

## **REBLOZYL (Luspatercept)**

Powder for Solution for Injection

### **1. NAME OF THE MEDICINAL PRODUCT**

Reblozyl Powder for Solution for Injection 25 mg/vial

Reblozyl Powder for Solution for Injection 75 mg/vial

### **2. QUALITATIVE AND QUANTITATIVE COMPOSITION**

Reblozyl Powder for Solution for Injection 25 mg/vial

Each vial contains 25 mg of luspatercept. After reconstitution, each mL of solution contains 50 mg luspatercept.

Reblozyl Powder for Solution for Injection 75 mg/vial

Each vial contains 75 mg of luspatercept. After reconstitution, each mL of solution contains 50 mg luspatercept.

Luspatercept is produced in Chinese Hamster Ovary (CHO) cells by recombinant DNA technology.

For the full list of excipients, see section 6.1.

### **3. PHARMACEUTICAL FORM**

Powder for solution for injection (powder for injection). White to off-white lyophilised powder.

### **4. CLINICAL PARTICULARS**

#### **4.1 Therapeutic indications**

Reblozyl is indicated in adults for the treatment of transfusion-dependent anaemia due to very low, low and intermediate-risk myelodysplastic syndromes (MDS) (see section 5.1).

Reblozyl is indicated in adults for the treatment of anaemia associated with transfusion-dependent and non-transfusion-dependent beta-thalassaemia (see section 5.1).

#### Limitation of use

Reblozyl is not indicated for use as a substitute for red blood cell (RBC) transfusions in patients who require immediate correction of anaemia.

#### **4.2 Posology and method of administration**

Reblozyl treatment should be initiated by a physician experienced in treatment of haematological diseases.

### Posology

Prior to each Reblozyl administration, the haemoglobin (Hb) level of patients should be assessed. In case of a red blood cell (RBC) transfusion occurring prior to dosing, the pre-transfusion Hb level must be considered for dosing purposes.

The recommended starting dose of Reblozyl is 1.0 mg/kg administered once every 3 weeks.

### *Myelodysplastic syndromes*

The recommended desired Hb concentration range is between 10 g/dL and 12 g/dL. Dose increase for insufficient response is provided below.

**Table 1: Dose increase for insufficient response**

<b>Dose at 1 mg/kg</b>	<b>Dose increase</b>
If after at least 2 consecutive doses at 1.0 mg/kg, a patient: <ul style="list-style-type: none"><li>• is not RBC transfusion- free, or</li><li>• does not reach Hb concentration of <math>\geq 10</math> g/dL and the Hb increase is <math>&lt; 1</math> g/dL</li></ul>	<ul style="list-style-type: none"><li>• Dose should be increased to 1.33 mg/kg</li></ul>
<b>Dose at 1.33 mg/kg</b>	<b>Dose increase</b>
If after at least 2 consecutive doses at 1.33 mg/kg, a patient: <ul style="list-style-type: none"><li>• is not RBC transfusion- free, or</li><li>• does not reach Hb concentration of <math>\geq 10</math> g/dL and the Hb increase is <math>&lt; 1</math> g/dL</li></ul>	<ul style="list-style-type: none"><li>• Dose should be increased to 1.75 mg/kg</li></ul>

The dose increase should not occur more frequently than every 6 weeks (2 administrations) and should not exceed the maximum dose of 1.75 mg/kg every 3 weeks. The dose should not be increased immediately after a dose delay.

For patients with a pre-dose Hb level of  $> 9$  g/dL and who have not yet achieved transfusion independence, a dose increase may be required at the physician's discretion; the risk of Hb increasing above the target threshold with concomitant transfusion cannot be excluded.

If a patient loses response (i.e. transfusion independence), the dose should be increased by one dose level (see Table 2).

### *Transfusion-dependent $\beta$ -thalassaemia*

In patients who do not achieve a response after  $\geq 2$  consecutive doses (6 weeks), at the 1.0 mg/kg starting dose, the dose should be increased to 1.25 mg/kg. Minimum response is defined as a reduction in RBC transfusion burden by at least a third after  $\geq 2$  consecutive doses (6 weeks), at the 1.0 mg/kg starting dose. The dose should not be increased beyond the maximum dose of 1.25 mg/kg every 3 weeks.

If a patient loses response (if the RBC transfusion burden increases again after an initial response) the dose should be increased by one dose level (see Table 3).

### *Non-transfusion-dependent $\beta$ -thalassaemia*

In patients who do not achieve or maintain a response, defined as an increase from baseline in pre-dose Hb of  $\geq 1$  g/dL, after  $\geq 2$  consecutive doses (6 weeks) at the same dose level (in absence of transfusions, i.e., at least 3 weeks after the last transfusion), the dose should be increased by one dose level (see Table 2). The dose should not exceed the maximum dose of 1.25 mg/kg every 3 weeks.

### Increase to next dose level

Increase to next dose level based on current dose is provided below.

**Table 2: Increase to next dose level for MDS**

Current dose	Increased dose
0.8 mg/kg	1 mg/kg
1 mg/kg	1.33 mg/kg
1.33 mg/kg	1.75 mg/kg

**Table 3: Increase to next dose level for  $\beta$ -thalassaemia**

Current dose	Increased dose
0.6 mg/kg*	0.8 mg/kg
0.8 mg/kg	1 mg/kg
1 mg/kg	1.25 mg/kg

\* Applicable only to non-transfusion-dependent  $\beta$ -thalassaemia.

#### Dose reduction and dose delay

In case of Hb increase  $> 2$  g/dL within 3 weeks in absence of transfusion, compared with the Hb value at previous dose, Reblozyl dose should be reduced by one dose level.

If the Hb is  $\geq 11.5$  g/dL in the absence of transfusion for at least 3 weeks, the dose should be delayed until the Hb is  $\leq 11.0$  g/dL. If there is also a concomitant rapid increase in Hb from the Hb value at previous dose ( $> 2$  g/dL within 3 weeks in absence of transfusion), a dose reduction to one step down should be considered after the dose delay.

Dose should not be reduced below 0.8 mg/kg (for MDS or transfusion-dependent  $\beta$ -thalassaemia) and below 0.6 mg/kg (for non-transfusion-dependent  $\beta$ -thalassaemia).

Reduced dose during treatment with luspatercept are provided below.

**Table 4: Reduced dose for MDS**

Current dose	Reduced dose
1.75 mg/kg	1.33 mg/kg
1.33 mg/kg	1 mg/kg
1 mg/kg	0.8 mg/kg

**Table 5: Reduced dose for  $\beta$ -thalassaemia**

Current dose	Reduced dose
1.25 mg/kg	1 mg/kg
1 mg/kg	0.8 mg/kg
0.8 mg/kg	0.6 mg/kg*

\*Applicable only to non-transfusion-dependent  $\beta$ -thalassaemia.

#### Dose modification due to adverse reactions

Instructions on dose interruptions or reductions for luspatercept treatment-related adverse reactions are outlined in Table 6.

**Table 6: Dose modification instructions**

<b>Treatment-related adverse reactions*</b>	<b>Dose instructions</b>
Grade 2 adverse reactions (see section 4.8), including Grade 2 hypertension (see sections 4.4 and 4.8)	<ul style="list-style-type: none"> <li>• Interrupt treatment</li> <li>• Restart at previous dose when adverse reaction has improved or returned to baseline</li> </ul>
Grade $\geq$ 3 hypertension (see sections 4.4 and 4.8)	<ul style="list-style-type: none"> <li>• Interrupt treatment</li> <li>• Restart at reduced dose once the blood pressure is controlled as per dose reduction guidance</li> </ul>
Other persistent Grade $\geq$ 3 adverse reactions (see section 4.8)	<ul style="list-style-type: none"> <li>• Interrupt treatment</li> <li>• Restart at previous dose or at reduced dose when adverse reaction has improved or returned to baseline as per dose reduction guidance</li> </ul>
Extramedullary haemopoiesis (EMH) masses causing serious complications (see sections 4.4 and 4.8)	<ul style="list-style-type: none"> <li>• Discontinue treatment</li> </ul>

\* Grade 1: mild; Grade 2: moderate; Grade 3: severe; and Grade 4: life-threatening.

#### Missed doses

In case of a missed or delayed scheduled treatment administration, the patient should be administered Reblozyl as soon as possible and dosing continued as prescribed with at least 3 weeks between doses.

#### Patients experiencing a loss of response

If patients experience a loss of response to Reblozyl, causative factors (e.g. a bleeding event) should be assessed. If typical causes for a loss of haematological response are excluded, dose increase should be considered as described above for the respective indication being treated (see Table 2 and Table 3).

#### Discontinuation

Reblozyl should be discontinued if patients do not experience a reduction in transfusion burden (for transfusion-dependent  $\beta$ -thalassaemia patients), or an increase from baseline Hb in the absence of transfusions (for non-transfusion-dependent  $\beta$ -thalassaemia patients), or a decrease in transfusion burden including no increase from baseline Hb (for MDS patients) after 9 weeks of treatment (3 doses) at the maximum dose level if no alternative explanations for response failure are found (e.g. bleeding, surgery, other concomitant illnesses) or if unacceptable toxicity occurs at any time.

#### Special populations

##### *Elderly*

No starting dose adjustment is required for Reblozyl (see section 5.2). Limited data are available in  $\beta$ -thalassaemia patients  $\geq$  60 years of age.

##### *Hepatic impairment*

No starting dose adjustment is required for patients with total bilirubin (BIL) > upper limit of normal (ULN) and/or alanine aminotransferase (ALT) or aspartate aminotransferase (AST) < 3 x ULN (see section 5.2). No specific dose recommendation can be made for patients with ALT or AST  $\geq$  3 x ULN or liver injury CTCAE Grade  $\geq$  3 due to lack of data (see section 5.2).

##### *Renal impairment*

No starting dose adjustment is required for patients with mild or moderate renal impairment (individual estimated glomerular filtration rate [eGFR] 30 to 89 mL/min). Only limited data are available for patients with moderate renal impairment.

No specific dose recommendation can be made for patients with severe renal impairment (individual eGFR < 30 mL/min) due to lack of clinical data (see section 5.2). Patients with renal impairment at baseline have been observed to have higher exposure (see section 5.2). Consequently, these patients should be closely monitored for adverse reactions and dose adjustment should be managed accordingly (see Table 6).

