Long-term health effects after resolution of acute Cryptosporidium parvum infection: a 1-year follow-up of outbreak-associated cases

Rhianwen E. Stiff,1,2 Angharad P. Davies,1,3 Brendan W. Mason,1,4 Hayley A. Hutchings1 and Rachel M. Chalmers1,3,*

Abstract

We describe a longitudinal study carried out in an adult outbreak-associated cohort to investigate health effects, including post-infectious irritable bowel syndrome, occurring after resolution of acute Cryptosporidium parvum infection. New symptoms self-reported up to 12 months included: weight loss (31%), abdominal pain (38%), diarrhea (33%), eye pain (9%), joint pain (33%), fatigue (22%) and symptoms consistent with irritable bowel syndrome (IBS) (28%). Two people were medically diagnosed with IBS. This study describes for the first time sequelae reported by patients up to 12 months after infection with C. parvum, which appear to be similar to those described with C. hominis.

Cryptosporidium is a protozoan parasite which causes symptoms of gastroenteritis including diarrhoea, vomiting and abdominal pain. It is the commonest cause of protozoal diarrhoea in the UK, with nearly 6000 laboratory notifications in 2012 [1], and it particularly affects children aged between 2 and 5 years. Its global significance has become better recognized since publication of the Global Enteric Multi-centre Study [2], which found it to be the second commonest pathogen, causing moderate to severe diarrhoea in children aged under 1 year in low-/middle-income countries. In immune-competent individuals cryptosporidiosis is often perceived as an unpleasant but relatively mild self-limiting illness. However, there is growing evidence to suggest that, like certain bacterial causes of gastroenteritis, it may have longer-term health effects which manifest after resolution of the acute infection. The two main species affecting humans are C. hominis (predominantly anthropoconitc) and C. parvum (both zoonotic and anthropoconitc) and, as might be expected, the epidemiology differs between them. In addition, previous work has suggested that differences may exist in their post-infectious sequelae [3, 4]. However, there have been very few studies on this subject.

In the UK, a case-control study of patients who had cryptosporidiosis found that infection with the species C. hominis (but not C. parvum) was associated with joint pain, eye pains, headaches and fatigue in the two months following infection [3]. A seronegative reactive arthritis has been reported in adults [5, 6] and children [7, 8] including one report of Reiter’s syndrome (arthritis, conjunctivitis and urethritis) [8]. It has also been suggested that Cryptosporidium infection may cause relapse in Crohn’s disease and ulcerative colitis [9–11]. A study in Sweden [12] followed up 459 cases who suffered C. hominis infection in two waterborne outbreaks and controls, finding that outbreak cases were more likely to report diarrhoea, abdominal pain and joint pain several months after infection than were controls. In terms of sequelae in developing countries, cryptosporidiosis is now recognized as being associated with stunting of growth, and with persistent diarrhoea. In studies in Brazil (among others), early childhood diarrhoea with Cryptosporidium was associated with impaired physical fitness and cognitive function 4–7 years later [13], and with increased diarrhoea morbidity in subsequent years [14]. It is therefore now believed that the effects of cryptosporidiosis go beyond the initial acute diarrhoeal episode, possibly due to an effect on the gastrointestinal epithelium (for example, villous blunting with chronic inflammation, and an association with the poorly understood entity ‘environmental enteropathy’) (see [15]).

Several agents of infectious gastroenteritis lead to an increased risk of developing irritable bowel syndrome (IBS). IBS is a common condition occurring in about 9–12% of

