The Underlying Aetiology of Infantile Spasms (West Syndrome): Information from the International Collaborative Infantile Spasms Study (ICISS)

John P Osborne MDa,b  , Stuart W Edwards PhDa,b, Fabienne Dietrich Alber MScc , Eleanor Hancock MDb, Anthony L Johnson PhDd , Colin R Kennedy MDe , Marcus Likeman FRCRf , Andrew L Lux PhDg , Mark Mackay MBBSh , Andrew Mallick PhDg , Richard W Newton MDi , Melinda Nolan MBBS j , Ronit Pressler PhDk, Dietz Rating MD l, Bernhard Schmitt MD m , Christopher M Verity FRCPCHn and Finbar J K O’Callaghan PhDb,o on behalf of the participating investigators\*

\*Participating investigators (principal investigators and local enrolling clinicians) to be listed on the web version and in any reprints along with the number of cases enrolled, if any.

a Department for Health, University of Bath, Claverton Down, Bath BA2 7AY.

b Children’s Department, Royal United Hospitals Bath NHS Foundation Trust, Combe Park, Bath BA1 3NG.

c Division of Neurology/Neuropsychology, University Children’s Hospital, Steinwiesstrasse 75, CH-8032 Zurich, Switzerland.

d Medical Research Council Clinical Trials Unit at UCL, Institute of Clinical Trials and Methodology, 90 High Holborn, , London, WC1V 6LJ.

e Clinical Neurosciences, Faculty of Medicine, University of Southampton. Mailpoint 803 G, Southampton General Hospital, Southampton, SO16 6YB

f Department of Paediatric Radiology, Bristol Royal Hospital for Children, Upper Maudlin Street, Bristol BS3 8AE.

g Department of Paediatric Neurology, Bristol Royal Hospital for Children, Upper Maudlin Street, Bristol BS3 8AE.

h Neurology Department, The Royal Children’s Hospital Melbourne, 50 Flemington Road, Parkville, Victoria 3058, Australia.

i Department of Neurology, Royal Manchester Children’s Hospital, Hathersage Road, Manchester, M13 9WL

j Starship Children’s Health, Private bag 92024, Auckland 1142, New Zealand.

k UCL Institute of Child Health, Clinical Neurosciences, London WC1N 1EH.

l Retired Professor of Paediatric Neurology, University of Heidelberg, Germany.

m Division of Paediatric Neurology, University Children’s Hospital, Steinwiesstrasse 75, CH-8032 Zurich, Switzerland.

n PIND research, Box 267, Addenbrookes Hospital, Cambridge CB2 0QQ.

oHead of Clinical Neurosciences Section, Room 41, 4th Floor PUW South, Institute of Child Health, University College London, London WC1N 1EH

Corresponding author:

Professor Finbar J K O’Callaghan, Head of Clinical Neurosciences Section, Room 41, 4th Floor PUW South, Institute of Child Health, University College London, London WC1N 1EH

Email: f.o'callaghan@ucl.ac.uk

Telephone: 0207 905 2927

Key words

Infantile spasms: West’s syndrome: Aetiology:

No of text pages: 7

No of words: 2002

No of references: 14

No of figures: 0

No of tables: 6 plus a further 5 for publication as a web appendix

Acknowledgements:

This research was sponsored by the Royal United Hospitals Bath NHS Foundation Trust and we thank their R&D department for all their input and support for the trial. The trial website was hosted by the University of Bath. This research was also supported by the NIHR Great Ormond Street Hospital Biomedical Research Centre. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. We thank the parents who gave their time and their permission for their infants to take part in the study at a difficult and traumatic moment. We also thank the members of the Data Monitoring and Ethics Committee who freely gave their time to review untoward events and the progress of the trial: Richard Purvis, Chairman, Linda Hunt, Jane Schulte and John Wilson. We thank Catherine Carter and Mark Scholefield for their time and input as Parent Advisors to the trial. We thank Gordon Taylor who provided the randomisation sequences. Administrative assistance was provided by Patricia Sheppard throughout the trial and also by Ros Conacher, Rowan Dalley-Smith, Jessica Graysmark, Veronica Kerr, Ewa Mapstone, Christina Padovani and Kathryn Wheeler. Carol Jackson, paediatric pharmacist, provided frequent help and advice. Phillip Lunt, Thomas Trentham and Richard Wood provided IT advice. Karen Giles built the results database. We also owe a massive debt of thanks to the clinicians and the EEG and MRI departments who took part. We thank the local research nurses for their help and assistance. The trial was funded by the Castang Foundation: significant additional funding was provided by the Bath Unit for Research in Paediatrics, the NIHR and the R&D department at the Royal United Hospital with smaller contributions from the BRONNER-BENDER Stiftung/Gernsbach and the University Children’s Hospital Zurich: we are extremely grateful to them all.

Conflict of Interest:

During the course of this study, FJKO’C, SWE, EH, ALL and JPO have received a payment from Marathon Pharmaceuticals for intellectual property. The study sponsor has received a payment from UCB Biopharma for intellectual property. DR received a grant from the Bonner-Bender stiftung. FDA, MCB, ALJ, CRK, ML, MTM, AMM, RWN, MN, RP, BS and CMV declare no competing interests.

Ethical publication statement:

We confirm that we have read the Journal’s position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

SUMMARY

**Objective:** To determine the underlying aetiologies in a contemporary cohort of infants with infantile spasms and to examine response to treatment.

**Methods**: Identification of the underlying aetiology and response to treatment in 377 infants enrolled in a clinical trial of the treatment of infantile spasms between 2007 and 2014 using a systematic review of history, examination and investigations. They were classified using the paediatric adaptation of ICD 10.