### *Paediatric population*

There is no relevant use of Reblozyl in the paediatric population for the indication of myelodysplastic syndromes, or in paediatric patients less than 6 months of age in  $\beta$ -thalassaemia.

The safety and efficacy of Reblozyl in the paediatric patients aged from 6 months to less than 18 years have not yet been established in  $\beta$ -thalassaemia. For non-clinical data, see section 5.3.

### Method of administration

For subcutaneous use.

After reconstitution, Reblozyl solution should be injected subcutaneously into the upper arm, thigh or abdomen. The exact total dosing volume of the reconstituted solution required for the patient should be calculated and slowly withdrawn from the single-dose vial(s) into a syringe.

The recommended maximum volume of medicinal product per injection site is 1.2 mL. If more than 1.2 mL is required, the total volume should be divided into separate similar volume injections and administered across separate sites using the same anatomical location but on opposite sides of the body.

If multiple injections are required, a new syringe and needle must be used for each subcutaneous injection. No more than one dose from a vial should be administered.

If the Reblozyl solution has been refrigerated after reconstitution, it should be removed from the refrigerator 15-30 minutes prior to injection to allow it to reach room temperature. This will allow for a more comfortable injection.

For instructions on reconstitution of the medicinal product before administration, see section 6.6.

## **4.3 Contraindications**

- Hypersensitivity to the active substance or to any of the excipients listed in section 6.1.
- Pregnancy (see section 4.6).

## **4.4 Special warnings and precautions for use**

### Traceability

In order to improve the traceability of biological medicinal products, the name and the batch number of the administered product should be clearly recorded.

### Thromboembolic events

In  $\beta$ -thalassaemia patients, thromboembolic events (TEEs) were reported in 3.6% (8/223) of patients treated with luspatercept in the double-blind phase of the pivotal study in transfusion-dependent patients and in 0.7% (1/134) of patients during the open-label phase of the pivotal study in non-transfusion-dependent patients. Reported TEEs included deep vein thrombosis (DVT), portal vein thrombosis, pulmonary emboli, ischaemic stroke and superficial thrombophlebitis (see section 4.8). All patients with TEEs were splenectomised and had at least one other risk factor for developing TEE (e.g. history of thrombocytosis or concomitant use of hormone replacement therapy). The occurrence of TEE was not correlated with elevated Hb levels. The potential benefit of treatment with luspatercept should be weighed against the potential risk of TEEs in  $\beta$ -thalassaemia patients with a splenectomy and other risk factors for developing TEE. Thromboprophylaxis according to current clinical guidelines should be considered in patients with  $\beta$ -thalassaemia at higher risk.

In MDS patients, TEEs were reported in 3.9% (13/335) of patients treated with luspatercept. Reported TEEs included cerebral ischemia and cerebrovascular accident in 1.2% (4/335) of patients. All TEEs occurred in patients with significant risk factors (atrial fibrillation, stroke or heart failure and peripheral vascular disease) and were not correlated with elevated Hb, platelet levels or hypertension.

### Extramedullary haematopoietic masses

In transfusion-dependent  $\beta$ -thalassaemia patients, extramedullary hematopoietic (EMH) masses were observed in 3.2% (10/315) of patients treated with luspatercept in the pivotal study and in the long-term follow-up study. Spinal cord compression symptoms due to EMH masses occurred in 1.9% (6/315) of patients treated with luspatercept (see section 4.8).

In non-transfusion-dependent  $\beta$ -thalassaemia patients, EMH masses were observed in 6.3% (6/96) of patients treated with luspatercept in the pivotal study. Spinal cord compression due to EMH masses occurred in 1.0% (1/96) of patients treated with luspatercept. During the open-label portion of the study, EMH masses were observed in 2 additional patients for a total of 8/134 (6.0%) of patients (see section 4.8).

$\beta$ -thalassaemia patients with EMH masses had known risk factors such as medical history of EMH masses at baseline or comorbidity of splenectomy, splenomegaly, hepatomegaly, low baseline Hb (<8.5 g/dL). Signs and symptoms may vary depending on anatomical location. Patients with  $\beta$ -thalassaemia should be monitored at initiation and during treatment for symptoms and signs or complications resulting from the EMH masses, and be treated according to clinical guidelines. Treatment with luspatercept must be discontinued in case of serious complications due to EMH masses. Luspatercept is not recommended for patients requiring treatment to control the growth of EMH masses.

#### Increased blood pressure

In MDS and  $\beta$ -thalassaemia pivotal studies, patients treated with luspatercept had an average increase in systolic and diastolic blood pressure of up to 5 mmHg from baseline (see section 4.8). An increased incidence of hypertension was observed in the first 12 months of treatment in non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (see section 4.8).

The treatment must be started only if the blood pressure is adequately controlled. Blood pressure should be monitored prior to each luspatercept administration. Luspatercept dose may require adjustment or may be delayed and patients should be treated for hypertension as per current clinical guidelines (see Table 6 in section 4.2). The potential benefit of treatment with Reblozyl should be re-evaluated in case of persistent hypertension or exacerbations of preexisting hypertension.

#### Traumatic fracture

In transfusion-dependent  $\beta$ -thalassaemia patients, traumatic fractures were observed in 0.4% (1/223) of patients treated with luspatercept.

In non-transfusion-dependent  $\beta$ -thalassaemia patients, traumatic fractures were observed in 8.3% (8/96) of patients treated with luspatercept. Patients should be informed of the risk of traumatic fracture.

#### Sodium content

This medicinal product contains less than 1 mmol sodium (23 mg) per dose, that is to say essentially 'sodium-free'.

### **4.5 Interaction with other medicinal products and other forms of interaction**

No formal clinical interaction studies have been performed. Concurrent use of iron-chelating agents had no effect on luspatercept pharmacokinetics.

### **4.6 Fertility, pregnancy and lactation**

#### Women of childbearing potential / Contraception in females

Women of childbearing potential have to use effective contraception during treatment with Reblozyl and for at least 3 months after the last dose. Prior to starting treatment with Reblozyl, a pregnancy test has to be performed for women of childbearing potential.

#### Pregnancy

Treatment with Reblozyl should not be started if the woman is pregnant (see section 4.3). There are no data from the use of Reblozyl in pregnant women. Studies in animals have shown reproductive toxicity

(see section 5.3). Reblozyl is contraindicated during pregnancy (see section 4.3). If a patient becomes pregnant, Reblozyl should be discontinued.

#### Breast-feeding

It is unknown whether luspatercept or its metabolites are excreted in human milk. Luspatercept was detected in the milk of lactating rats (see section 5.3). Because of the unknown adverse effects of luspatercept in newborns/infants, a decision must be made whether to discontinue breast-feeding during therapy with Reblozyl and for 3 months after the last dose or to discontinue Reblozyl therapy, taking into account the benefit of breast-feeding for the child and the benefit of therapy for the woman.

#### Fertility

The effect of luspatercept on fertility in humans is unknown. Based on findings in animals, luspatercept may compromise female fertility (see section 5.3).

### **4.7 Effects on ability to drive and use machines**

Reblozyl may have a minor influence on the ability to drive and use machines. The ability to react when performing these tasks may be impaired due to risks of fatigue, vertigo, dizziness or syncope (see section 4.8). Therefore, patients should be advised to exercise caution until they know of any impact on their ability to drive and use machines.

### **4.8 Undesirable effects**

#### Summary of the safety profile

##### *Myelodysplastic syndromes*

The most frequently reported adverse drug reactions in patients receiving Reblozyl (at least 15% of patients) were fatigue, diarrhoea, nausea, asthenia, dizziness, oedema peripheral and back pain. The most commonly reported Grade  $\geq 3$  adverse drug reactions (at least 2% of patients) included hypertension events (12.5%), syncope (3.6%), dyspnoea (2.7%), fatigue (2.4%) and thrombocytopenia (2.4%). The most commonly reported serious adverse drug reactions (at least 1% of patients) were urinary tract infection (1.8%), dyspnoea (1.5%) and back pain (1.2%).

Asthenia, fatigue, nausea, diarrhoea, hypertension, dyspnoea, dizziness and headache occurred more frequently during the first 3 months of treatment.

Treatment discontinuation due to an adverse event occurred in 10.1% of patients treated with luspatercept. The most common reason for discontinuation in the luspatercept treatment arm was progression of underlying MDS.

Dose delays due to pre-dose Hb  $\geq$ 12.0 g/dL occurred in 24.3% of luspatercept treated patients.

*Transfusion-dependent  $\beta$ -thalassaemia*

The most frequently reported adverse drug reactions in patients receiving Reblozyl (at least 15% of patients) were headache, bone pain and arthralgia. The most commonly reported Grade  $\geq$  3 adverse drug reaction was hyperuricaemia. The most serious adverse reactions reported included thromboembolic events of deep vein thrombosis, ischaemic stroke portal vein thrombosis and pulmonary embolism (see section 4.4).

Bone pain, asthenia, fatigue, dizziness and headache occurred more frequently during the first 3 months of treatment.

Treatment discontinuation due to an adverse reaction occurred in 2.6% of patients treated with luspatercept. The adverse reactions leading to treatment discontinuation in the luspatercept treatment arm were arthralgia, back pain, bone pain and headache.

*Non-transfusion-dependent  $\beta$ -thalassaemia*

The most frequently reported adverse drug reactions in patients receiving Reblozyl (at least 15% of patients) were bone pain, headache, arthralgia, back pain, prehypertension and hypertension. The most commonly reported Grade  $\geq$  3 and most serious adverse reaction (at least 2% of patients) reported was traumatic fracture. Spinal cord compression due to EMH masses occurred in 1% of patients.

Bone pain, back pain, upper respiratory tract infection, arthralgia, headache and prehypertension occurred more frequently during the first 3 months of treatment.

The majority of adverse drug reactions were non-serious and did not require discontinuation. Treatment discontinuation due to an adverse reaction occurred in 3.1% of patients treated with luspatercept. Adverse reactions leading to treatment discontinuation were spinal cord compression, extramedullary haemopoiesis and arthralgia.