Received 4 August 2017; Accepted 22 September 2017

Author affiliations: 1Swansea University Medical School, Singleton Park, Swansea, Wales, SA2 8PP, UK; 2Health Protection, Public Health Wales NHS Trust, Temple of Peace, Cathays Park, Cardiff, Wales, CF10 3NW, UK; 3Cryptosporidium Reference Unit, Public Health Wales Microbiology, Singleton Hospital, Swansea, Wales, SA2 8QA, UK; 4Communicable Disease Surveillance Centre, Public Health Wales NHS Trust, Temple of Peace, Cathays Park, Cardiff, Wales, CF10 3NW, UK.
*Correspondence: Rachel M. Chalmers, rachel.chalmers@wales.nhs.uk
Keywords: Cryptosporidium; cryptosporidiosis; long-term health effects; post-acute health effects; sequelae.
Abbreviations: IBS, irritable bowel syndrome; PI-IBS, post-infectious irritable bowel syndrome; 6MQ, 6 months questionnaire; 12MQ, 12 months questionnaire.
the population in the UK [16]. A validated diagnostic criteria assessment tool exists for IBS (http://romecriteria.org/). Post-infectious IBS (PI-IBS) is well documented, occurring in 25–38 % of patients with enteritis [16], for instance after Campylobacter, Salmonella or Shigella infection. People who have had a laboratory-confirmed diagnosis of bacterial gastroenteritis are nearly 12 times more likely to develop new-onset IBS in comparison with people who have not had a laboratory diagnosis of bacterial gastroenteritis [17]. PI-IBS appears to carry a rather better prognosis than non-PI-IBS [16]. For culture-confirmed bacterial gastroenteritis, a RR of 11.9 of new-onset IBS has been reported [18]. This risk is not confined to bacterial infection but has also been documented with Giardia lamblia [18], another protozoan parasite causing gastroenteritis. Infection of a rat model with C. parvum triggers long-term jejunal hypersensitivity and mast cell accumulation, pathological changes akin to those found in human patients with IBS [19, 20].

During spring 2012, an outbreak of cryptosporidiosis caused by C. parvum occurred in the UK (mainly northern England) associated with consumption of pre-cut bagged salad leaves [21]. Just over 300 cases were identified and, due to the nature of the products involved, most cases were adults. This was a rare opportunity to add to Hunter’s evidence [3] relating to the sequelae of infection with C. parvum in adults. We undertook a longitudinal study among this adult outbreak-associated cohort to investigate health effects, including PI-IBS, occurring after resolution of acute C. parvum infection.

Cases with illness onset between 14 May and 3 June 2012, aged >16 years, resident in northern England and confirmed as having C. parvum infection by the Cryptosporidium Reference Unit were invited to participate in the study. Consenting participants completed a self-administered web-based questionnaire at 6 and 12 months following laboratory diagnosis of cryptosporidiosis (known as 6MQ and 12MQ). We sought information about participants’ acute illness, as well as their symptoms and medical diagnoses prior to onset of acute cryptosporidiosis and during the following year. A review of previously reported health effects [3, 5–9, 12] informed our inclusion of questions on specific symptoms and diagnoses, as well as some with no known association, such as diabetes and chest pain, included for comparison. To investigate reported symptoms consistent with a diagnosis of IBS, the Rome III diagnostic criteria assessment tool (http://romecriteria.org/) was used. Participants were asked about the following conditions diagnosed by a medical practitioner: IBS, ulcerative colitis, Crohn’s disease, depression, anxiety, arthritis, diabetes or immunosuppression, either preceding their infection with Cryptosporidium or developing in the 12 months afterwards. In addition, data were also collected on self-reported symptoms, either consistent with IBS as indicated by Rome III criteria, weight loss, loss of appetite, nausea, recurrent vomiting, abdominal pain, diarrhoea, blood in stool, blurred vision, eye pain, recurrent headache, dizzy spells, fatigue, joint pain, back pain, fever or chest pain. Persons reporting pre-existing diagnosis or symptoms were excluded when enumerating new diagnosis or symptoms at 6MQ and 12MQ.

