Observational Study

Pathogens causing diarrhoea among Bangladeshi children with malignancy: Results from two pilot studies

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Abstract

BACKGROUND
Diarrhoea is a frequent symptom in children with cancer, and occurs due to a composite effect of underlying disease and immunosuppression consequent to therapy, malnutrition, and non-infective aetiologies such as mucositis. In a large proportion of cases, the aetiology of diarrhoea remains unknown but is often attributed to multiple pathogens including parasites.

AIM
To identify and describe the pathogens causing diarrhoea in Bangladeshi children with cancer.
INTRODUCTION

Diarrhoea is a frequent symptom in children with cancer[1], and occurs due to a composite effect of underlying disease and immunosuppression consequent to therapy, malnutrition, and non-infective aetiologies such as mucositis[2]. In a large proportion of cases, the aetiology of diarrhoea remains unknown but is often attributed to multiple pathogens including parasites[1,3]. In immunocompromised individuals, intestinal parasitic infections may run a severe course, at times leading to fatality[4]. However despite this, there are limited data on the epidemiology of such infections among children with malignancy in South Asia. In urban slums of Bangladesh, about five diarrhoeal episodes per year are reported among otherwise healthy infants[5], and in a typical year, a tertiary hospital admits more than 3600 children for diarrhoea, a significant proportion of which are caused by intestinal protozoa[6,7]. As the leading cause, Giardia lamblia has been shown to account for about 15% of identified pathogens causing diarrhoea in young children in urban slums of Bangladesh, while Cryptosporidium and Entamoeba histolytica each account for about 4%[8]. However, the profile of pathogens causing diarrhoea among Bangladeshi children with malignancy is not yet described.

To this end, we present the results of two pilot studies describing the frequency of pathogens identified during episodes of diarrhoea among paediatric oncology patients admitted to a tertiary referral hospital in Bangladesh. The role of cheaper and...
more widely available conventional microbiological tests (as opposed to molecular diagnostics) in detecting those pathogens was also investigated.

**MATERIALS AND METHODS**

**Participants and data collection**

Two pilot cross-sectional studies were conducted at Bangabandhu Sheikh Mujib Medical University Hospital (Dhaka, Bangladesh): The first one from April 2012 to March 2013, and the second from March 2016 to February 2017. Both studies involved hospitalised children with malignancies who developed diarrhoea, defined as an alteration in normal bowel pattern with the passage of three or more consecutive unformed stools within a 24 h period, during their admission. The two study designs differed slightly as summarised in Figure 1. Children with cancer who were hospitalised with or without being treated with chemotherapy during the study period and had diarrhoea at any stage during admission and whose parents/guardian provided consent to participate were eligible for inclusion. For the included children, a separate data form was used each year for collecting demographic and clinical data including age, gender, type and stage of cancer, phase of treatment, and hydration and circulatory status.

In the first study, following recruitment, a fresh stool sample was collected into a pre-labelled container for microscopy for parasites, cysts, and ova and aerobic culture on selective media for enteric bacterial pathogens using standard protocols. In addition, multiplexed, real time, polymerase chain reaction (PCR) for *Cryptosporidium* spp, *E. histolytica*, and *G. lamblia* was conducted on 54 of the total 58 samples using a commercial assay as described elsewhere[9]. A second stool sample was collected for identification of *Clostridium difficile* toxin and glutamate dehydrogenase by enzyme immunoassays (EIAs) using TOX A/B II™ and C. DIFF CHEK™-60 (TechLab®, Blacksburg, VA, United States). Some methodological details were presented at the 46th Congress of the International Society of Paediatric Oncology in Toronto, Canada 22nd–25th October, 2014, and the results of this study have been published in brief as conference proceedings[10].

In the second study, a single stool sample was collected in a pre-labelled container for microscopy for parasites, cysts, and ova and aerobic culture on selective media for enteric bacterial pathogens using standard protocols, as well as an enzyme-linked immunosorbent assay (ELISA) for *Cryptosporidium* using the *Cryptosporidium* Ag ELISA kit (DRG Diagnostics GmbH, Marburg, Germany). In a random subset (*n* = 39), *C. difficile* antigen and toxin were also investigated using TOX A/B II™ and C. DIFF CHEK™-60 immunoassays.

On the first day of diarrhoea, blood samples were obtained for complete blood count and serum creatinine and electrolytes, as part of the routine diagnostic workup. In both studies, blood tests were conducted at the Paediatric Haematology and Oncology Laboratory of Bangabandhu Sheikh Mujib Medical University; while in the first study, stool microbiology, ELISA, and molecular tests were carried out at the Microbiology laboratory of the International Centre for Diarrhoeal Disease Research (Dhaka, Bangladesh), in the second study, stool microbiology and ELISA were carried out at the Microbiology Laboratory of Bangabandhu Sheikh Mujib Medical University.

