Treatment regimens and outcomes in severe and moderate haemophilia A in the UK: The Thunder Study.

Scott M J [1,2,3], Xiang H [1], Hart D P [5], Palmer B [1], Collins P W [6], Stephensen D [5, 7], Sima C S [8], Hay C R M [1,2,4,]

1. UK National Haemophilia Database, City View House, Manchester
2. University Department of Clinical Haematology, Manchester Royal Infirmary, Manchester
3. Institute of Cancer Sciences, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester.
4. School of Vascular Medicine, The University of Manchester, UK.
5. The Royal London Hospital Haemophilia Centre, Barts and The London School of Medicine and Dentistry, Queen Mary University London, UK.
6. School of Medicine, Cardiff University, University Hospital of Wales, Cardiff
7. Kent Haemophilia & Thrombosis Centre, East Kent Hospitals University NHS Trust .
8. Roche/ Genentech, South San Francisco, CA, USA

Corresponding author: Charles.Hay@mft.nhs.uk

Running head: Treatment patterns and outcomes in haemophilia A

Keywords: Haemophilia A, prophylaxis, FVIII inhibitors, ABR, HJHS

Word Count: 2983 (excluding abstract, references and figure legends)

Abstract

Introduction: The THUNDER study provides an analysis of treatment patterns and outcomes in UK patients with severe or moderate Haemophilia A (SHA/ MHA) in 2015.

Methods: Patients with SHA or MHA registered with the UK National Haemophilia Database (NHD) were segregated by severity, inhibitor status and age. Haemophilia joint health score (HJHS) was derived from NHD records and treatment regimen and annualised bleed/ joint-bleed rate (ABR/ AJBR) from Haemtrack (HT) in HT-compliant patients.

Results: We report 1810 patients with SHA and 864 with MHA. Prophylaxis was used in 94.9% (n=130/137) of HT-compliant children <12 years with SHA, falling to 74.1% (n=123/166) aged ≥40 years. Median ABR increased with age (1.0, IQR 0.0 – 5.0, <12 years; 3.0 IQR, 1.0 - 8.0, ≥40 years). Inhibitors were present in 159 (8.8%) SHA and 34 (3.9%) MHA. Median ABR increased from 2.0 (<12 years) to 21.0 (≥40 years) in SHA inhibitor patients using prophylaxis. Prophylaxis was used by 68.8% of HT-compliant MHA patients (n=106) (median FVIII baseline 0.01 IU/mL) associated with a median (IQR) ABR of 3.0 (1.0 – 7.0).

Median HJHS (n=453) increased with age in SHA and MHA. Median (IQR) HJHS was higher in SHA inhibitor (17.0, 0.0 - 64.5) than non- or past-inhibitor patients (7.0, 0.0 – 23.0).

Conclusions: Increasing ABR with age persists despite current prophylaxis regimens. SHA and MHA had similar ABR/ AJBR and HJHS, leading to a suspicion that a subgroup of MHA may be relatively undertreated. More intensive prophylaxis may improve outcomes, but this requires further study.

Introduction

Although the severity of Haemophilia A (HA) is defined by the baseline factor VIII (FVIII) level, there is considerable overlap in bleeding phenotype between severe (SHA; <0.01 IU/mL) and moderate HA (MHA; 0.01-0.05 IU/mL) [1] and many patients with MHA have a severe bleeding phenotype [2].

The standard of care for SHA is prophylactic FVIII replacement therapy to elevate the patient's trough FVIII to a level adequate to prevent joint bleeding. Primary prophylaxis, usually initiated pre-emptively before the second birthday [3,4], minimises or prevents spontaneous bleeding events and arthropathy [5,6]. The role of FVIII prophylaxis in MHA is less clear, given that these patients already have a baseline FVIII level of ≥ 0.01 IU/mL and a variable bleeding phenotype. However, a subgroup of these patients suffer frequent haemarthroses and are therefore managed with FVIII prophylaxis [7].

Although FVIII prophylaxis effectively reduces the frequency of bleeding events, individualisation of treatment is required to achieve the best bleed control [8,9]. Although it is often advised to maintain a trough FVIII level ≥ 0.01 IU/mL, complete bleed-avoidance commonly requires a higher level [10,11]. Prophylaxis is also demanding, prone to poor compliance and, as currently practiced, does not completely prevent arthropathy [12,13]. Consequently, many patients are still treated with sub-optimal prophylaxis or on-demand treatment, resulting in a continuing unmet need.

Bypass therapy administered on-demand or as prophylaxis in patients with persistent inhibitors is only partially effective in treating or preventing haemarthroses [14–16]. Consequently, these patients experience a higher annualised bleed-rate and reduced life expectancy than patients lacking inhibitors [17]. The extent to which this morbidity may be minimised or prevented by early inhibitor eradication through immune tolerance induction is unknown.

Treatment and disease outcome of HA by age, disease severity and inhibitor status in complete national haemophilia cohorts are not well documented. The THUNDER study (Treatment of Haemophilia, Unmet Need and Disease Epidemiology in the Real world) was established to provide an analysis of real-world treatment of HA in the UK, derived prospectively from data collected by the UK National Haemophilia Database (NHD) and the Haemtrack (HT) patient-reported treatment diary [18] . Treatment practice and patterns were analysed in relation to patient-reported and objectively measured outcomes in the UK cohort of patients with SHA or MHA treated during 2015, to evaluate continued unmet need in this patient-group.

Materials and methods

Study objectives

The objective of this study was to describe the current standard of care and to evaluate unmet need in UK patients with SHA and MHA, by age and inhibitor status in the whole UK HT population. We evaluated the treatment regimen and outcome as reflected by patient reported annualised bleed/ joint bleed rates (ABR/ABJR); bleed-related pain and interruption of daily function, in patients fulfilling pre-set HT-compliance criteria only. Haemophilia Joint Health Score (HJHS) was analysed where available.

Data source and patient population

The UK NHD prospectively collects data for all UK patients registered as having a bleeding disorder. Diagnoses, adverse events and mortality are updated electronically in real time and treatment data is reported quarterly, including individual patient product and volume.

The HT system is a primarily electronic, home-therapy patient-reporting diary, which integrates with NHD systems [18]. Patients report treatment-related infusions, including product and dose administered and the reason for infusion. For treatments, patients also report severity of the bleed, cause (spontaneous or traumatic), location, associated pain and disruption of planned activities.