The results are shown in Table 1. One hundred and ninety-seven potential participants were invited, of whom 54 (27 %; 14 males and 40 females) took part. Response rates at 6MQ were significantly better among women than men (32.8 vs 18.7 %; difference 14.1 %, 95 % CI 1.3–25.5 %). There was no statistically significant difference in the mean age of those who did (41.8 years) and did not (41.5 years) participate (P=0.18). The 12MQ was completed by 39 of the original 54 participants (retention rate 72 %). Not all participants responded to each question, resulting in reduced denominators for some responses (Table 1). The mean duration of symptoms of acute cryptosporidiosis was 23 days (range 7–84 days). Six of 54 people spent a total of 95 days in hospital (mean hospital stay 15.8 days SD±13.3; range 2–34 days). Self-reported severity was described by 32/53 (60 %) as severe, 20/53 (38 %) as moderate and 1/53 as mild. Among the cohort’s 41 employees, 434 lost working days were reported. Pre-existing medically diagnosed IBS was reported by 11 of 54 (20 %) participants, but this did not appear to correlate with the severity of acute cryptosporidiosis. Those with pre-existing IBS reported a mean duration of illness of 24.8 days (SD±21.5; range 14–84 days); 2 of 11 were hospitalized for 2 and 5 days, respectively; and 55 % self-reported their acute episode as severe. Seven (66 %) reported that their IBS symptoms were unchanged at 6MQ; one reported that IBS symptoms had improved; one reported IBS symptoms had worsened and two reported ‘not applicable’. At 12MQ, four of nine (44 %) responders with pre-existing IBS reported a worsening in their IBS symptoms. At 6MQ, four of 43 (9 %) people without pre-existing IBS reported symptoms that fulfilled all Rome III criteria for diagnosing IBS, including one person who received a new IBS diagnosis from a doctor. Combining reports from 6MQ and 12MQ, a total of six (14 %) responders had symptoms meeting all Rome III criteria, and a total of two people received a new medical diagnosis of IBS. Additionally, new-onset gastrointestinal and non-gastrointestinal symptoms were reported at 6MQ and/or 12MQ by a high proportion of participants, including weight loss (31 %), abdominal pain (38 %), diarrhoea (33 %), eye pain (9 %), joint pain (33 %), fatigue (22 %) and dizzy spells (10 %) (Table 1).

This outbreak provided an unusual and fortuitous opportunity to recruit a cohort of adults with C. parvum, since a large proportion of Cryptosporidium cases usually occur in young children. Recruitment delay may have biased towards over-representation of those most adversely affected by, or those who attributed post-acute symptoms to, acute cryptosporidiosis. Hunter et al. [3] reported new or worsened symptoms following cryptosporidiosis in 40.9 % of case patients, including statistically significantly more cases than controls with weight loss (29.5 %), appetite loss (23 %), abdominal pain (26.2 %) and diarrhoea (29.5 %) at two
Table 1. Diagnoses received from medical practitioners and symptoms experienced by participants prior to acute cryptosporidiosis and during the 12 months following acute *C. parvum* infection

<table>
<thead>
<tr>
<th>Condition diagnosed by a medical practitioner</th>
<th>Number (% respondents)</th>
<th>Pre-existing symptom/diagnosis</th>
<th>Number (%) responders among those without pre-existing symptom/diagnosis</th>
<th>Findings from Hunter et al., New or worsened symptoms within the 2 months following <em>Cryptosporidium</em> infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritable bowel syndrome</td>
<td>11/54 (20 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulcerative colitis</td>
<td>1/54 (1.9 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crohn’s disease</td>
<td>1/54 (1.9 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>7/54 (13 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety</td>
<td>10/54 (18.5 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthritis</td>
<td>2/54 (3.7 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>1/54 (1.9 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illness resulting in immunosuppression</td>
<td>5/54 (9.3 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Symptoms self-reported by participants

