bluebirdbio®
recode for life™

EHA/ASCO Data Review

June 12, 2020

LET'S RECODE THE STORY

NASDAQ: BLUE

forward-looking statements

These slides and the accompanying oral presentation contain forward-looking statements and information. The use of words such as “may,” “might,” “will,” “should,” “expect,” “plan,” “anticipate,” “believe,” “estimate,” “project,” “intend,” “future,” “potential,” or “continue,” and other similar expressions are intended to identify forward-looking statements. For example, all statements we make regarding the initiation, timing, progress and results of our preclinical and clinical studies and our research and development programs, our ability to advance product candidates into, and successfully complete, clinical studies, the timing or likelihood of regulatory filings and approvals, and the timing and likelihood of entering into contracts with payors for value-based payments over time or reimbursement approvals, and our commercialization plans for approved products are forward looking. All forward-looking statements are based on estimates and assumptions by our management that, although we believe to be reasonable, are inherently uncertain. All forward-looking statements are subject to risks and uncertainties that may cause actual results to differ materially from those that we expected. These statements are also subject to a number of material risks and uncertainties that are described in our most recent quarterly report on Form 10-Q, as well as our subsequent filings with the Securities and Exchange Commission. Any forward-looking statement speaks only as of the date on which it was made. We undertake no obligation to publicly update or revise any forward-looking statement, whether as a result of new information, future events or otherwise, except as required by law.

Must Beat the Odds.

Period.

bluebirdbio
recode for life™

Compelling data across programs

ide-cel

mPFS over one year at 450 dose
20+ month PFS when CR achieved

LentiGlobin TDT

89% TI in non-β^0/β^0
75% TI in β^0/β^0

LentiGlobin SCD

99.5% Reduction in VOCs + ACS

bluebirdbio®
recode for life™

Multiple Myeloma - ide-cel:
Broad oncology strategy and development program supported by clinical data

BCMA Program

BMS Alignment

- U.S. 50/50 co-co
- Ex-U.S. BMS wholly-owned

Regulatory path enabling near-term launch:

- BLA resubmission no later than end of July
- MAA submission accepted

Broad clinical development program enabling potential expansion into earlier lines

ASCO 2020

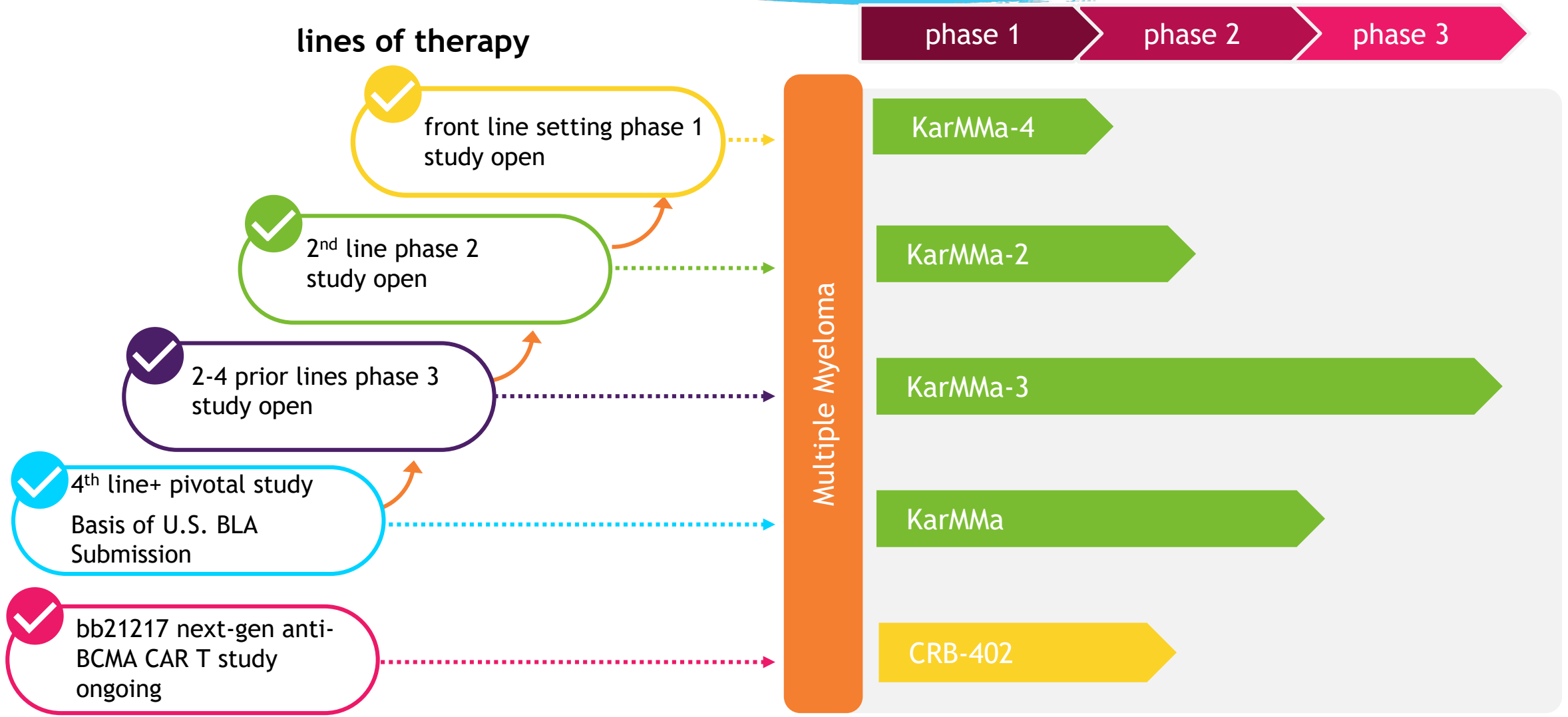
KarMMa Data

Mature and consistent data demonstrate deep and durable responses:

- CAR+ T cell persistence observed up to 1yr with meaningful detectable vector
- mPFS of 12.1 months at $450x10^6$ dose
- KarMMa N=128; CRB-401 N=67

bluebirdbio
recode for life™

Advancing into earlier lines of therapy and continuing to innovate



Studies ongoing in partnership with BMS

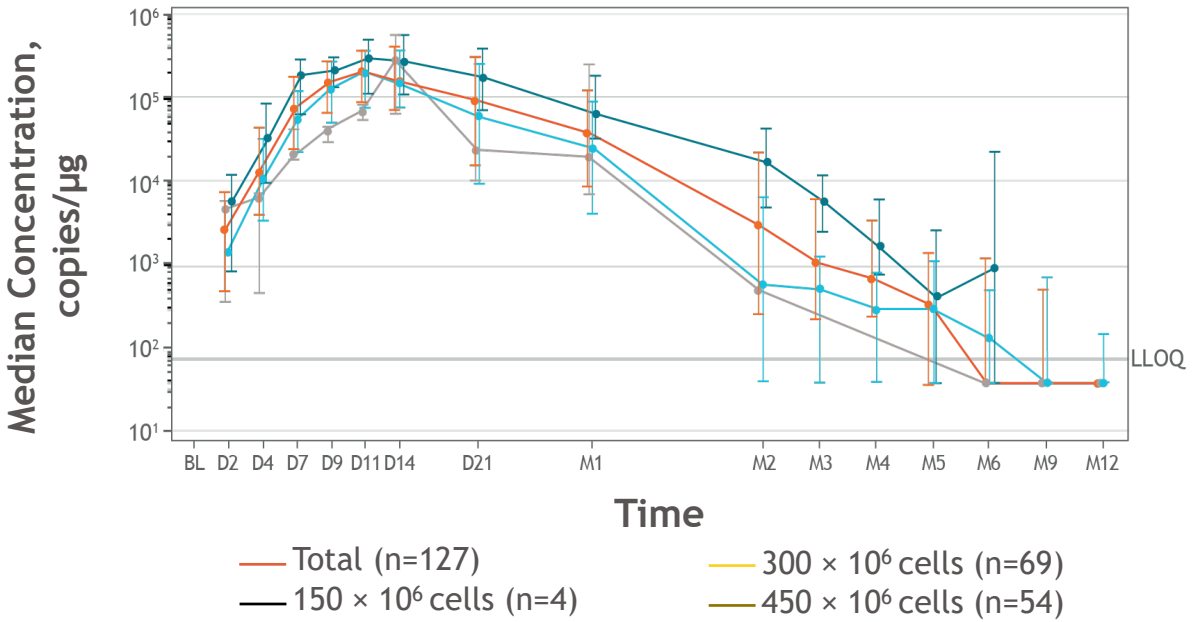
KarMMa: heavily pretreated, refractory patient population

