Resolution of Serious Vaso-Occlusive Pain Crises: Results from the Ongoing Phase 1/2 HGB-206 Group C Study of LentiGlobin for Sickle Cell Disease (bb1111) Gene Therapy

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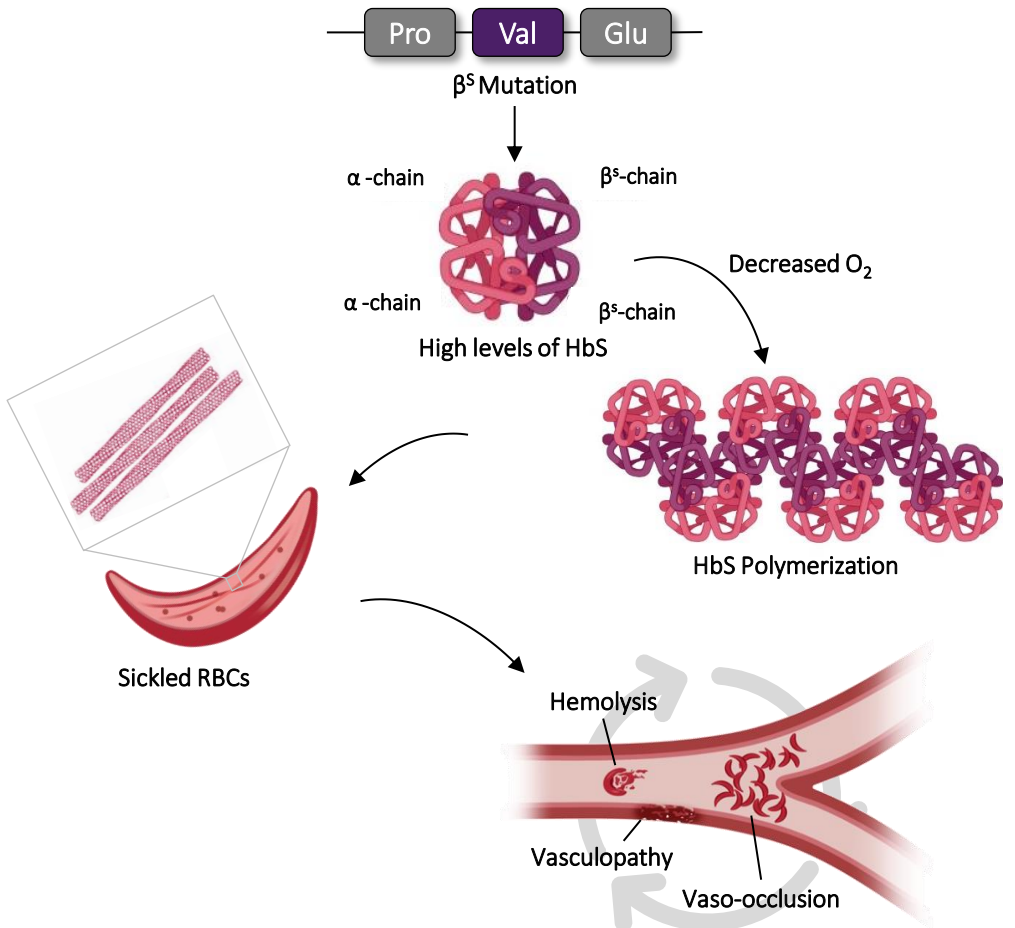
Disclosure

Markus Y. Mapara

Nothing to disclose

Sickle cell disease is characterized by high morbidity and early mortality

Pathophysiology of SCD[1]



Complications[2,3]

- Chronic daily pain
- Vaso-occlusive pain
- Anemia
- Cerebral vasculopathy/stroke
- Retinopathy
- Acute chest syndrome
- Pulmonary hypertension
- Hepato-splenic sequestration
- Cardiovascular complications
- Priapism
- Kidney disease
- Sudden death
- Leg ulcers
- Organ failure
- Osteonecrosis

> 50% of patients with SCD die before 45 years of age[2]

1. Kato GJ, et al. Nat Rev Dis Primer. 2018;4:18010; 2. Hassell K., Am J Prev Med 2010; 3. Kanter, et al. Blood Rev. 2013;27(6):279- 287; Glu, glutamic acid; Hbs, sickle hemoglobin; Pro, proline; RBC, red blood cell; SCD, sickle cell disease; Val, valine.

HGB-206: An Open-label, multicenter, phase 1/2 study of LentiGlobin gene therapy (bb1111) in patients with severe SCD

Group C Enrollment Criteria

- ≥ 12 and ≤ 50 years of age
- $\beta^S\beta^S$, $\beta^S\beta^0$, $\beta^S\beta^+$ genotype
- History of severe VOEs*
- Hydroxyurea failure or intolerance

Enrollment Completed
(NCT02140554)

Group C Key Outcomes

- Complete resolution of severe VOEs
- Weighted average HbA^{T87Q} ≥ 30% of unsupported total Hb for ≥ 6 months post-DP
- Weighted average: unsupported total Hb increase ≥ 3 g/dL vs baseline or total Hb ≥ 10 g/dL for ≥ 6 months post-DP
- ≥ 75% reduction in severe VOEs in 24 months post-DP

*Per inclusion criteria, severe VOEs include hospitalization or ER visit ≥ 24 hours or ≥ 2 visits to a day unit or ER over 72 hours, both requiring IV treatment, for the following: acute episodes of pain, acute chest syndrome, acute hepatic sequestration, and acute splenic sequestration. Additionally, priapism events that require visit to medical care facility (without inpatient admission) are sufficient to meet severe VOE criterion.

DP, drug product; ER, emergency room; Hb, hemoglobin; IV, intravenous; SCD, sickle cell disease; VOE, vaso-occlusive event.