**Data analysis**

Data were collated on a master Excel spread sheet before importing to Statistical Package for Social Sciences software (IBM SPSS Statistics for Windows, version 25.0; IBM Corp., Armonk, NY, United States). Categorical data were expressed as number and proportion while continuous data were expressed as range with measures of central tendency and/or dispersion. Some patients had more than one episode of diarrhoea and hospitalisation, and each presentation was counted separately towards the final denominator.

**RESULTS**

**First study**

During a 12-mo period from April 2012 to March 2013, a total of 58 diarrhoeal episodes were experienced by 51 patients. The demographic characteristics of children included in the study are outlined in Table 1. Of note, more than 50% of the children with diarrhoea included in the study were aged < 60 mo. Pathogens detected are listed in Table 1. There was an abundance of *G. lamblia* (68.5%), and non-toxigenic C.
**Study 1**
Period: April 2012 to March 2013
Children with haematological malignancies
Age group: 1-15 yr
Two stool specimens per episode of diarrhoea were collected: One for PCR testing for parasites including *Cryptosporidium*, stool microscopy and bacterial culture; and the second specimen for *Clostridium difficile* testing.

**Study 2**
Period: March 2016 to February 2017
Children with haematological and solid tumour malignancies
Age group: 0-18 yr
One stool sample per episode of diarrhoea was collected for bacterial culture, ELISA to detect *Cryptosporidium*, stool microscopy for other parasites, and *Clostridium difficile* testing in a subset.

Figure 1 Summary of study methods. PCR: Polymerase chain reaction; ELISA: Enzyme-linked immunosorbent assay.

difficile was detected in 13 episodes (22.4%).

In all but two episodes (96.6%), the children had a history of receiving antibiotic therapy or prophylaxis, on average 3.9 d (range 1-16) prior to or during the episode of diarrhoea. Antibiotics received included prophylaxis with oral trimethoprim-sulfamethoxazole (25.9%) or levofloxacin (19%), and treatment with cefepime plus amikacin (19%) or meropenem plus vancomycin (13.8%).

All three children with *Cryptosporidium* infection were male, aged 3.5, 4.5, and 6 years; two of them had acute lymphoblastic leukaemia (ALL) and the other had non-Hodgkin’s lymphoma. All three had severe neutropenia, with absolute neutrophil counts (ANCs) of 150, 20, and 180 per µL. Two patients had multiple parasitic co-infections: one with all three tested parasites and the other with *G. lamblia* and *Cryptosporidium* (Table 2). One of these children had severe dehydration.

**Second study**
During a 12-mo period from March 2016 to February 2017, a total of 70 diarrhoeal episodes were experienced by 66 patients. The demographic characteristics of children included in the study and the pathogens detected are outlined in Table 1. Of note, about 60% of children with diarrhoea included in the study were aged < 60 mo and the majority of pathogens detected were parasites.

Two out of three children with *Cryptosporidium* infection were male, aged 2.5 and 4 years, and the other was female, aged 5 years. One had rhabdomyosarcoma, another had a primitive neuroectodermal tumour, and the third patient had ALL. Two had severe neutropenia with ANC of 20 and 40, and the other had ANC of 790 per µL (Table 2).

**DISCUSSION**

These two pilot studies show that parasites, notably *G. lamblia*, are responsible for a large proportion of diarrhoeal aetiologies among children with malignancy in Bangladesh. A greater number of potential pathogens were detected with PCR compared to ELISA and conventional microbiological methods, as demonstrated in other studies[11]; however, the latter is still found to be useful.

Apart from an exceptionally high detection rate of giardiasis in the first study, the epidemiological profile of parasites was similar to that found among otherwise healthy Bangladeshi children with diarrhoea[7]. *G. lamblia* was detected at a significantly higher rate than among otherwise healthy Bangladeshi children 15.2%[4], and in children with cancer in other countries with a similar socioeconomic profile such as Mexico (28.7%)[13]. These differences may be attributed to both the study population (children with malignancy vs otherwise healthy children) as well as study methodologies (use of PCR in the current study, compared to conventional microscopic detection in the Mexican study). This could also be because of selection bias, as some children with diarrhoea or episodes of diarrhoea may have been missed.