Characteristics		Ide-cel Treated (N=128)
Age, median (range), y		61 (33–78)
Male, %		59
ECOG PS, %	0 1 2	45 53 2
R-ISS Stage,* %	I II III	11 70 16
High-risk cytogenetics [del(17p), t(4;14), t(14;16)],† %		35
High tumor burden (≥50% BMPCs), %		51
Tumor BCMA expression (≥50% BCMA+),‡ %		85
Extramedullary disease, %		39
Time since initial diagnosis, median (range), y		6 (1–18)
No. of prior anti-myeloma regimens, median (range)		6 (3–16)
Prior autologous SCT, %	1 >1	94 34
Any bridging therapies for MM, %		88
Refractory status, %	Anti-CD38 Ab-refractory Triple-refractory	94 84

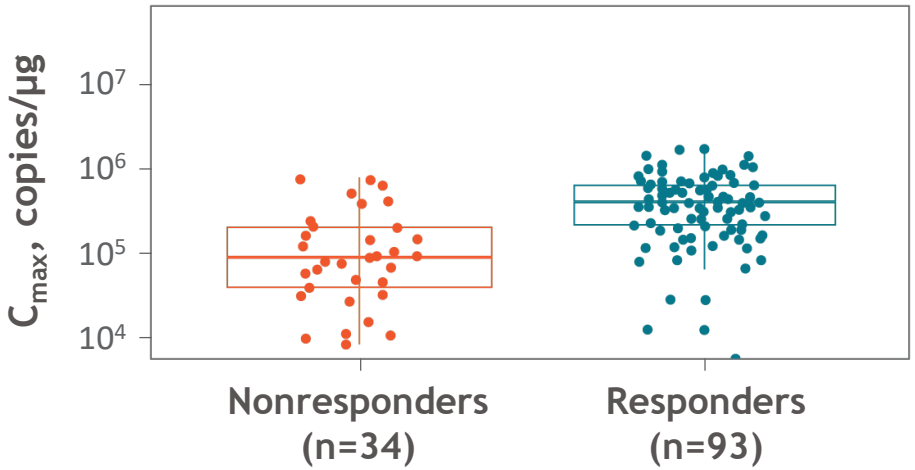
- Patients were heavily pretreated, refractory to last line per IMWG criteria, and mostly refractory to all 3 major MM drug classes
- The majority had high tumor burden and more than one third had extramedullary disease and high-risk cytogenetics
- Tumor BCMA expression identified by IHC in all patients
- Most patients (88%) received bridging therapy during CAR T cell manufacturing
  - Only 4% of patients responded (4 PR, 1 VGPR) to bridging therapy

CAR+ T cell expansion, persistence, and peak exposure

CAR+ T Cell Expansion and Persistence



Peak Vector Copies in Responders (≥PR) vs Nonresponders (<PR)

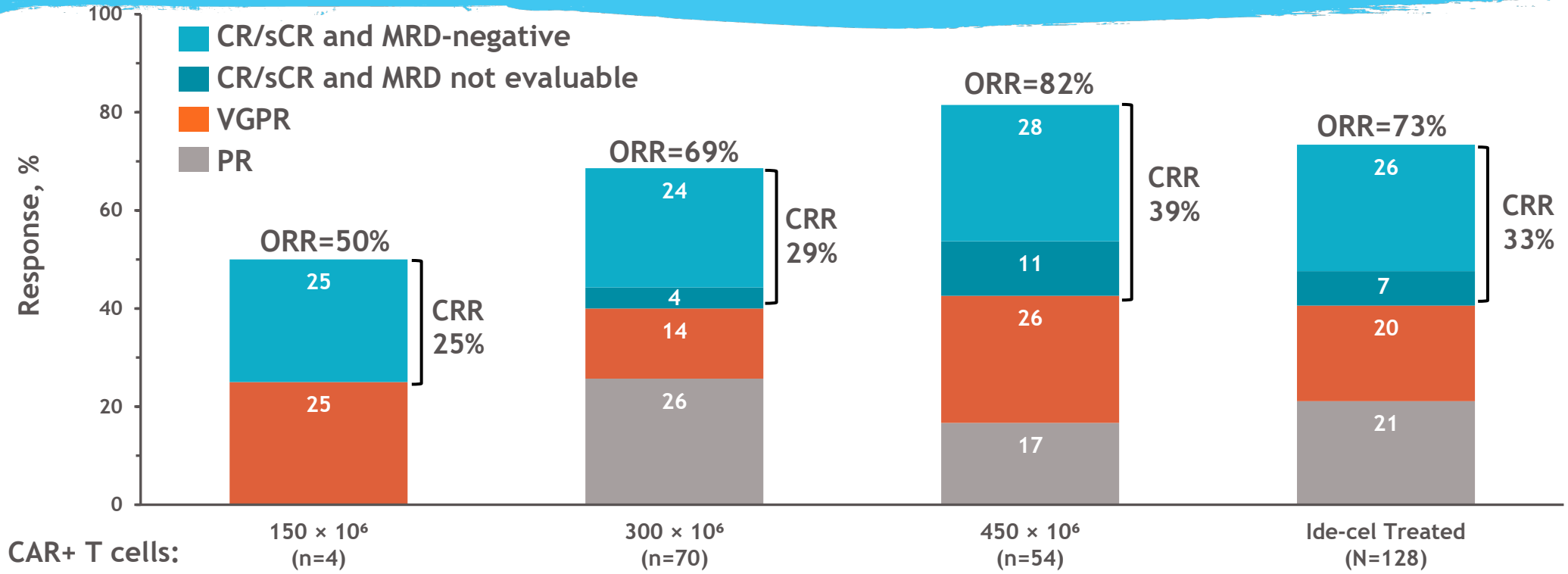


	Mo 1	Mo 3	Mo 6	Mo 9	Mo 12
Evaluable patients, n	118	100	49	27	11
Patients with detectable vector, n (%)	117 (99)	75 (75)	29 (59)	10 (37)	4 (36)

- Median peak CAR+ T cell expansion was at 11 d
- Median expansion increased at higher target doses with overlapping profiles
- Peak exposure higher in responders than nonresponders
- Durable persistence was observed up to 1 y

Data cutoff: 19 April 2019. Pharmacokinetic (PK) analysis population (N=127). One patient died on day 4 and had no evaluable PK samples and was therefore excluded. Error bars represent interquartile range. BL, baseline; C_{max}, maximum concentration; LLOQ, lower limit of quantitation; M, month.

82% ORR and 39% CR rate at 450 x 10^6 dose level



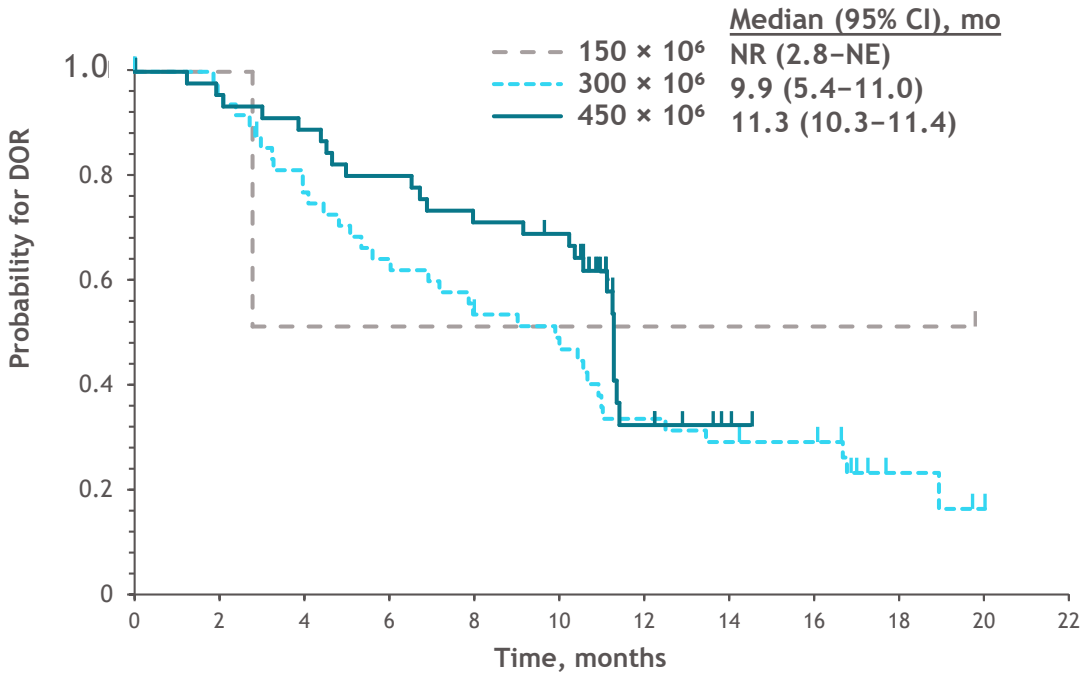
- Primary (ORR >50%) and key secondary (CRR >10%) endpoints met in the ide-cel treated population
  - *ORR of 73% (95% CI, 65.8–81.1; P<0.0001*)*
  - *CRR (CR/sCR) of 33% (95% CI, 24.7–40.9; P<0.0001)*
- Median time to first response of 1.0 mo (range, 0.5–8.8); median time to CR of 2.8 mo (range, 1.0–11.8)
- Median follow-up of 13.3 mo across target dose levels
- All patients with CR or sCR and were evaluable for MRD, were MRD-negative

bluebirdbio recode for life™

Data cutoff: 14 Jan 2020. MRD-negative defined as <10^5 nucleated cells by next generation sequencing. Only MRD values within 3 mo of achieving CR/sCR until progression/death (exclusive) were considered.
Values may not add up due to rounding.
CR/sCR, complete response/stringent CR; CRR, CR rate; MRD, minimal residual disease; ORR, overall response rate (≥PR); PR, partial response; VGPR, very good PR. **P* value at the primary data cutoff with same ORR and 95% CI.

