Research Article

Hydroxyurea Therapy in UK Children with Sickle Cell Anaemia – A Single Centre Experience

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Abbreviations

FBC	Full blood count
Hb	Haemoglobin
HbF	Foetal haemoglobin
MTD	Maximum tolerated dose
SCA	Sickle cell anaemia
TCD	Transcranial Doppler
VDJ	Variable diversity joining

Abstract:

Introduction
Despite the demonstrated efficacy of hydroxyurea therapy, children with sickle cell anaemia in the United Kingdom (UK) are preferentially managed with supportive care or transfusion. Hydroxyurea is reserved for children with severe disease phenotype. This is in contrast to North America and other countries where hydroxyurea is widely used for children of all clinical phenotypes. The conservative UK practice may in part be due to concerns about toxicity, in particular marrow suppression with high doses, and growth in children.

Methods and Results

We monitored 37 paediatric patients with sickle cell anaemia who were treated with hydroxyurea at a single UK treatment centre. Therapy was well tolerated and mild transient cytopenias were the only toxicity observed. Comparative analysis of patients receiving ≥26mg/kg/day versus <26 mg/kg/day demonstrates increasing dose has a significant positive effect on foetal haemoglobin (29.2% v 20.4%, p=0.0151), mean cell volume (94.4 v 86.5, p=0.0183) and reticulocyte count (99.66 x10^{9}/L v 164.3x10^{9}/L, p=0.0059). Marrow suppression was not a clinical problem with high dose treatment, haemoglobin 92.25 g/L v 91.81 g/L (ns), neutrophil count 3.3 x10^{9}/L v 4.8 x10^{9}/L (ns) and platelet count 232.4 x10^{9}/L v 302.2 x10^{9}/L (ns). Normal growth rates were maintained in all children. Good adherence to therapy was a significant factor in reducing hospitalisations

Conclusion

This study demonstrates the effectiveness and safety in practice of high dose hydroxyurea as a disease modifying therapy which we advocate for all children with sickle cell anaemia.

Introduction

In children with sickle cell anaemia (SCA), hydroxyurea therapy is effective at elevating foetal haemoglobin (HbF) and reducing the frequency of painful sickle crises[1-3]. Despite the demonstrated efficacy of hydroxyurea therapy, children with SCA are preferentially managed with supportive care or transfusion at United Kingdom (UK) treatment centres. Current UK clinical guidance is supportive care and prophylactic antibiotics for all children, and transfusion in instances of acute and chronic complications such as acute anaemia, acute chest syndrome, acute neurological deficit, stroke prevention and organ failure. Hydroxyurea is restricted to those with severe phenotype. Current guidelines recommend it is considered only in patients who experience recurrent episodes of acute pain (more than 3 hospitalisations in the previous 12 months or symptomatic in the community) or who have experienced two or more episodes of acute chest syndrome[4]. Referral to a specialist centre is required for hydroxyurea commencement and it is recommended that the patient and parents or carers have two separate documented discussions with treating clinicians, to include side effects such as subfertility, cytopenias and the possible risk of leukaemia or other malignancies[4]. The effect of such guidance is that few children with SCA in the UK benefit from hydroxyurea therapy. Currently 1.9% of UK patients with SCA <5 years of age receive hydroxyurea, and 11.3% of 5-17 year old UK SCA patients receive hydroxyurea[5].

Reluctance to incorporate hydroxyurea into first line treatment in the UK relates in part to concerns over long term safety and negative effects on growth, combined with a lack of awareness of potential treatment benefits. Since publication of the current UK Standards and Guidance for Clinical Care (2010), much more evidence as to the safety and efficacy of hydroxyurea therapy has become available[2,6-10]. In the USA, it is now recommended that all children with sickle cell anaemia be offered hydroxyurea therapy from 9 months of age[11].

Concerns over potential negative effects on growth were addressed initially in the 1999 HUG-KIDS phase I/II trial. Fifty two severely affected children aged 5-15 years were treated to maximum tolerated dose (MTD) with a median dose of 30mg/kg/day hydroxyurea for 1 year and no child experienced growth failure[12]. Following on from this, the HUSOFT extension study examined the effects of longer term treatment (up to 6 years) on 21 very young children, and reported that females maintained average growth rates and males increased average growth rates during hydroxyurea therapy[13].

Since hydroxyurea inactivates the enzyme ribonucleoside diphosphate reductase[14], it impairs both DNA replication and repair. This gives rise to concerns as to its carcinogenic and teratogenic potential. So far, two follow up studies have investigated the risks and benefits of very long-term use in adults [15,16]. The Multicentre Study of Hydroxyurea in Sickle Cell Anaemia trial had a 17.5 year follow up and some participants had received greater than 15 years cumulative exposure. This study found there was no increase in neoplasia by exposure to hydroxyurea[15]. Another single centre trial, where 131 adults were followed for up to 17 years, also reported that no cases of carcinogenesis occurred[16]. Importantly, both of these studies reported significantly improved survival in hydroxyurea treated patients[15,16]. More recently, investigators in the BABY-HUG phase III clinical trial sought to measure acquired genomic damage in infants, as a measure of carcinogenic potential. Karyotype analysis (to investigate chromosome/chromatid breaks), illegitimate variable-diversity-joining (VDJ) recombination events and micronucleated reticulocytes were monitored and there were no differences between hydroxyurea and placebo treated patients[10].