LentiGlobin for SCD gene therapy Overview

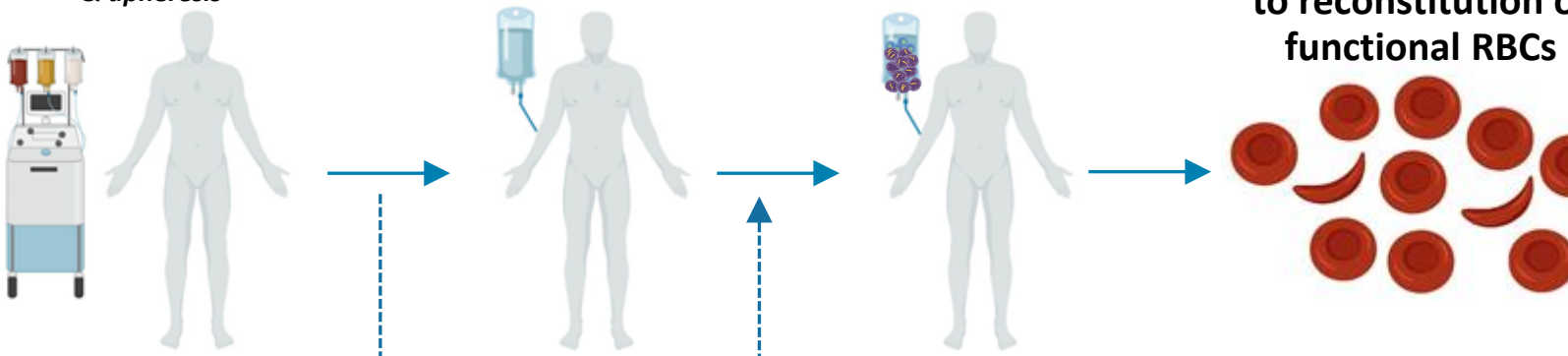
HSC collection
Mobilization with plerixafor & apheresis

Busulfan myeloablative conditioning

DP infusion

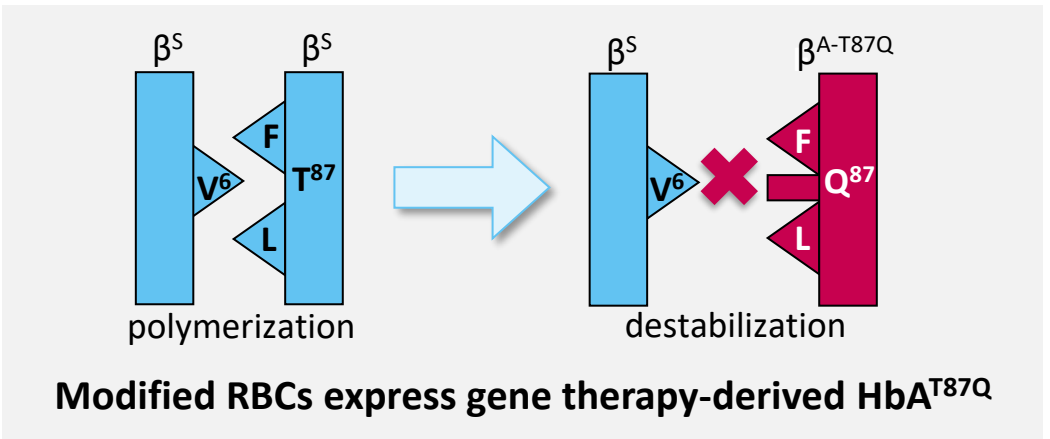
Transduced HSCs engraft and contribute to reconstitution of functional RBCs

2-year follow-up → **Long-term follow-up study (NCT02633943)**



LentiGlobin DP centralized manufacturing

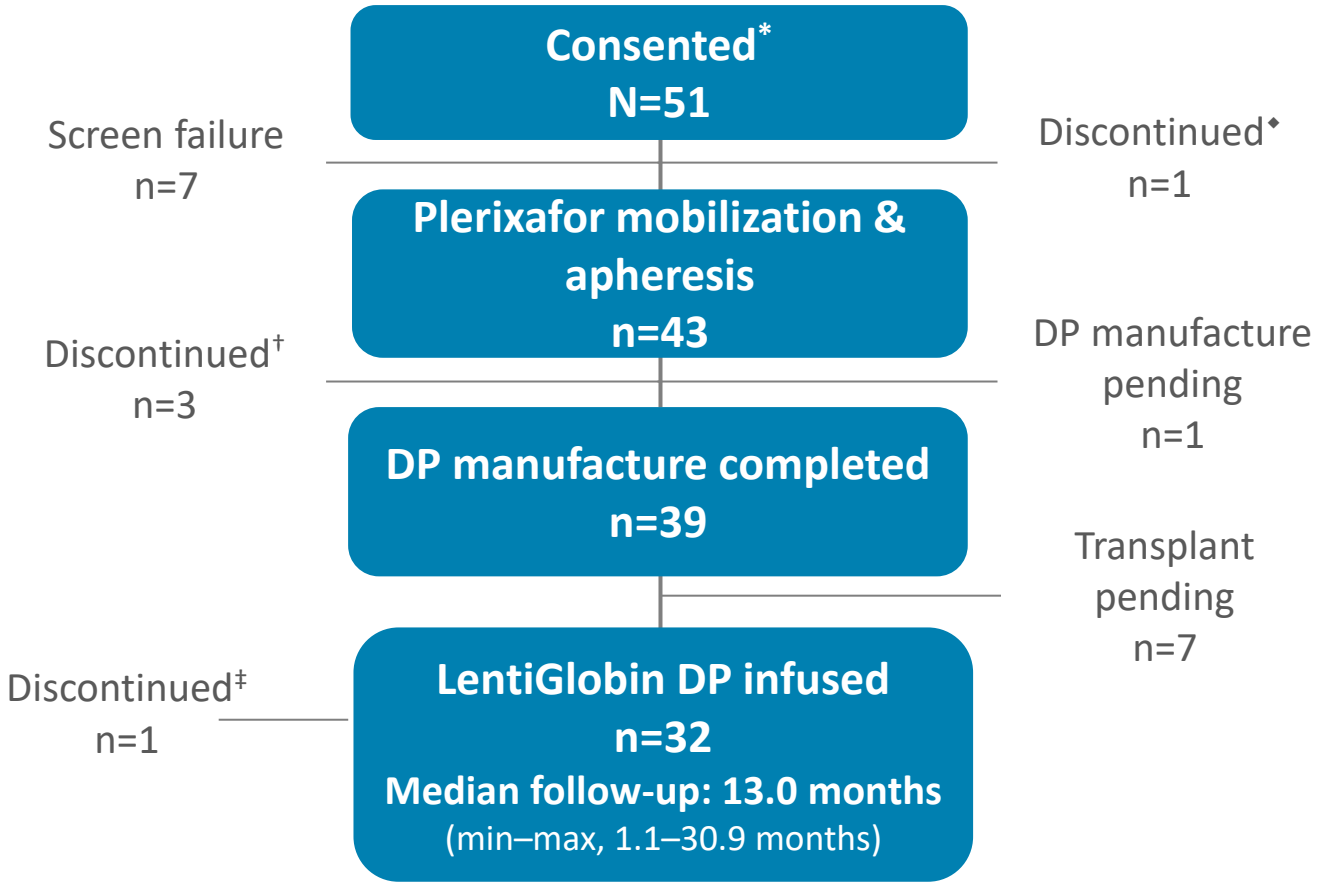
Select CD34+ cells — *Transduce with BB305 lentiviral vector* — *Cryopreserve, test, release DP*