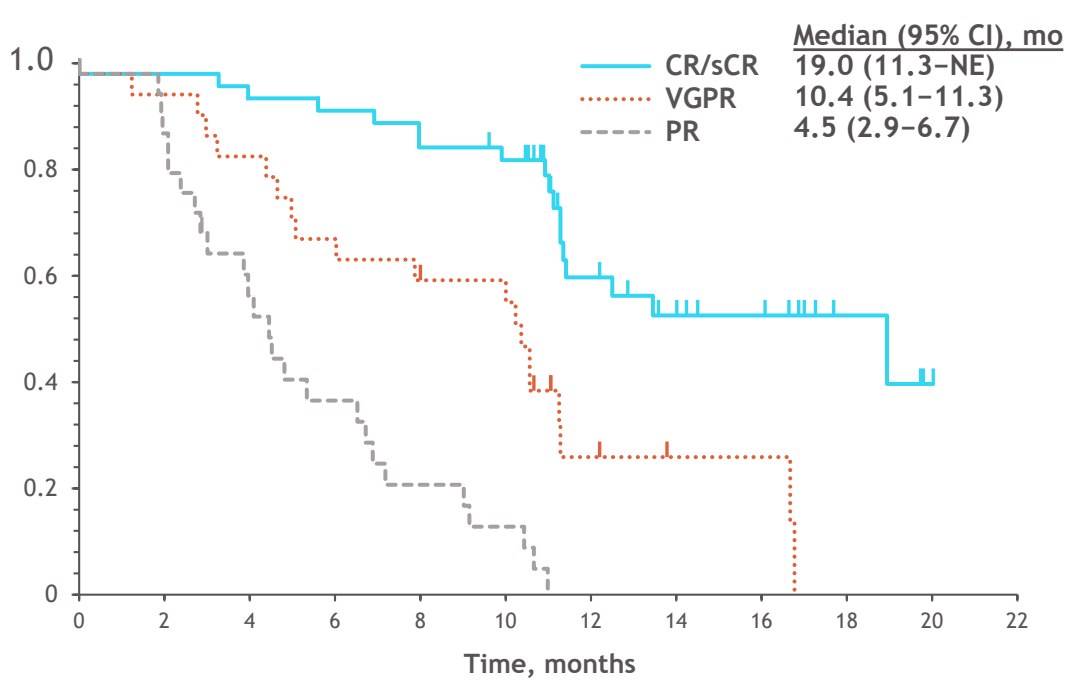
mDOR of 11.3 mo at 450 × 10^6 dose; mDOR of 19 mo in patients achieving CR/sCR

DOR by Target Dose



At risk, N												
150 × 10^6	2	2	1	1	1	1	1	1	1	1	0	
300 × 10^6	48	45	35	29	24	21	14	12	11	3	1	0
450 × 10^6	44	42	39	35	31	29	7	2	0	0	0	

DOR by Best Response



At risk, n												
CR/sCR	42	42	40	39	36	34	18	13	10	4	1	0
VGPR	25	24	21	17	15	14	4	2	2	0	0	
PR	27	23	14	9	5	3	0	0	0	0	0	

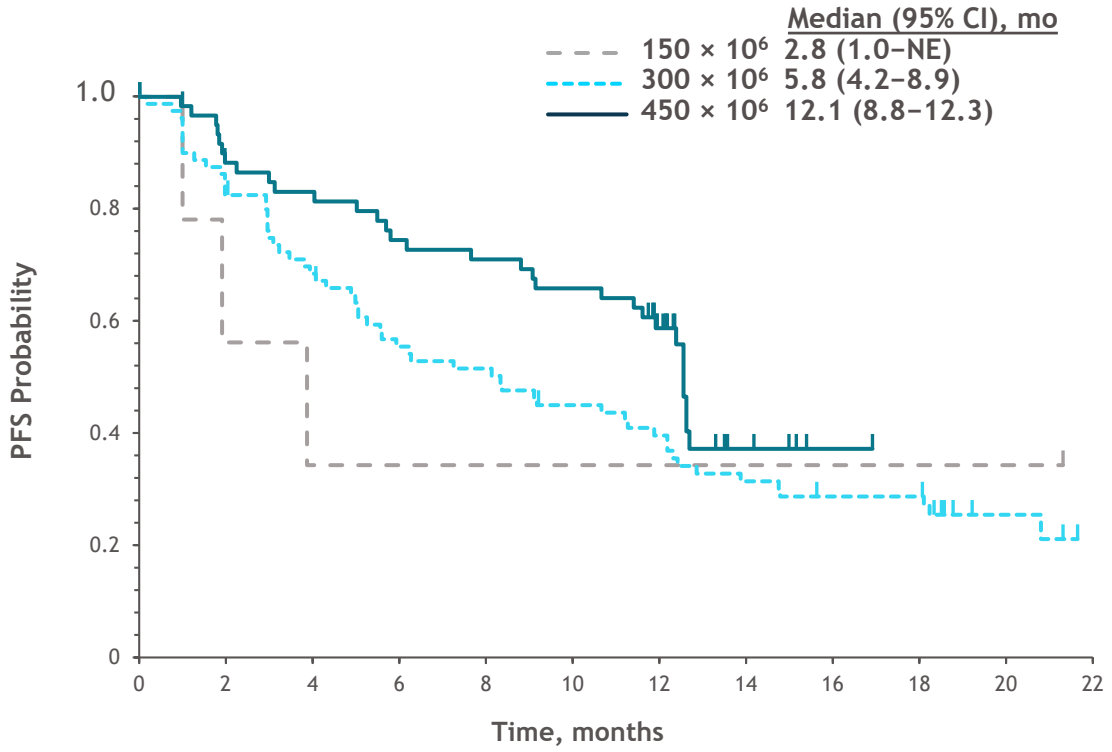
- Durable responses were observed across all target doses; DOR increased with depth of response

bluebirdbio® recode for life™

Data cutoff: 14 Jan 2020. CR/sCR, complete response/stringent CR; DOR, duration of response; NE, not estimable; NR, not reached; PR, partial response; VGPR, very good PR.

mPFS of 12.1 months at 450 x 10^6 dose level; mPFS of 20.2 months in patients with a CR/sCR

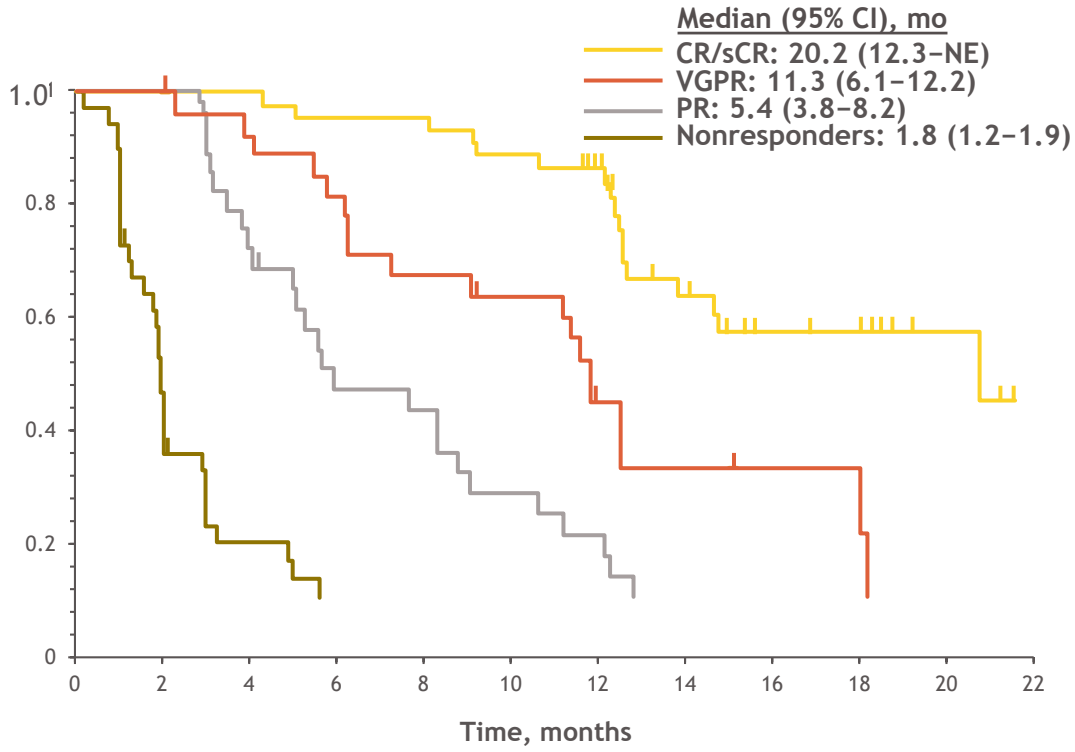
PFS by Target Dose



At risk, N												
150 × 10^6	4	2	1	1	1	1	1	1	1	1	1	0
300 × 10^6	70	56	42	33	29	24	17	14	11	7	2	0
450 × 10^6	54	44	40	36	34	31	17	4	1	0	0	

