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**Naomi Sirmai***
University of New South Wales, Sydney, New South Wales, Australia
**Lydia Garside**
**Dimitra Tzioumi**
Sydney Children's Hospital, Sydney, New South Wales, Australia

# Abusive Head Trauma in Infants: Incidence and Detection of Prior Brain Injury

**'[Aims] to quantify the incidence of prior presentations with features of brain injury in AHT, and to compare these figures to those in non-abusive head trauma'**

Diagnosis of abusive head trauma (AHT) is challenging; clinical signs are non-specific and perpetrator confessions are rare. Moreover, many infants sustain multiple episodes of abuse before presenting to medical practitioners. The objective of this study was to quantify the incidence of prior presentations with features of brain injury in AHT, and to compare these figures to those in non-abusive head trauma (non-AHT). Data on children under the age of two years who were assessed for AHT by the Child Protection Unit of Sydney Children's Hospital between 2008 and 2017 were collected, and AHT cases were compared with non-abusive cases. Of the 167 cases assessed for head trauma, 26 per cent had at least one prior presentation to medical care. This was 42 per cent of the AHT cases, and 11 per cent of the non-AHT cases. Odds ratio calculations revealed infants with AHT were 5.7 times more likely to have had a prior presentation than children with non-AHT (CI = 2.4–13.17, $p < 0.001$). Infants with AHT are much more likely than infants with non-AHT to have presented previously to medical practitioners. This difference suggests that there is an early diagnostic window within which abuse can be detected before it continues or escalates. Careful evaluation of an infant is of paramount importance, and may save a life. © 2020 John Wiley & Sons, Ltd.

KEY PRACTITIONER MESSAGES:

- Medical practitioners should consider the possibility of brain injury in a child presenting with non-specific symptoms, and consider that this brain injury could be abusive in nature.
- Suspicions of abusive head trauma should be increased if the child has presented with signs consistent with brain injury before.
- Suspicions of abusive head trauma should be increased if there is no mechanism of an injury provided by the child's carer.

KEY WORDS: non-accidental head injury; abusive head trauma; physical abuse; infant; retrospective cohort study; hospitals

## Introduction

Abusive head trauma (AHT) is inflicted injury to the head and its contents (American Academy of Pediatrics, 2001). It is the leading

*Correspondence to: Naomi Sirmai, UNSW Medicine, Wallace Wurth Building, 18 High St, Kensington NSW 2052, Australia. E-mail naomisirmai@hotmail.com



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cause of death in children who have been physically abused (Reece and Sege, 2000), with two out of three cases resulting in disability or death (Sieswerda-Hoogendoorn *et al*., 2012). The long-term sequelae include developmental delay, motor, sensory and language deficits, epilepsy, intellectual disability and behavioural disorders (Barlow *et al*., 2004; Duhaime *et al*., 1996; Ewing-Cobbs *et al*., 2006; Hymel *et al*., 2007; Lind *et al*., 2016; Maguire *et al*., 2009; Stipanicic *et al*., 2008). A 2016 study by Lind *et al*. which followed children who sustained severe AHT showed that only 15 per cent had 'good outcomes' according to the Glasgow Outcome Scale (Lind *et al*., 2016). Moreover, outcomes of AHT are worse than outcomes of non-AHT: a 1998 study found that moderate disability is more than three times as likely in AHT compared to non-AHT, and having an intellectual disability following AHT is nine times more likely than in non-AHT (Ewing-Cobbs *et al*., 1998). This is the case even when controlling for injury severity (Chevignard and Lind, 2014).

**'[AHT] is the leading cause of death in children who have been physically abused'**

The most common presumed mechanisms for AHT are shaking, impact, or the two combined. There is evidence to suggest that children are shaken anywhere from two to 30 times before finally presenting to medical practitioners and being diagnosed with abuse, and a 2010 study of perpetrator confessions found that 55 per cent of perpetrators report shaking their child at least once before (Adamsbaum *et al*., 2010).

Shaking with or without impact can cause a spectrum of brain injury from minor concussion to death. The clinical features of this spectrum in infants are largely non-specific. They include apnoea, altered level of consciousness, vomiting, seizures, increased head circumference and altered muscle tone (Adamsbaum *et al*., 2010; Arbogast *et al*., 2005; Fortin and Stipanicic, 2010; Hadley *et al*., 1989; Hobbs *et al*., 2005; Kemp, 2011).