Since the reporting of the BABY-HUG trial results, we have offered hydroxyurea as a first line treatment to all children over 9 months of age with SCA at this UK centre. Here, we sought to review the benefits of hydroxyurea therapy in a UK paediatric cohort, and to determine the effect of dose escalation and adherence to therapy in terms of improvement in haematological parameters and hospital admissions.

Methods

All children over 9 months of age were offered hydroxyurea therapy and no selection for disease severity was made. Baseline investigations were performed to confirm the absence of anaemia (haemoglobin (Hb) >50g/L), absence of cytopenias (neutrophils >1.0 x 10^9/L, platelets >100x10^9/L, reticulocytes >40x10^9/L) and absence of severe hepatic or renal impairment (estimated glomerular filtration rate >30mL/min/1.73m^2). Patients were not considered for hydroxyurea therapy if they had known hypersensitivity to hydroxyurea, were pregnant, had active hepatitis, showed any signs of myelosuppression or were receiving anti-retroviral therapy.

Treatment commenced at 15 mg/kg/day to be increased over the following 12 months to MTD or 35 mg/kg/day, whichever was achieved first. MTD was defined by haematological toxicity as the maximum dose where no myelosuppression was induced. On commencement of therapy, full blood counts (FBC) were monitored fortnightly for the first 4 weeks and then at 4 weekly intervals. Clinical assessment was made monthly and included frequency and severity of crises, complications of sickle cell disorders, compliance with treatment, adverse events, height and weight measurements and laboratory monitoring of hepatic and renal function, reticulocytes, FBC and haemoglobin electrophoresis. Dose was increased by 5mg/kg/day every 8 weeks, provided that no marrow toxicity was observed (defined as neutrophil count <0.75 $x10^9$/L or platelet count <75 $x10^9$/L or reticulocyte count <40 $x10^9$/L). FBCs were monitored fortnightly following dose increases for 4 weeks, and then at 4 weekly intervals.

Results

Ninety five percent of children and parents or carers offered hydroxyurea consented following discussion of current evidence in relation to side effects and benefits of treatment (n = 37). Hydrea in 500mg capsule or liquid formulation was prescribed. The mean age at start of therapy in our patients was 7 years (range 1 – 15), 34 patients were HbSS, 2 were HbSβ^0 thalassemia and 1 was HbSD. The mean dose achieved in patients who had been on therapy for more than 6 months was 28.5 mg/kg/day.

Significant improvements were recorded in haematological parameters post-hydroxyurea therapy; Hb increased to 92.0 g/L from 80.6 g/L, HbF increased to 26.35% from 9.90%, MCV increased to 91.06 from 77.49, reticulocytes decreased to 127.6 $x10^9$/L from 335.4 $x10^9$/L and neutrophils decreased to 3.95 $x10^9$/L from 6.37 $x10^9$/L (n=37; $p<0.001$ by paired t-test for each parameter; supplemental figure 1 (S1)). A significant reduction in platelets was also recorded in our patients (to 263.3 $x10^9$/L from 352.4 $x10^9$/L; $p=0.0007$; supplemental figure 1 (S1)).

At the time of review, 16 patients were receiving <26 mg/kg/day hydroxyurea and 21 patients were receiving ≥26 mg/kg/day. Comparative analysis of patients receiving <26 and ≥26 mg/kg/day indicated that dose had a significant effect on some parameters. Hb levels were increased post-hydroxyurea therapy irrespective of dose achieved (Figure 1A). Whereas HbF level, MCV and reticulocyte count were further improved in patients receiving ≥26 mg/kg/day (Figure 1B, 1C & 1D). Neutrophil and platelet counts were only significantly reduced in patients receiving ≥26mg/kg/day (Figure 1E & 1F). Patient age versus dose achieved is shown in Figure 1G.

Haemolysis was better controlled in patients receiving ≥26mg/kg/day. Bilirubin and lactate dehydrogenase (LDH) were significantly lower in patients receiving ≥26 mg/kg/day (Figure 2A & 2B). Concurrent monitoring of alanine amino transferase (ALT) and aspartate amino transferase (AST) showed no evidence of liver toxicity in any patient, although AST was significantly reduced in patients receiving ≥26mg/kg/day (Figure 2C & 2D). Serum creatinine and urea were monitored continuously and remained within age appropriate reference range for all patients.

Adherence to therapy was reported by the patient and parent or carer at each clinic visit. We identified 10 patients with poor adherence to therapy based on patient/parent/carer admission and confirmed that they had not collected prescriptions regularly enough to maintain prescribed daily dosing. Comparative analysis between these patients with poor adherence, and all other patients who were considered to have good adherence (based on patient/parent/carer reporting), indicates that improvement in haematological parameters is dependent on good adherence to therapy (Figure 3). Hb and HbF levels were significantly higher in patients with good adherence (Figure 3A & 3B). As would be expected, MCV was significantly higher with good adherence (Figure 3C), and reticulocyte and neutrophil counts were significantly lower (Figure 3D & 3E). Adherence had no significant effect on platelet count (Figure 3F) or haemolysis (Bilirubin/LDH; Figure 3G & 3H) however, both ALT and AST were significantly reduced with good adherence which may indicate beneficial effects on hepatic function (Figure 3I and 3J).