- PFS increased with higher target dose; median PFS was 12 mo at 450 × 10^6 CAR+ T cells

PFS by Best Response



CR/sCR	42	42	42	40	39	37	26	16	11	8	4	0
VGPR	25	25	22	20	16	14	8	3	2	0	0	
PR	27	16	10	9	5	1	0	0	0	0	0	
Nonresponders	34	8	83	70	64	56	35	19	13	8	4	0

- PFS increased by depth of response; median PFS was 20 mo in patients with CR/sCR

bluebirdbio recode for life™

Data cutoff: 14 Jan 2020. NE, not estimable; PFS, progression-free survival.

Safety profile consistent with known toxicities of CAR T therapy

CRS

Ide-cel Treated (N=128)	
≥1 CRS event, n (%)	107 (84)
Max. grade (Lee Criteria)* 1/2 3 4 5	100 (78) 5 (4) 1 (<1) 1 (<1)
Median onset, d (range)	1 (1–12)
Median duration, d (range)	5 (1–63)
Tocilizumab, n (%)	67 (52)
Corticosteroids, n (%)	19 (15)

Neurotoxicity

Ide-cel Treated (N=128)	
≥1 NT event, n (%)	23 (18)
Max. grade (CTCAE)* 1 2 3	12 (9) 7 (5) 4 (3)
Median onset, d (range)	2 (1–10)
Median duration, d (range)	3 (1–26)
Tocilizumab, n (%)	3 (2)
Corticosteroids, n (%)	10 (8)

- Ide-cel was tolerable across the dose range
- Grade ≥3 CRS or iiNT ≤6% at target dose of 450 × 10^6 CAR+ T cells
  - CRS frequency increased with dose, but mostly low grade
- Cytopenias were common; not dose related
- Infections (including bacterial, viral, fungal) were common (69%); not dose-related
- 5 deaths (4%) within 8 wk of ide-cel infusion (2 following disease progression, 3 from AEs) and 1 from an AE within 6 mo of ide-cel infusion

bluebirdbio® recode for life™

Data cutoff: 14 Jan 2020; CRS, cytokine release syndrome, iiNT, investigator identified neuotoxicity

Transfusion-dependent β-thalassemia (TDT): patients achieving transfusion independence across genotypes and ages

ASH 2019

Northstar-2 (HGB-207):

- **Non-β^0/β^0: 90% of patients achieving TI**

Northstar-3 (HGB-212):

- **β^0/β^0 and IVS-I-110: 2 patients evaluable for TI, achieve TI**

EHA 2020

Achieving and maintaining transfusion independence (TI) across ages and genotypes

- **Northstar-2 (HGB-207):**
  - **Non-β^0/β^0:** All patients treated
  - 89% successfully achieved TI

Northstar-3 (HGB-212):

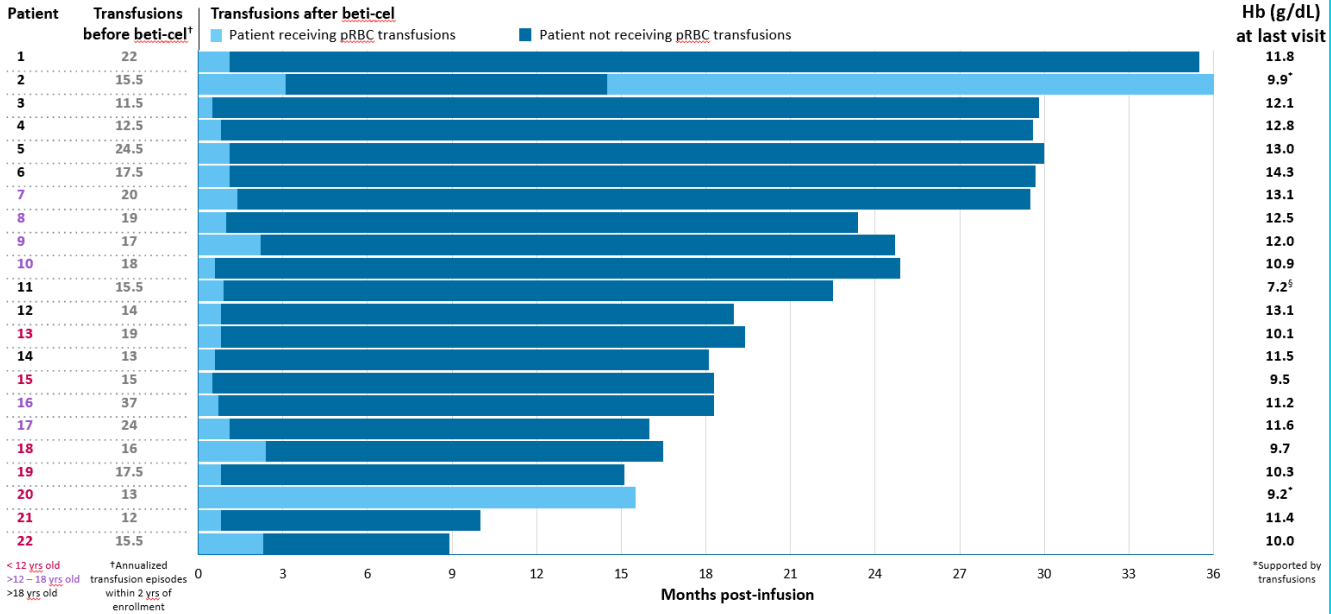
- **β^0/β^0 and IVS-I-110:** 85% of patients have been off transfusions for > 6 months

Compelling data supports commercial path

bluebirdbio®
recode for life™

Northstar-2: Non-β^0/β^0 patients achieving & maintaining transfusion independence

91% (20/22) of patients with >3 months of follow-up have stopped pRBC transfusions

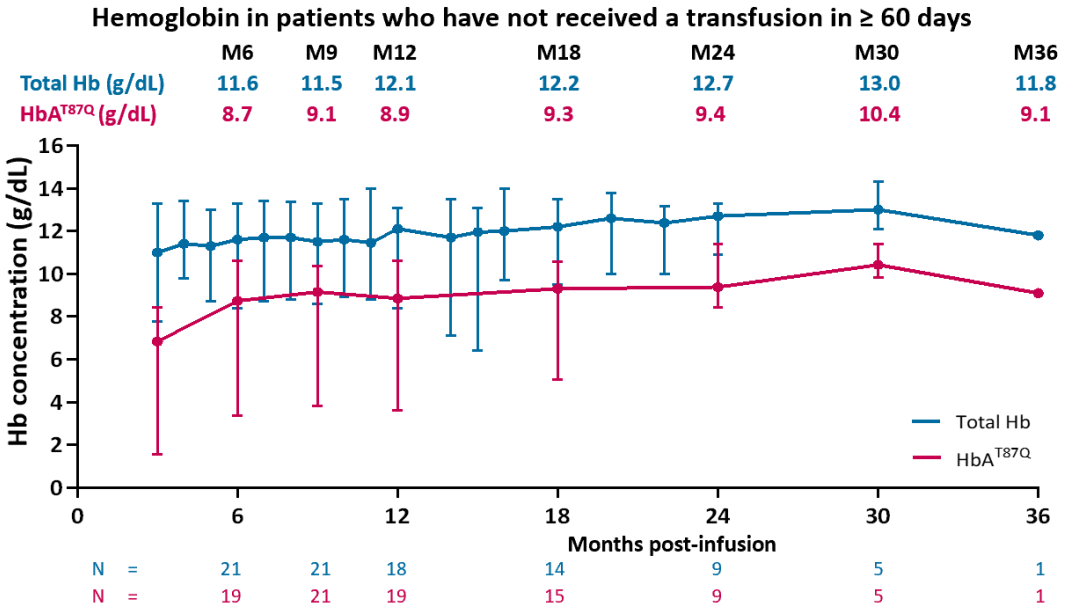


- 89% (17/19) of evaluable patients achieved primary endpoint: transfusion independence
- Patient 2 and Patient 20 had 46% and 16% reduction in pRBC transfusion volume, respectively, from 6 months to last follow-up

§Patient's total Hb level at Month 22 was 13.4 g/dL. Following a planned orthopedic surgery, the patient had blood loss, which required 1 pRBC transfusion; pRBC, packed red blood cell.