Patients with SHA and MHA are recommended to have a HJHS every 6-12 months. Workshops have been conducted in the UK to decrease inter-centre variability in HJHS scoring. Where HJHS is recorded electronically by the local haemophilia centre, it is available to the NHD to analyse. Patients with MHA using HT and those who have had a HJHS performed are predominantly phenotypically at the severe end of the moderate FVIII range (median (IQR) FVIII baseline of 0.01 (0.01-0.02) IU/mL). This means they are a selected subset of people with MHA.

All patients with SHA (FVIII < 0.01 IU/mL) or MHA (FVIII = 0.01 – ≤ 0.05 IU/mL) registered with the NHD during 2015 were included. The study duration was calendar year, 2015, this being the first period when we had sufficient patients compliant with HT reporting and with HJHS to permit meaningful analysis. HT data analysis (treatment administered and bleeding outcomes) was restricted to a group who fulfilled pre-set compliance criteria, reporting usage of >75% of FVIII or bypassing agent issued to them per year. Regular prophylaxis was defined as ≥2.5 infusions/week for >45 weeks/year (extended half-life FVIII had not been introduced at that time).

Study design and statistics

All statistical analyses are descriptive in nature. Continuous data are summarised as medians and interquartile range (IQR, 25^{th} – 75^{th} percentile). Categorical data are presented as counts and percentages. All statistical analyses were performed using Stata/SE 11.2 (StataCorp LLC, College Station, Tx, USA) and R (R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient demographics

During the study period, 1810 individuals with SHA and 864 with MHA were registered with the NHD with 1150 and 273, respectively, registered to use HT. Of these, 607 (52.8%) with SHA and 163 (59.7%) with MHA fulfilled the HT-compliance criteria and were included in the bleeding outcomes analysis. In MHA, HT use was largely confined to more severely affected patients who had a median (IQR) FVIII baseline 0.01 (0.01-0.02) IU/mL. A current inhibitor was reported in 159 (8.8%) of individuals with SHA and 34 (3.9%) with MHA. Disposal of these patients is summarised in table 1 and figure 1.

Haemtrack reported treatment practices and bleeding outcomes in SHA and MHA.

During the study period, there were a total of 1620 bleeds reported amongst the 770 individuals meeting the HT compliance criteria; 52.8% of these were reported to be traumatic. The cause of bleeding events varied with age; 63.0% of bleeds in individuals aged 0 – 11 years were reported as traumatic, compared with 48.2% in patients ≥ 40 years.

Non-inhibitor patients

Of 717 non-inhibitor patients with SHA or MHA reporting HT-compliant data during the study period, 563 (78.5%) had SHA and 154 (21.5%) MHA. Of these, 465 (82.5%) with SHA and 106 (68.8%) with MHA reported using regular prophylaxis. The proportion of patients using prophylaxis was highest in younger patients and fell progressively with increasing age. The distribution by age, treatment regimen, ABR and AJBR of the group with SHA reporting prophylaxis is summarised in table 2 and figure 2. The median (IQR) ABR in patients with SHA on prophylaxis was 2.0 (0.0 – 7.0) and 6.5 (2.0 – 17.8) on-demand. The median (IQR) AJBR was 1.0 (0.0 - 4.0) and 3.5 (0.0 – 12.8), respectively. In the SHA group using prophylaxis, 29% were bleed-free; 38% were joint-bleed-free. In the on-demand group, 19% were bleed-free and 28% reported no joint bleeding. ABR and AJBR increased with age in both the prophylaxis and on-demand groups (table 2, figure 2 & 3).

The ABR in the subgroup of MHA patients who met the HT compliance criteria was higher than SHA: median (IQR) ABR/ AJBR was 3.0 (1.0 – 7.0)/ 2.0 (0.0 – 5.0) in those reporting

prophylaxis and 11.0 (4.8 – 20.3)/ 5.0 (2.0 – 15.3) in those treated on-demand. For patients with MHA reporting prophylaxis, 24% and 30% were bleed-free or joint-bleed-free, respectively. In the on-demand group, this was 10% and 15%, respectively.

Inhibitor patients

A total of 53 patients with SHA or MHA *and* an inhibitor reported HT-compliant treatment in 2015; 44 (83.0%) with SHA and 9 (16.9%) MHA. Of these, 40 (90.9%) with SHA and 8 (88.8%) with MHA reported treatment consistent with regular FVIII or bypass-therapy prophylaxis.

For patients with SHA and an inhibitor using FVIII prophylaxis (n=27), the median (IQR) ABR was 1.0 (0.0 – 3.0) and for those with inhibitors using bypass-agent prophylaxis (n=8), the median (IQR) ABR was 14.5 (4.0 – 22.0). Five patients with SHA reported prophylaxis with both FVIII and bypass-agents during the study period, with a median (IQR) ABR of 10 (8.0 – 11.0).

Seven inhibitor patients with MHA and compliant with HT used FVIII prophylaxis, reporting a median (IQR) ABR of 2.0 (0.5 – 4.5).

Haemophilia joint health score in patients with severe and moderate haemophilia A

A HJHS (range 0 – 124) measured during the study period was available for 453 individuals (331 (18.3%) with SHA; 122 (14.1%) with MHA). The median (IQR) baseline FVIII level of the patients with MHA and a reported HJHS was 0.02 (0.01 – 0.03) IU/mL. Median HJHS increased incrementally with age in SHA and MHA, both in patients using prophylaxis and those using on-demand treatment.

The median (IQR) HJHS of patients with SHA using prophylaxis was 0.0 (0.0 – 1.0) at age 0 – 18 years and 65.0 (37.0 – 67.0) at age ≥ 60 years. The median (IQR) HJHS in patients treated on-demand was 0.0 (0.0 – 0.0), 0-18 years and 56.5 (53.0 – 60.0), aged >60 years (figure 4).

HJHS appeared higher in SHA patients with a current inhibitor compared to patients with no inhibitor history or a past inhibitor history, at all ages. Median (IQR) HJHS for patients with SHA and a current inhibitor (n=22) was 17.0 (0.0 - 64.5); for those with an inhibitor history, but no current inhibitor (n=45), it was 1.0 (0.0 – 15.5); and for those with no inhibitor history (n=264), it was 8.0 (0.0 – 26.0) (p=0.015). The distribution of HJHS in the people with MHA who had a HJHS performed suggests a similar pattern to SHA, although patient numbers were too low to confirm this definitively (figure 5).