Adherence to therapy also had a significant impact on the number of hospitalisations experienced by patients. Twenty seven hospitalisations totalling 126 admission days were recorded for the 10 patients with poor adherence, compared to 9 hospitalisations totalling 49 admission days in the 27 patients with good adherence (p<0.0001 by χ^2 test; 24 month follow up). Height and weight were monitored continuously for all patients and growth rates were maintained in all children irrespective of dose achieved or adherence to therapy (Figure 4).

Discussion

Our data demonstrates the significant improvements in haematological parameters that can be achieved with hydroxyurea therapy in UK paediatric patients with SCA. All children in this study had previously been managed at UK treatment centres with supportive care or transfusions. Importantly, hydroxyurea resulted in significant improvements in Hb, HbF, MCV, reticulocyte and neutrophil count which were apparent within 6 months of therapy commencement. Our data indicates that dose escalation is required to maximise beneficial effects, particularly in respect of HbF where patients receiving ≥26mg/kg/day achieved a median HbF level of 33.80%. HbF may protect HbS from de-oxygenation and polymerisation through local oxygen buffering, and is considered a good indicator of clinical disease severity[17] . Escalating dose to ≥26mg/kg/day exerted better control of haemolysis with increased Hb and deceased bilirubin, LDH and reticulocytes. Our study also highlights the critical importance of good adherence to therapy, particularly in respect to hospitalisations and admission days.

An increasing body of literature exists demonstrating the efficacy of hydroxyurea in SCA. The most notable recent demonstration in paediatric patients is arguably the BABY-HUG multicentre randomised controlled trial[2]. Similar to the improvements seen here, the BABY-HUG investigators reported significant improvements in Hb, HbF, MCV, reticulocyte count and neutrophil count in hydroxyurea treated patients. Further, the BABY-HUG investigators reported improvements in renal function and cerebral artery blood flow based on transcranial Doppler (TCD) velocity. Clinical events were also improved, with significantly reduced incidences of pain, acute chest syndrome, hospitalisation, transfusion, dactylitis and gastroenteritis[2].

The UK paediatric patient cohort in this study benefited from hydroxyurea therapy as expected based on previous reports of hydroxyurea use in SCA[2,12,13,18]. As such we believe it is now time to address the barriers to therapy that exist within the UK. No negative effects on growth were observed in this study and the only treatment related toxicities encountered were cytopenias, most frequently mild cytopenias which resolved without the need for dose reduction.

We considered neutrophil count <0.75 x10^9/L, or platelet count <75 x10^9/L, or reticulocyte count <40 x10^9/L clinically significant toxicities. Nine of the 37 children treated experienced significant cytopenia, totalling 22 separate episodes. Three children experienced a single episode (2 reticulocytopenia, 1 thrombocytopenia) while being clinically well. Laboratory monitoring was increased to weekly and counts recovered within 2 weeks (thrombocytopenia) and 6 weeks (reticulocytopenia) without the need for dose adjustment. One child experienced two episodes of reticulocytopenia 8 months apart while being clinically well, and 1 child experienced two episodes of thrombocytopenia 15 months apart while being clinically well. Both children were managed with increased laboratory monitoring and counts recovered within 2 weeks (thrombocytopenia) or 3 weeks (reticulocytopenia) without the need for dose adjustment. Three children experienced cytopenias following dose increase or alongside falling haemoglobin or neutrophil count, which required dose adjustment (6 thrombocytopenia and 1 reticulocytopenia). Hydroxyurea therapy was stopped and laboratory monitoring increased to weekly. Hydroxyurea was re-commenced following recovery of counts, which occurred within 1 – 3 weeks. Therapy was recommenced at the same dose for children receiving <20mg/kg/day or at a reduced dose for children receiving >20mg/kg/day. One child with severe phenotype experienced 7 episodes of cytopenia over 21 months (4 neutropenia, 3 reticulocytopenia). Each cytopenia was managed with increased laboratory monitoring and resolved without the need for dose reduction. We persisted with hydroxyurea therapy for this patient as significant improvement in clinical features were seen, including reduced crisis, return of conditional TCD to normal and increase in HbF from 7.0% to 32.7%. In our experience, isolated cytopenias are best managed initially with increased laboratory monitoring (weekly) while maintaining dose in clinically well children. Dose reduction or therapy cessation should be considered when an isolated cytopenia is persistent or deteriorates, or if more than one haematological parameter is affected.

While hydroxyurea therapy resulted in clinical improvement, in comparison to a supportive care approach, it also resulted in increased medication related burden on patients and families. In this respect, when children are established on a stable dose it may be possible to reduce monitoring to bimonthly to counteract some of this additional burden[20]. Achieving accurate dosing in children prescribed 500mg capsules frequently required an ‘asymmetric’ daily dosing schedule to achieve a desired weekly intake, and this adds an additional layer of complexity to daily administration. However, these issues were overcome in our patients and their families who were motivated by tangible treatment benefits such as improvements in laboratory values.