**Results**: 219 of 377 (58%) had a proven aetiology of whom 128 [58%] responded, 58 of 108 [54%] allocated hormonal treatment and 70 of 111 [63%] combination therapy. Fourteen of 17 (82%, 95% CI 59% to 94%) infants with stroke and infarct responded (compared to 114 of 202 for the rest of the proven aetiology group (56%, 95% CI 48% to 62%, Chi square 4.3, p=0.037): the better response remains when treatment allocation and lead time are taken into account (Odds ratio 5.1, 95% CI 1.1 to 23.6, p=0.037).

20 of 37 (54%, 95% CI 38% to 70%) infants with Down’s syndrome had cessation of spasms compared to 108 out of 182 (59%, 95% CI 52% to 66%, Chi square 0.35, p=0.55) for the rest of the proven aetiology group. The lack of a significant difference remains after taking treatment modality and lead-time into account (Odds ratio 0.8, 95% CI 0.4 to 1.7, p = 0.62). In Down’s infants treatment modality did not appear to affect response: 11 out of 20 (55%) allocated hormonal therapy responded, compared to 9 out of 17 (53%) allocated combination therapy.

**Significance**: This classification allows easy comparison with other classifications and with our earlier reports. Stroke and infarct has a better outcome than other aetiologies while Down’s syndrome might not respond to the addition of vigabatrin to hormonal treatment.

INTRODUCTION

Infantile spasms, also known as West syndrome, constitutes a severe form of infantile epilepsy that is difficult to treat and is associated with a poor outcome[[1](#_ENREF_1)]. The syndrome was the first described epileptic encephalopathy— a condition in which the epileptic activity itself contributes to cognitive and neurological decline[[2-4](#_ENREF_2)]. Infantile spasms have an estimated incidence of about 0.43 per 1000 live births and occur predominantly between 3 and 12 months of age with a peak incidence around 6–7 months[[5](#_ENREF_5)]. Approximately 60% of cases have a diagnosed neurological disorder – the underlying aetiology - that is considered to predispose the individuals to infantile spasms[[6-8](#_ENREF_6)]. To detect an underlying aetiology it is necessary to investigate the antenatal, perinatal and infant’s history, to examine the infant and to undertake relevant investigations. Despite this, some infants will have no detectable neurological disorder and there is no explanation as to why they have infantile spasms.

It is also unclear why some individuals with a particular neurological disorder develop infantile spasms while others, with the same disorder, do not. It is for this reason that it is preferable to talk about an underlying aetiology rather than a cause. The underlying aetiology usually carries, independently of the spasms, a risk of developmental impairment which may or may not be severe. As a result, infants with an underlying aetiology have, on average, a worse developmental outcome than the large minority of infants who have no such disorder identified[[9](#_ENREF_9)].

We have previously reported on the underlying aetiology of 207 infants in our earlier study, the United Kingdom Infantile Spasms Study (UKISS)[[6](#_ENREF_6)] which enrolled infants between June 1999 and the end of 2002. We thought that the more prevalent use of cranial magnetic resonance imaging and the development of diagnostic genetic technologies since 2002 would lead to improved diagnostic detection today and therefore we determined to see what new information was available during our next study, the International Collaborative Infantile Spasms Study (ICISS) which enrolled from 2007 to 2014[[10](#_ENREF_10)]. We also report the response to treatment for each identified aetiology, since this might help identify specific aetiologies that have a particular response to treatment.

METHODS

377 infants were enrolled between March 2007 and May 2014 into a randomized controlled trial comparing hormonal treatment (either prednisolone or tetracosactide depot) alone to hormonal treatment with vigabatrin. Full details have already been published[[10](#_ENREF_10)]. Minimum treatments were oral prednisolone 40mg per day, intramuscular Tetracosactide depot 0.5mg (40iu) on alternate days and oral vigabatrin 100mg per day. The hormonal treatments were given for 14 days followed by a reducing dose of oral prednisolone for 15 days while vigabatrin was continued for 3 months before reducing over the next month. A response to treatment in ICISS was defined as no witnessed spasms on and between days 14-42 from study entry[[11](#_ENREF_11)]. In order to allow direct comparison with the results from UKISS, we also present, in a web appendix, the response to treatment in the ICISS cohort using the definition applied in UKISS – no witnessed spasms on days 13 and 14 from study entry.

As part of the trial, investigators had to report on the underlying aetiology after investigations they considered appropriate, including history (including antenatal, perinatal and postnatal history), examination, fundoscopy, metabolic screen, chromosome analysis and cranial imaging. Report forms were scrutinized by two of the steering group (JPO and FJKO’C) and where considered necessary, additional information was requested. All report forms until age 18 months were scrutinized for aetiological information. Infants were classified as aetiology not known where key information was missing, such as history, examination or cranial scan. A metabolic screen was requested but the result was not chased if an aetiology was already established. An independent review of the cranial MRI scans by a paediatric neuro-radiologist was also requested when considered necessary (ML). The results were used to classify the underlying aetiology using the paediatric adaptation of the International Classification of Diseases 10th edition (ICD 10)[[12](#_ENREF_12)]. This adaptation also classifies aetiology by the timing of the onset of the disorder into the categories prenatal, perinatal, postnatal and “other (or not known)” where key information was missing. Diagnoses made using DNA techniques we have classified under chromosomal since no separate DNA category was available. Classification was performed by two investigators (FJKOC and JPO) independently and discrepancies were re-evaluated and a consensus decision made. Before starting the ICISS trial, it was suggested to us in a personal communication that infants with IS secondary to stroke responded particularly well to treatment. We proposed to report this group in detail. We have also looked at the infants with Down’s syndrome following a comment by one reviewer.

