An overview of parasitic infections of the gastro-intestinal tract in developed countries affecting immunocompromised individuals

Zohaib A. Siddiqui¹

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Abstract In both developed and developing countries, parasitic infections continue to be a frequent cause of mortality and morbidity. Due to the globalization of the world, doctors must be fully prepared to deal with a plethora of parasitic infections. More commonly the gastrointestinal (GI) tract is infected and in developed countries protozoans are more likely to be the cause of infection compared to helminths. These GI protozoa are progressively becoming recognized as important pathogens in patients that are immunocompromised. The number of immunocompromised patients is increasing and therefore the likelihood of similar infections will also increase. This paper aims to highlight the key GI parasites affecting immunocompromised individuals in developed countries, discussing diagnosis, treatment options and also prevention. *Cryptosporidium parvum* may be the most common GI parasite found in the immunocompromised host closely followed by *Cyclospora*, however, *Giardia duodenalis* is the most common GI parasite found in developed countries. The pathogenesis of parasitic infection is not clear, poorly understood and diagnostic testing remains difficult with management continuing to be a challenge.

Keywords Infection · Parasite · Immunocompromised · Developed world

Introduction

Worldwide, parasitic infections continue to be an important cause of mortality and morbidity for populations in developed and developing countries (Wright 2012). These infections are more common in developing nations, however due to the ease of international travel and the globalization of the food industry it is vital that doctors in developed countries are fully prepared to deal with these infections (Shields and Olson 2003). This paper aims to highlight the key GI parasites affecting immunocompromised individuals in developed countries, discussing diagnosis, treatment options and also prevention.

Often, the primary site of parasitic involvement is in the GI tract. GI parasites are of two main types; protozoans and helminths (Sinha et al. 2012). Protozoans, in developed countries, are more likely the cause of a gastrointestinal infection when compared to helminths. Helminth eggs are large and therefore more likely to be filtered, whereas some protozoans are chemically resistant to the water treatment and the eggs are small enough to pass through the filtration process (Harp 2003).

Protozoan infections have a significant impact on the health of humans and animals. Evidence has emerged showing that the infection could contribute to development of different forms of dysregulations within the intestinal tract including disseminated infection, especially in patients suffering from AIDS (Harp 2003). These GI protozoa are progressively becoming recognized as important pathogens in patients that are immunocompromised (Marcos and Gotuzzo 2013). This is especially important as the number of people who are immunocompromised increases as the human immunodeficiency virus (HIV) continues to spread in many parts of the world (Stark et al. 2009). The pathogenesis of parasitic infection is not clear, poorly

✉ Zohaib A. Siddiqui
zohaib.siddiqui@kcl.ac.uk

¹ King's College London, St Thomas Street, London SE1 9RT, UK

understood and diagnostic testing remains difficult and management remains challenging.

Recently, it has been found that an impaired host T cell immune response may facilitate an invasion by intestinal protozoa, however the exact pathogenesis at a cellular level remains unclear (Marcos and Gotuzzo 2013). Transplant patients along with patients infected with HIV have been reported to be at a higher risk of developing severe disease (Kristensen et al. 2016). *Cryptosporidium parvum* may be the most common GI parasite found in the immunocompromised host closely followed by *Cyclospora*, however, *Giardia duodenalis* is the most common GI parasite found in developed countries (Thompson 2000). In immunocompromised patients, due to the effective drug treatment and availability of these drugs, there is a lack of severe or serious complications from a *G. duodenalis* infection (Harp 2003).

It is through the emergence of the immunocompromising effect of AIDS that an increased amount of attention has been focused on parasites such as *Cryptosporidium*, which is now recognised as a significant cause of intestinal disease in both immunocompetent and immunocompromised patients alike (Chen et al. 2002). Microsporidia, such as *Enterocytozoon bieneusi*, have also appeared as a common cause of opportunistic infection of immunocompromised patients; partly due to improved molecular diagnostic assays. Microsporidia used to be characterised as a protozoa, however, recently it has reclassified as a fungi, not a parasite (Sak et al. 2010). In immunocompromised patients, effective drugs to combat these parasites have not been available. However, it has been found that reducing the level of immunosuppression along with antiparasitic therapy is the most effective treatment strategy (Marcos and Gotuzzo 2013).