Tabulated list of adverse reactions

The highest frequency for each adverse reaction that was observed and reported in patients in the pivotal studies in MDS,  $\beta$ -thalassaemia and the long-term follow-up study is shown in Table 7 below. The adverse reactions are listed below by body system organ class and preferred term. Frequencies are defined as: very common ( $\geq$  1/10), common ( $\geq$  1/100 to  $<$  1/10), uncommon ( $\geq$  1/1,000 to  $<$  1/100), rare ( $\geq$  1/10,000 to  $<$  1/1,000), very rare ( $<$  1/10,000), and not known (frequency cannot be estimated from the available data).

**Table 7. Adverse drug reactions (ADRs) in patients treated with Reblozyl for MDS and/or  $\beta$ -thalassaemia in the four pivotal studies**

System organ class	Preferred term	Frequency (all grades) for MDS	Frequency (all grades) for $\beta$ -thalassaemia
Infections and infestations	bronchitis	Common	Common <sup>a</sup>
	urinary tract infection	Very common	Common <sup>a</sup>
	respiratory tract infection	Common	

	upper respiratory tract infection	Common	Very common <sup>a</sup>
	influenza	Common	Very common
<b>Blood and lymphatic system disorders</b>	extramedullary haemopoiesis <sup>VI</sup>	Not known <sup>VII</sup>	Common
	thrombocytopenia	Common	
<b>Immune system disorders</b>	hypersensitivity <sup>I, VI</sup>	Common	Common
<b>Metabolism and nutrition disorders</b>	hyperuricaemia	Common	Common
	dehydration	Common	
	decreased appetite	Common	
	electrolyte imbalance <sup>IX</sup>	Very common	
<b>Psychiatric disorders</b>	insomnia	Common	Very common <sup>b</sup>
	anxiety	Common	Common
	irritability		Common
	confusional state	Common	
<b>Nervous system disorders</b>	dizziness	Very common	Very common
	headache	Very common	Very common
	migraine		Common <sup>b</sup>
	spinal cord compression <sup>VI</sup>		Common
	syncope/presyncope	Common	Common <sup>a</sup>
<b>Ear and labyrinth disorders</b>	vertigo/vertigo positional	Common	Common <sup>a</sup>
<b>Cardiac disorders</b>	atrial fibrillation	Common	
	cardiac failure	Common	
<b>Vascular disorders</b>	prehypertension		Very common <sup>b</sup>
	hypertension <sup>II, VI</sup>	Very common	Very common
	tachycardia	Common	
	thromboembolic events <sup>IV, VI</sup>	Common	Common
<b>Respiratory, thoracic and mediastinal disorders</b>	cough	Very common	
	epistaxis	Common	Common <sup>b</sup>
	dyspnoea <sup>VIII</sup>	Very common	Common
<b>Gastrointestinal disorders</b>	abdominal pain	Common	Very common <sup>b</sup>
	abdominal discomfort	Common	
	diarrhoea	Very common	Very common <sup>a</sup>
	nausea	Very common	Very common
<b>Skin and subcutaneous tissue disorders</b>	hyperhidrosis	Common	
<b>Musculoskeletal and connective tissue disorders</b>	back pain	Very common	Very common
	arthralgia <sup>VI</sup>	Common	Very common
	bone pain <sup>VI</sup>	Common	Very common
	myalgia	Common	
	muscular weakness	Common	
<b>Renal and urinary disorders</b>	proteinuria		Common <sup>b</sup>
	albuminuria		Common <sup>b</sup>

	kidney injury <sup>X</sup>	Common	
<b>General disorders and administration site conditions</b>	non-cardiac chest pain	Common	
	influenza-like illness	Common	
	fatigue	Very common	Very common <sup>a</sup>
	asthenia	Very common	Very common
	injection site reactions <sup>III, VI</sup>	Common	Common
	oedema peripheral	Very common	
<b>Investigations</b>	alanine aminotransferase increased	Common	Common <sup>V</sup>
	aspartate aminotransferase increased	Common	Very common <sup>V</sup>
	blood bilirubin increased	Common	Very common <sup>V</sup>
	gamma-glutamyltransferase increased	Common	
<b>Injury, poisoning and procedural complications</b>	traumatic fracture <sup>VI</sup>		Common <sup>b</sup>

\*The four pivotal studies are ACE-536-MDS-001 (ESA-refractory or intolerant MDS), ACE-536-MDS-002 (MDS), ACE-536-B-THAL-001 (transfusion-dependent  $\beta$ -thalassaemia) and ACE-536-B-THAL-002 (non-transfusion-dependent  $\beta$ -thalassaemia).

<sup>I</sup> Hypersensitivity includes eyelid oedema, drug hypersensitivity, swelling face, periorbital oedema, face oedema, angioedema, lip swelling, drug eruption.

<sup>II</sup> Hypertension includes essential hypertension, hypertension and hypertensive crisis.

<sup>III</sup> Injection site reactions include injection site erythema, injection site pruritus, injection site swelling and injection site rash.

<sup>IV</sup> TEEs include deep vein thrombosis, portal vein thrombosis, ischaemic stroke and pulmonary embolism.

<sup>V</sup> Frequency is based on laboratory values of any grade.

<sup>VI</sup> See section 4.8 Description of selected adverse reactions.

<sup>VII</sup> Reported only in post-marketing.

<sup>VIII</sup> Dyspnoea includes dyspnoea exertional for ACE-536-MDS-002.

<sup>IX</sup> Electrolyte imbalance includes bone, calcium, magnesium and phosphorus metabolism disorders and electrolyte and fluid balance conditions.

<sup>X</sup> ADR includes similar/grouped terms.

<sup>a</sup> ADRs observed in transfusion-dependent  $\beta$ -thalassaemia study ACE-536-B-THAL-001.

<sup>b</sup> ADRs observed in non-transfusion-dependent  $\beta$ -thalassaemia study ACE-536-B-THAL-002.

## Description of selected adverse reactions

### *Bone pain*

Bone pain was reported in 2.4% of MDS patients treated with luspatercept with all events being Grade 1-2.

Bone pain was reported in 36.5% of non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 6.1%), in 19.7% of transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 8.3%). In non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept, most events (32/35) were Grade 1-2, with 3 events Grade 3. No patient discontinued due to bone pain. In transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept, bone pain was most common in the first 3 months (16.6%) compared to months 4-6 (3.7%). Most events (41/44 events) were Grade 1-2, with 3 events Grade 3. One of the 44 events was serious, and 1 event led to treatment discontinuation.

### *Arthralgia*

Arthralgia was reported in 7.2% of MDS patients treated with luspatercept with 0.6% being  $\geq$  Grade 3.

Arthralgia was reported in 29.2% of non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 14.3%), in 19.3% of transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 11.9%). In non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept, most events (26/28) were Grade 1-2, with 2 events Grade 3. In the transfusion-dependent and non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept, arthralgia led to treatment discontinuation in 2 patients (0.9%) and 1 patient (1.0%), respectively.

#### *Hypertension*

MDS and  $\beta$ -thalassaemia patients treated with luspatercept had an average increase in systolic and diastolic blood pressure of up to 5 mmHg from baseline not observed in patients receiving placebo.

Hypertension events were reported in 12.5% of MDS patients treated with luspatercept (placebo 9.2%). Grade 3 hypertension events were reported in 25/335 patients (7.5%) treated with luspatercept (placebo 3.9%).

Hypertension was reported in 19.8% of non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 2.0%), and in 8.1% of transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 2.8%). See section 4.4.

An increased incidence of hypertension was observed over time in the first 8-12 months in non-transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept. See section 4.4.

In non-transfusion-dependent  $\beta$ -thalassaemia patients, most events (16/19) were Grade 1-2 with 3 events Grade 3 (3.1%) in patients treated with luspatercept (0.0% placebo). In transfusion-dependent  $\beta$ -thalassaemia patients, Grade 3 events were reported in 4 patients (1.8%) treated with luspatercept (placebo 0.0%). See section 4.4.

#### *Hypersensitivity*

Hypersensitivity-type reactions included eyelid oedema, drug hypersensitivity, swelling face, periorbital oedema, face oedema, angioedema, lip swelling, drug eruption.

Hypersensitivity-type reactions were reported in 4.6% of MDS patients (placebo 2.6%) and in 4.5% of transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept (placebo 1.8%). In clinical studies, all events were Grade 1-2. In transfusion-dependent  $\beta$ -thalassaemia patients treated with luspatercept, hypersensitivity led to treatment discontinuation in 1 patient (0.4%).

Face oedema occurred in 3.1% of non-transfusion-dependent  $\beta$ -thalassaemia patients (placebo 0.0%).

#### *Injection site reactions*

Injection site reactions included injection site erythema, injection site pruritus, injection site swelling and injection site rash.

Injection site reactions were reported in 3.6% of MDS patients.

Injection site reactions were reported in 5.2% of non-transfusion-dependent  $\beta$ -thalassaemia patients (placebo 0.0%), and in 2.2% of transfusion-dependent  $\beta$ -thalassaemia patients (placebo 1.8%). In clinical studies, all events were Grade 1 and none led to discontinuation.

#### *Thromboembolic events*

TEEs included deep vein thrombosis, portal vein thrombosis, ischaemic stroke and pulmonary embolism.

TEEs were reported in 3.9% of MDS patients (placebo 3.9%). Reported TEEs included cerebral ischemia and cerebrovascular accident in 1.2% of patients. All TEEs occurred in patients with significant risk factors (atrial fibrillation, stroke or heart failure and peripheral vascular disease) and were not correlated with elevated Hb, platelet levels or hypertension. See section 4.4.

TEEs occurred in 3.6% of transfusion-dependent  $\beta$ -thalassaemia patients receiving luspatercept (placebo 0.9%).

In the open-label phase of the pivotal study in non-transfusion-dependent  $\beta$ -thalassaemia, thromboembolic event (superficial thrombophlebitis) occurred in 0.7% of patients.

All TEEs events were reported in patients who had undergone splenectomy and had at least one other risk factor. See section 4.4.

#### *Extramedullary haematopoietic masses*

EMH masses occurred in 10/315 (3.2%) transfusion-dependent  $\beta$ -thalassaemia patients receiving luspatercept. All were reported in patients who had medical history of existing EMH masses or comorbidity of splenectomy, splenomegaly, hepatomegaly, low baseline Hb (<8.5 g/dL). Five events were Grade 1-2, 4 events were Grade 3, and 1 event was Grade 4. Three patients discontinued due to EMH masses. See section 4.4.