Pain associated with bleeding events

Pain associated with bleeding events is reported to HT on a scale of one to six, six being the highest level of pain. Patients are also requested to define bleeding episodes as minor or major/ life threatening. The median pain score reported for all minor bleeds (n=1181) was 3.0. For major bleeding (n=458), the median pain score was 5.0, although the number of episodes was substantially less than the number of minor bleeding events. There was no difference in reported pain according to the nature of the bleed (spontaneous, surgery/ dental or trauma/activity).

Disruption to planned activities associated with bleeding events and time from bleed-onset to treatment

During the study period, 51.0 % of bleeding episodes were reported to disrupt a planned activity. There appeared to be no relationship between the frequency of disruption and the age of the patient. The median (IQR) time elapsed from bleed onset to treatment was 2.0 (1.0 – 4.0) hours.

Discussion:

We report a prospective study of treatment practices and associated outcomes in a national cohort of 2674 UK patients with SHA and MHA during 2015. Around 53% of this population used HT, 55% of whom fulfilled compliance criteria, permitting analysis of treatment regimen and outcome. The SHA HT cohort are a representative sample of UK patients with SHA lacking inhibitors [18], but HT-using patients with MHA have a predominantly severe bleeding phenotype.

The proportion of children using prophylaxis was high (94%), decreasing to 74% of older adults. Prophylaxis has been the standard of care in children for many years [6,19]. The gradual uptake of prophylaxis in adult patients has been less consistent, despite good evidence to support its use [20]. There is considerable national variation, from zero to 100%, in the use of prophylaxis amongst adult patients, even in countries with similar healthcare systems and wealth [21,22]. The proportion of adults using prophylaxis in the UK has increased substantially over the past 10 years. Although we found relatively low ABRs in patients treated on-demand, this probably reflects treatment selection bias, since on-demand regimens are generally used in patients with a relatively mild bleeding phenotype in countries where prophylaxis is the standard of care.

The median ABR and AJBR was low in non-inhibitor patients with SHA treated prophylactically, especially in children < 12 years. However, large interpersonal variation was observed and a significant proportion of adult patients with SHA still have an unacceptably high ABR. This may relate to established arthropathy and the difficulty older patients experience distinguishing early bleeding from arthropathic discomfort or to inadequate prophylaxis.

We show that prophylaxis is only partially effective in preventing self-reported bleeding; only 29% of patients with SHA and 24% of patients with MHA using prophylaxis reported that they were bleed free. This suggests that individual tailoring of prophylaxis could be improved. Current UK guidelines recommend maintaining a trough FVIII level of > 0.01 IU/mL [3], However, patients with MHA and a median (IQR) FVIII baseline 0.01 (0.01 - 0.02) IU/mL were found to have a an ABR of median 3.0 on prophylaxis and 11.0 treated on-demand, both higher than observed in SHA. Since many patients with a FVIII baseline of ≤ 0.02 IU/mL have a severe haemophilia phenotype [7,11], a trough level as low as 0.01 IU/mL for FVIII prophylaxis is likely to be inadequate to render most patients bleed-free. Many patients may require a significantly higher trough level of at least 0.03 – 0.05 IU/mL.

Despite this, prophylaxis was used in a lower proportion of HT-using patients with MHA than in SHA (68.8% vs. 82.5). Patients with MHA were relatively undertreated, as previously reported [7]. Higher baseline FVIII levels in MHA may provide false-reassurance of bleed protection and prophylaxis not being started pre-emptively, as it is in SHA. Consequently, arthropathy may already be established before prophylaxis is instigated. We found similar HJHS in both SHA and MHA regardless of treatment regimen. It is important to recognise, however, that the patients with MHA included in this report are a selected subgroup, because patients with minimal bleeding are less likely to requite Home therapy, Haemtrack or regular HJHS assessments.

HJHS increased progressively with age in both SHA and MHA. This reflects progression of haemophilic arthropathy and the relative inadequacy of treatment regimens in past decades. Almost all UK patients with SHA under the age of 19 years will have received prophylaxis from the early infancy and consequently have a low HJHS. Those over the age of 40 years will have been treated

on-demand for much of their life and, therefore, have a high HJHS, whether currently treated on-demand or with prophylaxis.

Although determining inhibitor epidemiology was not a primary objective of this analysis, our data allows us to calculate an overall inhibitor prevalence of 7.2%; consistent with previous estimations in unselected HA populations [23–25]. It is interesting to note that in the HT subgroup the prevalence of inhibitors is remarkably similar (6.9%).

Patients with persistent inhibitors to FVIII, have significantly higher ABR and HJHS than non-inhibitor patients with a similar factor VIII level, especially amongst the older patients, where pre-existing arthropathy probably increases an individual's propensity to bleed. Surprisingly, although one might expect some arthropathy to develop in the period before successful inhibitor eradication, we found patients with a past inhibitor history to have a similar HJHS to patients who had never had an inhibitor. This reinforces the importance of prompt, active inhibitor eradication [17].

Many historic investigations of treatment practices have relied on survey data, an approach limited by reporting bias [25–29]. The HT system used by most UK haemophilia treatment centres, avoids this by prospectively reporting actual patient practice, rather than the expected or prescribed treatment. Although patient reported outcomes (PROs) and "real-world" data sources are susceptible to other forms of reporting bias, such as poor reporting compliance [30], our compliance checks are robust enough to eliminate many of these issues. Although PROs are relatively subjective and cannot be completely verified, by analysing only patients who fulfil pre-set reporting compliance criteria, cross-checked with NHD product issues data, we have a high degree of confidence that the outcome data presented is compliantly reported. Our selection criteria minimise reporting inaccuracies. Subjectivity in bleed reporting is reduced further by reporting only joint bleeding, which is less susceptible to misclassification.