In the broader sense, gastrointestinal parasites are known as infectious diseases of poverty (Mehraj et al. 2008). Their highest prevalence is found in areas of intense poverty in low/middle-income countries specifically tropical and subtropical regions of sub Saharan Africa, Asia and Latin America and the Caribbean (Harhay et al. 2010). Even in Europe and North America, these parasitic infections have been found to be most prevalent within the refugee communities and immigrant population (Harhay et al. 2010).

Cryptosporidium parvum

Cryptosporidium parvum is a protozoan species, one of many, that can cause cryptosporidiosis: a disease of the intestinal tract (Bouzid et al. 2013; Tzipori 1985). This parasite is monoxenous and very similar to the *Coccidia* class of parasites (Bouzid et al. 2013; Tzipori 1985;

Borowski et al. 2008). *Cryptosporidium parvum* is able to complete a whole life cycle inside a single host and is transmitted via the faecal-oral route and also is commonly transmitted through infected bodies of water (Janoff and Reller 1987; Ryan and Hijjawi 2015). *Cryptosporidium parvum* develops in the microvillus layer of the epithelial cells in the intestines of its host (Ryan and Hijjawi 2015). Here the parasite undergoes asexual merogony followed by gamogony, which results in the formation of oocysts; the oocysts then form four naked sporozoites (Aldeyarbi and Karanis 2016). Once the oocytes mature in the gut and are excreted from the host, they are infective. Within the original host, autoinfection may occur at a stage in the life cycle of the parasite when a thin walled oocyst excysts (Aldeyarbi and Karanis 2016).

The oocysts are relatively small (4–6 µm) however they are environmentally and chemically resistant; notably, the oocytes are resistant to chlorine that is used to disinfect bodies of water (Alum et al. 2014). Furthermore, the low concentration required for infection and the prolonged excretion of large numbers of oocysts make *C. parvum* ideal for waterborne transmission (Janoff and Reller 1987). Recreational bodies of water such as swimming pools and water parks are at a particularly high risk of infection and many outbreaks have been reported of cryptosporidiosis over the years (Cope et al. 2015). In 2010 nearly 30,000 inhabitants of a town in Sweden were affected by an outbreak of cryptosporidiosis and it was found that the drinking water contained a low number of oocytes; however this was enough to infect nearly half the town (Widerström et al. 2014).

Infections can be asymptomatic or from mild acute to severe chronic (Leitch and He 2012). During the intestinal stages the microvilli can be destroyed causing impaired digestion leading to mal-digestive diseases and mal-absorption (Leitch and He 2012). For many years, *C. parvum*, in both immunocompetent and immunocompromised patients, has been recognised as a significant cause of diarrhoea in humans (Fayer and Xiao 2007). In an immunocompetent patient infected with *C. parvum*, the symptoms commonly include diarrhoea, abdominal pain and less commonly vomiting (Fayer and Xiao 2007). As before, the infection resolves in weeks and is self-limiting. However, for the immunocompromised patient, a *C. parvum* infection may be a fatal and life threatening condition (Fayer and Xiao 2007). The diarrhoea may be unremitting and chronic thus leading to severe weight loss and dehydration. Furthermore, in immunocompromised patients, the parasites have been found frequently lodged within the bile ducts making the parasite very difficult to eradicate (Leitch and He 2012).

Diagnosing a *C. parvum* infection can be done by detecting oocysts in faecal smears, however, they are

difficult to detect due to the small size of the oocysts and therefore difficult to diagnose using this method (Vohra et al. 2012). As the oocysts are acid-fast a basic fuchsin stain can be used but more success has been found detecting them in clinical samples using specific monoclonal antibodies (Vohra et al. 2012). PCR and immunosorbent assays are used to diagnose this parasite by detecting *C. parvum* antigens in a sample of faeces (Chalmers and Katzer 2013). Due to a high percentage of people carrying antibodies to *C. parvum*, examining blood serum for the presence of antibodies is ineffective (Chalmers and Katzer 2013). The ELISA method may also be used to detect this parasite and may eliminate the difficulty due to the small size of the oocytes (Chalmers and Katzer 2013).