Data as of 7 April 2020

Median unsupported total Hb is ≥ 11.5 g/dL



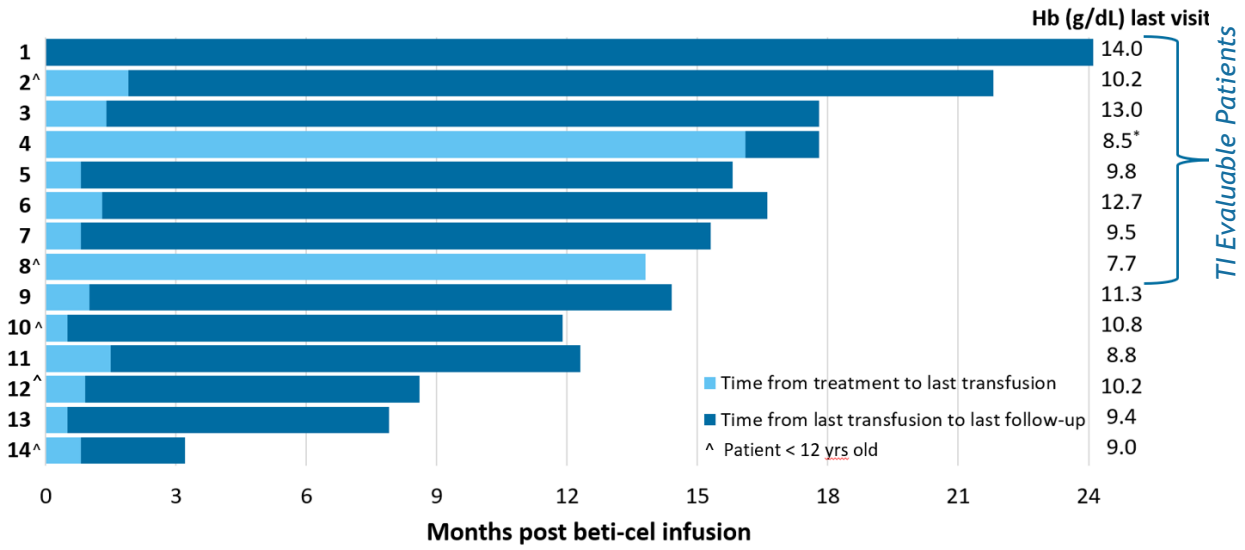
Median, min, max depicted

Data as of 3 March 2020

bluebirdbio® recode for life™

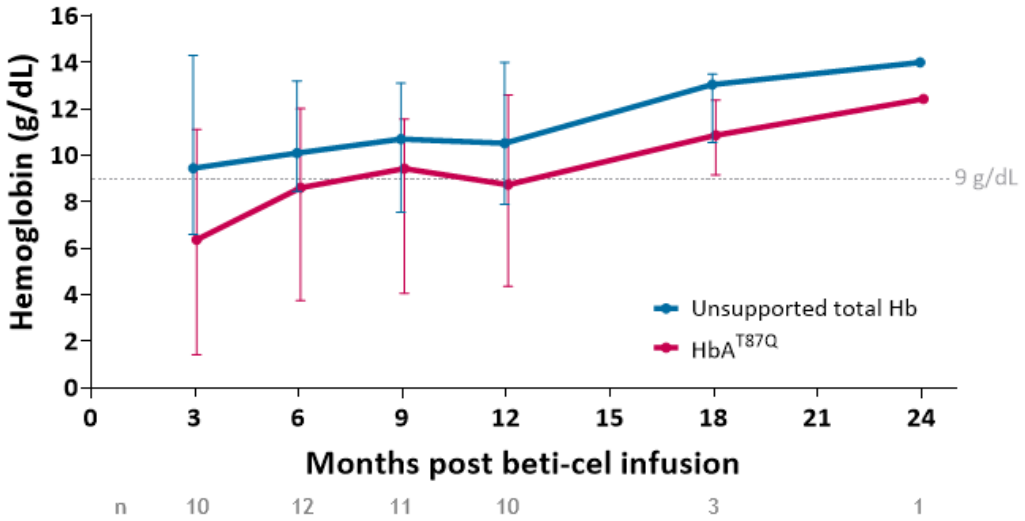
Northstar-3: β^0/β^0 patients continue to show compelling results

Transfusion status in patients with ≥ 3 months follow-up



- 85% (11/13) of patients have been off transfusions for > 6 months; prior to beti-cel infusion, these patients required 11 – 39.5 transfusions/year
- Patient 4 and Patient 8 continue to receive pRBC transfusions and had an 80% and 31% reduction in number of transfusions, respectively

Total Hb and HbA^{T87Q} over time in patients who have not received a transfusion in > 60 days



- As transduced HSCs engraft and produce mature RBCs, HbA^{T87Q} levels increase and stabilize approximately 6 - 9 months after beti-cel infusion

^Patient < 12 years old at consent; *Indicates pRBC transfusion in prior 60 days. Data as of 7 April 2020

Median, min, max depicted; Unsupported total Hb level is defined as Hb without any red blood cell transfusions within 60 days. Hb, hemoglobin. Data as of 3 March 2020

bluebirdbio recode for life™

Robust data supports commercial path forward

zynteglo®
(autologous CD34+ cells encoding $\beta^{A\text{-}T87Q}$-globin gene)

EU: Ready to Go

Ready to treat patients in Germany pending COVID-19 environment

Ongoing engagement with payers in additional EU markets supports access and reimbursement by end of 2020

Plan to pursue expanded label to include patients with β^0/β^0 genotypes and pediatrics

US: Clear Path

Updated data reinforce confidence in pursuing initial approval for patients with TDT and all genotypes

Learnings from FDA engagement leveraged across programs

US BLA Submission Planned for mid-2021 (Q2/Q3)

Sickle Cell Disease:
Totality of the clinical data validates transformative clinical results

ASH 2019

Early clinical benefit:

- 99% mean reduction in VOC and ACS

Group C patients:

- 17 patients; 9 patients with ≥6 months follow up and ≥4 VOC/ACS at baseline

Improvement in key markers of hemolysis

EHA 2020

Magnitude of clinical benefit:

- 99.5% mean reduction in VOC and ACS

More patients; more follow-up:

- 25 patients; 14 patients with ≥6 months follow up and ≥4 VOC/ACS at baseline

Consistent results across multiple markers:

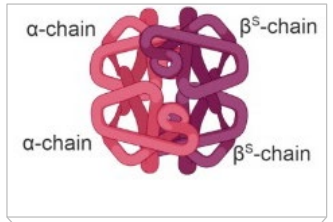
- Continued improvements in hemolysis markers, HbA^{T87Q} levels and pancellular expression

Clarity on U.S. regulatory path:

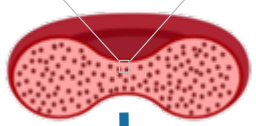
- Based on HGB-206 Group C

bluebirdbio®
recode for life™

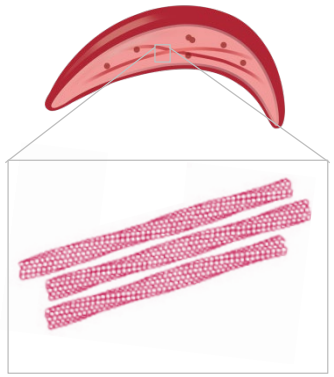
Sickle cell disease is characterized by high morbidity and early mortality

