by serology in immune-compromised subjects.

#### ***Laboratory tests***

Eosinophilia is usually present in the early stage, increasing several days after symptom onset and remaining high for a few weeks. Sputum analysis may demonstrate eosinophilia and Charcot-Leyden crystals [80,81]. Eosinophil counts are usually 5 to 12 percent but can be as high as 30 to 50 percent. Serum levels of immunoglobulins are usually elevated during early infection, including total immunoglobulin G (IgG) and total IgE levels.

#### ***Serological diagnosis***

Serological testing is a well-established tool for diagnosing *A. lumbricoides* infections. In VLM, cross-reactivity to *A. suum* should be anticipated, considering its genetic similarity. There are no commercially available specific test kits [63].

## **Chronic Ascariasis**

### *Stool examination*

Stool enrichment and use of SAF-fixative are highly sensitive methods for diagnosis, used widely in industrialized countries [82]. Before accepting a negative result, at least three stool samples should be tested. In highly endemic areas, where egg counts may be more relevant, the World Health Organization recommends the Kato Katz thick smear (stool examination) as the diagnostic tool of choice. In particular circumstances, no eggs may be present in the faeces to be detected by either method; when infection is due to male worms only or in the context of VLM [83]. Diagnosis therefore relies on serology or in some cases, on imaging. In contrast, even unfertilized female worms produce ova detectable in stool.

### *Molecular diagnosis*

Quantitative real-time PCR of faeces has been shown to be more sensitive than stool examination. Due to the extreme genetic similarity it used to be very difficult, near impossible, to differentiate *A. suum* from *A. lumbricoides* [54]. With recent advances in molecular biology, particularly utilizing polymorphic microsatellite loci, it has become possible to differentiate the two *Ascaris* species and even demonstrate chimera.

## **Treatment**

Pulmonary manifestations should be treated with supportive care, including bronchodilators and in severe cases consideration given to systemic corticosteroids. Before administering glucocorticoids, concomitant Strongyloidiasis must be excluded because of the risk of inducing the Strongyloides hyperinfection syndrome; a multi organ system dysfunction with septic shock. In urgent cases, Strongyloides hyperinfection can be prevented by empiric Ivermectin therapy. Anthelmintics are not effective against ascaris larvae and are therefore generally not recommended in the early phase. All patients with ascariasis should be treated in order to reduce morbidity, even those with asymptomatic infection. Benzimidazoles are the treatment of choice in adults and children. Mebendazol 2x100 mg/d for three days or at a single dose of 500 mg is usually curative. Especially in early infections with tissue larval migration Albendazole 400-500 mg is preferable, whereas Ivermectin has been found less effective [84-88]. Due to the reported teratogen effects of Benzimidazoles in animals, pregnant women are treated [84] with single dose Pyrantelpamoate (10 mg/kg up to a maximum of 1 g), which is effective in 90%. All mentioned agents are active against adult worms but not sufficient against larvae.

## **Follow up**

Stool testing may be performed two months following treatment of patients in non-endemic areas to ensure successful clearance. For a lack of far-reaching consequences and owing to the restrictive financial situation in most endemic countries, treating physicians might contemplate to forgo follow-up stool testing in asymptomatic patients.

## **Prevention**

Control strategies include sanitation improvements (especially the avoidance of using human or porcine faeces as fertilizers, use of treated water, availability of soap, and hand washing after defecation), health education, as well as mass anthelmintic treatment [89]. Presumptive treatment has been proposed and demonstrated to be effective in some circumstances [90-92]. Since ascariasis in industrialized countries has recently been associated with *A. suum*, specific hygienic measures are warranted for people who handle pigs or use pig excrements as crop fertilizers.