EMH masses occurred in 6/96 (6.3%) non-transfusion-dependent  $\beta$ -thalassaemia patients receiving luspatercept (placebo 2%). Most (5/6) were Grade 2 and 1 was Grade 1. One patient discontinued due to EMH masses. During the open-label portion of the study, EMH masses were observed in 2 additional patients for a total of 8/134 (6.0%) of patients. Most (7/8) were Grade 1-2 and manageable with standard clinical practice. In 6/8 patients, luspatercept was continued after onset of event. See section 4.4.

#### *Spinal cord compression*

Spinal cord compression or symptoms due to EMH masses occurred in 6/315 (1.9%) transfusion-dependent  $\beta$ -thalassaemia patients receiving luspatercept (placebo 0.0%). Four patients discontinued treatment due to Grade  $\geq 3$  symptoms of spinal cord compression. See section 4.4.

Spinal cord compression due to EMH masses occurred in 1/96 (1.0%) non-transfusion-dependent  $\beta$ -thalassaemia patient with a history of EMH masses receiving luspatercept (placebo 0.0%). This patient discontinued treatment due to Grade 4 spinal cord compression. See section 4.4.

#### *Traumatic fracture*

Traumatic fracture occurred in 8 (8.3%) non-transfusion-dependent  $\beta$ -thalassaemia patients receiving luspatercept (placebo 2.0%), and in 1 (0.4%) transfusion-dependent  $\beta$ -thalassaemia patient receiving luspatercept (placebo 0.0%). In non-transfusion-dependent  $\beta$ -thalassaemia patients, Grade  $\geq 3$  events were reported for 4 patients (4.2%) treated with luspatercept and in 1 patient (2.0%) receiving placebo.

#### *Immunogenicity*

In clinical studies in MDS, an analysis of 395 MDS patients who were treated with luspatercept and who were evaluable for the presence of anti-luspatercept antibodies showed that 36 (9.1%) patients tested positive for treatment-emergent anti-luspatercept antibodies, including 18 (4.6%) patients who had neutralising antibodies against luspatercept.

In clinical studies in transfusion-dependent and non-transfusion-dependent  $\beta$ -thalassaemia, an analysis of 380  $\beta$ -thalassaemia patients who were treated with luspatercept and who were evaluable for the presence of anti-luspatercept antibodies showed that 7 (1.84%)  $\beta$ -thalassaemia patients tested positive for treatment-emergent anti-luspatercept antibodies, including 5 (1.3%)  $\beta$ -thalassaemia patients who had neutralising antibodies against luspatercept.

Luspatercept serum concentration tended to decrease in the presence of neutralising antibodies. There were no severe systemic hypersensitivity reactions reported for patients with anti-luspatercept antibodies. There was no association between hypersensitivity type reactions or injection site reactions and presence of anti-luspatercept antibodies. Patients with treatment-emergent anti-luspatercept antibodies were more likely to report a serious treatment-emergent adverse event (69.4% [25/36] for anti-luspatercept antibodies-positive patients vs. 45.7% [164/359] for anti-luspatercept antibodies-negative patients) or a Grade 3 or 4 treatment-emergent adverse event (77.8% [28/36] for anti-luspatercept antibodies-positive patients vs. 56.8% [204/359] for anti-luspatercept

antibodies -negative patients) compared to patients without anti-luspatercept antibodies in the TD MDS pool.

#### Other special population

##### MDS patients without ring sideroblast (RS-)

RS- patients are more likely to experience serious adverse events, Grade 5 treatment -emergent adverse events, adverse events leading to drug discontinuation or dose reduction compared to patients with ring sideroblasts (RS+). In ACE-536-MDS-002 study, RS- patients showed higher incidence of some adverse reactions compared to RS+ patients in both treatment arms. When comparing RS subgroups in the luspatercept arm, asthenia, nausea, vomiting, dyspnoea, cough, thromboembolic events, alanine aminotransferase increased, aspartate aminotransferase increased, and thrombocytopenia occurred more frequently in the RS- subgroup.

##### MDS patients with mutational status SF3B1 non-mutated

Patients with mutational status SF3B1 non-mutated are more likely to experience Grade 3 or 4 treatment -emergent adverse events, serious adverse events, Grade 5 treatment -emergent adverse events, adverse events leading to drug discontinuation, dose reduction as well as dose interruption compared to patients with mutational status SF3B1 mutated. Known luspatercept adverse reactions with a frequency  $\geq 3\%$  higher in the non-mutated SF3B1 luspatercept arm subgroup included vomiting, dyspnoea, and hypertension.

## **4.9 Overdose**

Overdose with luspatercept may cause an increase of Hb values above the desired level. In the event of an overdose, treatment with luspatercept should be delayed until Hb is  $\leq 11$  g/dL.

## **5. PHARMACOLOGICAL PROPERTIES**

### **5.1 Pharmacodynamic properties**

Pharmacotherapeutic group: Antianaemic preparations, other antianaemic preparations, ATC code: B03XA06.

#### Mechanism of action

Luspatercept, an erythroid maturation agent, is a recombinant fusion protein that binds selected transforming growth factor- $\beta$  (TGF- $\beta$ ) superfamily ligands. By binding to specific endogenous ligands (e.g. GDF-11, activin B) luspatercept inhibits Smad2/3 signalling, resulting in erythroid maturation through expansion and differentiation of late-stage erythroid precursors (normoblasts) in the bone marrow, thereby restoring effective erythropoiesis. Smad2/3 signalling is abnormally high in disease models characterised by ineffective erythropoiesis, i.e. MDS and  $\beta$ -thalassaemia, and in the bone marrow of MDS patients.

#### Somatic mutations in MDS patients

Luspatercept demonstrated clinical benefit and favourability over epoetin alfa across multiple genomic mutations that are frequently observed in lower-risk MDS with the exception of CBL gene mutations.

#### Clinical efficacy and safety

##### Myelodysplastic syndromes

The efficacy and safety of luspatercept were evaluated in a Phase 3 multicentre, randomised, open-label, active controlled study COMMANDS (ACE-536-MDS-002) comparing luspatercept *versus* epoetin alfa in patients with anaemia due to International Prognostic Scoring System-Revised (IPSS-R) very low-, low- or intermediate-risk MDS or with myelodysplastic/ myeloproliferative neoplasm with ring sideroblasts and thrombocytosis (MDS/MPN RS-T) in ESA naïve patients (with endogenous sEPO levels of  $< 500$  U/L) who require red blood cell transfusions. For eligibility, patients were required to have had

2 to 6 RBC units/8 weeks confirmed for a minimum of 8 weeks immediately preceding randomization. Patients with deletion 5q (del5q) MDS were excluded from the study.

Patients were treated for at least 24 weeks, unless the patient experienced unacceptable toxicities, withdrew the consent or met any other treatment discontinuation criteria. The treatment was continued beyond week 24 in case of clinical benefit (defined as a transfusion reduction of  $\geq 2$  pRBC units/8 weeks compared with baseline) and absence of disease progression. Based on the outcome of these assessments, patients either were discontinued from treatment and entered into the Post-Treatment Follow-up Period or continued open-label treatment (with luspatercept or epoetin alfa) as long as the above criteria continued to be met or until the patient experienced unacceptable toxicities, withdrew consent, or met any other discontinuation criteria.

A total of 363 patients were randomized to receive subcutaneously luspatercept (N=182) or epoetin alfa (N=181) at 1.0 mg/kg every 3 weeks or at 450 U/kg every week, respectively. Randomization was stratified by RBC transfusion burden, RS status, and endogenous serum erythropoietin (sEPO) level at baseline. Two dose level increases were allowed for luspatercept (to 1.33 mg/kg and to 1.75 mg/kg). Doses were held and subsequently reduced for adverse reactions, reduced if the haemoglobin increased by  $\geq 2$  g/dL from the prior cycle, and held if the pre-dose haemoglobin was  $\geq 12$  g/dL. All patients received best supportive care, which included RBC transfusions, use of antibiotic, antiviral and antifungal therapy, and nutritional support as needed. BSC for this study excluded the use of ESAs outside of the study treatment. The key baseline disease characteristics in MDS patients in ACE-536-MDS-002 are shown in Table 8.

**Table 8. Baseline demographics and disease characteristics of MDS patients in ACE-536-MDS-002**

	<b>Luspatercept (N=182)</b>	<b>Epoetin alfa (N=181)</b>
<b>Demographics</b>		
<b>Age<sup>a</sup> (years)</b>		
<b>Median (min, max)</b>	74 (46, 93)	74 (31, 91)
<b>Age categories, n (%)</b>		
$\leq 64$ years	27 (14.8)	25 (13.8)
65-74 years	68 (37.4)	66 (36.5)
$\geq 75$	87 (47.8)	90 (49.7)
<b>Sex, n (%)</b>		
Male	109 (59.9)	92 (50.8)
Female	73 (40.1)	89 (49.2)
<b>Race, n (%)</b>		
Asian	19 (10.4)	25 (13.8)
Black	2 (1.1)	0
White	146 (80.2)	143 (79)
Not collected or reported	15 (8.2)	13 (7.2)
<b>Disease Characteristics</b>		
<b>Hb (g/dL), n (%)<sup>b</sup></b>		
<b>Median (min, max)</b>	7.80 (4.7, 9.2)	7.80 (4.5, 10.2)
<b>Time since original MDS diagnosis (months)<sup>c</sup></b>		
<b>Median</b>	7.97	5.13
<b>Serum EPO (U/L) categories, n (%)<sup>d</sup></b>		
$\leq 200$	145 (79.7)	144 (79.6)
$> 200$	37 (20.3)	37 (20.4)
<b>Median serum EPO</b>	77.245	85.370
<b>Serum ferritin (<math>\mu\text{g/L}</math>)</b>	623.00	650.00
<b>Median (min, max)</b>	(12.4, 3170.0)	(39.4, 6960.5)
<b>Baseline transfusion burden / 8 weeks<sup>e</sup> (pRBC units), n (%)</b>		
$< 4$ units	118 (64.8)	111 (61.3)
$\geq 4$ units	64 (35.2)	70 (38.7)