The NHD does not report bleed level data on patients that do not use HT, limiting analysis of non-HT users to a comparison of overall FVIII usage. This may introduce some reporting bias. However, the HT-data shows the outcome and limitations of treatment when it is used as intended by treatment centres. It will be interesting to see, as our HJHS data becomes more complete, whether HT-uncompliant patients have a poorer joint-outcome. Although this is the largest reported dataset of HJHS, only a small number of older patients are reported and there is likely to be a degree of inter- and intra-centre joint-scoring variability [31]. Furthermore, we are unable to confirm the presence of co-morbid musculoskeletal conditions that may contribute to HJHS. Although we have drawn only broad and general conclusions from our HJHS data, as the electronic reporting of HJHS to the NHD becomes more routine and the dataset expands, we will be able link HJHS to treatment frequency and intensity in addition to disease severity and other co-morbid conditions.

This is the first large-scale study using data derived from the HT system, demonstrating the great potential for this tool to generate treatment-level data in large cohorts of patients. Uptake and compliance with the system continues to increase. The dataset will evolve and there is potential to link with other large National Databases and information systems, expanding the number of non-traditional outcome measures available for analysis.

The THUNDER study demonstrates the limitations of prophylaxis as recently practiced in the UK. Whilst outcomes in children appear excellent, prophylaxis has not succeeded in attaining the desired

bleed-free status in many children and most adults. Arthropathy is observed from early adulthood onwards. Haemarthroses, when they occur, have a significant impact on daily life. Strategies to improve these outcomes should be targeted to reduce bleeding in patients with high ABRs. This should include more intense individualisation of prophylaxis, potentially requiring trough FVIII levels beyond 0.01 – 0.02 IU/mL, optimised pharmacokinetically in some patients. Prophylaxis should be started early in patients with MHA if spontaneous bleeding episodes occur. We should aim for our patients to be bleed-free and, as newer agents become increasingly available for routine clinical use, this may soon become a realistic aspiration.

Author contributions:

The analysis was conducted by BP, HX and MS in the UK NHD, with advisory input from CRMH, CS and the other co-authors. The first draft of the manuscript was written by CRMH and MS. Subsequent drafts were edited by CRMH, MS, DPH, CS, HX, BP and PWC and DS.

Acknowledgements:

This study was instigated and funded by Roche, AG, Basel, Switzerland. CS acted on their behalf and was involved as detailed above.

The authors would like to thank Ceri Hirst, an employee of Roche/ Genentech for her contribution to the study design. In addition, the authors would also like to thank the centre directors and staff of all UK haemophilia centres for their hard work in collecting data and responding to data queries. The staff at the National Haemophilia Database are also thanked for their contribution to data collection.

Conflicts of Interest:

MS is a Bayer Haemophilia Clinical Research Fellow and has received sponsorship to attend meetings from Bayer, Pfizer, Shire and Sobi.

CRMH has participated in Roche advisory panels and has received research support from Novo, Pfizer, Shire Bayer and Sobi and acted as speaker in sponsored symposia for Pfizer, Shire, Bayer, Sobi and Biotest.

HX and BP have no competing interests to declare

DPH – Has received research support from Shire, Octapharma and Bayer and has worked as a paid consultant or speaker for Pfizer, Shire, Sobi, Octapharma, Novo Nordisk, UniQure, Roche, Biotest and Bayer

PWC – Has worked as a paid consultant to Roche; has received research support and support to attend meetings from CSL Behring, NovoNordisk and Bayer.

CSS is employed by Roche/ Genentech and holds stock in the company.

DS – Has received research support from Pfizer and Novo Nordisk and has worked as paid speaker at sponsored educational meetings for Pfizer, Bayer and Shire

References:

1 Blanchette VS, Key NS, Ljung LR, Manco-Johnson MJ, van den Berg HM, Srivastava A. Definitions in hemophilia: Communication from the SSC of the ISTH. *J Thromb Haemost* 2014; **12**: 1935–9.

2 den Uijl IEM, Fischer K, Van Der Bom JG, Grobbee DE, Rosendaal FR, Plug I. Clinical outcome of moderate haemophilia compared with severe and mild haemophilia. *Haemophilia* 2009; **15**: 83–90.

3 Richards M, Williams M, Chalmers E, Liesner R, Collins P, Vidler V, Hanley J. A United Kingdom haemophilia centre doctors' organization guideline approved by the British committee for standards in haematology: Guideline on the use of prophylactic factor VIII concentrate in children and adults with severe haemophilia A. *Br J Haematol* 2010; **149**: 498–507.

4 Fischer K, Collins PW, Ozelo MC, Srivastava A, Young G, Blanchette VS. When and how to start prophylaxis in boys with severe hemophilia without inhibitors: Communication from the SSC of the ISTH. *J Thromb Haemost* 2016; **14**: 1105–9.

5 Aledort LM, Haschmeyer RH, Pettersson H. A longitudinal study of orthopaedic outcomes for severe factor VIII deficient haemophiliacs. *J Intern Med* 1994; **236**: 391–9.

6 Manco-Johnson MJ, Thomas C, Shapiro AD, Riske B, Hacker MR, Kilcoyne R, Ingram JD, Manco-Johnson ML, Funk S, Jacobson L, Valentino LA, Hoots KW, Buchanan GR, DiMichele D, Recht M, Brown D, Lesissinger C, Bleak S, Cohen A, Mathew P, et al. Prophylaxis versus Episodic Treatment to Prevent Joint Disease in Boys with Severe Hemophilia. *N Engl J Med* 2007; **357**: 335–544.

7 den Uijl I, Biesma D, Grobbee D, Fischer K. Outcome in moderate haemophilia. *Blood Transfus* 2014; **12**.

8 Carcao M, Srivastava A. Factor VIII:factor IX prophylaxis for severe hemophilia - ScienceDirect. *Semin Haematol* 2016; **53**: 3–9.

9 Oldenburg J. Optimal treatment strategies for hemophilia: Achievements and limitations of current prophylactic regimens. *Blood* 2015; **125**: 2038–44.

10 den Uijl IEM, Fischer K, Van Der Bom JG, Grobbee DE, Rosendaal FR, Plug I. Analysis of low frequency bleeding data: The association of joint bleeds according to baseline FVIII activity levels. *Haemophilia* 2011; **17**: 41–4.

11 den Uijl IEM, Mauser Bunschoten EP, Roosendaal G, Schutgens REG, Biesma DH, Grobbee DE, Fischer K. Clinical severity of haemophilia A: Does the classification of the 1950s still stand? *Haemophilia* 2011; **17**: 849–53.