Modified RBCs express gene therapy-derived HbA^{T87Q}

DP, drug product; Hb, hemoglobin; HSCs, hematopoietic stem cells; RBCs, red blood cells SCD, sickle cell disease.

HGB-206 Group C: Study disposition



*Currently active, not recruiting; ◆1 withdrew consent; †1 withdrew consent, 1 withdrew at investigator discretion, 1 mobilization failure; ‡1 death.

DP, drug product; max, maximum; min, minimum.

HGB-206 Group C: Patient characteristics for ITT population

N=43 Patients who started cell collection

Parameter	N=43
Age at consent, years, median (min–max)	**24** (12–38)
Age category 18–50 years, n 12– < 18 years, n	 **34** **9**
Gender, n	**18F 25M**
Genotype, n	**40** β^S/β^S **2** β^S/β^0 **1** β^S/β^+
SCD history	
Severe VOEs[*], n Annualized no. of events, median (min–max)	**39** **3.5** (0.5–16.0)
ACS, n Annualized no. of events, median (min–max)	**10** **0.5** (0.5–1)
Priapism, n	**2**
Any history of stroke, n	**6**

A severe VOE is as an event with no medically determined cause other than a vaso-occlusion, requiring a ≥24-hour hospital or emergency room observation unit visit or at least 2 visits to a day unit or ER over 72 hours with both visits requiring intravenous treatment for the following: acute episodes of pain, acute chest syndrome, acute hepatic sequestration, and acute splenic sequestration

ACS, acute chest syndrome; F, female; ITT, intent to treat; M, male; max, maximum; min, minimum; no., number; SCD, sickle cell disease; sVOE, severe vaso-occlusive event.

HGB-206 Group C: Treatment and drug product characteristics

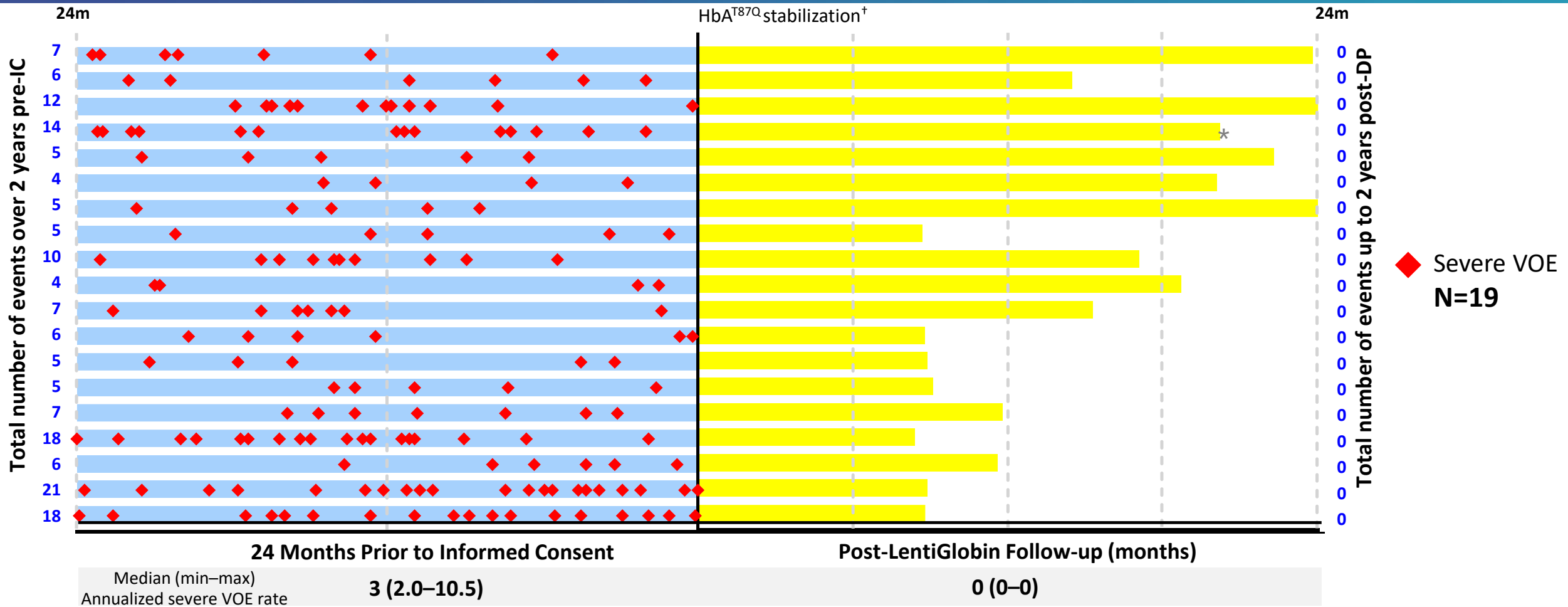
N=32 Infused Patients

Parameter	N=32
Treatment characteristics	Median (min – max)
No. of mobilization cycles	**2** (1–4)
CD34+ cells collected per mobilization cycle, x10^6 cells/kg	**10.4** (3.9–55.4)
Estimated average busulfan AUC, min*µmol[†]	**4843** (1445[⬥]–7322)
Neutrophil engraftment, ANC ≥ 500 /µl x 3 days, days	**19.5** (12–35)
Platelet engraftment, platelets > 50k /µl x 3 days, days[‡]	**30** (18–136)
Duration of hospitalization[§], days	**35** (26–65)
Drug product characteristics (per patient)	Median (min – max)
Vector copy number, copies/diploid genome	**3.8** (2.3–5.7)
CD34+ cells transduced, %	**80.2** (63–93)
CD34+ cell dose, x10^6 cells/kg	**6.8** (3.0–24.0)

[†]5 patients pending AUC result; [⬥] Data error is being corrected; [‡]3 patients pending platelet engraftment at days 29, 30, and 39 post-DP infusion, but on their way to achieving engraftment; [§] Duration of hospitalization from conditioning to discharge.