<table>
<thead>
<tr>
<th>Symptoms consistent with IBS as indicated by Rome III criteria</th>
<th>Number (% respondents)</th>
<th>Pre-existing symptom/diagnosis</th>
<th>Number (%) responders among those without pre-existing symptom/diagnosis</th>
<th>Findings from Hunter et al., New or worsened symptoms within the 2 months following <em>Cryptosporidium</em> infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not ascertained</td>
<td>4/43 (9.3 %)</td>
<td></td>
<td>6/43 (14 %)</td>
<td>2/31 (6.5 %)</td>
</tr>
<tr>
<td>Weight loss</td>
<td>2/54 (3.7 %)</td>
<td></td>
<td>14/52 (26.9 %)</td>
<td>16/52 (30.8 %)</td>
</tr>
<tr>
<td>Loss of appetite</td>
<td>2/54 (3.7 %)</td>
<td></td>
<td>12/52 (23.1 %)</td>
<td>13/52 (25 %)</td>
</tr>
<tr>
<td>Nausea</td>
<td>13/54 (24.1 %)</td>
<td></td>
<td>16/54 (29.6 %)</td>
<td>7/39 (17.9 %)</td>
</tr>
<tr>
<td>Recurrent vomiting</td>
<td>1/54 (1.9 %)</td>
<td></td>
<td>2/53 (3.8 %)</td>
<td>1/53 (2.6 %)</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>9/54 (16.7 %)</td>
<td></td>
<td>17/45 (37.8 %)</td>
<td>4/33 (12.1 %)</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>6/54 (11.1 %)</td>
<td></td>
<td>12/48 (25 %)</td>
<td>16/48 (33.3 %)</td>
</tr>
<tr>
<td>Blood in stool</td>
<td>2/54 (3.7 %)</td>
<td></td>
<td>3/54 (5.6 %)</td>
<td>1/39 (2.6 %)</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>1/54 (1.9 %)</td>
<td></td>
<td>1/53 (1.9 %)</td>
<td>4/53 (7.5 %)</td>
</tr>
<tr>
<td>Eye pain</td>
<td>0/54</td>
<td>3/54 (5.6 %)</td>
<td>5/54 (9.3 %)</td>
<td>1/39 (2.6 %)</td>
</tr>
<tr>
<td>Recurrent headache</td>
<td>6/54 (11.1 %)</td>
<td>1/48 (2.1 %)</td>
<td>2/48 (4.2 %)</td>
<td>0/35</td>
</tr>
<tr>
<td>Dizzy spells</td>
<td>6/54 (11.1 %)</td>
<td>3/48 (6.3 %)</td>
<td>5/48 (10.4 %)</td>
<td>0/35</td>
</tr>
<tr>
<td>Fatigue</td>
<td>9/54 (16.7 %)</td>
<td>7/45 (15.6 %)</td>
<td>10/45 (22.2 %)</td>
<td>2/33 (6.1 %)</td>
</tr>
<tr>
<td>Joint pain</td>
<td>8/54 (14.8 %)</td>
<td>6/46 (13 %)</td>
<td>15/46 (32.6 %)</td>
<td>3/33 (9.1 %)</td>
</tr>
<tr>
<td>Back pain</td>
<td>13/54 (24.1 %)</td>
<td>1/54 (1.9 %)</td>
<td>6/41 (14.6 %)</td>
<td>5/31 (16.1 %)</td>
</tr>
<tr>
<td>Fever</td>
<td>0/54</td>
<td></td>
<td>1/54 (1.9 %)</td>
<td>5/54 (9.3 %)</td>
</tr>
<tr>
<td>Other</td>
<td>0/54</td>
<td>1 no detail</td>
<td>1 mucus in stools, hypotension and renal impairment</td>
<td>1 vertigo</td>
</tr>
</tbody>
</table>