## **Conclusion**

Ascariasis is a common infection worldwide and may be acquired autochthonous in industrialized countries. Acute ascariasis may be characterized by pseudo-allergic and asthmatic migrating manifestations. In the early stage, eosinophilia is usually high and imaging may reveal migrating lung infiltrates (Löffler infiltrates). The differential diagnosis includes other larval helminthic infections including lung or liver fluke infection, Strongyloidiasis or acute Schistosomiasis, which may be difficult to differentiate at this stage and must rely on the history of exposure and serology. Cross-reactions between different serologic tests frequently occur. Stool Parasitology in the early stage does not reveal worm ova (pre-patency stage). Chronic infections, as most frequently seen in travelers and immigrants from highly endemic areas, are usually well tolerated but may be complicated by liver abscesses and intestinal, biliary or pancreatic obstruction. Imaging features may reveal the typical anatomy of adult worms. With increasing immigration from highly endemic areas, it is more and more important to take into account helminthic and other parasitic infections in order to allow safe and curative treatment in a timely fashion.

## **Acknowledgment**

The authors thank Dr Mohit Shah, Dr Sanjeev Mani and Dr Alpna Joshi (all from Mumbai) for advice. The

authors thank the Bad Mergentheimer Leberzentrum e.V. for support.

**Conflict of interest:** none

## References

- Dietrich CF, Lorentzen T, Appelbaum L, et al. EFSUMB Guidelines on Interventional Ultrasound (INVUS), Part III - Abdominal Treatment Procedures (Short Version). *Ultraschall Med* 2016;37:27-45.
- Dietrich CF, Lorentzen T, Appelbaum L, et al. EFSUMB Guidelines on Interventional Ultrasound (INVUS), Part III - Abdominal Treatment Procedures (Long Version). *Ultraschall Med* 2016;37:E1-E32.
- Dietrich CF, Cui XW, Chiorean L, Appelbaum L, Leen E, Ignee A. Local ablative procedures of the liver. *Z Gastroenterol* 2015;53:579-590.
- Dietrich CF, Chiorean L, Potthoff A, Ignee A, Cui X, Sparchez Z. Percutaneous sclerotherapy of liver and renal cysts, comments on the EFSUMB guidelines. *Z Gastroenterol* 2016;54:155-166.
- Dietrich CF, Nuernberg D. (Eds.). *Interventional ultrasound. A practical guide and atlas*. Stuttgart, Germany: Thieme, 2014.
- Brunetti E, Tamarozzi F, Macpherson C, et al. Ultrasound and Cystic Echinococcosis. *Ultrasound Int Open* 2018;4:E70-E78.
- Richter J, Azoulay D, Dong Y, et al. Ultrasonography of gallbladder abnormalities due to schistosomiasis. *Parasitol Res* 2016;115:2917-2924.
- Richter J, Botelho MC, Holtfreter MC, et al. Ultrasound assessment of schistosomiasis. *Z Gastroenterol* 2016;54:653-660.
- Dietrich CF, Kabaalioglu A, Brunetti E, Richter J. Fasciolosis. *Z Gastroenterol* 2015;53:285-290.
- Dietrich CF, Brunner V, Seifert H, Schreiber-Dietrich D, Caspary WF, Lembcke B. Intestinal B-mode sonography in patients with endemic sprue. *Intestinal sonography in endemic sprue. Ultraschall Med* 1999;20:242-247.
- Dietrich CF, Lembcke B, Jenssen C, Hocke M, Ignee A, Hollerweger A. Intestinal ultrasound in rare gastrointestinal diseases, update, part 1. *Ultraschall Med* 2014;35:400-421.
- Dietrich CF, Lembcke B, Jenssen C, Hocke M, Ignee A, Hollerweger A. Intestinal Ultrasound in Rare Gastrointestinal Diseases, Update, Part 2. *Ultraschall Med* 2015;36:428-456.