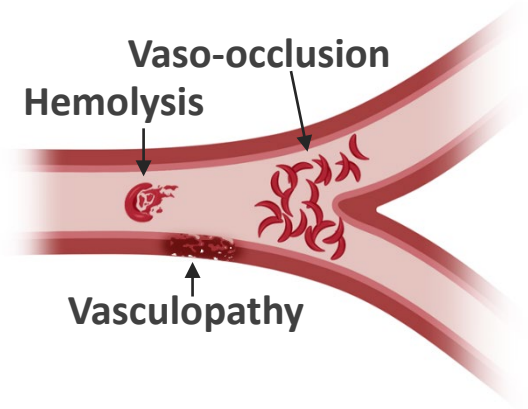


High levels of HbS in RBCs



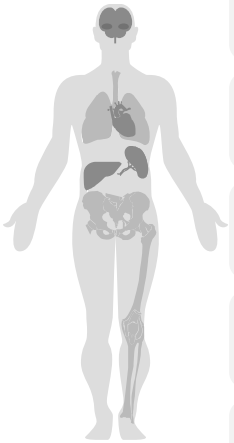
↓O_2 HbS polymerization & sickling





Complications

- 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

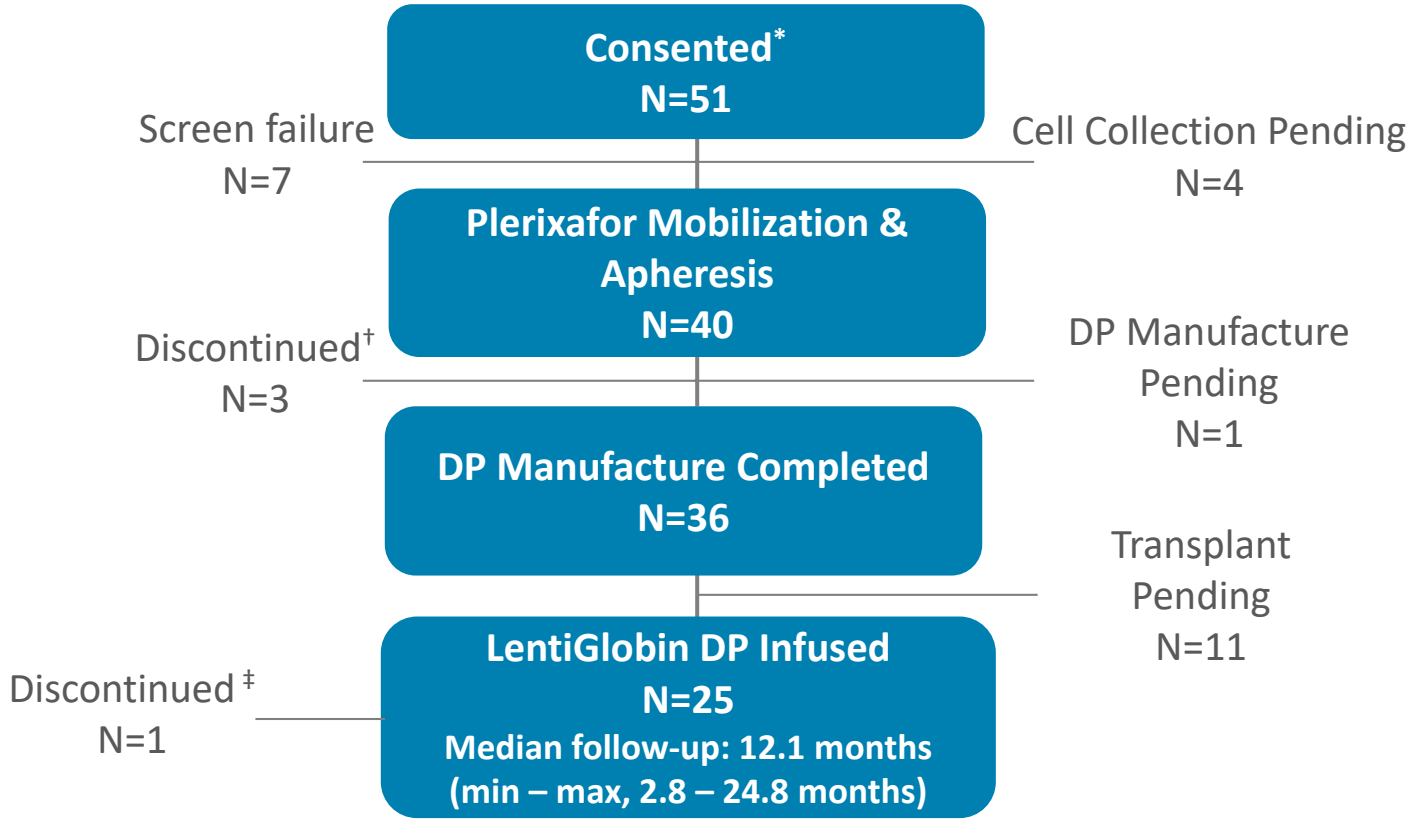


> 50% of patients with SCD die before 45 years of age[1]

bluebirdbio® recode for life™

1. Hassell K., Am J Prev Med 2010; CNS, central nervous system; Hb, hemoglobin; RBC, red blood cell

HGB-206 Group C: Patients infused to support BLA submission

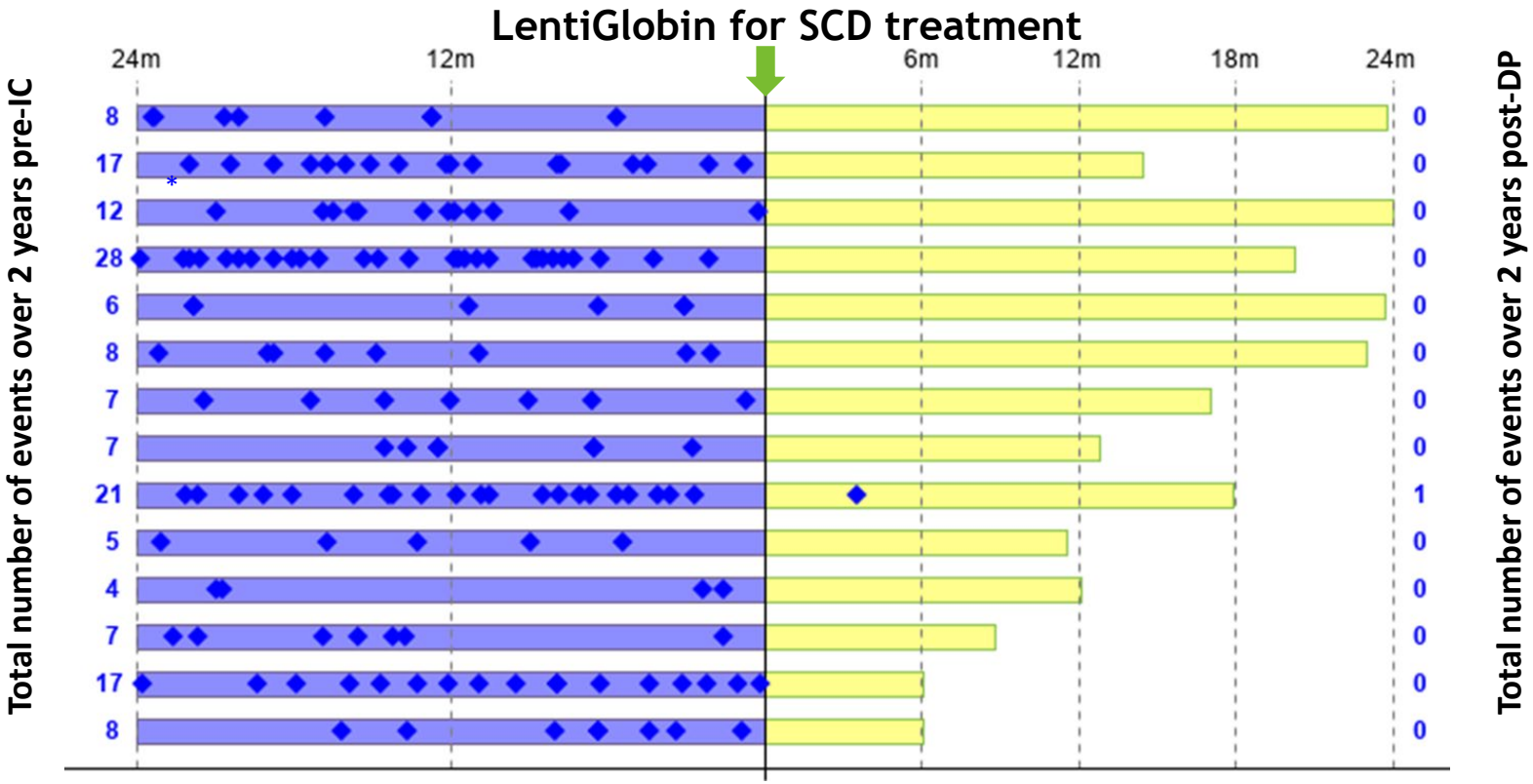


* Currently active, not recruiting; † 1 withdrew consent, 1 at investigator discretion, 1 mobilization failure; ‡ 1 death

DP, drug product

Data as of 3 March 2020

HGB-206 Group C: 99.5% mean reduction of annualized rate of VOCs + ACS post-LentiGlobin treatment