12 Hacker MR, Geraghty S, Manco-Johnson M. Barriers to compliance with prophylaxis therapy in haemophilia. *Haemophilia* 2001; **7**: 392–6.

13 Tagliaferri A, Feola G, Molinari AC, Santoro C, Rivolta GF, Cultrera DB, Gagliano F,

Zanon E, Mancuso ME, Valdre L, Mameli L, Amoresano S, Mathew P, Coppola A. Benefits of prophylaxis versus on- demand treatment in adolescents and adults with severe haemophilia A: the POTTER study. *Thromb Haemost* 2015; **114**: 35.

14 Franchini M, Coppola A, Tagliaferri A, Lippi G. FEIBA versus NovoSeven in hemophilia patients with inhibitors. *Semin Thromb Hemost* 2013; **39**: 772–8.

15 Matino D, Makris M, Dwan K, D'Amico R, Iorio A. Recombinant factor VIIa concentrate versus plasma-derived concentrates for treating acute bleeding episodes in people with haemophilia and inhibitors. *Cochrane database Syst Rev* 2015; **12**: 1–29.

16 Leissinger CA, Gringeri A, Antmen B, Berntorp E, Biasoli C, Carpenter S, Cortesi P, Jo H, Kavakli K, Lassila R, Morfini M, Négrier C, Rocino A, Schramm W, Serban M, Uscatescu M V, Windyga J, Zülfikar B, Mantovani L. Anti-Inhibitor Coagulant Complex Prophylaxis in Hemophilia with Inhibitors. *N Engl J Med* 2011; **365**: 1684–92.

17 Walsh CE, Soucie JM, Miller CH. Impact of inhibitors on hemophilia a mortality in the United States. *Am J Hematol* 2015; **90**: 400–5.

18 Hay CRM, Xiang H, Scott M, Collins PW, Liesner R, Dolan G, Hollingsworth R. The haemtrack home therapy reporting system: Design, implementation, strengths and weaknesses: A report from UK Haemophilia Centre Doctors Organisation. *Haemophilia* 2017; **23**: 728–35.

19 Nilsson IM, Berntorp E, Löfqvist T, Pettersson H. Twenty-five years' experience of prophylactic treatment in severe haemophilia A and B. *J Intern Med* 1992; **232**: 25–32.

20 Manco-Johnson MJ, Kempton CL, Reding MT, Lissitchkov T, Goranov S, Gercheva L, Rusen L, Ghinea M, Uscatescu V, Rescia V, Hong W. Randomized, controlled, parallel-group trial of routine prophylaxis vs. on-demand treatment with sucrose-formulated recombinant factor VIII in adults with severe hemophilia A (SPINART). *J Thromb Haemost* 2013; **11**: 1119–27.

21 Berntorp E, Dolan G, Hay C, Linari S, Santagostino E, Tosetto A, Castaman G, Alvarez-Roman M, Parra Lopez R, Oldenburg J, Albert T, Scholz U, Holmstrom M, Schved JF, Trossaert M, Hermans C, Boban A, Ludlam C, Lethagen S. European retrospective study of real-life haemophilia treatment. *Haemophilia* 2017; **23**: 105–14.

22 Carcao MD, Avila L, Leissinger C, Blanchette VS, Aledort L. An International Prophylaxis Study Group (IPSG) survey of prophylaxis in adults with severe haemophilia. *Haemophilia* 2017; **23**: e447–50.

23 Wight J, Paisley S. The epidemiology of inhibitors in haemophilia A: a systematic review. *Haemophilia* 2003; **9**: 418–35.

24 Witmer C, Young G. Factor VIII inhibitors in hemophilia A: Rationale and latest evidence. *Ther Adv Hematol* 2013; **4**: 59–72.

25 Biss TT, Chan AK, Blanchette VS, Iwenofu LN, Mclimont M, Carcao MD. The use of

prophylaxis in 2663 children and adults with haemophilia: Results of the 2006 Canadian national haemophilia prophylaxis survey. *Haemophilia* 2008; **14**: 923–30.

26 Ljung R, Aronis-Vournas S, Kurnik-Auberger K, Van Den Berg M, Chambost H, Claeyssens S, Van Geet C, Glomstein A, Hann I, Hill F, Kobelt R, Kreuz W, Mancuso G, Muntean W, Petrini P, Rosado L, Scheibel E, Siimes M, Smith O, Tusell J. Treatment of children with haemophilia in Europe: A survey of 20 centres in 16 countries. *Haemophilia* 2000; **6**: 619–24.

27 Blanchette P, Rivard G, Israels S, Robinson S, Ali K, Walker I, Stain AM, Blanchette V. A survey of factor prophylaxis in the Canadian haemophilia A population. *Haemophilia* 2004; **10**: 679–83.

28 Butler RB, Mcclure W, Wulff K. Practice patterns in haemophilia A therapy – a survey of treatment centres in the United States. 2003; : 549–54.

29 Zappa S, Mcdaniel M, Marandola J, Allen G. Treatment trends for haemophilia A and haemophilia B in the United States: Results from the 2010 practice patterns survey. *Haemophilia* 2012; **18**: 140–53.

30 Kaplan RM, Chambers DA, Glasgow RE. Big data and large sample size: A cautionary note on the potential for bias. *Clin Transl Sci* 2014; **7**: 342–6.

31 Nijdam A, Bladen M, Hubert N, Pettersson M, Bartels B, van der Net J, Liesner R, Petrini P, Kurnik K, Fischer K. Using routine Haemophilia Joint Health Score for international comparisons of haemophilia outcome: Standardization is needed. *Haemophilia* 2016; **22**: 142–7.

Tables and Figures:

Figure 1: Distribution of study population

Figure 2: Median annualised bleed rates for Haemtrack-compliant patients with severe haemophilia A using prophylaxis and on-demand treatment, categorised according to age and inhibitor status

Figure 3: Median annualised joint bleed rates for Haemtrack-compliant patients with severe haemophilia A using prophylaxis and on-demand treatment, categorised according to age and inhibitor status

Figure 4: Median Haemophilia Joint Health Score for patients with severe haemophilia A and moderate haemophilia A, categorised according to treatment type and age. The line represents the median value; the box interquartile range and the whiskers the lowest data still within 1.5 IQR of the lower quartile, and the highest data still within 1.5 IQR of the upper quartile.