ANC, absolute neutrophil count; AUC, area under the curve; DP, drug product; max, maximum; min, minimum; no., number.

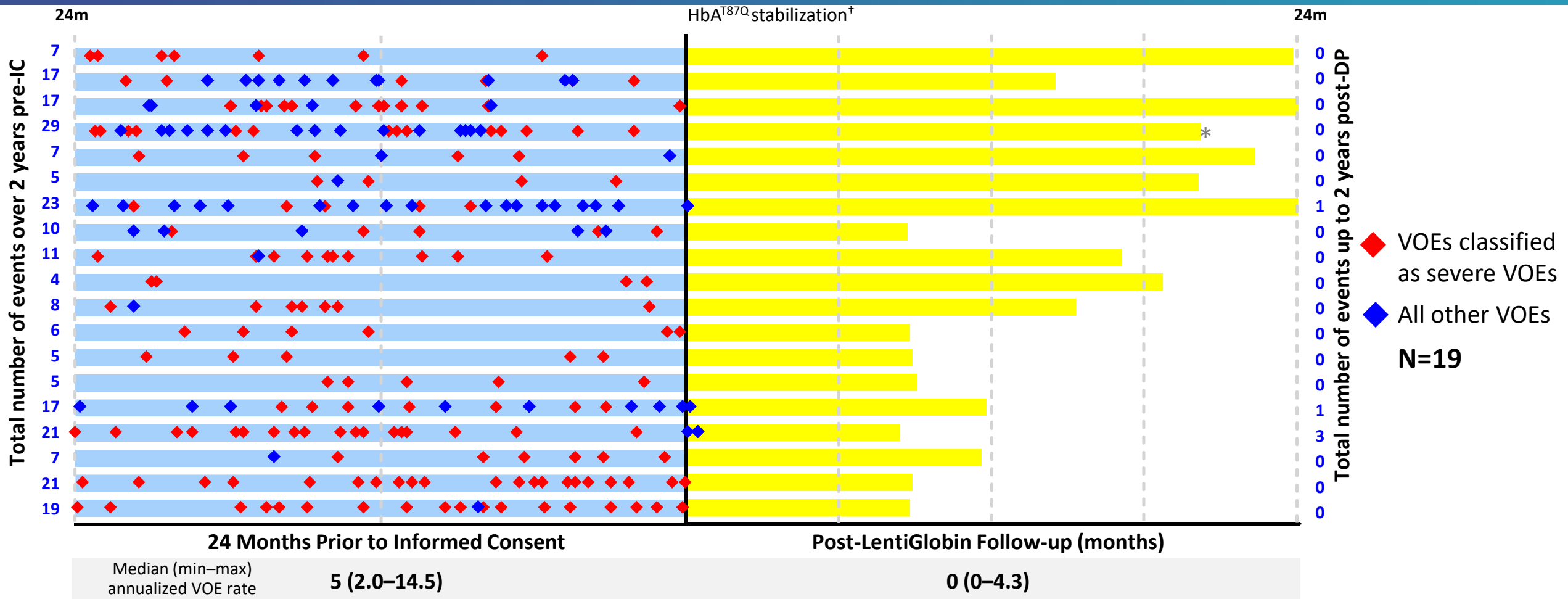
HGB-206 Group C: Complete resolution of severe VOEs post-LentiGlobin treatment



Protocol sVOEs are shown; Patients with ≥ 4 sVOE at baseline before IC and with ≥ 6 months of follow-up post-DP infusion are included. A severe VOE is as an event with no medically determined cause other than a vaso-occlusion, requiring a ≥24-hour hospital or emergency room observation unit visit or at least 2 visits to a day unit or ER over 72 hours with both visits requiring intravenous treatment for the following: acute episodes of pain, acute chest syndrome, acute hepatic sequestration, and acute splenic sequestration; †HbA^{T87Q} expression stabilizes within 6 months; *One death, unlikely related to LentiGlobin, > 18 months post treatment in a patient with significant baseline SCD-related cardiopulmonary disease.
Note: In the last datacut, one patient had a non-serious VOC at Day 107. This event is recorded as an investigator reported VOE but does not meet the definition of a protocol VOE

DP, drug product; ER, emergency room; IC, informed consent; max, maximum; min, minimum; sVOEs, severe VOEs; VOE, vaso-occlusive event; VOC, vaso-occlusive crises.

HGB-206 Group C: Complete resolution of VOEs ≥6 months post-LentiGlobin treatment