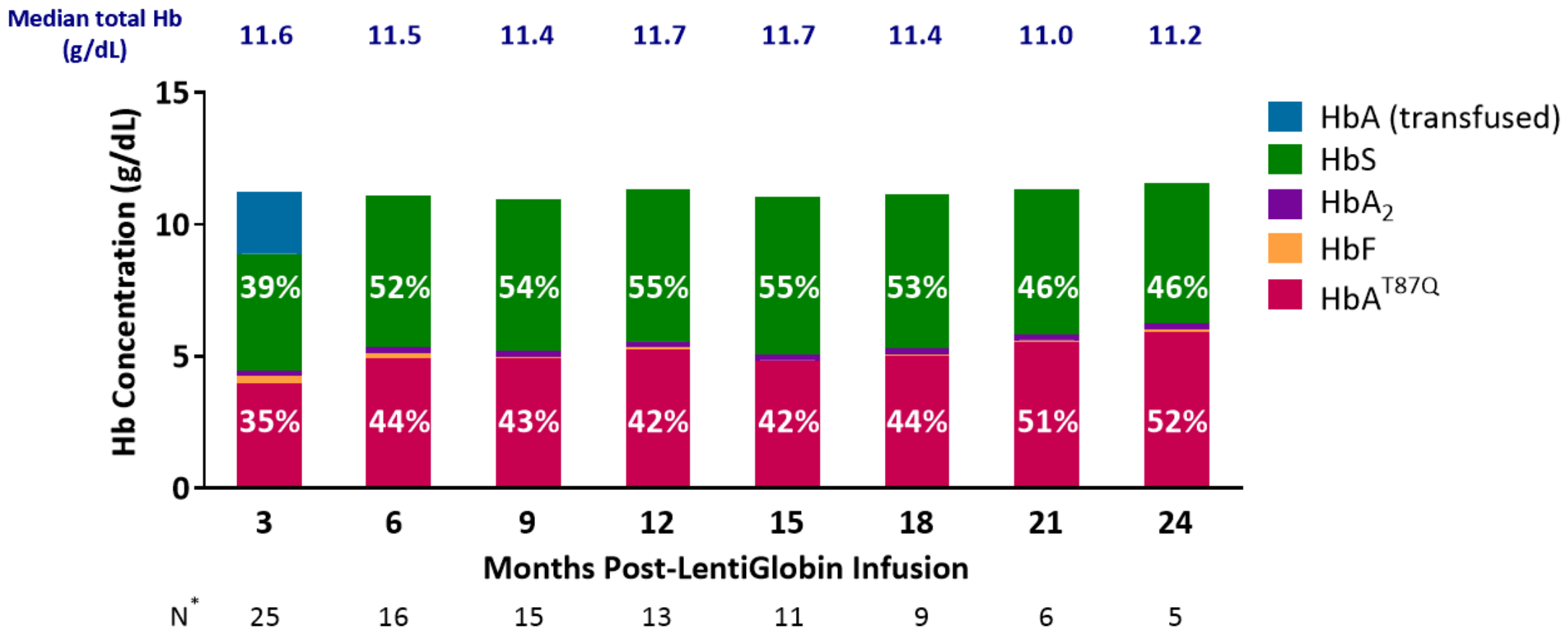
- No ACS or serious VOCs occurred in any Group C patient post-LentiGlobin treatment to date (2.8 – 24.8 months follow-up)
- One previously reported non-serious Grade 2 VOC was observed in 1 patient ~ 3.5 months post-LentiGlobin treatment

Investigator-reported AEs of VOC or ACS are shown; Patients with ≥ 4 VOC/ACS at baseline before IC and with ≥ 6 months of follow-up post-DP infusion are included

ACS, acute chest syndrome; CI, confidence interval; DP, drug product; IC, informed consent; VOC, vaso-occlusive crisis

Data as of 3 March 2020

HGB-206 Group C: Median HbS ≤60% and HbA^{T87Q} ≥40% at ≥6 months post-LentiGlobin treatment



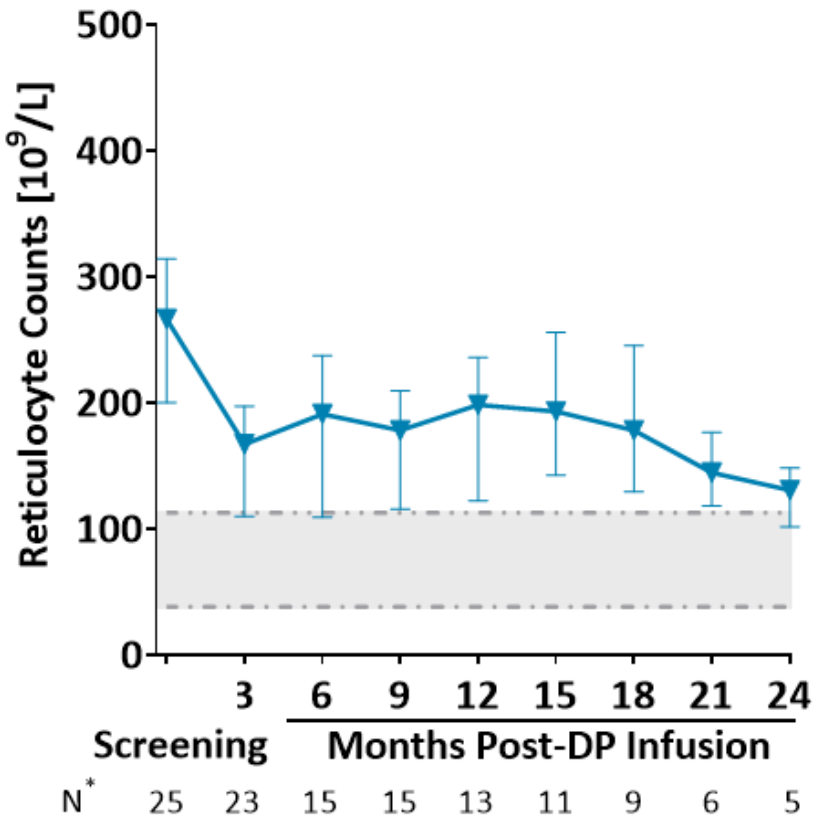
% represents median Hb fraction as % of total Hb; Hb, hemoglobin; * Number of patients with data available