**'Shaking with or without impact can cause a spectrum of brain injury from minor concussion to death'**

These signs can be missed or mischaracterised in emergency departments and GP clinics (Hymel *et al*., 2007). For example, signs of brain injury may be interpreted as a 'BRUE' – a 'brief resolved unexplained event' – for which neuroimaging and hospital admission is not indicated (Stunley and Tate, 2018).

Complicating timely diagnosis further, the child's clinical presentation is rarely accompanied by a satisfactory history consistent with abuse. Previous studies have shown that the most common history of the mechanism of the injury provided in cases of AHT is a history of a low-impact fall from a short height (e.g. one metre), or no history of trauma at all – sometimes with deliberate falsification of details to protect the perpetrator (Byard, 2006; Hettler and Greenes, 2003; Hymel *et al*., 2007; Reece and Sege, 2000).

Neuroimaging is absolutely fundamental to the diagnosis of AHT, and important in the ongoing management of the child. Current guidelines suggest that the best choice for imaging children presenting acutely with suspected head trauma is computed tomography (CT) – followed by magnetic resonance imaging (MRI) of the head and spine if the CT reveals intracranial injury or skull fracture (Kemp *et al*., 2009; Royal College of Radiologists and the Society and College of Radiographers, 2017). There is understandably controversy in the broader medical community regarding the use of CT in children, given the increased risk of cancer following exposure to ionising radiation (Bajoghli *et al*., 2010; Goske, 2014; Pearce *et al*., 2012). It is not unreasonable to acknowledge the radiation dose in a risk–benefit context. Notwithstanding, the literature widely acknowledges that even a small benefit



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**'Given the severe consequences of AHT, there should be a low threshold for considering intracranial injury and performing a CT to investigate'**

outweighs the potential long-term effects of ionising radiation, and, given the severe consequences of AHT, there should be a low threshold for considering intracranial injury and performing a CT to investigate (Jenny *et al*., 1999).

In the context of our understanding that most children are shaken, and potentially suffer brain injury, several times before diagnosis, it is logical to assume that many of the children we diagnose with AHT will have previously presented to medical practitioners with signs of brain injury. Indeed, studies have demonstrated that the diagnosis may be missed by medical practitioners, only to be diagnosed at later presentations. A 1999 study found that 31.3 per cent of infants with AHT had previously presented to physicians with signs of AHT, but the diagnosis went unrecognised at that time (Jenny *et al*., 1999). In their study, the mean time to correct diagnosis was seven days. This study was replicated in a 2016 report by Letson *et al*., which found that 31 per cent of infants with AHT had at least one prior presentation. Of note is that in the years since the Jenny study, the rate of missed diagnoses has not improved (Letson *et al*., 2016).

These findings suggest that there is a window of opportunity within which AHT can be diagnosed before it continues and escalates, causing severe disability or death. The missed diagnosis of AHT is a relatively unexplored area of research, and no study yet has compared abusive with non-abusive head trauma. This distinction is important due to the difference in outcomes and rates of repeated injury between the two groups.

**'We identify the probability of prior presentation for children under the age of two years who have either AHT or non-AHT'**

In this study, we build on previous findings by comparing abusive and non-abusive groups. Specifically, we identify the probability of prior presentation for children under the age of two years who have either AHT or non-AHT.

## Aims

The primary objective of this study was to establish whether children with AHT are more likely to have had previous presentations with clinical features consistent with brain injury than children with non-abusive head injury (non-AHT). The secondary objectives were to: 1) establish whether children with AHT tend to present with a history of a mechanism of an injury, or with signs or symptoms and no history; and 2) to establish whether the group found to be 'indeterminate' (neither definitively abusive nor non-abusive) is clinically more similar to the abusive or the non-abusive groups.

## Methods

### *Study Design*

After obtaining ethics approval from our local Human Research Ethics Committee, we conducted a retrospective review of cases of head trauma seen by the Child Protection Unit (CPU) at our local Children's Hospital, from the 10 years between 1 January 2008 and 31 December 2017.