- Dietrich CF, Brunner V, Lembcke B. Intestinal ultrasound in rare small and large intestinal diseases. *Z Gastroenterol* 1998;36:955-970.
- Dietrich CF. (Ed.). *EFSUMB Course Book on Ultrasound*. London, 2012.
- Dold C, Holland CV. *Ascaris and ascariasis*. *Microbes Infect* 2011;13:632-637.
- Dridelle R. *Parasites. Tales of Humanity's Mostly Unwelcome Guests*. University of California Press, 2010.
- Bouchet F, Baffier D, Girard M, Morel P, Paicheler JC, David F. Paléoparasitologie en contexte pléistocène: premières observations à la Grande Grotte d'Arcy-sur-Cure (Yonne), France. *Comptes rendus de l'Académie des sciences. Paris, Série 3, Sciences de la vie* 1996;319:147-151.
- Takata I. Experimental infection of man with *Ascaris* of man and the pig. *Kitasato Arch Exp Med* 1951;23:151-159.
- Ansel M, Thibaut M. Value of the specific distinction between *tascaris lumbricoides* Linne 1758 and *Ascaris suum* Goeze 1782. *Int J Parasitol* 1973;3:317-319.
- Loreille O, Bouchet F. Evolution of ascariasis in humans and pigs: a multi-disciplinary approach. *Mem Inst Oswaldo Cruz* 2003;98 Suppl 1:39-46.
- Leles D, Gardner SL, Reinhard K, Iniguez A, Araujo A. Are *Ascaris lumbricoides* and *Ascaris suum* a single species? *Parasit Vectors* 2012;5:42.
- Zhou C, Li M, Yuan K, Deng S, Peng W. Pig *Ascaris*: an important source of human ascariasis in China. *Infect Genet Evol* 2012;12:1172-1177.
- Arizono N, Yoshimura Y, Tohzaka N, et al. Ascariasis in Japan: is pig-derived *Ascaris* infecting humans. *Jpn J Infect Dis* 2010;63:447-448.
- Galvin TJ. Development of human and pig ascaris in the pig and rabbit. *J Parasitol* 1968;54:1085-1091.
- Soe MJ, Kapel CM, Nejsum P. *Ascaris* from Humans and Pigs Appear to Be Reproductively Isolated Species. *PLoS Negl Trop Dis* 2016;10:e0004855.
- Criscione CD, Anderson JD, Sudimack D, et al. Disentangling hybridization and host colonization in parasitic roundworms of humans and pigs. *Proc Biol Sci* 2007;274:2669-2677.
- Miller LA, Colby K, Manning SE, et al. Ascariasis in humans and pigs on small-scale farms, Maine, USA, 2010-2013. *Emerg Infect Dis* 2015;21:332-334.
- Nejsum P, Parker ED Jr, Frydenberg J, et al. Ascariasis is a zoonosis in denmark. *J Clin Microbiol* 2005;43:1142-1148.
- Hoeningl M, Valentin T, Zollner-Schwetz I, et al. Pulmonary ascariasis: two cases in Austria and review of the literature. *Wien Klin Wochenschr* 2010;122 Suppl 3:94-96.
- Hoeningl M, Seeber K, Valentin T, Zollner-Schwetz I, Krause R. Pulmonary ascariasis in patients from wealthy countries: shift in epidemiology? *Int J Infect Dis* 2012;16:e888.
- Izumikawa K, Kohno Y, Izumikawa K, et al. Eosinophilic pneumonia due to visceral larva migrans possibly caused by *Ascaris suum*: a case report and review of recent literatures. *Jpn J Infect Dis* 2011;64:428-432.
- Shiekh KA, Baba AA, Ahmad SM, Shera AH, Patnaik R, Sherwani AY. Mechanical small bowel obstruction in children at a tertiary care centre in Kashmir. *Afr J Paediatr Surg* 2010;7:81-85.
- Javid G, Zargar S, Shah A, Shoukat A, Iqbal A, Gupta A. Etiology and outcome of acute pancreatitis in children in Kashmir (India). An endemic area of hepatobiliary ascariasis. *World J Surg* 2013;37:1133-1140.
- Spillmann RK. Pulmonary ascariasis in tropical communities. *Am J Trop Med Hyg* 1975;24:791-800.
- Diemert DJ. Ascariasis. In: Guerrant RL, Weller PF, Walker DH. *Tropical Infectious Diseases: Principles, Pathogens and Practice*. 3rd ed. Philadelphia: Saunders Elsevier, 2011.