Statistical Analysis

The analyses were done by intention to treat. Chi square tests were used for simple comparisons of proportions. Logistic regression was used for multiple multivariable analyses when the primary outcome was binary (eg response to treatment). T tests or Willcoxon rank sum test, depending on normality of distribution, were used for comparison of continuous data. The primary explanatory variable of interest was the effect of treatment but we also examined the effect of lead time, aetiology and age as appropriate. The analyses were undertaken by FJKO’C.

RESULTS

377 infants were enrolled into ICISS and we have results on aetiology in 376 since one case (0.3%) was withdrawn before investigations were complete and was classified as aetiology not known. 157 (42%) had no identified aetiology and 219 (58%) had a proven aetiology of whom 128 responded, 58 of 108 (54%) allocated hormonal treatment and 70 of 111 (63%) allocated combination therapy. Table 1 shows a summary of numbers and response by prenatal, perinatal, postnatal and other categories. Details of specific diseases and their response to treatment is given in the following tables by prenatal, non chromosomal (table 2), prenatal chromosomal (table 3), perinatal (table 4), postnatal (table 5) and other (table 6). The tables also show the subgroups used in the paediatric adaptation of ICD 10. There were no disagreements in the specific disease classifications by the two individuals involved but there were initially nine disagreements over the likely timing of the disorder. These were all satisfactorily resolved.

Fourteen of 17 (82%, 95% CI 59% to 94%) infants with stroke and infarct responded compared to 114 out of 202 for the rest of the proven aetiology group as a whole (56%, 95% CI 48% to 62%: Chi square 4.3, p=0.037). The better response for the stroke group (Table 6) remains when treatment allocation and lead time are taken into account (Odds ratio 5.1, 95% CI 1.1 to 23.6, p=0.037).

20 of 37 (54%, 95% CI 38% to 70%) infants with Down’s syndrome had cessation of spasms compared to 108 out of 182 (59%, 95% CI 52% to 66%, Chi square 0.35, p=0.55) infants in the rest of the proven aetiology group. The lack of a significant difference in response between the two groups remains after taking treatment and lead-time into account (Odds ratio 0.8, 95% CI 0.4 to 1.7, p = 0.62, see Table 7). There was no significant difference in response in the Downs syndrome children according to their treatment modality: 11 out of 20 (55%) allocated to hormonal therapy responded, compared to 9 out of 17 (53%) allocated to combination therapy. We noted that the Down’s infants were older (age at enrolment) than the rest of the proven aetiology group (mean age 249 compared to 219 days, Wilcoxon rank-sum z=-2.192, p=0.028).

DISCUSSION

Classification of aetiologies allows us to look at the presumed causes of illness and how this may change over time. It also enables the study of outcomes for specific patient groups. In this paper we were interested to see if the outcome of spasms differed according to underlying aetiology. We used the paediatric adaptation of ICD 10 to classify aetiologies and this facilitated comparison with the earlier UKISS study that had also used ICD 10. There are some classifications that no longer seem appropriate to us, but we have continued to use the classification as originally suggested. For example, a number of metabolic diseases are classified in the paediatric adaptation of ICD 10 as postnatal aetiologies when it seems reasonable to suggest that they would have caused neurological damage in the prenatal period. Despite such issues, by publishing the full details using ICD 10 it is possible to allow direct comparison with the results from our earlier study. It will also be possible for future researchers to amalgamate our outcomes with theirs, for the meta-analyses of outcomes, including a re-allocation of categories if appropriate. We have however, amalgamated cortical dysplasia and focal cortical dysplasia into one category as the difference is nowadays meaningless.

We do not report infants with developmental impairment at onset of the spasms as having a proven aetiology unless there was a detected underlying aetiology. We believe this to be important since the spasms themselves might have been responsible for the developmental impairment at the time of diagnosis of their spasms. In this study, no infant was reported as having a CT scan to make an aetiological diagnosis. Cranial MRI was the investigation of choice.

ICISS recruited nearly twice as many infants as the UKISS[[6](#_ENREF_6" \o "Osborne, 2010 #2136)] aetiological study: 377 versus 207. The 58% in whom an underlying aetiology was identified was similar to the 61% in UKISS while the percentage not fully investigated was lower in the ICISS study (0.3% v 12%). There was no evidence in UKISS, which followed infants not enrolled into the clinical trial as well as those who were, of biased enrollment into the clinical trial related to underlying aetiology (although infants known to have tuberous sclerosis were excluded from both clinical trials) but we have no direct evidence about this from ICISS. The proportion of infants with proven aetiology were the same in UKISS and in ICISS and thus there is no reason to suspect a bias in recruitment related to aetiology.

Eight cortical dysplasias (2%) were identified in ICISS compared to one (0.2%) in UKISS. This probably reflects the increased use of cranial MRI in the later study. However, more detailed investigations that might have identified a focal lesion such as cortical dysplasia, for example FDG-PET, SPECT or MEG, were rarely undertaken and none were reported to us. It should be remembered that children with tuberous sclerosis complex were excluded from the study. In fact five infants with tuberous sclerosis complex were recruited because the diagnosis was made after randomization. These children are not included in the cortical dysplasia category.