	<b>Luspatercept (N=182)</b>	<b>Epoetin alfa (N=181)</b>
<b>MDS Classification WHO 2016 at baseline, n (%)</b>		
MDS-SLD	1 (0.5)	4 (2.2)
MDS-MLD	50 (27.5)	47 (26.0)
MDS-RS-SLD	2 (1.1)	6 (3.3)
MDS-RS-MLD	127 (69.8)	118 (65.2)
MDS/MPN-RS-T	2 (1.1)	5 (2.8)
Missing	0	1 (0.6)
<b>IPSS-R classification risk category, n (%)</b>		
Very low	16 (8.8)	17 (9.4)
Low	130 (71.4)	133 (73.5)
Intermediate	34 (18.7)	29 (16.0)
Other / missing	2 (1.1)	2 (1.1)
<b>Ring sideroblast status (per WHO criteria), n (%)</b>		
RS+	133 (73.1)	130 (71.8)
RS-	49 (26.9)	50 (27.6)
Missing	0	1 (0.6)
<b>SF3B1 mutation status, n (%)</b>		
Mutated	114 (62.6)	101 (55.8)
Non-mutated	65 (35.7)	72 (39.8)
Missing	3 (1.6)	8 (4.4)

Hb = haemoglobin; IPSSR=International Prognostic Scoring System-Revised; MDS-SLD=MDS with single lineage dysplasia; MDS-MLD=MDS with multilineage dysplasia; MDS-RS-SLD=MDS with ring sideroblasts with single lineage dysplasia; MDS-RS-MLD= MDS with ring sideroblasts with multilineage dysplasia; MDS/MPN-RS-T= myelodysplastic/myeloproliferative neoplasms with ring sideroblasts and thrombocytosis; RS+=with ring sideroblasts; RS-= without ring sideroblasts; SF3B1= Splicing Factor 3B Subunit 1A MDS mutation

<sup>a</sup> Age was calculated based on the informed consent signing date.

<sup>b</sup> After applying the 14/3-day rule (only Hb values that are measured at least 14 days after a transfusion may be used unless there is another transfusion within 3 days after the Hb assessment. If a transfusion within 3 days after the Hb assessment occurs, that Hb value will be used despite being < 14 days after the previous transfusion), the baseline Hb value (efficacy) is defined as the lowest Hb value from the central, or local laboratory, or pre-transfusion Hb from transfusion records that is within the 35 days prior to the first dose of study drug, if it was available.

<sup>c</sup> The number of months from the date of original diagnosis to the date of informed consent.

<sup>d</sup> Baseline EPO was defined as the highest EPO value within the 35 days preceding the first dose of study drug.

<sup>e</sup> Collected over 8 weeks prior to randomisation.

The efficacy results are summarised below.

**Table 9: Efficacy results in MDS patients in ACE-536-MDS-002**

<b>Endpoint</b>	<b>Luspatercept (N=182)</b>	<b>Epoetin alfa (N=181)</b>
<b>Primary endpoint</b>		
<b>• RBC-TI for 12 weeks with associated concurrent mean Hb increase of <math>\geq 1.5</math> g/dL (Weeks 1-24)</b>		
Number of responders (response rate %) (95% CI)	110 (60.4) (52.9, 67.6)	63 (34.8) (27.9, 42.2)
Common Risk Difference (95% CI) <sup>a</sup>	25.4 (15.8, 35.0)	
p-value	<0.0001	
Odds Ratio (95% CI) <sup>a</sup>	3.1 (2.0, 4.8)	
<b>Secondary endpoints</b>		
<b>• HI-E per IWG <math>\geq 8</math> weeks (Weeks 1-24)<sup>b</sup></b>		
Number of responders (response rate %) (95% CI)	135 (74.2) (67.2, 80.4)	96 (53.0) (45.5, 60.5)
Common Risk Difference (95% CI) <sup>a</sup>	21.5 (12.2, 30.7)	

p-value	<0.0001	
Odds Ratio (95% CI) <sup>a</sup>	2.8 (1.8, 4.5)	
<b>• RBC-TI for 24 weeks (Weeks 1-24)</b>		
Number of responders (response rate %) (95% CI)	87 (47.8) (40.4, 55.3)	56 (30.9) (24.3, 38.2)
Common Risk Difference (95% CI) <sup>a</sup>	16.3 (7.1, 25.4)	
p-value	0.0003	
Odds Ratio (95% CI) <sup>a</sup>	2.3 (1.4, 3.7)	
<b>• RBC-TI for ≥24 weeks (Weeks 1-48)</b>		
	163	167
Number of responders (response rate %) (95% CI)	99 (60.7) (52.8, 68.3)	66 (39.5) (32.1, 47.4)
Common Risk Difference (95% CI) <sup>a</sup>	20.7 (10.8, 30.6)	
p-value	p <0.0001 <sup>c</sup>	
Odds Ratio (95% CI) <sup>a</sup>	2.6 (1.6, 4.3)	

Hb=haemoglobin; RBC = red blood transfusion

<sup>a</sup>Based on CMH test stratified by baseline RBC transfusion burden (< 4, ≥ 4 pRBC units), RS status (RS+, RS-) and sEPO level (≤ 200, > 200 U/L). 1-sided p-value is presented.

<sup>b</sup>HI-E = haematological improvement – erythroid. The proportion of patients meeting the HI-E criteria as per International Working Group (IWG) 2006 criteria sustained over a consecutive 56-day period during the indicated treatment period. For patients with baseline RBC transfusion burden of ≥ 4 units/8 weeks, HI-E was defined as a reduction in RBC transfusion of at least 4 units/8 weeks. For patients with baseline RBC transfusion burden of < 4 units/8 weeks, HI-E was defined as a mean increase in Hb of ≥ 1.5 g/dL for 8 weeks in the absence of RBC transfusions.

<sup>c</sup>Nominal p-value

The treatment effect of luspatercept on RBC-TI ≥12 weeks and Hb increase of ≥1.5 g/dL was higher than epoetin alfa across all clinically relevant baseline demographic and most disease characteristic subgroups, except in patients without ring sideroblasts, where the treatment effect of luspatercept was comparable to epoetin alfa.

*Myelodysplastic syndromes in ESA-refractory or -intolerant patients* The efficacy and safety of luspatercept were evaluated in a Phase 3 multicentre, randomised, double-blind, placebo-controlled study MEDALIST (ACE-536-MDS-001) in adult patients with anaemia requiring RBC transfusions (≥ 2 units/8 weeks) due to International Prognostic Scoring System-Revised (IPSS-R) very low-, low- or intermediate-risk MDS who have ring sideroblasts (≥ 15%). Patients were required to have either received prior treatment with an erythropoiesis- stimulating agent (ESA) with inadequate response, to be ineligible for ESAs (determined to be unlikely to respond to ESA treatment with serum erythropoietin (EPO) > 200 U/L), or intolerant to ESA treatment. Patients with deletion 5q (del15q) MDS, without ring sideroblasts (RS-), white blood cell count >13 x 10<sup>9</sup>/L, neutrophils < 0.5 x 10<sup>9</sup> /L, platelets <50 x 10<sup>9</sup>/L or with prior use of a disease modifying agent for treatment of MDS were excluded from the study.

Patients in both arms were treated for 24 weeks, then continued treatment if they had demonstrated clinical benefit and absence of disease progression. The study was unblinded for analyses when all patients had at least received 48 weeks of treatment or discontinued treatment.

A total of 229 patients were randomised to receive luspatercept 1.0 mg/kg (n=153) or placebo (n=76) subcutaneously every 3 weeks. A total of 128 (83.7%) and 68 (89.5%) patients receiving luspatercept and placebo respectively completed 24 weeks of treatment. A total of 78 (51%) and 12 (15.8%) patients receiving luspatercept and placebo respectively completed 48 weeks of treatment. Dose titration up to 1.75 mg/kg was allowed. Dose could be delayed or reduced depending upon Hb level. All patients were eligible to receive best supportive care (BSC), which included RBC transfusions, iron-chelating agents, use of antibiotic, antiviral and antifungal therapy, and nutritional support, as needed. The key baseline disease characteristics in patients with MDS study in ACE-536-MDS-001 are shown in Table 10.

**Table 10. Baseline characteristics in MDS patients with <5% marrow blasts in study ACE-536-MDS- 001**

	<b>Luspatercept (N=153)</b>	<b>Placebo (N=76)</b>
<b>Demographics</b>		
<b>Age<sup>a</sup> (years)</b> Median (min, max)	71 (40, 95)	72 (26, 91)
<b>Age categories, n (%)</b>		
≤64 years	29 (19.0)	16 (21.1)
65-74 years	72 (47.1)	29 (38.2)
≥75	52 (34.0)	31 (40.8)
<b>Sex, n (%)</b>		
Male	94 (61.4)	50 (65.8)
Female	59 (38.6)	26 (34.2)
<b>Race, n (%)</b>		
Black	1 (0.7)	0 (0.0)
White	107 (69.9)	51 (67.1)
Not collected or reported	44 (28.8)	24 (31.6)
Other	1 (0.7)	1 (1.3)
<b>Disease characteristics</b>		
<b>Serum EPO (U/L) categories<sup>b</sup>, n (%)</b>		
< 200	88 (57.5)	50 (65.8)
200 to 500	43 (28.1)	15 (19.7)
> 500	21 (13.7)	11 (14.5)
Missing	1 (0.7)	0

	<b>Luspatercept (N=153)</b>	<b>Placebo (N=76)</b>
<b>Serum ferritin (µg/L)</b> Median (min,max)	1089.2 (64, 5968)	1122.1 (165, 5849)
<b>IPSS-R classification risk category, n (%)</b>		
Very low	18 (11.8)	6 (7.9)
Low	109 (71.2)	57 (75.0)
Intermediate	25 (16.3)	13 (17.1)
Other	1 (0.7)	0
<b>Baseline RBC Transfusion burden/ 8 weeks<sup>c</sup>, n (%)</b>		
≥ 6 units	66 (43.1)	33 (43.4)
≥ 6 and < 8 units	35 (22.9)	15 (20.2)
≥ 8 and < 12 units	24 (15.7)	17 (22.4)
≥ 12 units	7 (4.6)	1 (1.3)
< 6 units	87 (56.9)	43 (56.6)
≥ 4 and < 6 units	41 (26.8)	23 (30.3)
< 4 units	46 (30.1)	20 (26.3)
<b>Hb<sup>d</sup> (g/dL)</b> Median (min, max)	7.6 (6, 10)	7.6 (5, 9)
<b>SF3B1, n (%)</b>		
Mutated	149 (92.2)	65 (85.5)
Unmutated	12 (7.8)	10 (13.2)
Missing	0	1 (1.3)

EPO=erythropoietin; Hb=haemoglobin; IPSS-R=International Prognostic Scoring System-Revised

<sup>a</sup> Time since original MDS diagnosis was defined as the number of years from the date of original diagnosis to the date of informed consent.