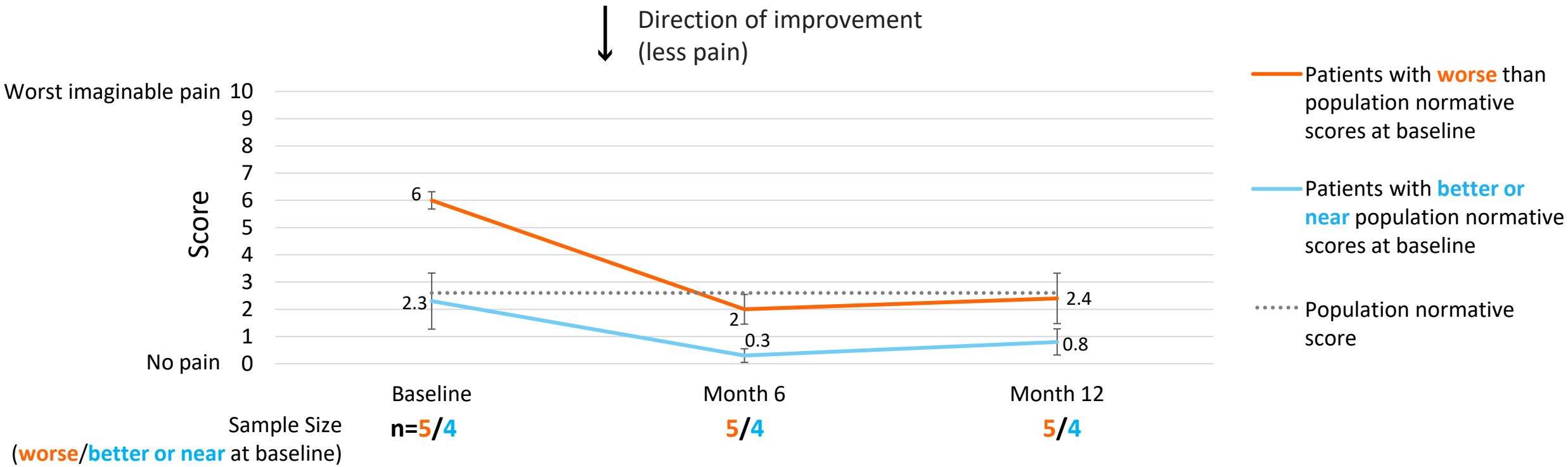


Protocol VOE are shown; Patients with ≥ 4 sVOE at baseline before IC and with ≥ 6 months of follow-up post-DP infusion are included. A VOE includes episodes of acute pain with no medically determined cause other than a vaso-occlusion, lasting more than 2 hours and severe enough to require care at a medical facility, a VOE includes acute episodes of pain, acute chest syndrome, acute hepatic sequestration, and acute splenic sequestration; †HbA^{T87Q} expression stabilizes within 6 months; *One death, unlikely related to LentiGlobin, > 18 months post treatment in a patient with significant baseline SCD-related cardiopulmonary disease.
Note: In the last datacut, one patient had a non-serious VOC at Day 107. The event is recorded as an investigator reported VOE but does not meet the definition of a protocol VOE

DP, drug product; IC, informed consent; max, maximum; min, minimum; sVOEs, severe VOEs; VOE, vaso-occlusive event; VOC, vaso-occlusive crisis.

HGB-206 Group C: Decrease in patient-reported pain intensity

PROMIS-57 Pain Intensity NRS



Sample Size (worse/better or near at baseline)

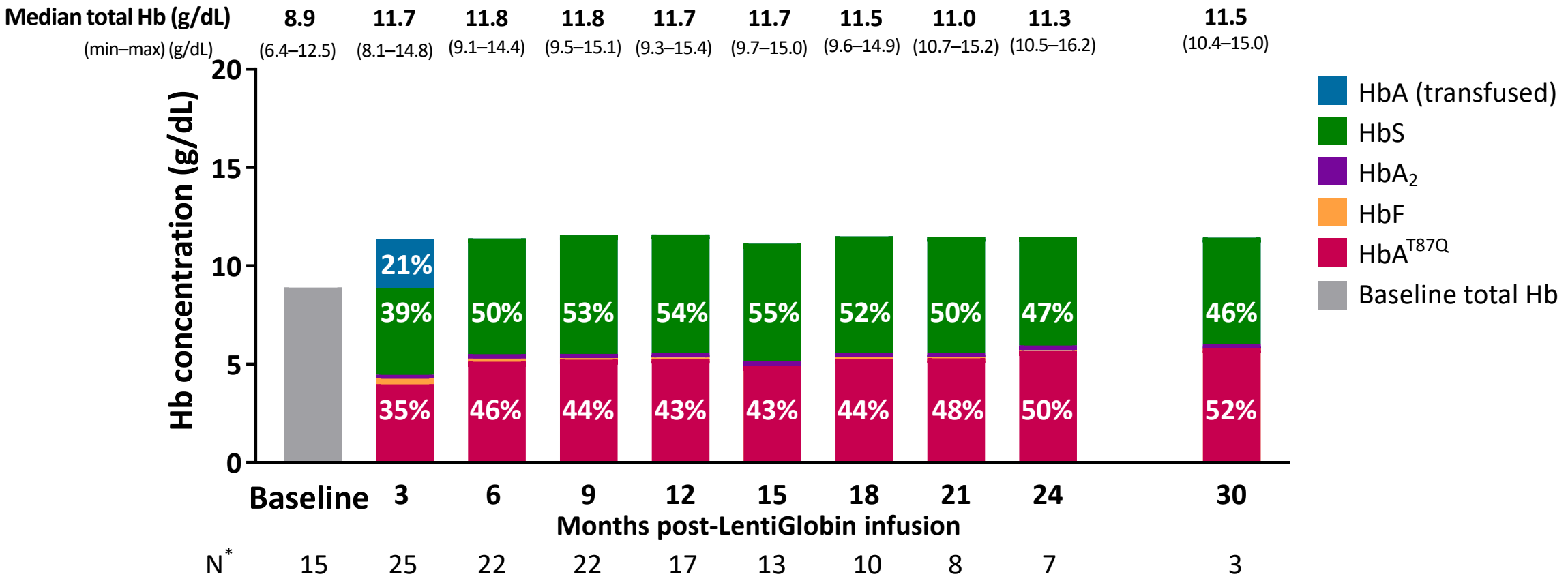
Baseline	Month 6	Month 12
n=5/4	5/4	5/4

Patients with baseline values (n):	At Month 12
Worse than population normative values (n=5)	All 5 patients reported improvement, including clinically meaningful improvement in 4 patients
Better or near population normative values (n=4)	Patients either remained stable (n=2) or reported clinically meaningful improvement (n=2)

Average pain (0-10) over the past 7 days

NRS, Numeric Rating Scale; PROMIS, Patient Reported Outcomes Measurement Information System

HGB-206 Group C: Median HbA^{T87Q} ≥ 40% at ≥ 6 months post-LentiGlobin treatment