Interestingly, the *Cryptosporidium* burden reported in these pilot studies (4%-5%) is similar to what has been reported in children with cancer in neighbouring countries; e.g., 3.8% in Iran, 4% in Turkey, 2% in Malaysia, 1.3% in India, and 9.6% in Egypt[4,13-16].
Table 1: Patient demographics and laboratory results of hospitalised paediatric oncology patients with diarrhoea at Bangabandhu Sheikh Mujib Medical University hospital, n (%)  

| Particulars                  | Study 1 | Study 2 |
|------------------------------|---------|---------|
| Male:Female                  | 32:19   | 47:19   |
| Age in mo, range (mean)      | 13-180 (70.8) | 11-216 (73.2) |
| Age group                    |         |         |
| ≤ 60 mo                      | 32 (55.2) | 41 (58.6) |
| 61-120 mo                    | 16 (27.6) | 15 (21.4) |
| > 120 mo                     | 10 (17.2) | 14 (20) |
| Diagnosis                    |         |         |
| ALL                          | 37 (63.8) | 40 (57.1) |
| NHL                          | 17 (29.4) | 10 (14.3) |
| AML                          | 4 (7.9) | 7 (10) |
| Others                       |         | 1 (1.4) |
| Solid tumours                |         | 12 (17.1) |
| Phase of treatment           |         |         |
| Induction                    | 37 (63.8) | 43 (61.4) |
| Consolidation                | 14 (24.1) | 10 (14.3) |
| Maintenance                  | 6 (10.3) | 12 (17.1) |
| Not applicable               | 1 (1.7) | 5 (7.1) |
| ANC category                 |         |         |
| < 500/mm²                    | 47 (81) | 42 (60) |
| ≥ 500/mm²                    | 11 (19) | 28 (40) |
| Number of bowel motions/d    |         |         |
| ≥ 10                         | 29 (50) | 10 (14.2) |
| 6-9                          | 19 (32.8) | 40 (57.1) |
| ≤ 5                          | 10 (17.2) | 20 (28.6) |
| Pathogens detected in stool samples |         |         |
| *Giardia lamblia*            | 37 (68.5) | 1 (1.4) |
| *Entamoeba histolytica*      | 7 (13) | 10 |
| *Cryptosporidium*            | 3 (5.6) | 3 (4.3) |
| *Clostridium difficile*      | 13 (22.4) | 2 (5.1) |
| *Campylobacter jejuni*       | 2 (3.4) | 1 (1.4) |
| *Salmonella spp*             | 1 (1.7) | 1 (1.4) |
| *Shigella sonnei*            | 0 (0) | 1 (1.4) |
| *Vibrio cholerae*            | 0 (0) | 1 (1.4) |

1Each episode of diarrhoea was included as a separate event counting towards the denominator used for each characteristic, with the exception of gender (where each child was counted only once irrespective of the number of episodes of diarrheal experienced);  
2In the first study, only 54 of the total 58 samples were processed by polymerase chain reaction for parasites, and in the second study *Clostridium difficile* was investigated in only 39 randomly selected samples out of the total 70 samples, of which 2 were positive, none were toxin-positive. ALL: Acute lymphoblastic leukaemia; AML: Acute myeloblastic leukaemia; ANC: Absolute neutrophil count per µL; NHL: Non-Hodgkin's lymphoma.

The slight variation in these rates is likely because of disparities in testing practice, diagnostic methods used, age groups included, and study design[1,11]. Conversely, an Australian study that investigated 149 stool samples from 60 paediatric oncology patients with diarrhoea found none to be positive for *Cryptosporidium*. Contamination of drinking water may be the source of many *Cryptosporidium* infections in Bangladesh, whereas in Australia exposure to contaminated recreational water (e.g., swimming pools) is the most common source of infection[17]. A comparative study involving Jordanian children demonstrated that compared to children without cancer, paediatric oncology patients had higher prevalence of *Cryptosporidium* infection (5.1% vs 14.4%, P ≤ 0.05)[18]. These data suggest that the aetiological role of *Cryptosporidium* is dependent on cancer as an underlying co-morbidity, as well socio-economic and geographic variables among others.

In our setting, in the first dedicated pilot study, 22.4% children were found to be
positive for *C. difficile* in their stool with an absence of toxin positivity based on EIA; while in the second study 5.1% (only in 39 subjects tested) were positive for *C. difficile* (none were toxin positive). In comparison, among Dutch immunocompromised children admitted to a tertiary hospital, the prevalence of *C. difficile* detected by culture and cytotoxin tissue culture assay was 27.4%, with over half toxin-positive[19]. In contrast, the prevalence of toxigenic *C. difficile* among symptomatic paediatric oncology patients was found to be 8.7% in a prospective Australian study (based on culture and EIA for toxin A and cytopathic assay for toxin B), with an additional 4% with non-toxigenic *C. difficile*[20]. Interestingly, in this study, the prevalence of toxigenic and non-toxigenic *C. difficile* was higher among asymptomatic children (19% and 6.7% respectively) indicating that toxigenic *C. difficile* may be part of children’s indigenous gastrointestinal flora, particularly in young infants, as observed in other studies[20,21]. The prevalence of toxigenic *C. difficile* colonisation may also be higher in children with underlying malignancy. The colonisation rate of *C. difficile* among asymptomatic Iranian children with cancer was 25% by stool culture, 92% of which were toxicogenic based on cytopathic effect on HeLa cells[22]. Although no studies of Bangladeshi children with malignancy exist, among otherwise healthy Bangladeshi children hospitalised with diarrhoea, 1.6% were infected with *C. difficile* diagnosed by cell cytotoxin assay in 1993-1994[23].