36. Piekarski G. Ascariasis. Causative agent: *Ascaris lumbricoides* hominis. *Dtsch Med Wochenschr* 1980;105:1406-1408.
37. Müller G. Studies on the life span of *Ascaris* eggs in garden soil. *Zentralbl Bakteriol Orig* 1953;159:377-379.
38. Ramamoorthy KG. Anaesthesia and *Ascaris* pneumonia (Loeffler's syndrome). *Indian J Anaesth* 2015;59:125-126.
39. Sandouk F, Haffar S, Zada MM, Graham DY, Anand BS. Pancreatic-biliary ascariasis: experience of 300 cases. *American Journal of Gastroenterology* 1997;92:2264-2267.
40. Olsen LS, Kelley GW, Sen HG. Longevity and Egg-Production of *Ascaris suum*. *Trans Am Microsc Soc* 1958;77:380-383.
41. Reeder MM. The radiological and ultrasound evaluation of ascariasis of the gastrointestinal, biliary, and respiratory tracts. *Semin Roentgenol* 1998;33:57-78.
42. Tietze PE, Tietze PH. The roundworm, *Ascaris lumbricoides*. *Prim Care* 1991;18:25-41.
43. Permin A, Henningsen E, Murrell KD, Roepstorff A, Nansen P. Pigs become infected after ingestion of livers and lungs from chickens infected with *Ascaris* of pig origin. *Int J Parasitol* 2000;30:867-868.
44. Chu WG, Chen PM, Huang CC, Hsu CT. Neonatal ascariasis. *J Pediatr* 1972;81:783-785.
45. Boes J, Medley GF, Eriksen L, Roepstorff A, Nansen P. Distribution of *Ascaris suum* in experimentally and naturally infected pigs and comparison with *Ascaris lumbricoides* infections in humans. *Parasitology* 1998;117:589-596.
46. Murrell KD, Eriksen L, Nansen P, Slotved HC, Rasmussen T. *Ascaris suum*: a revision of its early migratory path and implications for human ascariasis. *J Parasitol* 1997;83:255-260.
47. Douvres FW, Tromba FG, Malakatis GM. Morphogenesis and migration of *Ascaris suum* larvae developing to fourth stage in swine. *J Parasitol* 1969;55:689-712.
48. Roberts FHS. The large roundworm of pigs, *Ascaris lumbricoides* L., 1758 : its life history in Queensland, economic importance and control. Australia/Brisbane, Govt. Printer, 1934.
49. Pullan RL, Smith JL, Jasrasaria R, Brooker SJ. Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. *Parasit Vectors* 2014;7:37.
50. Lenk EJ, Redekop WK, Luyendijk M, Rijnsburger AJ, Severens JL. Productivity Loss Related to Neglected Tropical Diseases Eligible for Preventive Chemotherapy: A Systematic Literature Review. *PLoS Negl Trop Dis* 2016;10:e0004397.
51. Ahmed A, Al-Mekhlafi HM, Azam MN, et al. Soil-transmitted helminthiasis: a critical but neglected factor influencing school participation of Aboriginal children in rural Malaysia. *Parasitology* 2012;139:802-808.
52. Taylor-Robinson DC, Maayan N, Soares-Weiser K, Donagan S, Garner P. Deworming drugs for soil-transmitted intestinal worms in children: effects on nutritional indicators, haemoglobin, and school performance. *Cochrane Database Syst Rev* 2015;2015:Cd000371.