<sup>b</sup> Baseline EPO was defined as the highest EPO value within 35 days of the first dose of study drug.

<sup>c</sup> Collected over 16 weeks prior to randomisation.

<sup>d</sup> Baseline Hb was defined as the last value measured on or before the date of the first dose of investigational product (IP). After applying the 14/3 day rule, baseline Hb was defined as the lowest Hb value that was within 35 days on or prior

to the first dose of IP.

The efficacy results are summarised below.

**Table 11. Efficacy results in patients with MDS in study ACE-536-MDS-001**

Endpoint	Luspatercept (N=153)	Placebo (N=76)
<b>Primary endpoint</b>		
• <b>RBC-TI ≥ 8 weeks (Weeks 1-24)</b> Number of responders (response rate %)	58 (37.9)	10 (13.2)
• Common risk difference on response rate (95% CI)	24.56 (14.48, 34.64)	
Odds ratio (95% CI) <sup>a</sup>	5.065 (2.278, 11.259)	
p-value <sup>a</sup>	< 0.0001	
<b>Secondary endpoints</b>		
• <b>RBC-TI ≥ 12 weeks (Weeks 1-24)</b> Number of responders (response rate %)	43 (28.1)	6 (7.9)
• Common risk difference on response rate (95% CI)	20.00 (10.92, 29.08)	
Odds ratio (95% CI) <sup>a</sup>	5.071 (2.002, 12.844)	
p-value <sup>a</sup>	0.0002	
• <b>RBC-TI ≥ 12 weeks (Weeks 1-48)</b> Number of responders (response rate %) <sup>b</sup>	51 (33.3)	9 (11.8)
• Common risk difference on response rate (95% CI)	21.37 (11.23, 31.51)	
Odds ratio (95% CI) <sup>a</sup>	4.045 (1.827, 8.956)	
p-value <sup>a</sup>	0.0003	

Endpoint	Luspatercept (N=153)	Placebo (N=76)
<b>Transfusion event frequency<sup>c</sup></b>		
• <b>Weeks 1-24</b> Interval transfusion rate (95% CI)	6.26 (5.56, 7.05)	9.20 (7.98, 10.60)
Relative risk vs. placebo	0.68 (0.58, 0.80)	
• <b>Weeks 25-48</b> Interval transfusion rate (95% CI)	6.27 (5.47, 7.19)	8.72 (7.40, 10.28)
Relative risk vs. placebo	0.72 (0.60, 0.86)	
<b>RBC Transfusion units<sup>c</sup></b>		
• <b>Weeks 1-24</b> Baseline transfusion burden <6 units/8 weeks		
LS Mean (SE)	7.2 (0.58)	12.8 (0.82)
95% CI for LS mean	6.0, 8.3	11.1, 14.4
LS mean difference (SE) (luspatercept vs. placebo) 95% CI for LS mean difference	-5.6 (1.01) -7.6, -3.6	
Baseline transfusion burden ≥6 units/8 weeks		
LS Mean (SE)	18.9(0.93)	23.7(1.32)
95% CI for LS mean	17.1, 20.8	21.1, 26.4
LS mean difference (SE) (luspatercept vs. placebo) 95% CI for LS mean difference	-4.8 (1.62) -8.0, -1.6	
• <b>Weeks 25-48</b> Baseline transfusion burden <6 units/8 weeks		
LS Mean (SE)	7.5 (0.57)	11.8(0.82)
95% CI for LS mean	6.3, 8.6	10.1, 13.4
LS mean difference (SE) (luspatercept vs. placebo) 95% CI for LS mean difference	-4.3 (1.00) -6.3, -2.3	

Baseline transfusion burden $\geq 6$ units/8 weeks		
LS Mean (SE)	19.6(1.13)	22.9(1.60)
95% CI for LS mean	17.4, 21.9	19.7, 26.0
LS mean difference (SE) (luspatercept vs. placebo) 95% CI for LS mean difference	-3.3(1.96) -7.1, 0.6	

RBC-TI: RBC Transfusion Independent; CI: confidence interval; CMH = Cochran-Mantel-Haenszel;

<sup>a</sup> CMH test stratified for average baseline transfusion burden ( $\geq 6$  units *versus*  $< 6$  units per 8 weeks), and baseline IPSS-R score (very low or low vs. intermediate).

<sup>b</sup> After the Week 25 disease assessment visit, patients who were no longer deriving benefit discontinued therapy; few placebo patients contributed data for evaluation at the later timepoint compared with luspatercept (n=12 vs. n=78 respectively).

<sup>c</sup> Post-hoc analysis using baseline imputation.

A treatment effect in favour of luspatercept over placebo was observed in most subgroups analysed using transfusion independence  $\geq 12$  weeks (during week 1 to week 24), including patients with high baseline endogenous EPO level (200-500 U/L) (23.3% vs. 0%, explorative analysis).

Only limited data are available for the group with transfusion burden of  $\geq 8$  units/8 weeks. Safety and efficacy have not been established in patients with a transfusion burden of  $> 12$  units/8 weeks.

*Exploratory findings*

**Table 12. Exploratory efficacy results in patients with MDS in study ACE-536-MDS-001**

Endpoint	Luspatercept (N=153)	Placebo (N=76)
<b>mHI-E<sup>a</sup></b>		
• <b>Weeks 1-24</b>		
Number of responders (response rate %)	81 (52.9)	9 (11.8)
(95% CI)	(44.72, 61.05)	(5.56, 21.29)
RBC transfusion reduction of 4 units/8 weeks, n (%)	52/107 (48.6)	8/56 (14.3)
Mean Hb increase of $\geq 1.5$ g/dL for 8 weeks, n (%)	29/46 (63.0)	1/20 (5.0)
• <b>Weeks 1-48</b>		
Number of responders (response rate %)	90 (58.8)	13 (17.1)
(95% CI)	(50.59, 66.71)	(9.43, 27.47)
RBC transfusion reduction of 4 units/8 weeks, n (%)	58/107 (54.2)	12/56 (21.4)
Mean Hb increase of $\geq 1.5$ g/dL for 8 weeks, n (%)	32/46 (69.6)	1/20 (5.0)
<b>Mean change from baseline in mean serum ferritin with imputation by baseline (ITT population)</b>		
Mean change from baseline in mean serum ferritin averaged over Weeks 9 through 24 ( $\mu\text{g/L}$ ) <sup>b</sup>		
LS Mean (SE)	9.9 (47.09)	190.0 (60.30)
95% CI for LS Mean	-82.9, 102.7	71.2, 308.8
Treatment comparison (luspatercept vs. placebo) <sup>c</sup>		
LS mean difference (SE)	-180.1 (65.81)	
95% CI for LS mean difference	-309.8, -50.4	

Hb=haemoglobin

<sup>a</sup> mHI-E = modified haematological improvement – erythroid. The proportion of patients meeting the HI-E criteria as per International Working Group (IWG) 2006 criteria sustained over a consecutive 56-day period during the indicated treatment period. For patients with baseline RBC transfusion burden of  $\geq 4$  units/8 weeks, mHI-E was defined as a reduction in RBC transfusion of at least 4 units/8 weeks. For patients with baseline RBC transfusion burden of  $< 4$  units/8 weeks, mHI-E was defined as a mean increase in Hb of  $\geq 1.5$  g/dL for 8 weeks in the absence of RBC transfusions.

<sup>b</sup> If a subject did not have a serum ferritin value within the designated postbaseline interval, the serum ferritin is imputed from the baseline value.

<sup>c</sup> Analysis of covariance was used to compare the treatment difference between groups (including nominal p-value), with the change in serum ferritin as the dependent variable, treatment group (2 levels) as a factor, and baseline serum ferritin value as covariates, stratified by average baseline RBC transfusion requirement ( $\geq 6$  units vs.  $< 6$  units of RBC per 8 weeks), and baseline IPSS-R (very low or low vs. intermediate).

The median duration of the longest RBC Transfusion Independent (RBC-TI) period among responders in the luspatercept treatment arm was 30.6 weeks.

A total of 62.1% (36/58) of the luspatercept responders who achieved RBC-TI  $\geq 8$  weeks from Weeks 1-24 had 2 or more episodes of RBC-TI at the time of analysis.

*Transfusion-dependent  $\beta$ -thalassaemia*

The efficacy and safety of luspatercept were evaluated in a Phase 3 multicentre, randomised, double-blind, placebo-controlled study BELIEVE (ACE-536-B-THAL-001) in adult patients with transfusion-dependent  $\beta$ -thalassaemia-associated anaemia who require RBC transfusions (6-20 RBC units/24 weeks) with no transfusion-free period  $> 35$  days during that period.

Patients in both the luspatercept and placebo arms were treated for at least 48 and up to 96 weeks. After unblinding, placebo patients were able to cross-over to luspatercept.

A total of 336 adult patients were randomised to receive luspatercept 1.0 mg/kg (n=224) or placebo (n=112) subcutaneously every 3 weeks. Dose titration to 1.25 mg/kg was allowed. Dose could be delayed or reduced depending upon Hb level. All patients were eligible to receive BSC, which

included RBC transfusions, iron-chelating agents, use of antibiotic, antiviral and antifungal therapy, and nutritional support, as needed. The study excluded patients with Hb S/ $\beta$ -thalassaemia or alpha ( $\alpha$ )-thalassaemia or who had major organ damage (liver disease, heart disease, lung disease, renal insufficiency). Patients with recent DVT or stroke or recent use of ESA, immunosuppressant or hydroxyurea therapy were also excluded. The key baseline disease characteristics in patients with  $\beta$ -thalassaemia in study ACE-536-B-THAL-001 are shown in Table 13.