### *Population*

The study population was derived from the 524 patients under two years of age who received a formal assessment by the hospital's specialist CPU for possible physical abuse. In total, 174 of these patients were assessed for head trauma, and, of these, 167 files could be retrieved. Records were obtained using the CPU's internal database of cases seen, and then accessed either on electronic medical records or via retrieval of paper records. Cases with missing data or irretrievable records were excluded from the study.

### *Data Collection and Analysis*

Basic demographic information was collected about each child, including their sex and age at the time of assessment. Also collected was information regarding their presentation at hospital – the triage notes, presenting symptoms and clinical signs and the results of any imaging and investigations performed.

Features of brain injury recorded were apnoea, altered level of consciousness, vomiting, seizures, increased head circumference and altered muscle tone. Also recorded were examination and investigative findings such as bruising of the head or face and retinal haemorrhages. Data from any and all of their prior presentations with signs of brain injury, including the information listed above, and the diagnosis they were assigned at the time were also collected.

**‘Features of brain injury recorded were apnoea, altered level of consciousness, vomiting, seizures, increased head circumference and altered muscle tone’**

A ‘prior presentation’ was defined as a situation where:

1. The child was seen and evaluated by a medical practitioner

   AND

2. The child had symptoms or signs that could have been consistent with brain injury

   AND

3. The diagnosis of abuse was not considered.

For each prior presentation, the time between that assessment and the final diagnosis of head trauma was recorded.

Of the 167 children assessed by the CPU for AHT, we compared the 57 cases diagnosed as abusive by a specialist child protection physician to the 88 cases which were determined to be non-abusive in nature, and compared both to the remaining 22 cases that were not able to be definitively diagnosed as abusive nor non-abuse, named ‘indeterminate’ for the purpose of this study. The classification of cases was determined by the child protection specialist managing the case; a decision derived from history, physical examination, investigation results and social work consultation. In addition, all cases had neurosurgery, neurology and radiology reviews.

### *Statistical Analysis*

Abusive, non-abusive and indeterminate groups were compared using the $\chi 2$ test, and odds ratios were calculated to compare outcome variables. A $p$-value $<0.05$ was interpreted as statistically significant.

## Results

### *Demographic Characteristics*

**'Our cohort was comprised of 163 children under the age of two years seen by the CPU in the last 10 years for assessment of their head trauma'**

Our cohort was comprised of 163 children under the age of two years seen by the CPU in the last 10 years for assessment of their head trauma. Our cohort had 105 males (63%) and 62 females (37%). The mean age of our cohort was 211 days (6.9 months), with a range of 63–717 days. The mean age of the AHT group was 195 days (6.4 months, range: 63–717), the mean age of the non-AHT group was 215 days (7.9 months, range: 20–684), and the mean age of the indeterminate group was 239 days (7 months, range: 118–711) (Table 1).

**Table 1.** Demographic, clinical and neuroimaging data of comparative subject groups on final presentation

| | | Abusive (*N* = 57) | Non-abusive (*N* = 88) | Indeterminate (*N* = 22) |
|---|---|---|---|---|
| **Age at final presentation, days** | Mean | 195 | 215 | 239 |
| | Range | 63–717 | 20–684 | 77–711 |
| **Gender, n (%)** | Male | 34 (60%) | 55 (62.5%) | 16 (73%) |
| | Female | 23 (40%) | 33 (37.5%) | 6 (27%) |
| **Prior presentation with features consistent with head injury? (%)** | | 24 (42%) | 10 (11%) | 10 (45%) |
| **Presenting signs, n (%)** | Altered level of consciousness | 23 (40%) | 10 (11%) | 8 (26%) |
| | Vomiting | 13 (23%) | 14 (16%) | 4 (18%) |
| | Bruising of the head/face, subconjunctival haemorrhage | 18 (31.5%) | 5 (5.5%) | 3 (13.5%) |
| | Altered respiration/apnoea | 15 (26%) | 2 (2%) | 3 (13.5%) |
| | Seizure(s) | 21 (37%) | 7 (8%) | 11 (5%) |
| | Altered muscle tone | 7 (12%) | 5 (5.5%) | 0 (0%) |
| | Increased head circumference | 16 (28%) | 7 (8%) | 7 (32%) |
| **Information from parents/carers** | History of an injury provided (%) | 7 (12.5%) | 49 (55.5%) | 5 (22.5%) |
| | Nil history of an injury (%) | 50 (87.5%) | 39 (44.5) | 17 (77.5%) |
| **Imaging and investigative findings, n (%)** | Retinal haemorrhages | 35 (61%) | 9 (10%) | 6 (27%) |
| | Rib fractures | 27 (47%) | 1 (1%) | 1 (4.5%) |
| | Subdural haemorrhage | 53 (93%) | 22 (25%) | 19 (86%) |
| | Skull fracture | 15 (26%) | 71 (80%) | 2 (9%) |
| | Subcutaneous/subgaleal haemorrhage | 2 (3.5%) | 33 (37.5%) | 2 (9%) |
| | Extradural/epidural haemorrhage | 2 (3.5%) | 12 (13.5%) | 1 (4.5%) |
| | Subarachnoid haemorrhage | 9 (16%) | 6 (7%) | 1 (4.5%) |
| | Hypoxic/ischaemic injury | 26 (45%) | 2 (2%) | 2 (9%) |
| | Cerebral contusion | 5 (9%) | 4 (4.5%) | 2 (9%) |
| | Cerebral oedema | 14 (24.5%) | 1 (1%) | 3 (13.5%) |
| | Diffuse axonal injury | 5 (9%) | 0 (0%) | 0 (0%) |
| | Intraparenchymal haemorrhage | 8 (14%) | 2 (2%) | 1 (4.5%) |
| **Death from head injury, n (%)** | | 6 (12%) | 0 (0%) | 1 (4.5%) |