53. Lejkina ES. Research on ascariasis immunity and immunodiagnosis. *Bull World Health Organ* 1965;32:699-708.
54. Lamberton PH, Jourdan PM. Human Ascariasis: Diagnostics Update. *Curr Trop Med Rep* 2015;2:189-200.
55. Ashraf HZ, Ahangar AG, Dar FA, et al. Popliteal artery embolism by *Ascaris lumbricoides*: a case report. *Ulus Travma Acil Cerrahi Derg* 2009;15:619-620.
56. Gupta P, Sundaram V, Abraham G, Shantha GP, Mathew M. Obstructive uropathy from *Ascaris lumbricoides*. *Kidney Int* 2009;75:1242.
57. Osoegawa M, Matsumoto S, Ochi H, et al. Localised myelitis caused by visceral larva migrans due to *Ascaris suum* masquerading as an isolated spinal cord tumour. *J Neurol Neurosurg Psychiatry* 2001;70:265-266.
58. Katz U, Shoenfeld Y. Pulmonary Eosinophilia. *Clin Rev Allergy Immunol* 2008;34:367-371.
59. Phillips JA, Harrold AJ, Whiteman GV, Perelmutter L. Pulmonary infiltrates, asthma and eosinophilia due to *Ascaris suum* infestation in man. *N Engl J Med* 1972;286:965-970.
60. Bragagnoli G, Silva MT. *Ascaris lumbricoides* infection and parasite load are associated with asthma in children. *J Infect Dev Ctries* 2014;8:891-897.
61. Beaver PC, Snyder CH, Carrera GM, Dent JH, Lafferty JW. Chronic eosinophilia due to visceral larva migrans; report of three cases. *Pediatrics* 1952;9:7-19.
62. Schneider R, Obwaller A, Auer H. Immunoblot for the detection of *Ascaris suum*-specific antibodies in patients with visceral larva migrans (VLM) syndrome. *Parasitol Res* 2015;114:305-310.
63. Schneider R, Auer H. Incidence of *Ascaris suum*-specific antibodies in Austrian patients with suspected larva migrans visceralis (VLM) syndrome. *Parasitol Res* 2016;115:1213-1219.
64. Pinelli E, Herremans T, Harms MG, Hoek D, Kortbeek LM. Toxocara and *Ascaris* seropositivity among patients suspected of visceral and ocular larva migrans in the Netherlands: trends from 1998 to 2009. *Eur J Clin Microbiol Infect Dis* 2011;30:873-879.
65. Sakakibara A, Baba K, Niwa S, et al. Visceral larva migrans due to *Ascaris suum* which presented with eosinophilic pneumonia and multiple intra-hepatic lesions with severe eosinophil infiltration--outbreak in a Japanese area other than Kyushu. *Intern Med* 2002;41:574-579.
66. Petithory JC. Can *Ascaris suum* cause visceral larva migrans? *Lancet* 1996;348:689.
67. de Silva NR, Guyatt HL, Bundy DA. Morbidity and mortality due to *Ascaris*-induced intestinal obstruction. *Trans R Soc Trop Med Hyg* 1997;91:31-36.
68. de Silva NR, Guyatt HL, Bundy DA. Worm burden in intestinal obstruction caused by *Ascaris lumbricoides*. *Trop Med Int Health* 1997;2:189-190.
69. Teneza-Mora NC, Lavery EA, Chun HM. Partial small bowel obstruction in a traveler. *Clin Infect Dis* 2006;43:214, 256-218.
70. Hamid R, Bhat N, Baba A, et al. Use of gastrografin in the management of worm-induced small bowel obstruction in children. *Pediatr Surg Int* 2015;31:1171-1176.