Stiff et al., *Journal of Medical Microbiology* 2017;66:1607–1611

1609
months following acute infection. A study of a waterborne cryptosporidiosis outbreak in Milwaukee [9] found that 39% of cases experienced a relapse of diarrhoeal symptoms after initial resolution, but this study did not follow patients up for longer than a maximum of three months, and in most cases for less than that. Evidence pertaining to periods longer than this is very scant. One study of cryptosporidiosis in Sweden (without controls) found persistent gastrointestinal symptoms in up to eight of 53 (15%) patients 25–36 months post-infection: of interest, in this group, no difference was noted between cases who had been infected with *C. hominis* and those with *C. parvum* [22]. Another larger study [12], also in Sweden, followed cases up at various time periods between 2.5 and 11.5 months post-*C. hominis* infection, in two locations, and found that 49 and 56% of cases, respectively, reported symptoms during this period, with fatigue, headache, abdominal pain and diarrhoea being commonest. In our study, following *C. parvum* infection, cases reported new-onset weight loss (30.8%), loss of appetite (25%), abdominal pain (37.8%) and diarrhoea (33.3%). The figures are strikingly similar to those of Hunter et al [3], and furthermore our study suggests persistence of these gastrointestinal symptoms beyond the two months studied by Hunter, and up to a year after acute cryptosporidiosis. Of interest also is that certain non-gastrointestinal sequelae were previously found to be significantly associated only with *C. hominis* [3]. For example, new-onset eye pain was reported by 5/54 (9%) of our participants in either 6MQ or 12MQ in comparison with the previously reported nearly 10.9% of *C. hominis* and none of *C. parvum* cases with new or worsening eye pain [3]; new or worsening joint pain was found in 22% of cases in Hunter *et al.’s* study and 33% in ours. However, interpretation of our findings requires caution. Case numbers are small; there was no available control population (unlike Hunter *et al.’s* study), with cases simply acting as their own controls before and after infection; symptoms reported are common among the general adult population; and recall bias may also have contributed.

Medical diagnoses may underestimate the incidence of post-acute health effects. For example, although 15 of 46 (33%) participants reported new onset of joint pains at 6MQ and/or 12MQ, only three (20%) consulted healthcare services resulting in one new diagnosis of arthritis. Hunter also found that only about a third of those reporting joint pains intended to report it to a medical practitioner, and concluded that therefore the symptoms may have been relatively mild [3]. Among our participants 20% disclosed a pre-existing diagnosis of IBS, considerably greater than the reported UK population level of 9–12% [16]. This could suggest that those with pre-existing IBS may more readily present to health services, or be more likely to have participated in our research study; alternatively, we cannot discount that those with IBS may be pre-disposed to more symptomatic cryptosporidiosis.

Four individuals without pre-existing IBS reported new symptoms that met Rome III criteria at 6MQ and a further 2 at 12MQ (14% in total). This does not necessarily equate to a diagnosis of IBS because other underlying pathological causes of symptoms must be excluded (by history, examination or clinical investigations) before considering IBS, and two people reported alternative plausible causes for their symptoms. The Rome III criteria are validated for the diagnosis of IBS, not specifically for PI-IBS, and require certain symptoms to be present for 6 months or more. It could be argued that duration of symptoms for diagnosing PI-IBS should be amended to ‘since resolution of acute infection’. If this were applied in our study, 8/43 (19%) participants without pre-existing IBS reported symptoms that met these modified criteria at 6MQ – there having hardly been a chance for them to have experienced symptoms of sequelae for 6 whole months. At 12MQ, 28% reported symptoms consistent with Rome III criteria for IBS if those with symptom duration shorter than 6 months were included - twice as many as the number reporting the same symptoms for 6 months or more. Two patients were diagnosed as having IBS by a medical practitioner during the 12 month period following infection. In summary, we found that within twelve months following acute *C. parvum* infection, two adults without pre-existing irritable bowel syndrome received a new medical diagnosis of IBS and up to 28% (12/43) self-reported new onset of IBS-consistent symptoms. PI-IBS appears to have a better prognosis than IBS diagnosed in the absence of recent known gastrointestinal infection [16], and usually resolves without medical intervention. Patients may gain reassurance if made aware of this potential longer term health effect and likely clinical course at the time of receiving their cryptosporidiosis diagnosis.

The results presented here lend support to the notion of post-infectious sequelae after cryptosporidiosis. In addition this is the first time non-GI symptoms have been reported following *C. parvum*, as opposed to *C. hominis* infection. Despite the small number of participants and uncertainties discussed, the outcomes from this follow-up study add to available information on the self-reported and medically diagnosed health effects occurring following resolution of acute cryptosporidiosis. Our ongoing work will compare self-reported symptoms among patients with *C. hominis*, *C. parvum* and without *Cryptosporidium* infection. Quantifying post-acute health sequelae assists healthcare and environmental health professionals in providing more complete advice and support to patients with cryptosporidiosis in a timely manner. In turn, this may reduce subsequent use of healthcare services such as repeated GP consultations and laboratory testing. Since, in the EU, there is no licensed treatment for cryptosporidiosis, identifying and increasing awareness of post-acute health effects may assist policy decision-makers to understand the potential longer-term burden of disease and prioritise interventions to prevent *Cryptosporidium* infection.