**Table 13. Baseline characteristics in patients with transfusion-dependent  $\beta$ -thalassaemia in study ACE-536-B-THAL-001**

	<b>Luspatercept (N=224)</b>	<b>Placebo (N=112)</b>
<b>Demographics</b>		
<b>Age (years)</b> Median (min, max)	30.0 (18, 66)	30.0 (18, 59)
<b>Age categories, n (%)</b>		
≤ 32	129 (57.6)	63 (56.3)
> 32 to ≤ 50	78 (34.8)	44 (39.3)
> 50	17 (7.6)	5 (4.5)
<b>Sex, n (%)</b>		
Male	92 (41.1)	49 (43.8)
Female	132 (58.9)	63 (56.3)
<b>Race, n (%)</b>		
Asian	81 (36.2)	36 (32.1)
Black	1 (0.4)	0
White	122 (54.5)	60 (53.6)
Not collected or reported	5 (2.2)	5 (4.5)
Other	15 (6.7)	11 (9.8)
<b>Disease characteristics</b>		
<b>Pretransfusion Hb threshold<sup>a</sup>, 12 week run-in (g/dL)</b> Median (min, max)	9.30 (4.6, 11.4)	9.14 (6.2, 11.5)
<b>Baseline transfusion burden 12 weeks</b> Median (min, max) (units/12 weeks) (Week -12 to Day 1)	6.12 (3.0, 14.0)	6.27 (3.0, 12.0)
<b><math>\beta</math>-thalassaemia gene mutation grouping, n (%)</b>		
$\beta$ 0/ $\beta$ 0	68 (30.4)	35 (31.3)
Non- $\beta$ 0/ $\beta$ 0	155 (69.2)	77 (68.8)
Missing <sup>b</sup>	1 (0.4)	0

<sup>a</sup>The 12-week pretransfusion threshold was defined as the mean of all documented pretransfusions Hb values for a subject during the 12 weeks prior to Cycle 1 Day 1.

<sup>b</sup>"Missing" category includes patients in the population who had no result for the parameter listed.

The study was unblinded for analyses when all patients had at least received 48 weeks of treatment or discontinued treatment.

The efficacy results are summarised below.

**Table 14. Efficacy results in patients with transfusion-dependent  $\beta$ -thalassaemia in study ACE-536-B-THAL-001**

<b>Endpoint</b>	<b>Luspatercept (N=224)</b>	<b>Placebo (N=112)</b>
<b>Primary endpoint</b>		
<b>≥ 33% reduction from baseline in RBC transfusion burden with a reduction of at least 2 units for 12 consecutive weeks compared to the 12-week interval prior to treatment</b>		

<b>Primary endpoint – Weeks 13-24</b>	47 (21.0)	5 (4.5)
Difference in proportions (95% CI) <sup>a</sup>	16.5 (10.0, 23.1)	
p-value <sup>b</sup>	< 0.0001	
<i>Secondary endpoints</i>		
<b>Weeks 37-48</b>	44 (19.6)	4 (3.6)
Difference in proportions (95% CI) <sup>a</sup>	16.1 (9.8, 22.3)	
p-value <sup>b</sup>	< 0.0001	
<b>≥ 50% reduction from baseline in RBC transfusion burden with a reduction of at least 2 units for 12 consecutive weeks compared to the 12-week interval prior to treatment</b>		
<b>Weeks 13-24</b>	16 (7.1)	2 (1.8)
Difference in proportions (95% CI) <sup>a</sup>	5.4 (1.2, 9.5)	
p-value <sup>b</sup>	0.0402	
<b>Weeks 37-48</b>	23 (10.3)	1 (0.9)
Difference in proportions (95% CI) <sup>a</sup>	9.4 (5.0, 13.7)	
p-value <sup>b</sup>	0.0017	

CI: confidence interval.

<sup>a</sup> Difference in proportions (luspatercept + BSC – placebo + BSC) and 95% CIs estimated from the unconditional exact test.

<sup>b</sup> P-value from the Cochran Mantel-Haenszel test stratified by the geographical region.

### Exploratory findings

**Table 15. Exploratory efficacy results in patients with transfusion-dependent  $\beta$ -thalassaemia in study ACE-536-B-THAL-001**

Endpoint	Luspatercept (N=224)	Placebo (N=112)
<b><math>\geq 33\%</math> reduction from baseline in RBC transfusion burden with a reduction of at least 2 units for 12 consecutive weeks compared to the 12-week interval prior to treatment</b>		
Any consecutive 12 weeks*	173 (77.2)	39 (34.8)
Difference in proportions (95% CI) <sup>a</sup>	42.4 (31.5, 52.5)	
Any consecutive 24 weeks*	116 (51.8)	3 (2.7)
Difference in proportions (95% CI) <sup>a</sup>	49.1 (41.3, 56.2)	
<b><math>\geq 50\%</math> reduction from baseline in RBC transfusion burden with a reduction of at least 2 units for 12 consecutive weeks compared to the 12-week interval prior to treatment</b>		
Any consecutive 12 weeks*	112 (50.0)	9 (8.0)
Difference in proportions (95% CI) <sup>a</sup>	42.0 (32.7, 49.9)	
Any consecutive 24 weeks*	53 (23.7)	1 (0.9)
Difference in proportions (95% CI) <sup>a</sup>	22.8 (16.5, 29.1)	
<b>Least square (LS) mean change from baseline in transfusion burden (RBC units/48 weeks)</b>		
<b>Weeks 1 to Week 48</b>		
LS mean	-4.69	+1.17
LS mean of difference (luspatercept-placebo) (95% CI) <sup>b</sup>	5.86(-7.04, -4.68)	
<b>Weeks 49 to Week 96</b>		
LS mean	-5.43	+1.80
LS mean of difference (luspatercept-placebo) (95% CI) <sup>b</sup>	-7.23 (-13.84, -0.62)	

ANCOVA = analysis of covariance; CI: confidence interval.

<sup>a</sup> Difference in proportions (luspatercept + BSC – placebo + BSC) and 95% CIs estimated from the unconditional exact test.

<sup>b</sup> Estimates are based on ANCOVA model with geographical regions and baseline transfusion burden as covariates

\*Placebo patients are assessed up to prior to crossing over to luspatercept. For the rolling analyses at any consecutive 12 / 24 weeks, luspatercept treatment arm does not include placebo patients who crossed over to luspatercept.

A reduction in mean serum ferritin levels was observed from baseline in the luspatercept arm compared to an increase in the placebo arm at Week 48 (-235.56  $\mu\text{g/L}$  vs. +107.03  $\mu\text{g/L}$  which resulted in a least square mean treatment difference of -342.59  $\mu\text{g/L}$  (95% CI: -498.30, -186.87).

85% (147/173) of luspatercept responders who achieved at least a 33% reduction in transfusion burden during any consecutive 12-week interval achieved 2 or more episodes of response at the time of analysis.

### *Non-transfusion-dependent $\beta$ -thalassaemia*

The efficacy and safety of luspatercept were evaluated in a Phase 2 multicentre, randomised, double-blind, placebo-controlled study BEYOND (ACE-536-B-THAL-002) in adult patients with non-transfusion-dependent  $\beta$ -thalassaemia-associated anaemia (Hb concentration  $\leq 10$  g/dL).

A total of 145 adult patients receiving RBC transfusions (0-5 RBC units in the 24-week period prior to randomization), with a baseline Hb level  $\leq 10.0$  g/dL (defined as average of at least 2 Hb measurements  $\geq 1$  week apart within 4 weeks prior to randomization) were randomized to receive luspatercept (n=96) or placebo (n=49) subcutaneously every 3 weeks. Patients were stratified at randomization based on their baseline Hb level and their non-transfusion-dependent  $\beta$ -thalassaemia (NTDT) patient-reported outcome (PRO; NTDT-PRO) Tiredness/Weakness (T/W) weekly domain score. Dose titration to 1.25 mg/kg was allowed. Dose could be delayed or reduced depending upon Hb level. Overall, 53% of luspatercept

patients (n=51) and 92% of patients on placebo (n=45) had their dose increased to 1.25 mg/kg within the 48-week treatment period. Among patients receiving luspatercept, 96% were exposed for 6 months or longer and 86% were exposed for 12 months or longer. A total of 89 (92.7%) patients receiving luspatercept and 35 (71.4%) patients receiving placebo completed 48 weeks of treatment.

All patients were eligible to receive BSC, which included RBC transfusions, iron-chelating agents, use of antibiotic, antiviral, and antifungal therapy, and nutritional support, as needed. Concurrent treatment for anemia with blood transfusions was allowed, at the discretion of the physician, for low haemoglobin levels, symptoms associated with anemia (eg, haemodynamic or pulmonary compromise requiring treatment) or comorbidities. The study excluded patients with Hb S/ $\beta$ -thalassaemia or alpha ( $\alpha$ )-thalassaemia or who had major organ damage (liver disease, heart disease, lung disease, renal insufficiency), active hepatitis C or B, or HIV. Patients with recent DVT or stroke or recent use of ESA, immunosuppressant or hydroxyurea therapy, or on chronic anticoagulant or uncontrolled hypertension were also excluded. Only a limited number of patients with comorbidities associated with underlying anemia such as pulmonary hypertension, liver and kidney disease and diabetes were included in the study.

The key baseline disease characteristics in the Intention-To-Treat (ITT) population with non-transfusion-dependent  $\beta$ -thalassaemia in study ACE-536-B-THAL-002 are shown in Table 16.