Despite high rates of colonisation, with even toxigenic strains of *C. difficile* among asymptomatic children with malignancy, it is important to have an accurate estimate of the prevalence in our population since it has been shown that colonisation with a toxigenic strain is predictive of subsequent *C. difficile* infection[24]. Further studies using PCR to detect presence of *C. difficile* toxins would be useful given the limited sensitivity of EIAs used in the current studies.

There were several limitations to these studies. First, the sample sizes were small, the study methodologies were different across the two studies, diagnostic tools used were not uniform, the age groups differed, and in the second study *C. difficile* was tested in only a small subset of patients; hence the findings are not generalisable. However, despite these shortfalls, these two are the first ever studies in Bangladeshi children with malignancy, who present with diarrhoea. While molecular diagnostic tools detect an array of stool pathogens with greater sensitivity, conventional laboratory diagnostic methods are also useful.

### ARTICLE HIGHLIGHTS

**Research background**

Diarrhoea is a frequently occurring symptom among children with cancer. In a large proportion of cases, the aetiology of diarrhoea remains unknown but often multiple pathogens are

### Table 2 Summary of paediatric oncology patients with diarrhoea from whose stool samples *Cryptosporidium* was detected

| Patients | Age in yr | Gender | Primary diagnosis | Phase of treatment | Preceding hospital stay in d | Frequency of bowel motions/d | Fever | Mucositis | Stool microscopy | ANC |
|----------|-----------|--------|------------------|--------------------|-----------------------------|-----------------------------|-------|------------|------------------|-----|
| Study 1  |           |        |                  |                    |                             |                             |       |            |                  |     |
| Patient 1| 4.5       | Male   | NHL              | Induction          | 15                          | 16                          | Present| Present    | 11-20 pus cells per HPF | 150 |
| Patient 2| 3.5       | Male   | ALL              | Maintenance        | 0                           | 6-9                         | Present| Absent     | > 50 pus cells per HPF | 20  |
| Patient 3| 6         | Male   | ALL              | Maintenance        | 0                           | 3                           | Present| Absent     | > 10 per HPF          | 180 |
| Study 2  |           |        |                  |                    |                             |                             |       |            |                  |     |
| Patient 1| 4         | Male   | RMS              | Induction          | 7                           | > 10                        | Absent| Absent     | Normal            | 790 |
| Patient 2| 5         | Female | PNET             | Induction          | 0                           | 6-9                         | Present| Present    | Pus cells         | 20  |
| Patient 3| 2.5       | Male   | ALL              | Induction          | 22                          | 6-9                         | Present| Absent     | Normal            | 40  |

1 Days in hospital prior to the onset of diarrhoea. ALL: Acute lymphoblastic leukaemia; ANC: Absolute neutrophil count per µL; HPF: High power field; NHL: Non-Hodgkin’s lymphoma; PNET: Primitive neuroectodermal tumour; RMS: Rhabdomyosarcoma.
attributed.

**Research motivation**
There is little or no information about pathogens responsible for diarrhoea among children with cancer in Bangladesh, a country where diarrhoeal diseases are endemic.

**Research objectives**
To describe pathogens causing diarrhoea in Bangladeshi children with cancer.

**Research methods**
Two cross-sectional pilot studies were carried out involving hospitalised paediatric oncology patients with diarrhoea. Stool samples were tested by conventional microscopy and culture techniques and by polymerase chain reaction for parasites and bacteria, as well as immunoassays for *Clostridium difficile*, and enzyme-linked immunosorbent assay for *Cryptosporidium* antigen.

**Research results**
In the first study *Giardia lamblia* was detected in around 69% of samples, *Entamoeba histolytica* in 13%, *Cryptosporidium* in 6%, non-toxigenic *C. difficile* in 22% and other bacteria in 5%. In the second study, *Entamoeba histolytica* was detected in 10% of samples, *Cryptosporidium* in 4%, *G. lamblia* in 1%, non-toxigenic *C. difficile* in 5% and other bacteria in 6% of samples.

**Research conclusions**
These pilot data suggest that parasites are important aetiologies of diarrhoea among Bangladeshi children with malignancy.

**Research perspectives**
In a resource poor setting such as Bangladesh, while molecular diagnostic tools allow detection of an array of stool pathogens with greater frequency, conventional laboratory diagnostic methods are still useful.

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