**Funding information**

The authors received no specific grant from any funding agency.
Conflicts of interest
The authors declare that there are no conflicts of interest.

References
Burden and aetiology of diarrhoeal disease in infants and young 
children in developing countries (the Global Enteric Multicenter 
Study, GEMS): a prospective, case-control study. Lancet 2013;382: 
209–222.
sequelae of human cryptosporidiosis in immunocompetent 
Heavy cryptosporidial infections in children in northeast Brazil: 
comparison of Cryptosporidium hominis and Cryptosporidium par- 
5. Hay EM, Winfield J, McKendrick MW. Reactive arthritis associated 
6. Ozgül A, Tanıyüksel M, Yazıcıoglu K, Arpacioglu O. Sacroiliitis 
associated with Cryptosporidium parvum in an HLA-B27-negative 
7. Shepherd RC, Smail PJ, Sinha GP. Reactive arthritis complicating 
8. Cron RQ, Sherry DD. Reiter’s syndrome associated with crypto- 
9. Manthey MW, Ross AB, Soergel KH. Cryptosporidiosis and inflam- 
matory bowel disease. Experience from the Milwaukee outbreak. 
cryptosporidiosis as a cause of sudden recurrence of digestive 
4:469–470.
11. Vadlamudi N, Maclin J, Dimmitt RA, Thame KA. Cryptosporidial 
infection in children with inflammatory bowel disease. J Crohns 
Post-infection symptoms following two large waterborne out- 
breaks of Cryptosporidium hominis in Northern Sweden, 2010- 
Association of early childhood diarrhea and cryptosporidiosis with 
impaired physical fitness and cognitive function four-seven years 
later in a poor urban community in northeast Brazil. Am J Trop 
Cryptosporidiosis in northeastern Brazilian children: association 
15. Bartelt LA, Lima AA, Kosek M, Peñatario Yori P, Lee G et al. ‘Bar-
riers’ to child development and human potential: the case for 
including the “neglected enteric protozoa” (NEP) and other enter-
opathy-associated pathogens in the NTDs. PLoS Negl Trop Dis 
2013;7:e2125.
Society of Gastroenterology guidelines for the management of 
17. Rodríguez LA, Ruígnóez A. Increased risk of irritable bowel syn-
drome after bacterial gastroenteritis: cohort study. BMJ 1999;318: 
565–566.
18. Hanekiv K, Dizdar V, Langeland N, Hausken T. Development of 
functional gastrointestinal disorders after Giardia lamblia infection. 
Transient neonatal Cryptosporidium parvum infection triggers 
long-term jejunal hypersensitivity to distension in immunocompe-
sporidium parvum isolate-dependent postinfectious jejunal hyper-
sensitivity and mast cell accumulation in an immunocompetent 
outbreak of Cryptosporidium parvum across England & Scotland 
associated with consumption of fresh pre-cut salad leaves, May 
22. Insulander M, Silverlas C, Lebbad M, Karlsson L, Mattsson JG 
et al. Molecular epidemiology and clinical manifestations of 
human cryptosporidiosis in Sweden. Epidemiol Infect 2013;141: 
1009–1020.
et al. Massive outbreak of waterborne Cryptosporidium infection 
in Milwaukee, Wisconsin: recurrence of illness and risk of secondary 

Five reasons to publish your next article with a Microbiology Society journal
1. The Microbiology Society is a not-for-profit organization.
2. We offer fast and rigorous peer review – average time to first decision is 4–6 weeks.
3. Our journals have a global readership with subscriptions held in research institutions around 
the world.
4. 80% of our authors rate our submission process as ‘excellent’ or ‘very good’.
5. Your article will be published on an interactive journal platform with advanced metrics.

Find out more and submit your article at microbiologyresearch.org.