Currently, the UK National Haemoglobinopathy Registry shows only 9.5% of all UK patients with SCA <18 years of age receive hydroxyurea therapy[5]. In the absence of substantive evidence to contradict safety, we advocate the use of hydroxyurea as a disease modifying therapy for all UK children with SCA. Future UK clinical guidelines should place more focus on achievable benefits with hydroxyurea, and broaden the application to many more children.

Conflict of interest

The authors declare they have no competing interests.

References

(1) deMontalembert M, Belloy M, Bernaudin F, Gouraud F, Capdeville R, Mardini R, Philippe N, Jais J, Bardakdjian J, Ducrocq R, MaierRedelsperger M, Elion J, Labie D, Girot R. Three-year follow-up of hydroxyurea treatment in severely ill children with sickle cell disease. J Pediatr Hematol Oncol 1997;19:(4)313-318.

(2) Wang WC, Ware RE, Miller ST, Iyer RV, Casella JF, Minniti CP, Rana S, Thornburg CD, Rogers ZR, Kalpatthi RV, Barredo JC, Brown RC, Sarnaik SA, Howard TH, Wynn LW, *et al.* Hydroxycarbamide in very young children with sickle-cell anaemia: A multicentre, randomised, controlled trial (BABY HUG). Lancet 2011;377:(9778)1663-1672.

(3) Charache S, Terrin M, Moore R, Dover G, Barton F, Eckert S, McMahon R, Bonds D, Orringer E, Jones S, Strayhorn D, Rosse W, Phillips G, Peace D, Johnsontelfair A, *et al.* Effect of hydroxyurea on the frequency of painful crises in sickle-cell-anemia. N Engl J Med 1995;332:(20)1317-1322.

(4) NHS Sickle Cell and Thalassaemia Screening Programme. Sickle cell disease in childhood: Standards and guidelines for clinical care (2nd edition). 2010 (accessed 07 August 2017).

(5) MDSAS. National Haemoglobinopathy Registry Annual Report 2015/16. (accessed 07 August 2017) http://www.nhr.nhs.uk/wp-content/uploads/2017/02/NHR_AnnualReport_201516.pdf.

(6) Lagunju I, Brown BJ, Sodeinde O. Hydroxyurea lowers transcranial doppler flow velocities in children with sickle cell anaemia in a nigerian cohort. Pediatr Blood Cancer 2015;62:(9)1587-1591.

(7) Le PQ, Gulbis B, Dedeken L, Dupont S, Vanderfaeillie A, Heijmans C, Huybrechts S, Devalck C, Efira A, Dresse M, Rozen L, Benghiat FS, Ferster A. Survival among children and adults with sickle cell disease in belgium: Benefit from hydroxyurea treatment. Pediatr Blood Cancer 2015;62:(11)1956-1961.

(8) de Castro Lobo CL, Pinto JFC, Nascimento EM, Moura PG, Cardoso GP, Hankins JS. The effect of hydroxcarbamide therapy on survival of children with sickle cell disease. Br J Haematol 2013;161:(6)852-860.

(9) Thornburg CD, Files BA, Luo Z, Miller ST, Kalpatthi R, Iyer R, Seaman P, Lebensburger J, Alvarez O, Thompson B, Ware RE, Wang WC, BABY HUG Investigators. Impact of hydroxyurea on clinical events in the BABY HUG trial. Blood 2012;120:(22)4304-4310.

(10) McGann PT, Flanagan JM, Howard TA, Dertinger SD, He J, Kulharya AS, Thompson BW, Ware RE, BABY HUG Investigators. Genotoxicity associated with hydroxyurea exposure in infants with sickle cell anemia: Results from the BABY-HUG phase III clinical trial. Pediatr Blood Cancer 2012;59:(2)254-257.

(11) Yawn BP, Buchanan GR, Afenyi-Annan AN, Ballas SK, Hassell KL, James AH, Jordan L, Lanzkron SM, Lottenberg R, Savage WJ, Tanabe PJ, Ware RE, Murad MH, Goldsmith JC, Ortiz E, *et al.* Management of sickle cell disease summary of the 2014 evidence-based report by expert panel members. JAMA 2014;312:(10)1033-1048.

(12) Kinney T, Helms R, O'Branski E, Ohene-Frempong K, Wang W, Daeschner C, Vichinsky E, Redding-Lallinger R, Gee B, Platt O, Ware R, Pediat Hydroxyurea Grp. Safety of hydroxyurea in children with sickle cell anemia: Results of the HUG-KIDS study, a phase I/II trial. Blood 1999;94:(5)1550-1554.

(13) Hankins J, Ware R, Rogers Z, Wynn L, Lane P, Scott J, Wang W. Long-term hydroxyurea therapy for infants with sickle cell anemia: The HUSOFT extension study. Blood 2005;106:(7)2269-2275.

(14) Krakoff I, Brown N, Reichard P. Inhibition of ribonucleoside diphosphate reductase by hydroxyurea. Cancer Res 1968;28:(8)1559-1565.