Currently, there is no chemotherapeutic treatment that has been effective for the treatment of *C. parvum*; however, some success has been reported using nitazoxanide and paromomycin (Sparks et al. 2015). However a drug trial using paromomycin proved it to be only as effective as a placebo (Checkley et al. 2015). Alleviating symptoms by rehydrating the patient is crucial. Many antimicrobial agents have shown promise in vitro trials but fail to replicate such results in controlled in vivo trials (Checkley et al. 2015). With immunocompromised patients, the best form of treatment has been to improve the immunodeficiency (Sparks et al. 2015). In AIDS patients, using antiretroviral agents has shown success by increasing the CD4+ T-lymphocytes (Sparks et al. 2015).

Preventing a *C. parvum* infection can only be done by avoiding exposure to it (Painter et al. 2015). Immunocompromised patients are advised to boil water before drinking it (Painter et al. 2015).

Cyclospora cayetanensis

Cyclospora cayetanensis, an apicomplexan parasite of the upper small intestinal tract, was first reported in the 1970s but it wasn't until 1996 that *C. cayetanensis* was brought to the attention of the public due to an outbreak of this parasite in Canada and the United States (US) (Strausbaugh and Herwaldt 2000). It causes diarrhoea in its hosts that can last a long period of time; it is also a cause of traveller's diarrhoea (Shields and Olson 2003). *Cyclospora cayetanensis* is from the Coccidian class and produces an environmentally resistant and small oocyst (Mansfield and Gajadhar 2004). It is slightly larger than the *C. parvum* oocyst and also unlike the *C. parvum* oocyst, it is not infective immediately after it has been passed as faeces (Mansfield and Gajadhar 2004). The oocysts must complete sporulation to become infective, which can take between 7 and 15 days in ideal conditions (Ortega and

Sanchez 2010). Once the oocyst has been ingested, it excysts and releases sporozoites which infect the duodenal and jejunal epithelial cells (Ortega and Sanchez 2010). Following this, a reproductive process occurs where the sporozoites multiply asexually. The oocysts, once formed, are excreted by the host but are not infective due to the oocysts being unsporulated (Ortega and Sanchez 2010).

The process by which this parasite is transmitted remains unclear due to the slow sporulation of the oocysts; therefore it is unlikely that the parasite is passed directly from an infected individual to an uninfected one (Ortega and Sanchez 2010). Both food and water have been implicated as the modes of transmission with studies being done on both (Chacín-Bonilla 2008). Food being important from countries where *C. cayetanensis* is endemic has caused outbreaks in developed countries in the past (Chacín-Bonilla 2010). An example would be in 1996 where raspberries imported to the US from Guatemala were contaminated and it was speculated that this was due to water that was used in the growing of the raspberries (Lalonde and Gajadhar 2016).

The symptoms resulting from a *C. cayetanensis* infection are similar to *C. parvum* as previously discussed; watery diarrhoea, abdominal pain and cramping and nausea which can present as mild to severe (Sánchez-Vega et al. 2014). Other symptoms can include flatulence, weight loss, low-grade fever, fatigue and anorexia (Sánchez-Vega et al. 2014). However it has been found that in areas where *C. cayetanensis* is endemic, the clinical presentation is more frequently asymptomatic (Thima et al. 2014). Immunocompetent hosts tend to shelter a smaller amount of parasites when compared to an immunocompromised host (Ortega and Sanchez 2010). The parasites mainly are found in the jejunum and don't usually present as severe in immunocompetent patients (Ortega and Sanchez 2010). This has meant that the symptoms from this parasite are more lethal in patients who are immunocompromised; on average patients with HIV were found to suffer from diarrhoea for 141.8 more days than HIV-negative hosts (Shields and Olson 2003). It has also been found that in patients suffering from AIDS, they lost on average 3.7 kg more than their immunocompetent counterparts (Ortega and Sanchez 2010). Complications following an infection from this parasite may result in Reiter syndrome, Guillain-Barre syndrome and biliary tract infections (Connor et al. 2001).