71. Lynser D, Handique A, Daniala C, Phukan P, Marbaniang E. Sonographic images of hepato-pancreatico-biliary and intestinal ascariasis: A pictorial review. *Insights Imaging* 2015;6:641-646.
72. Sandouk F, Haffar S, Zada MM, Graham DY, Anand BS. Pancreatic-biliary ascariasis: experience of 300 cases. *Am J Gastroenterol* 1997;92:2264-2267.
73. Khuroo MS, Zargar SA. Biliary ascariasis. A common cause of biliary and pancreatic disease in an endemic area. *Gastroenterology* 1985;88:418-423.
74. Khuroo MS, Mahajan R, Zargar SA, Javid G, Sapru S. Prevalence of biliary tract disease in India: a sonographic study in adult population in Kashmir. *Gut* 1989;30:201-205.
75. Khuroo MS, Rather AA, Khuroo NS, Khuroo MS. Hepatobiliary and pancreatic ascariasis. *World J Gastroenterol* 2016;22:7507-7517.
76. Sharma M. Echogenic shadow in the common bile duct. Diagnosis: Biliary ascariasis. *Gastroenterology* 2011;141:e14-e15.
77. Rauniyar RK, Agrawal CS, Baboo S, Singh RK, Sharma U, Rao JS. Live ascariasis of gall bladder and bile duct: clinical and radiological features. *Trop Doct* 2004;34:46-48.
78. Somani P, Sharma M, Pathak A, Patil A, Kumar A, Sreesh S. Endoscopic ultrasound imaging of pancreatic duct ascariasis. *Endoscopy* 2016;48 Suppl 1 UCTN:E33-E34.
79. Sharma M, Somani P, Patil A. Double Trouble in Acute Pancreatitis. *Gastroenterology* 2016;150:833-834.
80. Weller PF, Bach DS, Austen KF. Biochemical characterization of human eosinophil Charcot-Leyden crystal protein (lysophospholipase). *J Biol Chem* 1984;259:15100-15105.
81. Guo L, Johnson RS, Schuh JC. Biochemical characterization of endogenously formed eosinophilic crystals in the lungs of mice. *J Biol Chem* 2000;275:8032-8037.
82. Vandenberg O, Van Laethem Y, Souayah H, Kutane WT, van Gool T, Dediste A. Improvement of routine diagnosis of intestinal parasites with multiple sampling and SAF-fixative in the triple-faeces-test. *Acta Gastroenterol Belg* 2006;69:361-366.
83. Inatomi Y, Murakami T, Tokunaga M, Ishiwata K, Nawa Y, Uchino M. Encephalopathy caused by visceral larva migrans due to *Ascaris suum*. *J Neurol Sci* 1999;164:195-199.
84. Keiser J, Utzinger J. Efficacy of current drugs against soil-transmitted helminth infections: systematic review and meta-analysis. *JAMA* 2008;299:1937-1948.
85. Vercruyse J, Behnke JM, Albonico M, et al. Assessment of the anthelmintic efficacy of albendazole in school children in seven countries where soil-transmitted helminths are endemic. *PLoS Negl Trop Dis* 2011;5:e948.
86. Legesse M, Erko B, Medhin G. Efficacy of albendazole and mebendazole in the treatment of *Ascaris* and *Trichuris* infections. *Ethiop Med J* 2002;40:335-343.
87. Legesse M, Erko B, Medhin G. Comparative efficacy of albendazole and three brands of mebendazole in the treatment of ascariasis and trichuriasis. *East Afr Med J* 2004;81:134-138.
88. Samuel F, Degarege A, Erko B. Efficacy and side effects of albendazole currently in use against *Ascaris*, *Trichuris* and hookworm among school children in Wondo Genet, southern Ethiopia. *Parasitol Int* 2014;63:450-455.
89. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLoS Med* 2014;11:e1001620.
90. Guyatt HL, Bundy DA, Evans D. A population dynamic approach to the cost-effectiveness analysis of mass anthelmintic treatment: effects of treatment frequency on *Ascaris* infection. *Trans R Soc Trop Med Hyg* 1993;87:570-575.
91. Guyatt HL, Chan MS, Medley GF, Bundy DA. Control of *Ascaris* infection by chemotherapy: which is the most cost-effective option? *Trans R Soc Trop Med Hyg* 1995;89:16-20.
92. Bundy DA, Guyatt HL. Schools for health: Focus on health, education and the school-age child. *Parasitol Today* 1996;12:suppl 1-16.