(15) Steinberg MH, McCarthy WF, Castro O, Ballas SK, Armstrong FD, Smith W, Ataga K, Swerdlow P, Kutlar A, DeCastro L, Waclawiw MA, Investigators Multictr Study Hydro. The risks and benefits of long-term use of hydroxyurea in sickle cell anemia: A 17.5 year follow-up. Am J Hematol 2010;85:(6)403-408.

(16) Voskaridou E, Christoulas D, Bilalis A, Plata E, Varvagiannis K, Stamatopoulos G, Sinopoulou K, Balassopoulou A, Loukopoulos D, Terpos E. The effect of prolonged administration of hydroxyurea on morbidity and mortality in adult patients with sickle cell syndromes: Results of a 17-year, single-center trial (LaSHS). Blood 2010;115:(12)2354-2363.

(17) Platt O, Thorington B, Brambilla D, Milner P, Rosse W, VichinskyY E, Kinney T. Pain in sickle-cell disease - rates and risk-factors. N Engl J Med 1991;325:(1)11-16.

(18) Zimmerman S, Schultz W, Davis J, Pickens C, Mortier N, Howard T, Ware R. Sustained long-term hematologic efficacy of hydroxyurea at maximum tolerated dose in children with sickle cell disease. Blood 2004;103:(6)2039-2045.

(19) Kuczmarski RJ, Ogden CL, Guo SS. 2000 CDC Growth charts for the United States: Methods and development. National Center for Health Statistics. Vital Health Stat, 2002:11:(246)

(20) Strouse JJ & Heeney MM. Hydroxyurea for the treatment of sickle cell disease: Efficacy, barriers, toxicity and management in children. Pediatr Blood Cancer 2012;59:(6)365-371.

Legends

Figure 1. Hydroxyurea (HU) improves haematological parameters. Increased Hb (A), increased HbF (B), increased MCV (C) and decreased reticulocytes (D) were observed post-treatment irrespective of dose achieved, although treating with ≥26mg/kg further improved HbF, MCV and reticulocyte count. Treatment with ≥26mg/kg also resulted in decreased neutrophils (E) and platelets (F). Lines indicate mean ± SD, statistics by paired t-test for pre/post treatment comparison and by t-test for dose comparison. Dose achieved did not correlate with patient age (G), dotted line indicates 26mg/kg threshold used for dose comparison.

Figure 2. Hydroxyurea (HU) improves control of haemolysis. Bilirubin (A) and lactate dehydrogenase (LDH; B) were reduced in children receiving ≥26mg/kg hydroxyurea. Alanine amino transferase (ALT) remained stable irrespective of dose (C) and aspartate amino transferase (AST) was reduced in children receiving ≥26mg/kg (D). Lines indicate mean ± SD, statistics by paired t-test for pre/post treatment comparison and by t-test for dose comparison. Grey shading indicates normal reference range for each parameter measured.

Figure 3. Effects of good adherence to therapy. Good adherence to therapy had a significant effect on Hb (A), HbF (B), MCV (C), reticulocyte count (D) and neutrophil count (E) but not on platelet count (F). No significant effects were recorded in bilirubin (G) or LDH (H) but ALT (I) and AST (J) were

significantly reduced by good adherence to therapy. Lines indicate mean ± SD, statistics by t-test, grey shading represents normal reference range for each parameter (G-J).

Figure 4. Growth rates in children following hydroxyurea therapy. Height (A) and weight (B) were maintained in children treated with hydroxyurea. Arrow indicates commencement of hydroxyurea therapy. Data shown is height for age (A) and weight for age (B) z-score calculated using CDC growth chart[19]

Supplemental Figure 1. Hydroxyurea (HU) improves haematological parameters. Significant improvements in haemoglobin (Hb), foetal haemoglobin (HbF), mean cell volume (MCV), reticulocyte count and neutrophil count were recorded post-HU therapy in UK paediatric patients with sickle cell anaemia. Platelets were also significantly reduced post-HU therapy.