There was a statistically significant difference between the age of the AHT and non-AHT groups ($p = 0.03$), suggesting that the AHT group are likely to be younger. However, the wide range observed in the age of all groups suggests that this is of little clinical significance.

### *Prior Presentations*

A total of 44 patients (26%) in our cohort had presented previously to medical practitioners with signs that could indicate neurological injury. This included 24 of the AHT cohort (42%), ten of the non-AHT cohort (11%) and ten of the indeterminate cohort (45%).

The odds ratio of having a prior presentation was calculated to show that the AHT group was 5.7 times more likely to have a prior presentation than the non-AHT group (CI = 2.4–13.17, $p < 0.001$). There was a statistically significant difference between the non-AHT and indeterminate groups: the children diagnosed as 'indeterminate' were 6.5 times more likely to have had a prior presentation than children with non-AHT (CI = 2.2–18.8, $p < 0.001$). Importantly, there was no statistically significant difference between the AHT and the indeterminate groups (CI = 0.3–2.3, $p = 0.79$), suggesting that they were equally likely to have had a prior presentation.

Concerning the group with at least one prior presentation, the median number of days between the initial presentation with signs of injury and the final diagnostic presentation was ten, with a range of 1–114. In the AHT group, the median number of days between initial and final presentation was 14 (range = 1–114). In the non-AHT group, the median was 4.5 days (range = 1–10). In the indeterminate group, the median was 44 days (range = 1–112).

For our 44 patients who had at least one prior presentation, there were a total of 72 'diagnostic opportunities', meaning that some patients saw doctors multiple times before finally being diagnosed with head trauma – be that AHT or non-AHT. The most common presenting complaints in these 'diagnostic opportunities' were vomiting (18 instances), irritability (11), head swelling (10), and 'fits' (8). The most common clinical features as documented by medical practitioners were vomiting (28 instances), altered level of consciousness (12), seizures (8), and increased head circumference (8). The most common diagnoses assigned were respiratory infection (10 instances), reflux (9), and gastrointestinal upset (7). No formal diagnosis was given in 32 instances. One patient presented to hospital with vomiting five times over 112 days before neuroimaging was performed and head injury was diagnosed. In all these instances, head injury was only documented as a differential diagnosis three times, in three different patients. Table S1 summarises the details of all our population's prior presentations (see the online Supporting Information).