Figure 5: Mean Haemophilia Joint Health Score for patients with severe haemophilia A and moderate haemophilia A categorised according to inhibitor status

Table 1: Study population categorised according to age at study mid-point and compliance with Haemtrack (HT) reporting for **(a)** severe haemophilia A, and **(b)** moderate haemophilia A.

Table 2: Number of non-inhibitor Haemtrack-compliant patients with SHA, categorised according to age, treatment type and associated annual bleed rate (ABR)/ annual joint bleed rate (AJBR)

Figure 1:

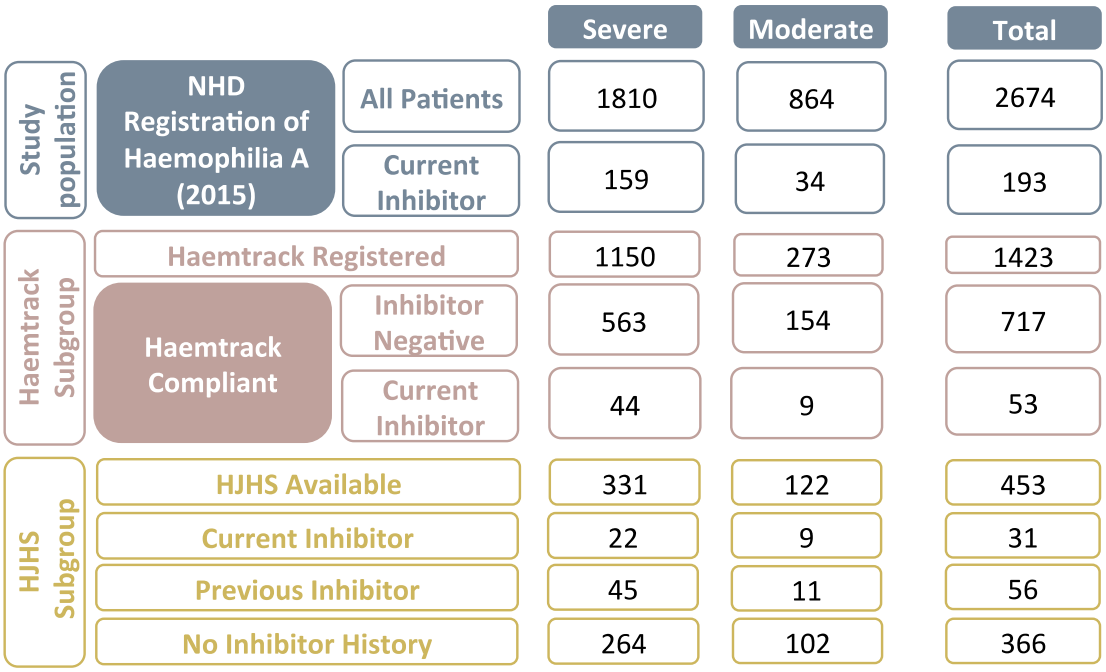
Severe
Moderate
Total
Study population
NHD Registration of Haemophilia A (2015)
All Patients
1810
864
2674
Current Inhibitor
159
34
193
Haemtrack Subgroup
Haemtrack Registered
1150
273
1423
Haemtrack Compliant
Inhibitor Negative
563
154
717
Current Inhibitor
44
9
53
HJHS Subgroup
HJHS Available
331
122
453
Current Inhibitor
22
9
31
Previous Inhibitor
45
11
56
No Inhibitor History
264
102
366