Forty whole chromosome disorders, 37 with Down’s syndrome, were identified in ICISS (11%) compared to 6 in UKISS (0.3%), five with Down’s syndrome. The large increase in infants with Down’s syndrome must simply be due to more infants with Down’s being enrolled. The number of infants with other genetic conditions has increased from 2% in UKISS to 7% in ICISS, presumably because of better methods of detection including the use of DNA analyses. It is possible that the enthusiasm for investigating in those with no proven aetiology was affected by their response to treatment with those responding and doing well being less likely to have had further investigations such as DNA analyses. In addition more tests will have been available towards the end of the trial in 2014 than at the beginning in 2007. The disparity may be even greater now in 2019 as genetic technologies and access to them have continued to improve.

The absolute numbers of infants with hypoxic ischaemic encephalopathy was lower, 6% in ICISS and 11% in UKISS . Similarly the prevalence of periventricular ischaemia and haemorrhage was lower (3% in ICISS and 6% in UKISS) and for stroke or infarct (5% in ICISS and 8% in UKISS). These differences might possibly reflect improvements in perinatal care. Conversely, the percentage with metabolic disease due to hypoglycaemia were increased, 3% in ICISS compared to 1% in UKISS. This difference, although small, does not suggest that the prevention and management of hypoglycaemia has improved.

In ICISS [10], infants with proven aetiology had a worse prognosis than those with no identified aetiology both for cessation of spasms, 58% and 73% respectively (difference 15%, 95% CI 4.97-25.04, chi 8.9, p=0.003), and for development at 18 months [13] as assessed by the Vineland Adaptive Behaviour Scales, VABS 66.8 and 82.5 respectively (66.8[SE 1.0] vs 82.5[1.5], difference 15.7 [95% CI 12.2-19.2], p<0.001). In ICISS, looking at response to treatment by the timing of the initial insult, the numbers in some groups are small which would make comparison unreliable.

Numbers are inevitably small when looking at specific aetiologies. The largest aetiological group were the children with Down’s syndrome where the response rate of 54% in ICISS and 55% in UKISS were similar but again here the ICISS definition of response is more stringent but the treatment more successful leading to similar response rates. These response rates are almost identical to the response rate of 59% found in this study (and 60% in UKISS) for pre-natal aetiologies and suggests that infants with Down’s syndrome do not have a different response overall to treatment than those with other aetiologies. However, The Down’s infants are older on average. This might be due to the later maturation of the brain making the age at which Down’s infants are susceptible to infantile spasms older on average. This observation might be useful for determining likely predisposing factors or even causes for infantile spasms. We also noted that Down’s infants did not seem to benefit from the addition of vigabatrin to hormonal treatment.

Infants with stroke or infarct did respond better than expected comparing favourably to the response rate for the rest of the proven aetiology group. This suggests that this group of infants does have a better prognosis than other aetiologies. This conclusion is supported by the results from UKISS which, using a different treatment regime, also found more infants with stroke or infarct to have responded. It may be that these children have a better outcome because their spasms result from a discrete insult to an otherwise normal brain as compared with other children in the proven aetiology group who have a more diffuse injury or a more generalized disorder of brain development.

The aetiological classification used in this paper (and UKISS) is much more precise than the poorly defined and understood traditional categories of symptomatic, cryptogenic and idiopathic that others have rightly criticized [[14](#_ENREF_14" \o "Paciorkowski, 2011 #2163) [15](#_ENREF_15" \o "Berg, 2010 #3171)]. We have not made any judgements concerning the probability of causality and have simply reported all the underlying aetiologies that were identified including diagnoses, such as arachnoid cysts, that other investigators may have omitted because of their uncertain relationship to the risk of infantile spasms. This approach may, in time, lead to the identification of underlying aetiologies, previously thought to be unimportant, that appear more frequently than expected – thus suggesting a role in infantile spasms.

Since the publication of our original paper on the aetiology of infantile spasms, several authors have published on the subject and some have suggested new and useful aetiological classification systems. Paciorkowski et al., for example, propose a genetic and biologic classification system that is flexible and has much merit[[14](#_ENREF_14" \o "Paciorkowski, 2011 #2163)]. The recent position paper of the ILAE on the classification of the epilepsies proposes that aetiologies of all the epilepsies should be thought of in terms of six potentially overlapping categories that should be considered at every step of the diagnostic pathway: structural, genetic, infectious, metabolic, immune and unknown[[4](#_ENREF_4)]. The aetiological sub-groups were chosen because of their potential therapeutic consequences. Our data can easily be rearranged to fit these other classification systems but we have chosen to use the system used in our previous paper to facilitate comparison between the two studies.

We conclude that MRI has likely improved the detection of cortical dysplasias. Genetic diagnoses are also more likely to be detected. Our results do not suggest to us that any particular aetiology has a better or worse outcome than any other, except for infants with stroke and infarct. Down’s infants might not respond better to the addition of vigabatrin with hormonal treatment but this observation needs to be confirmed. There is also a suggestion that there are reduced proportions of children presenting with infantile spasms secondary to hypoxic ischaemic encephalopathy and this might possibly reflect improvements in prenatal and perinatal care. The death rate in ICISS was very low and the response rate high. We would therefore advocate the use of combination therapy in all aetiological groups including stroke – although for tuberous sclerosis the best treatment has yet to be determined.

Key Points:

1. Multiple underlying aetiologies are found in infants with infantile spasms.
2. Cranial MRI and genetic testing has increased the number of specific aetiologies.
3. Down’s syndrome infants might not respond to the addition of vigabatrin.
4. Infants with stroke and infarct have a better than average response to treatment.

REFERENCES

1. Pavone P, Striano P, Falsaperla R, et al. Infantile spasms syndrome, West syndrome and related phenotypes: what we know in 2013. Brain & development 2014;**36**(9):739-51 doi: 10.1016/j.braindev.2013.10.008[published Online First: Epub Date]|.