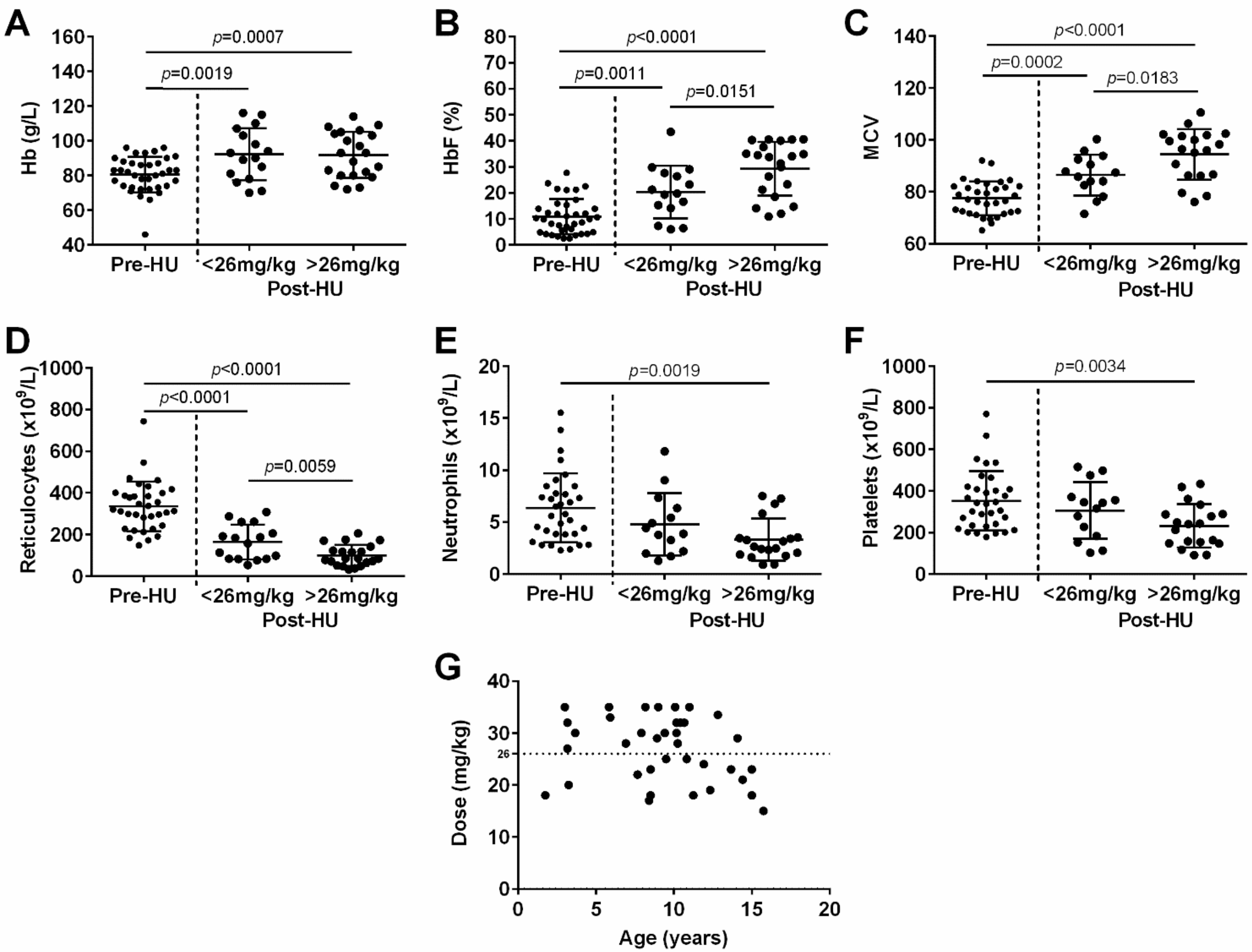

Figure 1 Hydroxyurea (HU) improves haematological parameters. *Increased Hb (A), increased HbF (B), increased MCV (C) and decreased reticulocytes (D) were observed post-treatment irrespective of dose achieved, although treating with ≥26mg/kg further improved HbF, MCV and reticulocyte count. Treatment with ≥26mg/kg also resulted in decreased neutrophils (E) and platelets (F). Lines indicate mean ± SD, statistics by paired t-test for pre/post treatment comparison and by t-test for dose comparison. Dose achieved did not correlate with patient age (G), dotted line indicates 26mg/kg threshold used for dose comparison.*