Figure 2

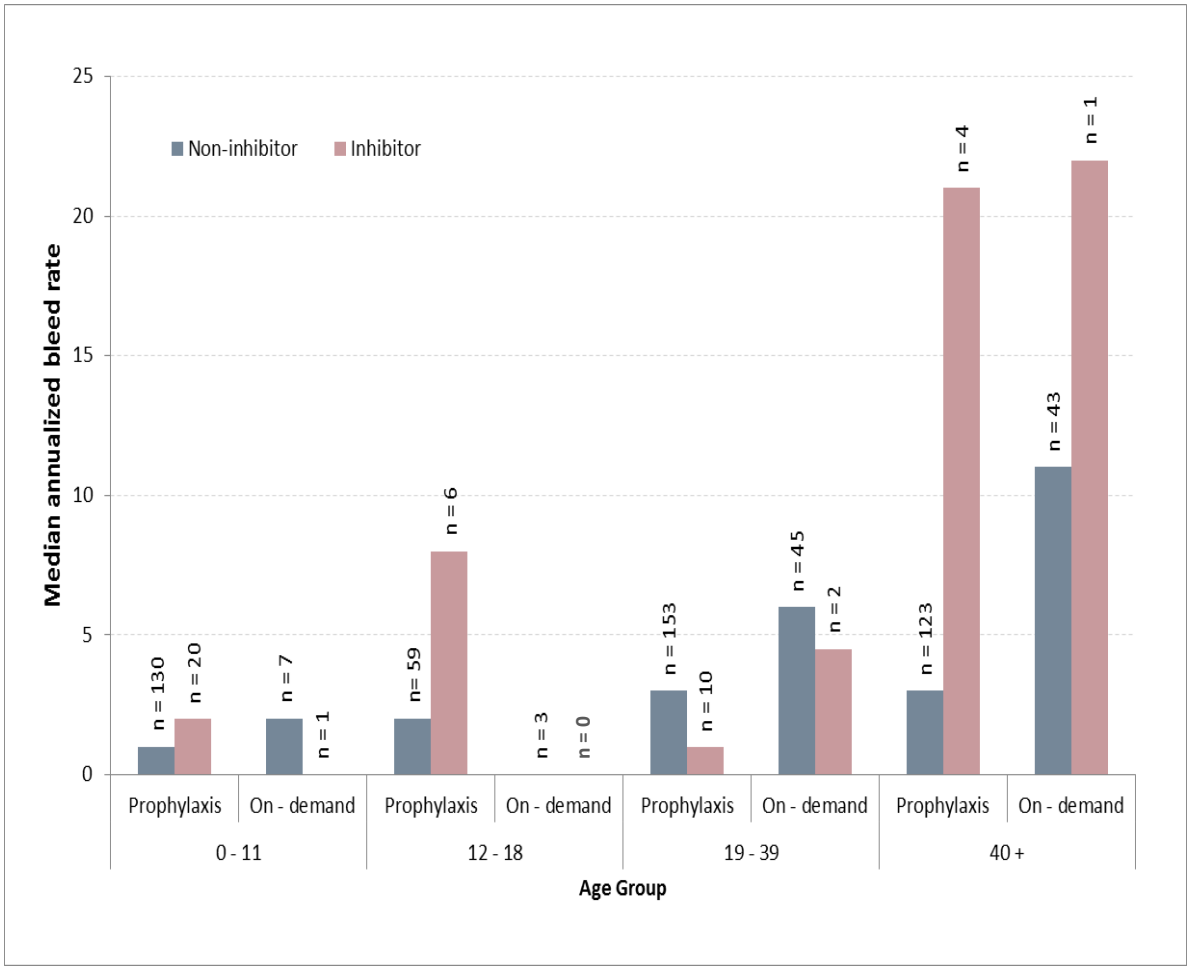

Figure 3

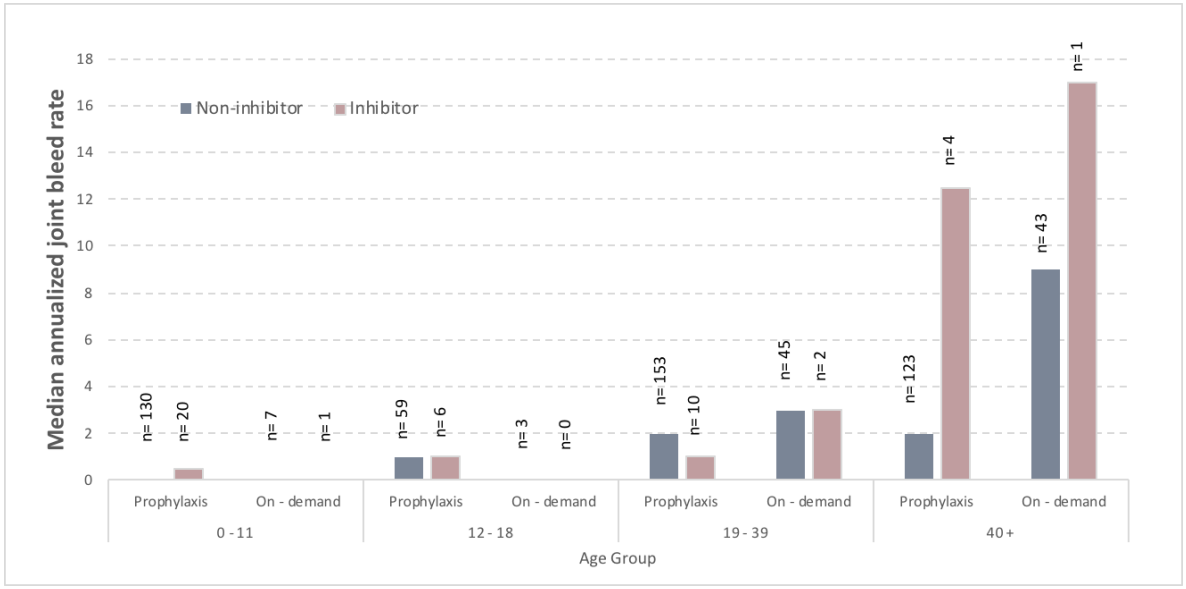

Figure 4

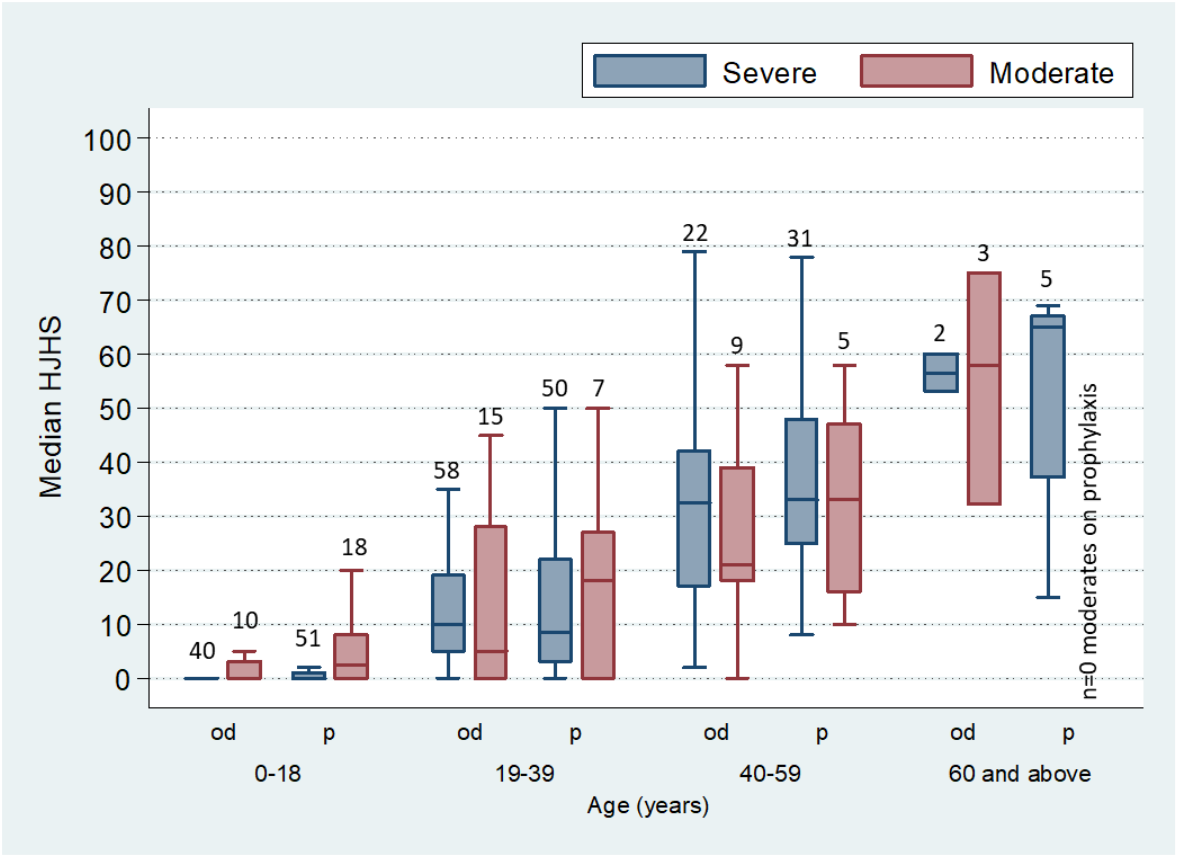
Severe
Moderate
Median HJHS
100
90
80
70
60
50
40
30
20
10
0
40
10
51
18
58
15
50
7
22
9
31
5
2
3
5
n=0 moderates on prophylaxis
od
p
od
p
od
p
od
p
0-18
19-39
40-59
60 and above
Age (years)