2. Illingworth RS. Sudden mental deterioration with convulsions in infancy. Archives of disease in childhood 1955;**39**:529-37

3. Engel J, Jr., International League Against E. A proposed diagnostic scheme for people with epileptic seizures and with epilepsy: report of the ILAE Task Force on Classification and Terminology. Epilepsia 2001;**42**(6):796-803

4. Scheffer IE, Berkovic S, Capovilla G, et al. ILAE classification of the epilepsies: Position paper of the ILAE Commission for Classification and Terminology. Epilepsia 2017;**58**(4):512-21 doi: 10.1111/epi.13709[published Online First: Epub Date]|.

5. Riikonen R. Epidemiological data of West syndrome in Finland. Brain & development 2001;**23**(7):539-41

6. Osborne JP, Lux AL, Edwards SW, et al. The underlying etiology of infantile spasms (West syndrome): information from the United Kingdom Infantile Spasms Study (UKISS) on contemporary causes and their classification. Epilepsia 2010;**51**(10):2168-74 doi: 10.1111/j.1528-1167.2010.02695.x[published Online First: Epub Date]|.

7. Karvelas G, Lortie A, Scantlebury MH, et al. A retrospective study on aetiology based outcome of infantile spasms. Seizure 2009;**18**(3):197-201 doi: 10.1016/j.seizure.2008.09.006[published Online First: Epub Date]|.

8. Ohtahara S, Ohtsuka Y, Yamatogi Y, et al. Prenatal etiologies of West syndrome. Epilepsia 1993;**34**(4):716-22

9. Lux AL, Edwards SW, Hancock E, et al. The United Kingdom Infantile Spasms Study (UKISS) comparing hormone treatment with vigabatrin on developmental and epilepsy outcomes to age 14 months: a multicentre randomised trial. The Lancet. Neurology 2005;**4**(11):712-7 doi: 10.1016/S1474-4422(05)70199-X[published Online First: Epub Date]|.

10. O'Callaghan FJ, Edwards SW, Alber FD, et al. Safety and effectiveness of hormonal treatment versus hormonal treatment with vigabatrin for infantile spasms (ICISS): a randomised, multicentre, open-label trial. The Lancet. Neurology 2017;**16**(1):33-42 doi: 10.1016/S1474-4422(16)30294-0[published Online First: Epub Date]|.

11. Lux AL, Osborne JP. A proposal for case definitions and outcome measures in studies of infantile spasms and West syndrome: consensus statement of the West Delphi group. Epilepsia 2004;**45**(11):1416-28 doi: 10.1111/j.0013-9580.2004.02404.x[published Online First: Epub Date]|.

12. Crawshaw P. The new BPA classification. Archives of disease in childhood 1995;**73**(6):563-7

13. O'Callaghan FJK, Edwards SW, Alber FD, et al. Vigabatrin with hormonal treatment versus hormonal treatment alone (ICISS) for infantile spasms: 18-month outcomes of an open-label, randomised controlled trial. The Lancet. Child & adolescent health 2018;**2**(10):715-25 doi: 10.1016/S2352-4642(18)30244-X[published Online First: Epub Date]|.

14. Paciorkowski AR, Thio LL, Dobyns WB. Genetic and biologic classification of infantile spasms. Pediatric neurology 2011;**45**(6):355-67 doi: 10.1016/j.pediatrneurol.2011.08.010[published Online First: Epub Date]|.

15. Berg AT, Berkovic SF, Brodie MJ, et al. Revised terminology and concepts for organization of seizures and epilepsies: report of the ILAE Commission on Classification and Terminology, 2005-2009. Epilepsia 2010;**51**(4):676-85 doi: 10.1111/j.1528-1167.2010.02522.x[published Online First: Epub Date]|.

TABLE 1

**SUMMARY OF FINDINGS**

|  |  |  |  |
| --- | --- | --- | --- |
| SUBGROUP | SUBGROUPNUMBERS | TREATMENT ALLOCATIONHORMONE ALONE | TREATMENT ALLOCATIONHORMONE PLUS VIGABATRIN |
| Prenatal, not chromosomal | 5333 responders (62%) | 2413 responders (54%) | 2920 responders (69%) |
| Prenatal chromosomal | 6736 responders (54%) | 3318 responders (55%) | 3418 responders (53%) |
| **Prenatal total** | 12069 responders (58%) | 5731 responders (54%) | 6338 responders (60%) |
| Perinatal | 5531 responders (56%) | 2612 responders (46%) | 2919 responders (66%) |
| Postnatal | 188 responders (44%) | 116 responders (55%) | 72 responders (29%) |
| Other | 2620 responders (77%) | 149 responders (64%) | 1211 responders (92%) |
| **TOTALS** | 219128 responders (58%) | 10858 responders (54%) | 11170 responders (63%) |

This table shows a summary of numbers in each aetiological group with response to treatment by treatment group. The prenatal group is shown divided into not chromosomal, chromosomal (inc DNA) and in total.TABLE 2 – PRENATAL part 1, excluding chromosomal and DNA