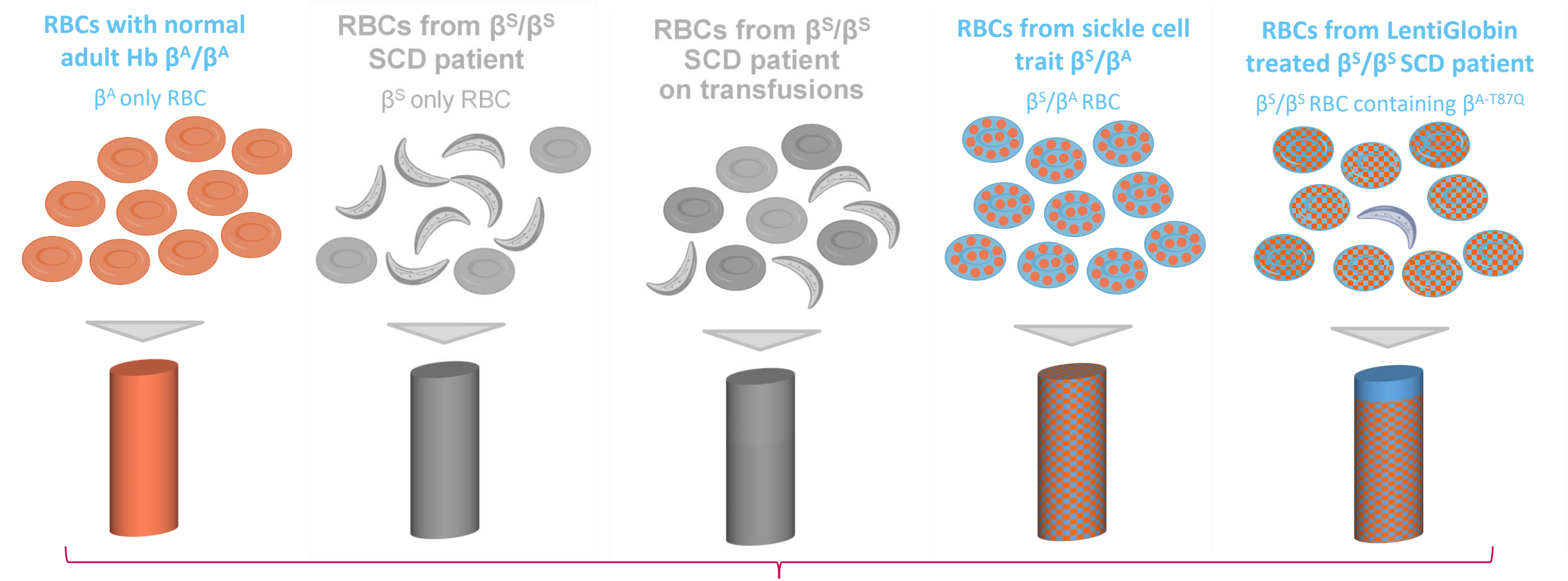


- In patients with ≥ 6 months of follow-up, median total Hb increased from 8.9 g/dL at baseline to ≥ 11.8 g/dL at Month 6
- At last visit in adolescents with ≥ 6 months of follow-up (n=6), median total Hb and HbA^{T87Q} were 13.5 g/dL and 6.1 g/dL, respectively

% represents median Hb fraction as % of total Hb; *Number of patients with data available. Hb, hemoglobin; max, maximum; min, minimum.

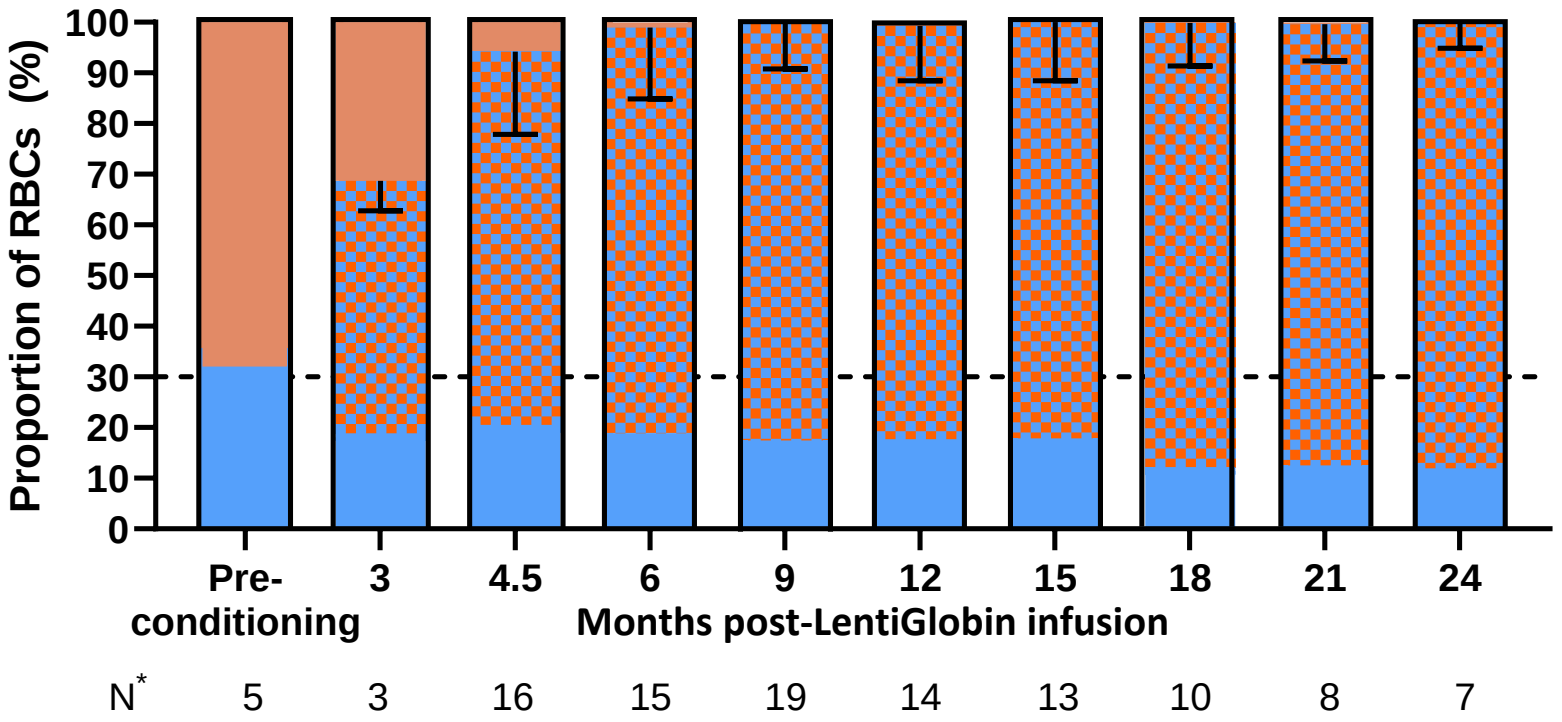
Exploratory assay allows for single-cell analysis of Hb expression

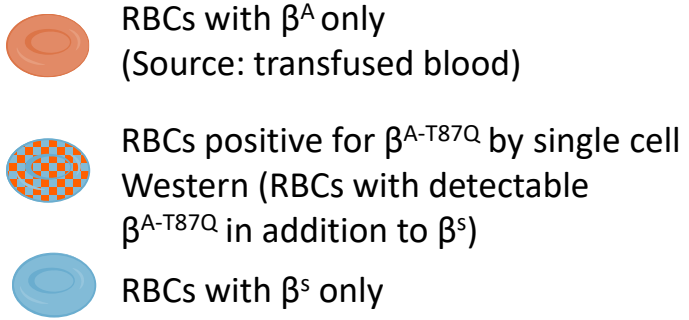
- Single red blood cell western with anti-β^S or anti-β^A/$\beta^{A\text{-}T87Q}$ antibodies



Hb, hemoglobin; RBCs, red blood cells; SCD, sickle cell disease.