Figure 5

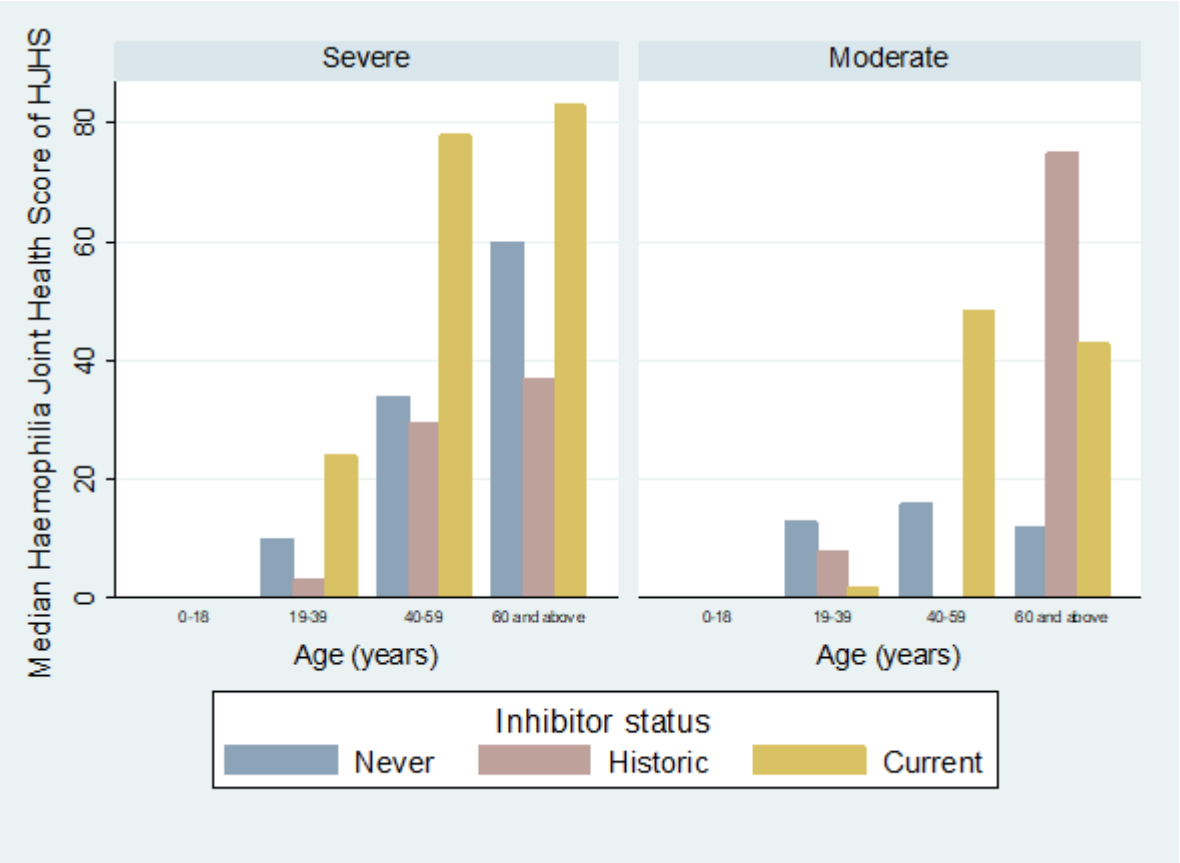

Table 1 (a)

	Severe			
Age/ years	Total, n (%)	HT Compliant, n (%)	HT Non-compliant, n (%)	Not HT registered, n (%)
0 - 12	491 (27.1)	178 (36.3)	121 (24.6)	192 (39.1)
13 – 24	446 (24.6)	118 (26.5)	158 (35.4)	170 (38.1)
25 – 36	395 (21.8)	124 (31.4)	133 (33.7)	138 (34.9
37 – 49	258 (14.3)	105 (40.7)	71 (27.5)	82 (31.8)
≥ 50	220 (12.2)	91 (41.4)	51 (23.2)	78 (35.5)

Table 1 (b)

	Moderate			
Age/ years	Total, n (%)	HT Compliant, n (%)	HT Non-compliant, n (%)	Not HT registered, n (%)
0 - 12	147 (17.0)	20 (13.6)	28 (19.0)	99 (67.3)
13 – 24	160 (18.5)	35 (21.9)	27 (16.9)	98 (61.3)
25 – 36	182 (21.1)	32 (17.6)	32 (17.6)	118 (64.8)
37 – 49	152 (17.6)	29 (19.1)	25 (16.4)	98 (64.5)
≥ 50	223 (25.8)	25 (11.2)	20 (9.0)	178 (79.8)

Table 2.

	Prophylaxis			On-demand		
Age (yrs)	n (%)	ABR (IQR)	AJBR (IQR)	n (%)	ABR (IQR)	AJBR (IQR)
0-11	130 (95)	1.0 (0.0-5.0)	0.0 (0.0 – 1.0)	7 (5)	2.0 (1.5-4.0)	0 (0 – 0.5)
12-18	59 (95)	2.0 (0.0 -7.0)	1.0 (0.0 – 3.0)	3 (5)	0.0 (0.0 -1.0)	0.0 (0.0 – 1.0)
19-39	153 (77)	3.0 (1.0 -8.0)	2.0 (0.0 – 6.0)	45 (23)	6.0 (0.0 13.0)	3.0 (0.0 – 7.0)
>-40	123 (74)	3.0 (1.0 – 8.0)	2 (0 – 6.5)	43 (26)	11 (2.5 - 27.0)	9.0 (1.5 – 18.0)