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroup | Specific disease | Numbers | Responders |
| Malformationsif not chromosomal | Agenesis of the corpus callosum | 2 | 0 |
| Cerebellar dysplasia | 1 | 1 |
| Cortical dysplasia | 8 | 7 |
| Dysmorphic | 1 | 1 |
| Hemispheric malformation | 1 | 1 |
| Hemispheric dysplasia | 1 | 1 |
| heterotopia | 1 | 1 |
| holoprosencephaly | 1 | 0 |
| Lissencephaly | 9 | 4 |
| Microcephaly | 5 | 1 |
| Neuronal migration defect | 1 |  |
| pachygyria | 1 |  |
| Periventricular nodular heterotopia | 3 | 2 |
| Polymicrogyria | 1 | 1 |
| Septo-optic dysplasia | 1 | 1 |
| Small cerebral hemisphere | 1 |  |
| Thin corpus callosum | 3 | 2 |
| ventriculomegaly | 1 | 1 |
| Other malformations (specific diseases) | Neurofibromatosis | 1 | 1 |
| Tuberous Sclerosis | 5 | 3 |
|  | Crouzon’s | 1 | 0 |
|  | Kabuki syndrome | 1 | 1 |
| Other | arthrogryposis | 1 | 1 |
|  | Infection CMV | 1 | 1 |
|  | Stroke or infarct | 1 | 1 |

This table shows the number of infants with each specific disease and with response to treatment. There were 120 infants in the prenatal group including chromosomal with 66 responders (56% response rate).

CMV = cytomegalovirusTABLE 2 – PRENATAL part 2, CHROMOSOMAL (including DNA)

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroup | Specific disease | Numbers | Responders |
| Chromosomal | 47XXX | 2 | 1 |
|  | 47XXY | 1 | 1 |
|  | ARX mutation | 1 | 1 |
|  | Col 4A1 mutation | 1 | 0 |
|  | del 16p 13.11 | 2 | 2 |
|  | del 1p36, dup 14q32 | 1 | 1 |
|  | del 3p26.3 | 1 | 0 |
|  | del 7p | 1 | 1 |
|  | del 7q 11.23 | 1 | 1 |
|  |  del 9p24 dup 11p13 | 1 | 1 |
|  | Down’s syndrome | 37 | 20 |
|  | dup 15 | 1 | 1 |
|  | dup 16p 13.3 | 1 | 0 |
|  |  dup 16p11.2, del 7q31.1 | 1 | 1 |
|  | Dup 2p(inc NRXN 1) | 1 | 1 |
|  | dup 3q29 | 1 | 0 |
|  |  idic 15 (47, XX, + idic(15)(q13)) | 1 | 1 |
|  | familial neuromuscular disorder | 1 | 1 |
|  | mitochondrial disorder | 3 | 1 |
|  |  Partial trisomy 15 | 1 | 0 |
|  |  Partial trisomy 16 AND partial monosomy 18 | 1 | 0 |
|  | Rea 11q 24 | 1 | 0 |
|  | Ring chromosome 14 | 1 | 0 |
|  |  STXB1 gene mutation | 1 | 0 |
|  |  STXBPA mutation | 1 | 1 |
|  | Tetrasomy 15q | 1 | 1 |
|  | Trisomy 5p | 1 | 1 |

This table shows the number of infants with each specific disease and with response to treatment.

Del = deletion, dup= duplication, idic=isodicentric, Rea=re-arrangement.

TABLE 3 PERINATAL

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroup | Specific disease | Numbers | Responders |
|  | HIE | 24 | 16 |
|  | Intracranial non-traumatic haemorrhage | 2 | 2 |
|  | IVH | 3 | 0 |
|  | Maternal factors – drug abuse | 1 | 0 |
|  | meningitis | 1 | 0 |
|  | microcephaly | 1 | 0 |
|  | PPHN – bleed into choroid plexus and ventricular dilatation | 1 | 0 |
|  | PVH/PVL | 8 | 6 |
|  | Stroke or infarct | 3 | 1 |
|  | Transient endocrine or metabolic disease - hypoglycaemia | 11 | 6 |

This table shows the number of infants with each specific disease in the perinatal group and with response to treatment. There were 55 infants in the group with 31 responders (56%).

HIE = Hypoxic Ischaemic Encephalopathy, IVH = intraventricular haemorrhage, PPHN = persistent pulmonary hypertension of the newborn, PVL/PVH = Periventricular leucomalacia/periventricular haemorrhage.

TABLE 4 – POSTNATAL

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroup | Specific disease | Numbers | Responders |
| Endocrine or metabolic | Acyl Co-A dehydrogenase deficiency | 1 | 1 |
|  | Amino aciduria (propionicacidaemia) | 1 | 1 |
|  | B12 deficiency | 1 | 1 |
|  | CSF neurotransmitter disease | 1 | 0 |
|  | Lactic acidosis (not further specified) | 1 | 0 |
|  | Low folinic acid | 1 | 0 |
|  | Menke’s disease | 1 | 0 |
|  | Mitochondrial disease | 3 | 1 |
|  | Organic aciduria (methylmalonic) | 1 | 1 |
|  | Serene deficiency | 1 | 0 |
| External injury | Trauma or non-accidental | 3 | 1 |
| Nervous system | Encephalitis | 1 | 1 |
|  | Meningitis | 2 | 2 |

This table shows the number of infants in the postnatal group with each specific disease and with response to treatment. There were 18 infants in the postnatal group with 8 responders (44%).

CSF = cerebrospinal fluid.

TABLE 5 – OTHER GROUP

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroup | Specific disease | Numbers | Response |
|  | Bilateral vocal chord paralysis | 1 | 1 |
|  |  Brain neoplasm - benign (hypothalamic hamartoma) | 1 | 0 |
|  |  Endocrine or metabolic - hypothalamic hypothyroidism | 1 | 0 |
|  | Leukodystrophy | 1 | 1 |
|  | Macrocephaly | 1 | 1 |
|  | Microcephaly | 3 | 2 |
|  | Neurodegenerative disorder | 1 | 1 |
|  | Sensoryneural deafness | 1 | 0 |
|  | Stroke or infarct | 13 | 12 |
|  | Subdural collection | 1 | 1 |
|  | Unexplained calcification | 1 | 0 |
|  | White matter volume loss | 1 | 1 |

This table shows the number of infants in the other group with each specific disease and with response to treatment. There were 26 infants in the other group with 20 responders (77%).