HGB-206 Group C: Near pancellular expression of HbA^{T87Q}
≥ 6 months post-LentiGlobin treatment





- Median (min–max) HbA^{T87Q}/RBC was 15.3 (11.7–20)† pg in patients with ≥ 6 months follow-up, which is comparable to the 13–18 pg of HbA/RBC in individuals with sickle cell trait‡ and higher than 10 pg of HbF/RBC in those with HPFH§

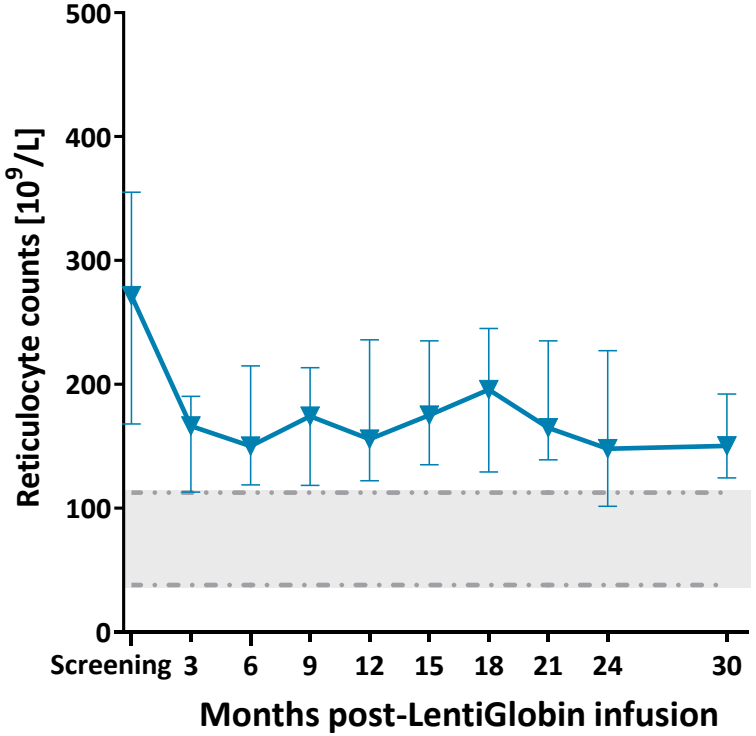
Mean & SD are depicted; Reducing HbS to < 30% is recommended by guidelines for exchange RBC transfusions for patients with SCD (indicated by dashed line); *Number of patients with data available; †Calculated as (% HbA^{T87Q} of total Hb/% RBCs containing $\beta^{A\text{-}T87Q}$) x MCH; ‡Calculated to 13–18 pg HbA/RBC using 50% HbA/RBC for the lower end of the range and 60% HbA/RBC for the upper end of the range; §Estimated in Steinberg MH et al., Blood 2014.

Hb, hemoglobin; HPFH, hereditary persistence of fetal hemoglobin; max, maximum; MCH, mean corpuscular hemoglobin; min, minimum; pg, picogram; RBCs, red blood cells; SD, standard deviation.

Data as of 20 August 2020

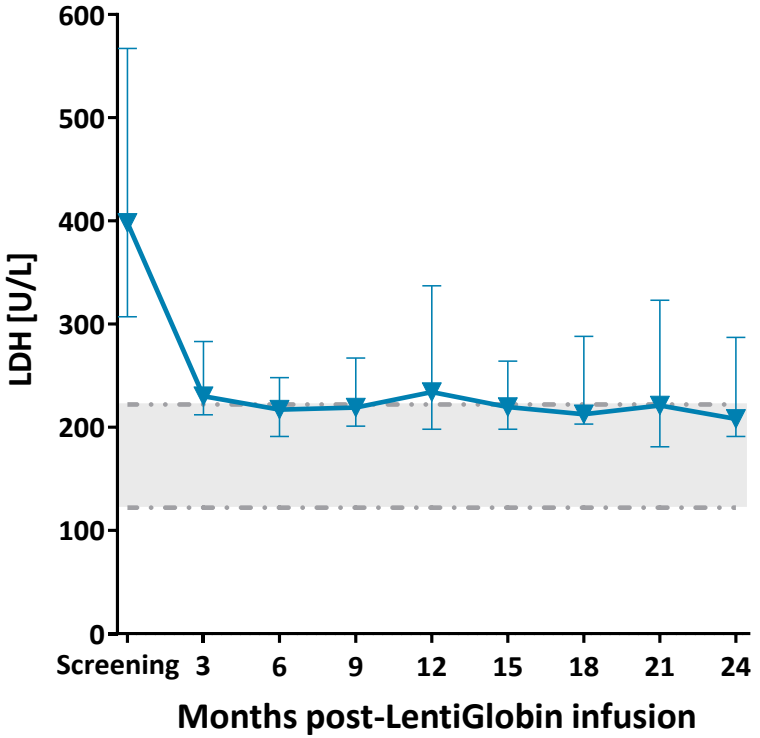
HGB-206 Group C: Hemolysis markers approaching near-normal levels post-LentiGlobin treatment