bluebirdbio recode for life™

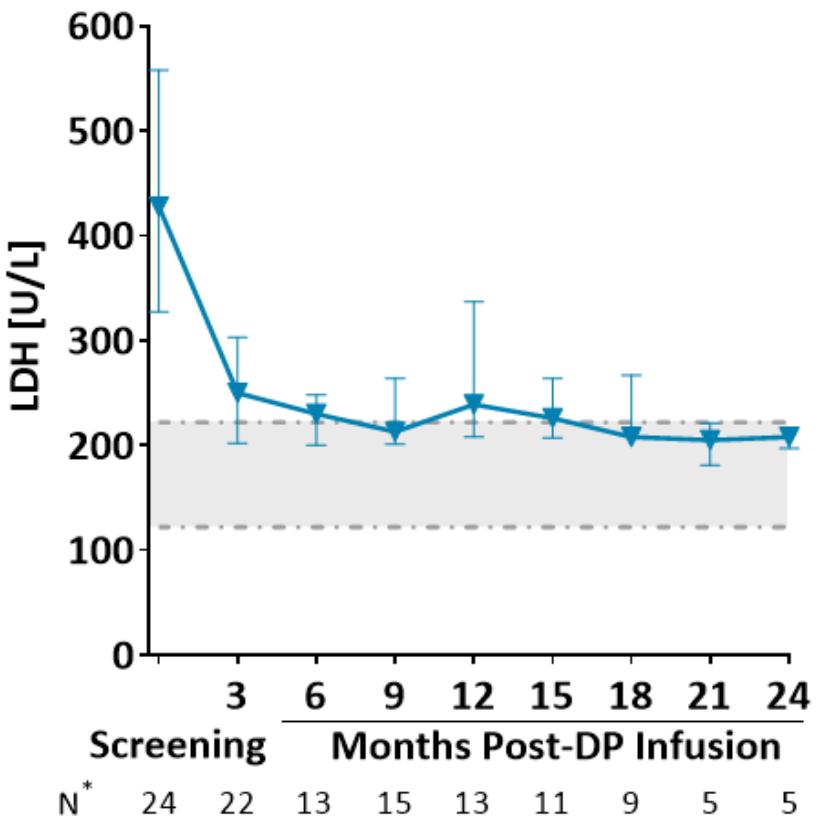
Data as of 3 March 2020

HGB-206 Group C: Decrease in hemolysis markers post-LentiGlobin treatment

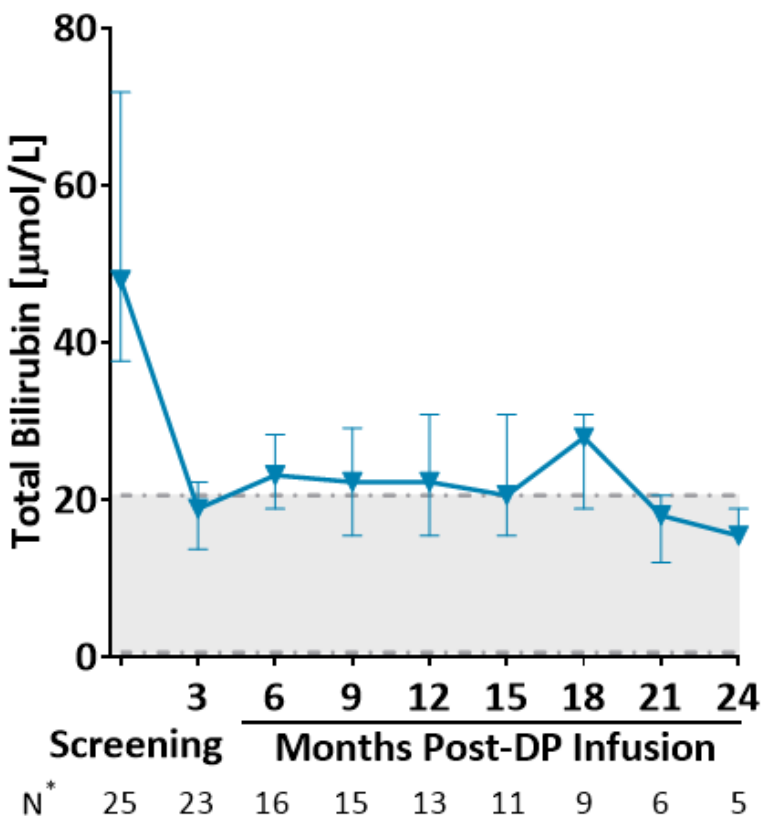
Reticulocyte Counts



Lactate Dehydrogenase



Total Bilirubin

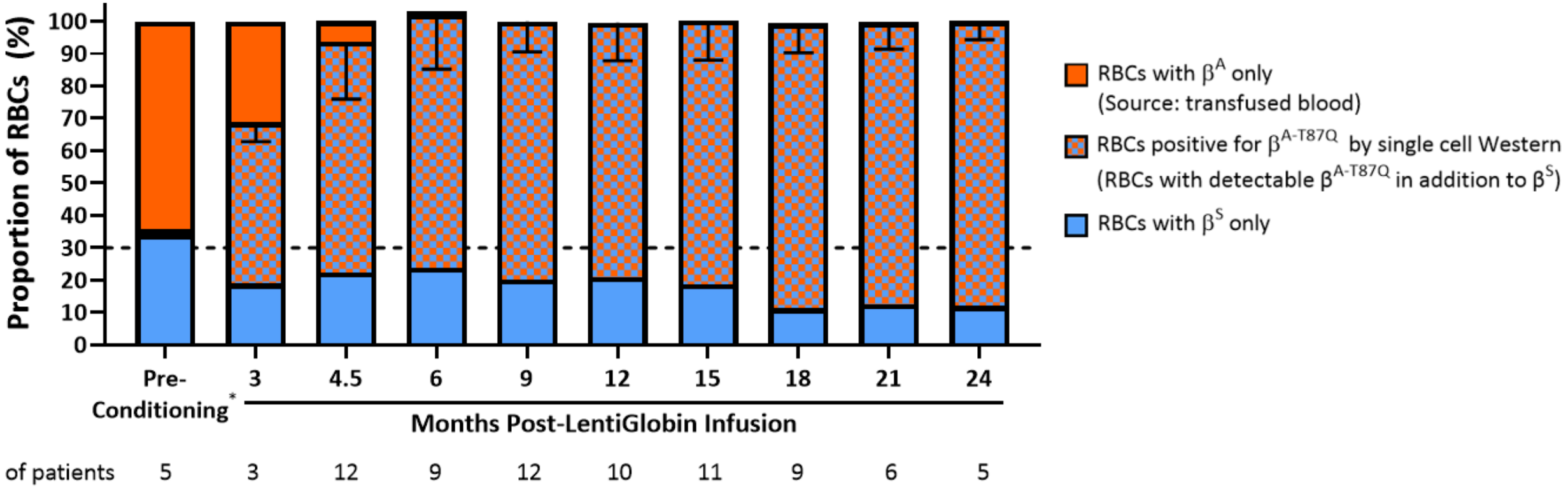


Median (Q1, Q3) depicted; Dot-dash lines denote lower and upper limits of normal values; * Number of patients with data available

Data as of 3 March 2020

Average proportion of RBCs containing $\beta^{A\text{-}T87Q}$ from LentiGlobin-treated patients is ≥70% by month 6 and ~90% by month 18

- Single RBC western assay was performed in subset of HGB-206 Group C patient samples



- **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);* Pre-conditioning sample does not contain any $\beta^{A\text{-}T87Q}$, signal is due to error rate of multiples; † Calculated as (% HbA^{T87Q} of total Hb/% RBCs containing $\beta^{A\text{-}T87Q}$) x MCH; ‡ Calculated to 13-18 pg/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;123(4):481-5.

HPFH, hereditary persistence of fetal hemoglobin; MCH, mean corpuscular hemoglobin; RBCs, red blood cells; SD, standard deviation

Data as of 3 March 2020

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

Non-hematologic ≥ Grade 3 AEs *Post-DP infusion in ≥ 2 patients**	**N=25** n (%)
Stomatitis	15 (60)
Febrile neutropenia	11 (44)
Increased ALT	3 (12)
Increased AST	3 (12)
Increased GGT	3 (12)
Increased total bilirubin	3 (12)
Nausea	3 (12)
Premature menopause	2 (8)
Upper abdominal pain	2 (8)
Serious AEs *Post-DP infusion in ≥ 2 patients*	
Nausea	2 (8)
Opioid withdrawal syndrome	2 (8)
Vomiting	2 (8)

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

- 3 patients with DP-related AEs (all nonserious and ≤ Grade 2)[†]
- No cases of veno-occlusive liver disease
- No graft failure
- No vector-mediated RCL and no insertional oncogenesis
- One death, unlikely related to LentiGlobin: A 27-year-old patient with history of VOC/ACS, pulmonary hypertension, and venous thrombosis died ~20 months post-treatment after sudden onset of shortness of breath followed by cardiac arrest
  - Post-DP: No VOCs/ACS (vs 28 episodes in 2 years pre-study); no sickle-related adverse events or ≥ Grade 3 AEs
    - At last study visit, Hb was 13.9 g/dL, with HbA^{T87Q} 36% and HbS 56%
  - Autopsy showed no evidence of pulmonary embolism, stroke or clinically significant sickling
    - Death was due to CV disease, with findings of cardiomegaly, cardiac fibrosis and pulmonary congestion
  - Per PIs, pre-existing SCD-related cardiac disease and pulmonary hypertension may have been contributing factors

[†] 1 pt with Grade 2 nonserious neutropenic fever on study day 10 (resolved on study day 18); 1 pt with post-DP infusion Grade 2 AEs of nail discoloration and constipation as well as Grade 1 AEs of runny nose and cough. This pt also had 3 AEs with onset pre-DP infusion (nonserious Grade 2 alopecia, Grade 1 vomiting and Grade 1 fatigue) which were initially assessed as DP-related, but attribution was changed to not DP-related after datacut date; 1 pt with 1 event of nonserious Grade 2 back pain

ACS, acute chest syndrome; CV, cardiovascular; DP, drug product; Hb, hemoglobin; PIs, principal investigators; RCL, replication competent lentivirus; VOC, vaso-occlusive crisis

bluebirdbio recode for life™

Data as of 3 March 2020

Updated, accelerated plan based on compelling VOE data

HGB-206 Group C

Sickle Cell Disease, history of vaso-occlusive events (VOEs) over 24 months

Ongoing Phase 1/2, single arm, multi-center, U.S. study
N=41 (Group C)

- Primary Endpoint: Complete resolution of severe VOEs
- Key Secondary Endpoint:
  - HbA^{T87Q} and total Hb
- ≥ 12 years of age - ≤ 50 years of age

HGB-210

Sickle Cell Disease, history of VOEs over 24 months

Phase 3, single arm, multi-center, global study

- Primary Endpoint: HbA^{T87Q} and Total Hb
- Key Secondary Endpoint:
  - Reduction in severe VOEs

1. HGB-206 Group C: Basis of BLA submission in 2H 2021

2. Primary endpoint: VOEs

3. HGB-210: Serving as confirmatory study

Closing

BLUE is executing and on track for catalysts ahead

Q2'20 Recap

- FDA alignment on SCD path based on HGB-206 Group C
- Operational savings of $500m through mid-2022
- BMS partnership restructure with $200m ex-U.S. monetization
- ~$540m equity offering complete

Looking Ahead

- Ide-cel BLA on track for resubmission
- KarMMa studies actively enrolling
- ZYNTEGLO first commercial patients to be treated 2H 2020
- Finalizing Lenti-D CALD EU MAA Submission by end of 2020
- Executing on accelerated SCD regulatory path

Cash runway extended into 2023

bluebirdbio®
recode for life™