### *Symptoms or History of Presenting Complaint*

In total, 106 out of 167 of our cohort (63.5%) presented with symptoms alone, and no history of an injury. This was 87.5 per cent of the AHT group, compared to 44.5 per cent of the non-AHT group and 77.5 per cent of the indeterminate group. Odds ratio calculations revealed that the AHT group

**'A total of 44 patients (26%)… had presented previously to medical practitioners with signs that could indicate neurological injury'**

**'Some patients saw doctors multiple times before finally being diagnosed with head trauma'**

**'In total, 106 out of 167 of our cohort (63.5%) presented with symptoms alone, and no history of an injury'**



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was 8.9 times more likely to present with symptoms and no history than the non-AHT group (CI = 3.6–21.9, $p < 0.001$). There was a statistically significant difference between the non-AHT and indeterminate groups: the indeterminate group was 4.3 times more likely to present with symptoms than the non-AHT group (CI = 1.4–12.6, $p = 0.009$). However, there was no statistically significant difference between the AHT and indeterminate groups (CI = 0.5–7.5, $p = 0.25$).

### *Deaths in our Cohort*

**'Seven patients in our cohort died'**

Seven patients in our cohort died – and all as a result of their brain injury. Six cases were deemed to be AHT and one was deemed indeterminate. On clinical examination, all seven of these patients had retinal haemorrhages. Neuroimaging revealed that six of the patients who died had cerebral oedema, and four had global hypoxic-ischaemic brain injury. Of the seven deaths, three patients had one or more prior presentations. These three cases were all deemed AHT upon final presentation. Each of these three children had previously presented with vomiting (see Table S2 in the online Supporting Information).

### *Key Findings*

Key findings from this study are summarised in Table 2.

## Discussion

**'Prior presentations with possible head trauma are far more common in abusive cases than non-abusive ones'**

We hypothesised that a significant proportion of infants who have been diagnosed with AHT had previously seen medical practitioners, with clinical features of brain injury that were not recognised as being caused by brain injury at the time. Our results confirm this hypothesis and provide preliminary evidence that prior presentations with possible head trauma are far more common in abusive cases than non-abusive ones.

This builds upon the findings of Jenny *et al*.'s (1999) study, and the similar findings of Letson *et al*. (2016), which found that 31.2 per cent of their cohort of children with AHT had seen physicians previously with features of brain injury. Their mean time to correct diagnosis was seven days. This is compared to our cohort, where we found that 42 per cent of children with AHT had presented previously with features of brain injury: the median time to correct diagnosis being 14 days. Jenny *et al*. (1999) included children between the ages of two and three years in their study, whereas we restricted our population

**Table 2.** Key findings

| | TOTAL | Abusive head trauma | Non-abusive head trauma | Indeterminate |
|---|---|---|---|---|
| **Cohort numbers** | 167 | 57 | 88 | 22 |
| **Prior presentation (%)** | 44 (26%) | 24 (42%) | 10 (11%) | 10 (45%) |
| **Median number of days to correct diagnosis in those with a prior presentation (range)** | 10 (1–114) | 14 (1–114) | 4.5 (1–10) | 44 (1–112) |
| **Died from their head trauma** | 7 | 6 | 0 | 1 |

to infants under the age of two. This may help to explain the difference in findings. Notwithstanding this, our population is broadly comparable to similar studies in population size and demographics including gender.

### *Time before Diagnosis*

Among those who had previously presented, the median number of days to correct diagnosis – the time between the first presentation with signs of brain injury and the final diagnosis – was significantly higher in the abusive than the non-abusive group. This may partially help to explain the difference in outcomes between the two groups. Outcomes of AHT are significantly worse than outcomes of non-AHT (Johnson *et al*., 1995). A 1998 study found that moderate disability is more than three times as likely in AHT compared to non-AHT, and having an intellectual disability following AHT is nine times more likely than in non-AHT. Only four of the 20 children with AHT had a 'good' recovery, compared to 11 of the children with non-AHT (Ewing-Cobbs *et al*., 1998). This delayed diagnosis, combined with the fact that children generally sustain multiple abusive injuries before diagnosis, likely explains this difference (Adamsbaum *et al*., 2010).

### *History of an Injury*

A 2010 study by Adamsbaum *et al*. that compared confessed and non-confessed cases of AHT found no statistically significant difference between clinical findings in the two groups (Adamsbaum *et al*., 2010). This suggests that histories alone are an unreliable means of diagnosis, and that the lack of a comprehensive explanation of the mechanism of an injury should alert the practitioner to the possibility of abuse.