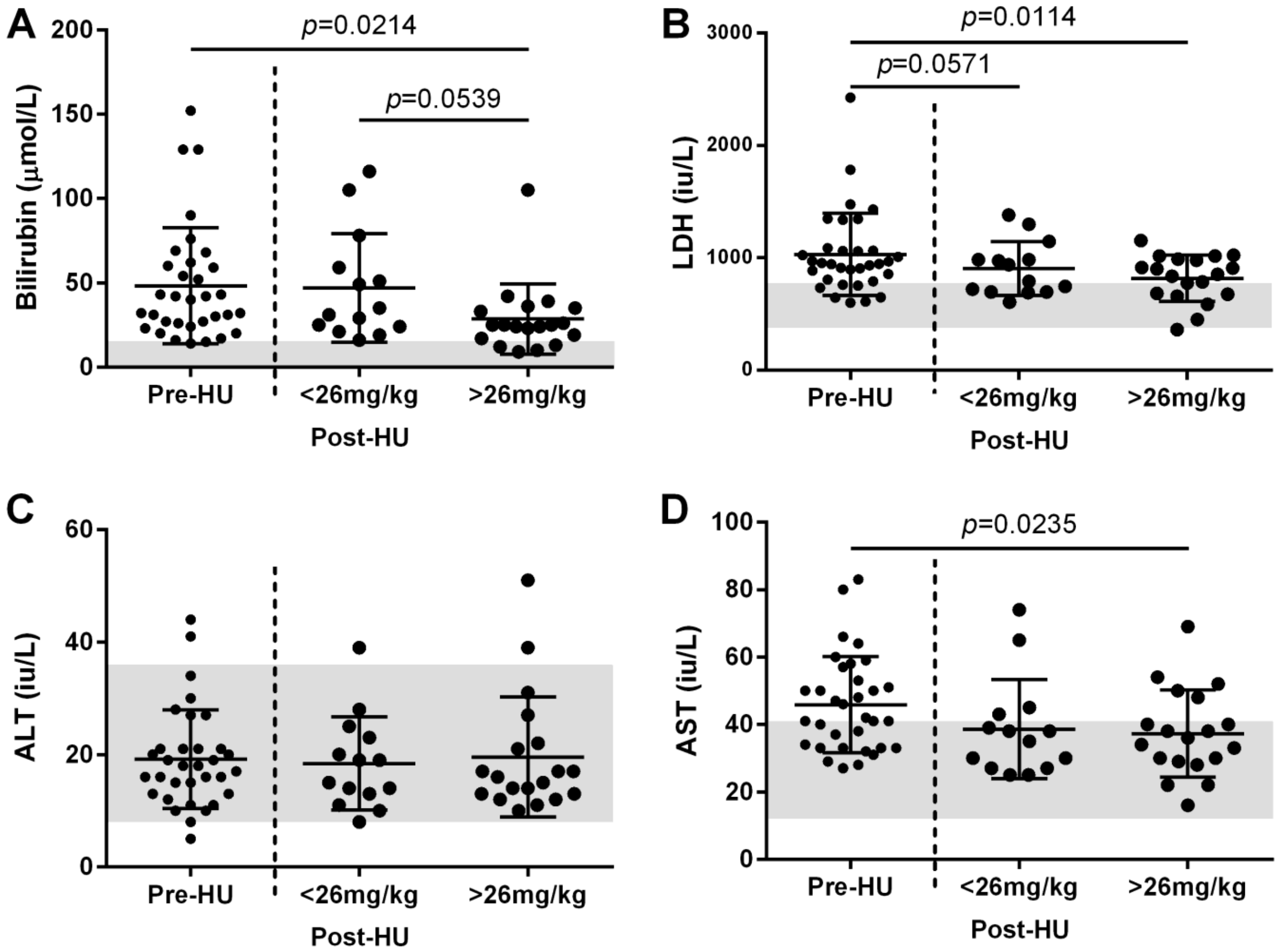

Figure 2 Hydroxyurea (HU) improves control of haemolysis. *Bilirubin (A) and lactate dehydrogenase (LDH; B) were reduced in children receiving ≥26mg/kg hydroxyurea. Alanine amino transferase (ALT) remained stable irrespective of dose (C) and aspartate amino transferase (AST) was reduced in children receiving ≥26mg/kg (D). Lines indicate mean ± SD, statistics by paired t-test for pre/post treatment comparison and by t-test for dose comparison. Grey shading indicates normal reference range for each parameter measured*