Reticulocyte counts



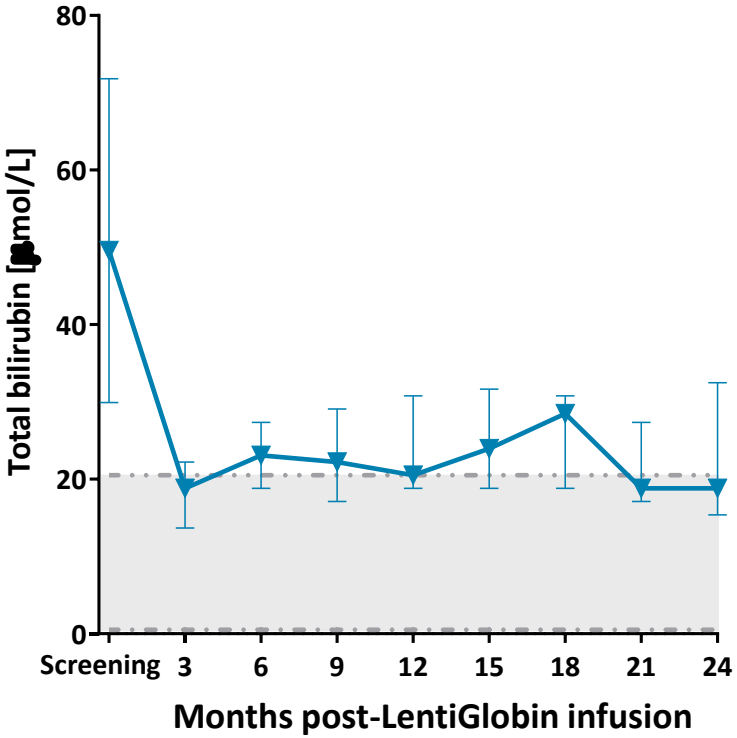
N*	31	26	23	22	17	14	10	9	7	3

Lactate dehydrogenase



N*	31	25	21	23	17	14	10	7	7

Total bilirubin



N*	32	26	24	23	17	14	10	9	7

Median (Q1, Q3) depicted; Dot-dash lines denote lower and upper limits of normal values; *Number of patients with data available; Q1, quartile 1; Q3, quartile 3.

HGB-206 Group C: Safety profile post-LentiGlobin treatment

Treatment-emergent ≥ Grade 3 AEs *Reported in ≥ 2 patients*[*]	**N=32** n (%)
Stomatitis	21 (65.6)
Febrile neutropenia	14 (43.8)
Increased ALT	4 (12.5)
Increased AST	4 (12.5)
Increased GGT	4 (12.5)
Increased blood bilirubin	2 (6.3)
Nausea	4 (12.5)
Premature menopause	2 (6.3)
Upper abdominal pain	2 (6.3)
Serious treatment-emergent AEs *Reported in ≥ 2 patients*	
Abdominal pain	2 (6.3)
Nausea	2 (6.3)
Drug withdrawal syndrome	2 (6.3)
Vomiting	2 (6.3)

[*]Hematologic AEs commonly observed post-transplantation have been excluded;
AEs, adverse events; ALT, alanine aminotransferase; AST, aspartate aminotransferase; GGT, gamma-glutamyl transferase.

- 1 patient with a nonserious Grade 2 DP-related AE[†]
- No cases of veno-occlusive liver disease
- No graft failure
- No vector-mediated RCL and no insertional oncogenesis
- One death, unlikely related to LentiGlobin, > 18 months post treatment in a 27-year-old patient with significant baseline SCD-related cardiopulmonary disease
  - Autopsy showed cardiac biventricular dilation with concentric LVH and moderate cardiac interstitial fibrosis; there was no evidence of pulmonary embolism or stroke
  - Per PI, the patient appeared to have sudden death associated with cardiac fibrosis and other chronic organ injury

[†]1 patient with Grade 2 nonserious neutropenic fever on study day 10 (resolved on study day 18).

ACS, acute chest syndrome; AE, adverse event; DP, drug product; LVH, left ventricular hypertrophy; PIs, principal investigators; RCL, replication competent lentivirus; SCD, sickle cell disease; VOC, vaso-occlusive crisis.

HGB-206 Group C: Summary

- Complete resolution of severe VOEs with up to 24 months of follow-up
  - Complete resolution of VOEs after stabilization of HbA^{T87Q} expression[†], with up to 24 months of follow-up
- Decrease in patient-reported pain intensity over 12 months of follow-up
- Median total Hb is consistently ≥ 11 g/dL ≥ 6 months post-LentiGlobin treatment, with a median anti-sickling HbA^{T87Q} ≥ 40%
- Near pancellular expression of HbA^{T87Q} ≥ 6 months post-LentiGlobin, with, on average, ~90% of RBCs containing HbA^{T87Q} at ≥ 18 months post treatment
- Key markers of hemolysis approaching near-normal levels post-LentiGlobin treatment
- The safety profile post-LentiGlobin for SCD gene therapy remains generally consistent with myeloablative single-agent busulfan conditioning and underlying SCD

[†]HbA^{T87Q} expression stabilizes within 6 months.

Hb, hemoglobin; RBC, red blood cell; SCD, sickle cell disease; VOE, vaso-occlusive event.

Temporary Suspension of bluebird bio LentiGlobin for Sickle Cell Disease (bb1111) studies

- Data in this presentation are accurate as of 20 August 2020. Beyond this data cutoff, Suspected Unexpected Serious Adverse Reactions (SUSARs) of acute myeloid leukemia (AML) and myelodysplastic syndrome (MDS) were reported in two patients from the Phase 1/2 HGB-206 study.
  - One patient who was treated more than 5 years ago in Group A was diagnosed with AML.
  - MDS was reported in a patient treated in Group C.
- In line with the clinical study protocols for the Phase 1/2 HGB-206 and Phase 3 HGB-210 studies, bluebird bio had placed both studies on temporary suspension. As of Feb 2021, the FDA has placed the clinical studies of LentiGlobin for SCD on clinical hold.
- Both SUSARs are currently under investigation in close partnership with study investigators and regulatory agencies to determine whether there is a causal link to the study vector, BB305. bluebird bio plans to share updates with the community once more information is available.
- The above safety events are separate from and in addition to the Group A patient who was diagnosed with MDS in 2018 and passed away due to relapsed AML in 2020. The development of the 2018 MDS case was unlikely related to LentiGlobin for SCD and attributed to busulfan conditioning as determined by the independent data monitoring committee and the primary investigator treating the patient since the gene therapy vector integration was not present in cancer cells and a monosomy 7 mutation frequently associated with myeloid cancer was identified in the patient. [1]

[1]Hsieh et al 2020 Blood Advances

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