TABLE 6

Multivariable logistic regression of early clinical response in the proven aetiology group comparing those with stroke to those without stroke.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Responders Day 14-42 | Adjusted Odds Ratio (95%CI) | p value |
| Stroke |  | 5.1 (1.1 to 23.6) | 0.037 |
| Present | 14 / 17 |  |  |
| Absent | 114/202 |  |  |
| Treatment modality |  | 1.6 (0.9 to 2.8) | 0.01 |
| Combination | 70 / 111 |  |  |
| Hormonal | 58 / 108 |  |  |
| Lead time |  | 0.5 (0.3 to 0.9) | 0.012 |
| < 28 days | 91 / 140 |  |  |
| > 28 days | 36 / 76 |  |  |

\* 3 children did not have a lead-time to treatment recorded

TABLE 7

Multivariable logistic regression of early clinical response in the proven aetiology group comparing those with Down’s syndrome to those without Down’s syndrome.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Responders Day 14-42 | Adjusted Odds Ratio (95% CI) | p value |
| Down’s |  | 0.8 (0.4 to 1.7) | 0.62 |
| Present | 20 / 37 |  |  |
| Absent | 108 / 182 |  |  |
| Treatment modality |  | 1.5 (0.9 to 2.6 | 0.15 |
| Combination | 70 / 111 |  |  |
| Hormonal | 58 / 108 |  |  |
| Lead-time |  | 0.8 (0.7 to 0.98 | 0.03 |
| < 28 days | 91 / 140 |  |  |
| > 28 days | 36 / 76 |  |  |

\* 3 children did not have a lead-time to treatment recorded

TO BE PUBLISHED AS A WEB APPENDIX ONLY

The following tables (1A, 2A, 3A, 4A and 5A) show the number of infants for each specific disease with treatment allocation and response to allocated treatment. Response is given by treatment allocation using two definitions of response: 14-42 refers to the ICISS definition of response (no observed spasms on and between Days 14-42) and 13-14 to the UKISS definition of response (no observed spasms on Days 13 and14). Abreviations are listed with the relevant tables in the main published text.

TABLE 1A – PRENATAL part 1, excluding chromosomal and DNA

|  |
| --- |
| **PRENATAL GROUP** n=120, ICISS responders 66 (56%)UKISS responders *96* (*80%*) |
| Subgroup | Specific disease | n | Prednisolonealone | TetracosactideDepot alone | Prednisolone with vigabatrin | Tetracosactide depot with vigabatrin |
| 14-42 refers to the ICISS definition of response13-14 refers to the UKISS definition of response | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 |
| Malformationsif not chromosomal | Agenesis of the corpus callosum | 2 | 1 | 0 | 0 |  |  |  | 1 | 0 | 0 |  |  |  |
| Cerebellar dysplasia | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Cortical dysplasia | 8 | 4 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| Dysmorphic | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Hemispheric malformation | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
| Hemispheric dysplasia | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
| heterotopia | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
| holoprosencephaly | 1 |  |  |  | 1 | 0 | 0 |  |  |  |  |  |  |
| Lissencephaly | 9 | 3 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 | 1 |
| Microcephaly | 5 | 2 | 0 | 1 |  |  |  | 3 | 1 | 2 |  |  |  |
| Neuronal migration defect | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
| pachygyria | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Periventricular nodular heterotopia | 3 | 1 | 0 | 0 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1 |
| Polymicrogyria | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Septo-optic dysplasia | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Small cerebral hemisphere | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
| Thin corpus callosum | 3 | 2 | 2 | 2 |  |  |  | 1 | 0 | 1 |  |  |  |
| ventriculomegaly | 1 | 1 | 1 | 0 |  |  |  |  |  |  |  |  |  |
| Other malformations (specific diseases) | Neurofibromatosis | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
| Tuberous Sclerosis | 5 | 3 | 1 | 1 |  |  |  | 1 | 1 | 1 | 1 | 0 | 1 |
|  | Crouzon’s | 1 | 1 | 0 | 1 |  |  |  |  |  |  |  |  |  |
|  | Kabuki syndrome | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
| Other | arthrogryposis | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  | Infection CMV | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | Stroke or infarct | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |

TABLE 2A – PRENATAL part 2, CHROMOSOMAL including DNA

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Subgroup | Specific disease | n | Prednisolone alone | Tetracosactide depot alone | Prednisolone with vigabatrin | Tetracosactide depot with vigabatrin |
| 14-42 refers to the ICISS definition of response13-14 refers to the UKISS definition of response | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 |
| Chromosomal | 47XXX | 2 | 1 | 0 | 0 |  |  |  |  |  |  | 1 | 1 | 1 |
|  | 47XXY | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | ARX mutation | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  | col 4A1 mutation | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
|  | del 16p 13.11 | 2 |  |  |  | 1 | 1 | 1 | 1 | 1 | 1 |  |  |  |
|  | del 1p36, dup 14q32 | 1 |  |  |  | 1 | 1 | 1 |  |  |  |  |  |  |
|  | del 3p26.3 | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
|  | del 7p | 1 |  |  |  | 1 | 1 | 1 |  |  |  |  |  |  |
|  | del 7q 11.23 | 1 | 1 | 0 | 1 |  |  |  |  |  |  |  |  |  |
|  |  del 9p24 dup 11p13 | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  | Down’s syndrome | 37 | 13 | 7 | 8 | 7 | 4 | 5 | 15 | 7 | 13 | 2 | 2 | 2 |
|  | dup 15 | 1 |  |  |  | 1 | 1 | 1 |  |  |  |  |  |  |
|  | dup 16p 13.3 | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 1 |
|  |  dup 16p11.2, del 7q31.1 | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  | dup 2p(inc NRXN 1) | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | dup 3q29 | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 0 |
|  |  Isodicentric 15 (47, XX, + idic(15)(q13)) | 1 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | familial neuromuscular disorder | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | mitochondrial disorder | 3 | 2 | 1 | 2 |  |  |  | 1 | 0 | 1 |  |  |  |
|  |  Partial trisomy 15 | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
|  |  Partial trisomy 16 AND partial monosomy 18 | 1 | 1 | 0 | 1 |  |  |  |  |  |  |  |  |  |
|  | Rea 11q 24 | 1 | 1 | 0 | 1 |  |  |  |  |  |  |  |  |  |
|  | Ring chromosome 14 | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 1 |
|  |  STXB1 gene mutation | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 0 |
|  |  STXBPA mutation | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  | Tetrasomy 15q | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  | Trisomy 5p | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |

TABLE 3A PERINATAL

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Subgroup | Specific disease | N | Prednisolonealone | TetracosactideDepot alone | Prednisolone with vigabatrin | Tetracosactide depot with vigabatrin |
| 14-42 refers to the ICISS definition of response13-14 refers to the UKISS definition of response | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 |
|  | HIE | 24 | 5 | 3 | 3 | 3 | 2 | 2 | 10 | 5 | 9 | 6 | 6 | 5 |
|  | Intracranial non-traumatic haemorrhage | 2 | 1 | 1 | 1 |  |  |  |  |  |  | 1 | 1 | 1 |
|  | IVH | 3 | 3 | 0 | 2 |  |  |  |  |  |  |  |  |  |
|  | Maternal factors – drug abuse | 1 | 1 | 0 | 1 |  |  |  |  |  |  |  |  |  |
|  | meningitis | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  | microcephaly | 1 |  |  |  | 1 | 0 | 0 |  |  |  |  |  |  |
|  | PPHN – bleed into choroid plexus and ventricular dilatation | 1 |  |  |  |  |  |  | 1 | 0 | 0 |  |  |  |
|  | PVH/PVL | 8 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 2 | 3 | 2 | 1 | 1 |
|  | Stroke or infarct | 3 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |  |  |  |
|  | Transient endocrine or metabolic disease - hypoglycaemia | 11 | 3 | 1 | 2 | 3 | 2 | 2 | 5 | 3 | 5 |  |  |  |

TABLE 4A POSTNATAL GROUP

|  |
| --- |
| **POSTNATAL GROUP** n=18 ICISS responders 8 (44%)UKISS responders *11* (*61%*) |
| Subgroup | Specific disease | n | Prednisolone alone | Tetracosactide depot alone | Prednisolone with vigabatrin | Tetracosactide depot with vigabatrin |
| 14-42 refers to the ICISS definition of response13-14 refers to the UKISS definition of response | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 |
| Endocrine or metabolic |  Acyl Co-A dehydrogenase deficiency | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  |  Amino aciduria (propionicacidaemia) | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  | B12 deficiency | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  |  CSF neurotransmitter disease | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  | Lactic acidosis (not further specified) | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
|  | Low folinic acid | 1 |  |  |  |  |  |  | 1 | 0 | 1 |  |  |  |
|  | Menke’s disease | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 1 |
|  | Mitochondrial disease | 3 | 2 | 1 | 2 | 1 | 0 | 1 |  |  |  |  |  |  |
|  | Organic aciduria (methylmalonic) | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  | Serene deficiency | 1 |  |  |  |  |  |  |  |  |  | 1 | 0 | 0 |
| External injury | Trauma or non-accidental | 3 | 1 | 0 | 0 |  |  |  | 2 | 1 | 1 |  |  |  |
| Nervous system | Encephalitis | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  | Meningitis | 2 | 2 | 2 | 2 |  |  |  |  |  |  |  |  |  |

TABLE 5A – OTHER GROUP

|  |
| --- |
| **OTHER GROUP** n= 26 ICISS responders 20 (77%)UKISS responders *21* (*81%*) |
| Subgroup | Specific disease | n | Prednisolone alone | Tetracosactide depot alone | Prednisolone with vigabatrin | Tetracosactide depot with vigabatrin |
| 14-42 refers to the ICISS definition of response.13-14 refers to the UKISS definition of response | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 | n | 14-42 | 13-14 |
|  | Bilateral vocal chord paralysis | 1 |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |
|  |  Brain neoplasm - benign (hypothalamic hamartoma) | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  |  Endocrine or metabolic - hypothalamic hypothyroidism | 1 |  |  |  | 1 | 0 | 0 |  |  |  |  |  |  |
|  | Leukodystrophy | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |
|  | Macrocephaly | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | Microcephaly | 3 | 1 | 0 | 0 |  |  |  | 2 | 2 | 2 |  |  |  |
|  | Neurodegenerative disorder | 1 |  |  |  | 1 | 1 | 1 |  |  |  |  |  |  |
|  | Sensoryneural deafness | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  | Stroke or infarct | 13 | 1 | 1 | 1 | 5 | 5 | 5 | 7 | 6 | 7 |  |  |  |
|  | Subdural collection | 1 |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |
|  | Unexplained calcification | 1 | 1 | 0 | 0 |  |  |  |  |  |  |  |  |  |
|  | White matter volume loss | 1 | 1 | 1 | 1 |  |  |  |  |  |  |  |  |  |