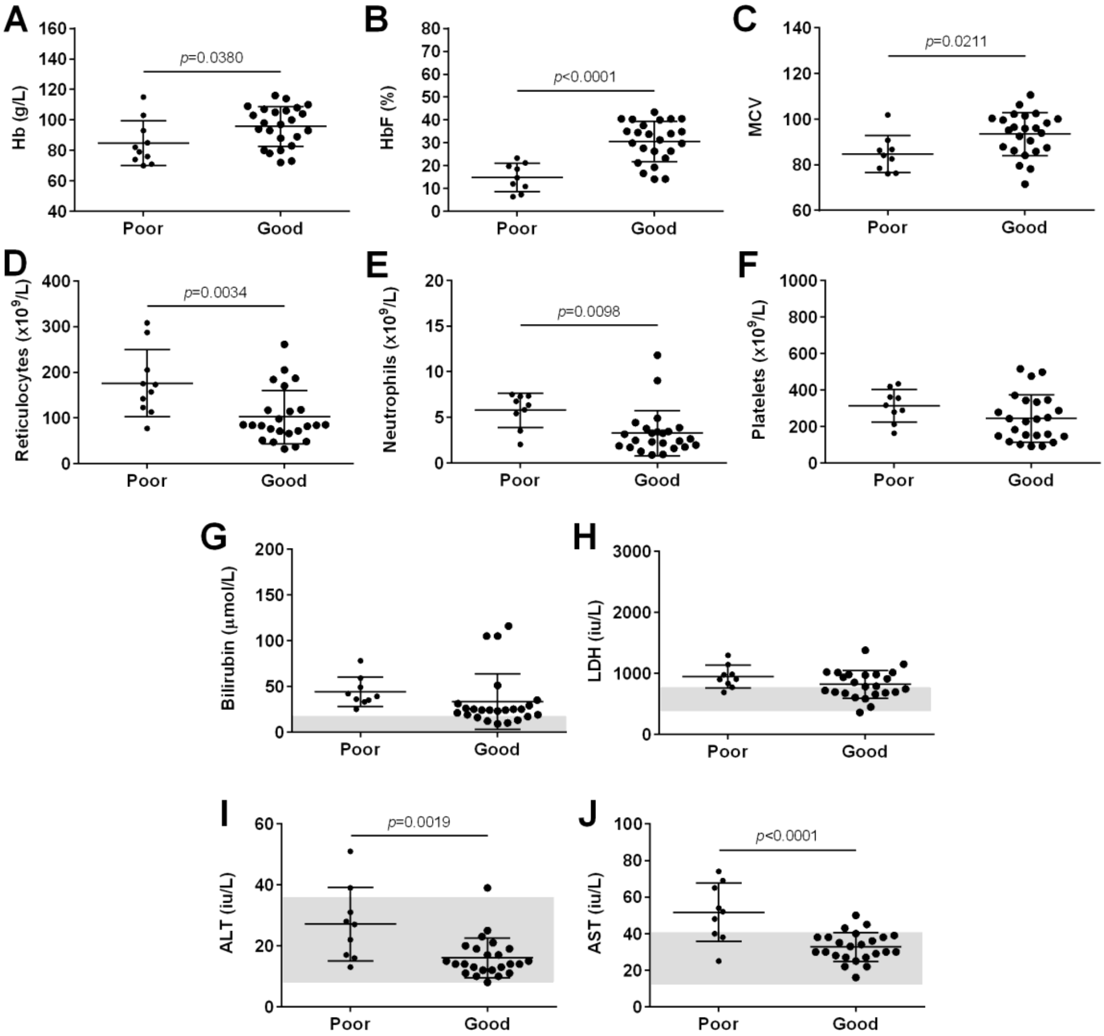

Figure 3 Effects of good adherence to therapy. *Good adherence to therapy had a significant effect on Hb (A), HbF (B), MCV (C), reticulocyte count (D) and neutrophil count (E) but not on platelet count (F). No significant effects were recorded in bilirubin (G) or LDH (H) but ALT (I) and AST (J) were significantly reduced by good adherence to therapy. Lines indicate mean ± SD, statistics by t-test, grey shading represents normal reference range for each parameter (G-J).*

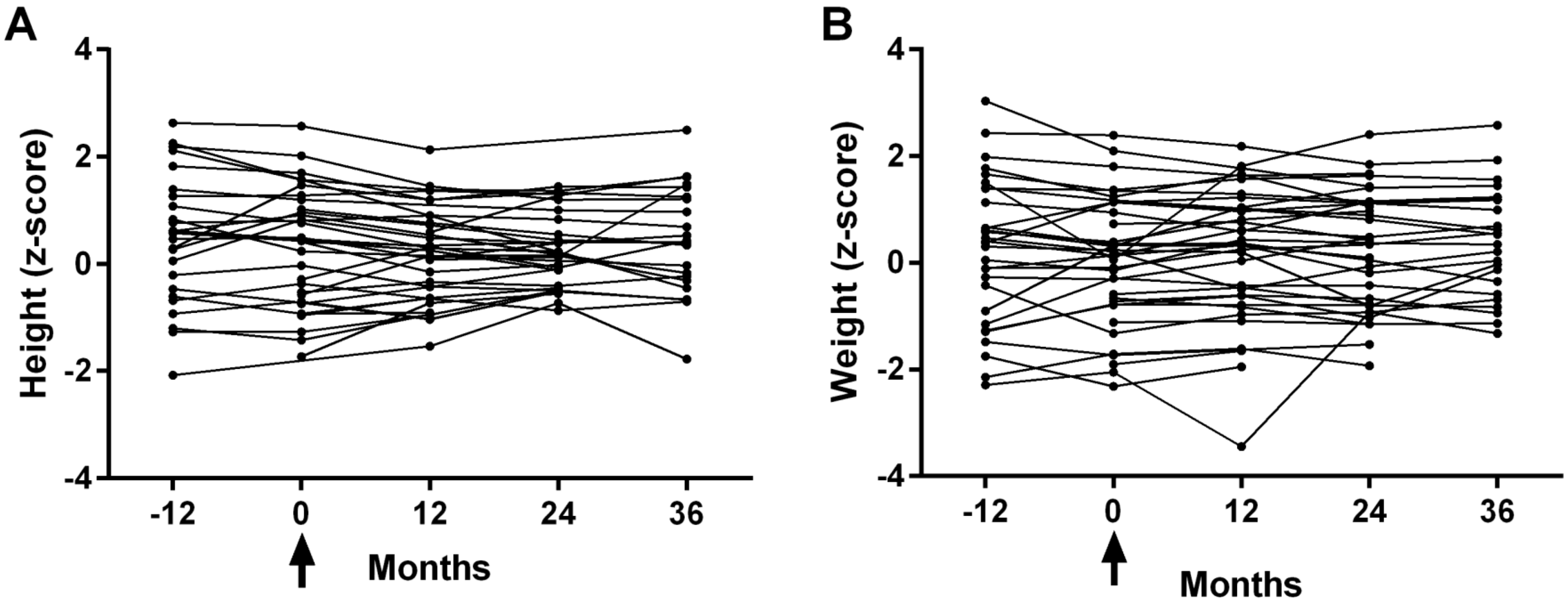

Figure 4 Growth rates in children following hydroxyurea therapy. *Height (A) and weight (B) were maintained in children treated with hydroxyurea. Arrow indicates commencement of hydroxyurea therapy. Data shown is height for age (A) and weight for age (B) z-score calculated using CDC growth chart[19]*