Acknowledging this, we also analysed whether the groups in our study presented with either a comprehensive history of the mechanism of their injury, or with just symptoms alone. For example, the difference between presenting with the history of 'a fall 1.5m from a change table' and presenting with 'seizures and apnoea' and no history of any injury. Our finding, that abusive cases are significantly less likely to present with a history of a mechanism of an injury than non-abusive cases, validates the current clinical practice of establishing a 'film-reel'-like recount of how the injury occurred.

The implications of this in practice are that, if an infant presents with head injury and no history of an injury that might have caused it, suspicion of abuse should be increased. All seven of the patients in our cohort who died presented with symptoms, and no account of any injury.

**'If an infant presents with head injury and no history of an injury that might have caused it, suspicion of abuse should be increased'**

### *The 'Indeterminate' Group*

Statistical analysis was performed to compare the AHT and non-AHT groups, and to compare the indeterminate group with each. Of note is the finding that there was no statistically significant difference between the AHT and indeterminate groups in terms of prior presentations and whether they presented with signs or with a history of an injury. This is clinically significant, as it suggests that those cases that appear 'indeterminate' to the clinician have an appearance far more similar to the abusive cases than to the non-abusive

ones. Essentially, our study adds weight to the idea that the indeterminate and AHT groups are likely the same.

### *Limitations, Strengths and Recommendations*

Our study's primary limitations include its relatively small sample size and patient pool from a single paediatric hospital. In addition, there were several patients with significant AHT who were not included in the study as they were just days over the age of two. Confidence intervals could be narrowed by including more patients – from different child protection units, or from further back in our unit's records.

An issue faced during data collection was retrieving medical records. Prior to 2010, medical records at Sydney Children's Hospital were not digitised. This meant that patient records had to be ordered and transported to the hospital, before being sifted through manually. In these cases, imaging reports were available, but the images themselves were not. This speaks to another issue, which was the lack of standardisation in the amount of data available for each case.

**'Our findings likely underestimate the number and proportion of prior presentations'**

The difficulty retrieving medical records from other hospitals and general practitioners (GPs) means that our estimate of prior presentations in our population is an absolute minimum. Our findings likely underestimate the number and proportion of prior presentations, as it is very possible that a greater number in our cohort had seen doctors previously, but these visits were not visible on their electronic or paper medical records. Future studies may seek to contact the GPs of the patients involved to ensure that no visits are missed and that our picture of the patient's clinical history is complete.

Another limitation of our study is the fact that medical judgements are made on the basis of available evidence and clinical experience; both of which are coloured by the personal bias of physicians. For example, practitioners may be biased towards a diagnosis of 'abuse' if a child has presented with injury many times previously – even if these injuries have been explained. In the same way, practitioners may be biased towards a diagnosis of 'non-abusive injury' if a child presents with a simple skull fracture and no other injury – even if this skull fracture remains unexplained. The results of our study are derived from the findings of physicians, all of whom are affected by these biases in some way, so there is an obvious, if unavoidable, element of circular reasoning in our results.

In a similar vein, the non-AHT group was used as a 'control' group in this study, but, of course, there were selection factors that led them to be referred to the CPU for evaluation, making them a poor representation of cases of non-abusive head injury in the general population, most of which we never see.

## Conclusion

Our study illustrates that, compared with infants with non-AHT, infants with AHT are much more likely to have presented previously to medical practitioners with signs of brain injury. The significant incidence of prior presentations in the AHT group suggests that, for a proportion, there is an early

diagnostic window within which abusive injury can be detected before it continues or escalates.

We would recommend careful evaluation of every child presenting with non-specific symptoms such as vomiting, seizures, altered level of consciousness or apnoea to ensure that they do not have a brain injury. A rigorous history and careful examination, looking for other signs of trauma, and judicious neuroimaging is of paramount importance, and may save a life.

**‘A rigorous history and careful examination, looking for other signs of trauma, and judicious neuroimaging is of paramount importance, and may save a life’**

## Conflict of Interest

There are no conflicts of interests.

## Ethics approval

This project is ethics-approved by Geraldine Bicol (Sydney Children's Hospital Network Research Governance Officer) as of 26 February 2018. HREC reference number: LNR/17/SCHN/486.

## Contributions of authors

Naomi Sirmai collected and analysed data and wrote the manuscript. Data collection and analysis were supervised and reviewed by Dr Garside and Dr Tzioumi. The manuscript was reviewed and edited by Dr Garside.

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## Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.