Diagnosing a *C. cayetanensis* infection is difficult due to the low numbers and nondescript appearance of the oocysts that are found in faeces (Ortega and Sanchez 2010). In one study in the United Kingdom (UK) laboratories were asked to identify samples that were positive for *Cyclospora* and only 58% identified them correctly (Cann et al. 2000). To increase the chance of detecting the oocysts it is important

to obtain multiple samples of stool from the suspected host on different days due to the intermittent shedding of the oocysts (Eberhard et al. 1997). Methods similar to those used to identify *C. parvum* are used such as acid-fast staining. Sporulation studies, molecular detection techniques and microscopy are all techniques that can be used to examine a sample suspected of a *C. cayetanensis* infection (Eberhard et al. 1997). Differentiating between *C. cayetanensis* oocysts and the oocysts from the *C. parvum* parasite, ultraviolet microscopy can be used because the oocysts from the *Cyclospora* auto-fluoresce and those of *Cryptosporidium* do not (Ahmad and Sinha 2014).

The treatment of choice for this infection is trimethoprim-sulfamethoxazole (TMP–SMX), however if the patient is allergic to sulfa products then Ciprofloxacin may be used as an alternative or nitazoxanide (Agholi et al. 2013). Treatment failure using Ciprofloxacin has been reported and elsewhere it is mentioned that it can be moderately effective in some cases (Lalonde and Gajadhar 2016). Supportive treatment should be considered if the patient is severely allergic to TMP–SMX; however, this depends on the severity of the symptoms (Lalonde and Gajadhar 2016).

As the modes of transmission of *C. cayetanensis* is poorly understood, preventing the spread of this parasite can be an issue (Mansfield and Gajadhar 2004). Most outbreaks reported in developing countries have been from fruit, vegetables and contaminated water; therefore when travelling to countries where the parasite is endemic it is best to avoid what has been mentioned (Ortega 2014). As recent as 2013 there were over 600 cases of cyclosporiasis potentially linked to fresh produce reported in the US (Ortega 2014). Monitoring of imported foods is vital as treatment for the removal of *C. cayetanensis* oocysts has not been developed and therefore filtered water and good agricultural practise should be implemented (Robertson et al. 2000). Developed countries should be taking an active stance in aiding countries where these diseases are endemic due to the globalisation of the food systems thus reducing the risk of importation of unsafe foods.

Conclusion

Further investigations into intestinal parasites will be vital to healthcare in developed countries so that we may cultivate more effective methods of treatment and more importantly, prevention (Norman et al. 2015). With the number of immunocompromised individuals increasing in developed countries, protozoan infections are likely to increase due to the opportunistic nature of these parasites (Kennedy et al. 2015). The effect that these infections have

on patients who are immunocompromised, such as with patients suffering from AIDS, they may develop much more severe symptoms and are at a greater risk of contracting further infections; biliary tract infections are an example (Mohammadnejad et al. 2015). As the immune response to these protozoan infections is complex and not fully understood, it is becoming increasingly more important to study them both in vitro and in vivo to develop more effective forms of treatment (Giannini and Battistuzzi 2015). Certain stages during the life cycle of these protozoans allow them to become environmentally resistant and therefore are able to survive for long periods of time in harsh conditions. Filters used in water treatment facilities are able to remove helminths eggs due to their large size; however, with protozoans their oocysts are significantly smaller and are able to pass through these filters. Furthermore, some protozoans can become resistant to chemicals used in water treatment such as chlorine and therefore are difficult to remove in this way (Alum et al. 2014).

Due to the globalisation of food systems and the increased demand placed on developing countries, where parasitic infections are endemic, by developed countries, the ability to detect and effectively screen for these potentially lethal parasites is paramount (Ortega and Sanchez 2010). In the US alone the import of spinach and lettuce went up by over 300% each in the span of 5 years (2000–2005) and over 15% of the total vegetable supply is outsourced and imported (Ortega and Sanchez 2010). Furthermore, commonly, outbreaks from protozoan parasites occur in public bodies of water so the importance to be able to screen and test for these parasites are becoming increasingly significant (Ng-Hublin et al. 2015). With laboratories in the United Kingdom not being able to identify oocysts of certain protozoans with a high sensitivity, it is important that more is done to improve methods of detection; in one report in the UK, 42% of tests on samples infected with *Cyclospora* were unable to identify this protozoan (Cann et al. 2000). The importance of simply being able to detect these parasites accurately is pivotal if we are able to effectively screen for them while importing food, providing clean water and recreational spaces.

Compliance with ethical standards

Conflict of interest None.

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