**Table 16. Baseline characteristics in patients with non-transfusion-dependent  $\beta$ -thalassaemia in study ACE-536-B-THAL-002**

	ITT population	
	Luspatercept (N=96)	Placebo (N=49)
<b>Demographics</b>		
<b>Age (years)</b>		
Median (min, max)	39.5 (18, 71)	41 (19, 66)
<b>Sex, n (%)</b>		
Male	40 (41.7)	23 (46.9)
Female	56 (58.3)	26 (53.1)
<b>Race, n (%)</b>		
Asian	31 (32.3)	13 (26.5)
White	59 (61.5)	28 (57.1)
Other	6 (6.3)	8 (16.3)
<b>Disease characteristics</b>		
<b><math>\beta</math>-thalassaemia diagnosis, n (%)</b>		
$\beta$ -thalassaemia	63 (65.6)	34 (69.4)
HbE/ $\beta$ -thalassaemia	28 (29.2)	11 (22.4)
$\beta$ -thalassaemia combined with $\alpha$ -thalassaemia	5 (5.2)	4 (8.2)
<b>Baseline Hb level<sup>a</sup> (g/dL)</b>		
Median (min, max)	8.2 (5.3, 10.1)	8.1 (5.7, 10.1)
<b>Patients with mean baseline Hb level<sup>a</sup> category (g/dL), n (%)</b>		
< 8.5	55 (57.3)	29 (59.2)
<b>Baseline NTDT-PRO T/W domain score<sup>b</sup>, n (%)</b>		
Median (min, max)	4.3 (0, 9.5)	4.1 (0.4, 9.5)

	ITT population	
	Luspatercept (N=96)	Placebo (N=49)
<b>Baseline NTDT-PRO T/W domain score<sup>b</sup> category, n (%)</b> ≥ 3	66 (68.8)	35 (71.4)
<b>Baseline transfusion burden (units/24 weeks)</b> Median (min, max)	0 (0, 4)	0 (0, 4)
<b>Splenectomy, n (%)</b> Yes	34 (35.4)	26 (53.1)
<b>MRI LIC (mg/g dw)<sup>c</sup>, n</b> Median (min, max)	95 3.9 (0.8, 39.9)	47 4.1 (0.7, 28.7)
<b>MRI spleen volume (cm<sup>3</sup>), n</b> Median (min, max)	60 879.9 (276.1, 2419.0)	22 1077.0 (276.5, 2243.0)
<b>Baseline use of ICT, n (%)</b>	28 (29.2)	16 (32.7)
<b>Baseline serum ferritin (µg/L)<sup>d</sup></b> Median (min, max)	456.5 (30.0, 3528.0)	360.0 (40.0, 2265.0)

Hb = haemoglobin; HbE = haemoglobin E; ICT = Iron Chelation Therapy; LIC = liver iron concentration; max = maximum; min = minimum; MRI = magnetic resonance imaging; NTDT-PRO T/W = non-transfusion-dependent β-thalassaemia patient-reported outcome tiredness and weakness domain score;

<sup>a</sup> Mean of at least 2 Hb values by the central laboratory during the 28-day screening period.

<sup>b</sup> Baseline defined as the average of non-missing NTDT-PRO T/W domain score over 7 days before Dose 1 Day 1.

<sup>c</sup> The value of LIC was either the value collected from the electronic Case Report Form (eCRF) or the value derived from T2\*, R2\*, or R2 parameter depending on which techniques and software were used for MRI LIC acquisition.

<sup>d</sup> Baseline mean serum ferritin was calculated during the 24 weeks on or prior to Dose 1 Day 1. Baseline ICT was calculated during the 24 weeks on or prior to Dose 1 Day 1.

The efficacy results are summarised below.

**Table 17. Efficacy results in patients with non-transfusion-dependent β-thalassaemia in study ACE-536-B-THAL-002**

	ITT population	
Endpoint	Luspatercept (N=96)	Placebo (N=49)
<b>Primary endpoint</b>		
<b>Increase from baseline ≥1.0 g/dL in mean Hb over continuous 12-week interval (in absence of transfusions)</b>		
<b>• Week 13-24</b> Response rate <sup>a</sup> , n [(%) (95% CI)] <sup>b</sup>	74 [(77.1) (67.4, 85.0)]	0.0 [(0.0) (0.0, 7.3)]
p-value <sup>c</sup>	< 0.0001	

CI = confidence interval; Hb = haemoglobin

<sup>a</sup> Defined as number of patients with ≥ 1.0 g/dL Hb increase in the absence of RBC transfusion compared to baseline (i.e. the average of ≥2 Hb measurements at ≥ 1 week apart within 4 weeks before Dose 1 Day 1).

<sup>b</sup> The 95% CI for response rate (%) was estimated from the Clopper-Pearson exact test.

<sup>c</sup> The odds ratio (luspatercept vs. placebo) with 95% CI and p-value were estimated from the CMH test stratified by baseline Hb category (<8.5 vs. ≥ 8.5 g/dL) and baseline NTDT-PRO T/W domain score category (≥ 3 vs. < 3) defined at randomization as covariates.

Note: Patients with missing Hb at Week 13-24 were classified as non-responders in the analysis.

A total of 77.1% of luspatercept treated patients achieved an increase from baseline  $\geq 1.0$  g/dL in mean Hb over continuous 12-week interval (in absence of transfusions) (Week 13-24). This effect was maintained in the 57.3% of patients who reached Week 144 of treatment.

### Paediatric population

The safety and efficacy of luspatercept in pediatric or adolescent patients (under 18 years of age) has not been established.

## **5.2 Pharmacokinetic properties**

### Absorption

In healthy volunteers and patients, luspatercept is slowly absorbed following subcutaneous administration, with the  $C_{max}$  in serum often observed approximately 7 days post-dose across all dose levels. Population pharmacokinetic (PK) analysis suggests that the absorption of luspatercept into the circulation is linear over the range of studied doses, and the absorption is not significantly affected by the subcutaneous injection location (upper arm, thigh or abdomen). Interindividual variability in AUC was approximately 37% in both  $\beta$ -thalassaemia and MDS patients.

### Distribution

At the recommended doses, the geometric mean apparent volume of distribution was 9.56 L for MDS patients and 7.26 L for  $\beta$ -thalassaemia patients. The small volume of distribution indicates that luspatercept is confined primarily in extracellular fluids, consistent with its large molecular mass.

### Biotransformation

Luspatercept is expected to be catabolised into amino acids by general protein degradation process.

### Elimination

Luspatercept is not expected to be excreted into urine due to its large molecular mass that is above the glomerular filtration size exclusion threshold. At the recommended doses, the geometric mean apparent total clearance was 0.47 L/day for MDS patients and 0.44 L/day for  $\beta$ -thalassaemia. The geometric mean half-lives in serum were approximately 14.1 days for MDS patients and 11 days for  $\beta$ -thalassaemia patients.

### Linearity/non-linearity

The increase of luspatercept  $C_{max}$  and AUC in serum is approximately proportional to increases in dose from 0.125 to 1.75 mg/kg. Luspatercept clearance was independent of dose or time.

When administered every three weeks, luspatercept serum concentration reaches the steady state after 3 doses, with an accumulation ratio of approximately 1.5.

### Hb response

In patients who received  $< 4$  units of RBC transfusion within 8 weeks prior to the study, Hb increased within 7 days of treatment initiation and the increase correlated with the time to reach luspatercept  $C_{max}$ . The greatest mean Hb increase was observed after the first dose, with additional smaller increases observed after subsequent doses. Hb levels returned to baseline value approximately 6 to 8 weeks from the last dose (0.6 to 1.75 mg/kg). Increasing luspatercept serum exposure (AUC) was associated with a greater Hb increase in patients with ESA refractory or -intolerant MDS or  $\beta$ -thalassaemia.

In non-transfusion-dependent  $\beta$ -thalassaemia patients who had a baseline transfusion burden of 0 to 5 units within 24 weeks, increasing luspatercept serum exposure (time-averaged AUC) was associated with a greater probability of achieving a Hb increase ( $\geq 1$  g/dL or  $\geq 1.5$  g/dL) and a longer duration of such Hb increases. The luspatercept serum concentration achieving 50% of the maximum stimulatory effect on Hb production was estimated to be 7.6  $\mu$ g/mL.

## Special populations

### *Elderly*

Population PK analysis for luspatercept included patients with ages ranging from 27 to 95 and 18 to 71 years old, for MDS and  $\beta$ -thalassaemia patients, respectively, with a median age of 72.5 years for MDS patients and of 33 years for  $\beta$ -thalassaemia patients. No clinically significant difference in AUC or clearance was found across age groups in MDS patients ( $\leq 64$ , 65-74, and  $\geq 75$  years) or in  $\beta$ -thalassaemia patients (18 to 71 years).

### *Hepatic impairment*

Population PK analysis for luspatercept included patients with normal hepatic function (BIL, ALT, and AST  $\leq$  ULN; N = 62 for  $\beta$ -thalassaemia patients and N=311 for MDS patients), mild hepatic impairment (BIL  $> 1 - 1.5 \times$  ULN, and ALT or AST  $>$  ULN; N = 89 for  $\beta$ -thalassaemia patients and N=126 for MDS patients), moderate hepatic impairment (BIL  $> 1.5 - 3 \times$  ULN, any ALT or AST; N = 157 for  $\beta$ -thalassaemia patients and N= 32 for MDS patients), or severe hepatic impairment (BIL  $> 3 \times$  ULN, any ALT or AST; N = 73 for  $\beta$ -thalassaemia patients and N=1 for MDS patients) as defined by the National Cancer Institute criteria of hepatic dysfunction. Effects of hepatic function categories, elevated liver enzymes (ALT or AST, up to  $3 \times$  ULN) and elevated total BIL (4 – 246  $\mu\text{mol/L}$ ) on luspatercept clearance were not observed. No clinically significant difference in mean steady state  $C_{\text{max}}$  and AUC was found across hepatic function groups. PK data are insufficient for patients with liver enzymes (ALT or AST)  $\geq 3 \times$  ULN. No PK data are available for patients with liver cirrhosis (Child-Pugh Classes A, B and C) as no dedicated study was performed.

### *Renal impairment*

Population PK analysis for luspatercept included patients with normal renal function (individual eGFR  $\geq 90$  mL/min; N = 302 for  $\beta$ -thalassaemia patients and N= 169 for MDS patients), mild renal impairment (individual eGFR 60 to 89 mL/min; N = 171), or moderate renal impairment (eGFR 30 to 59 mL/min/ $1.73 \text{ m}^2$ ; N = 4 for  $\beta$ -thalassaemia patients and N = 88 for MDS patients) as defined by Modification of Diet in Renal Disease (MDRD) formula. Luspatercept serum exposure (AUC) was 24% to 41% higher in patients with mild to moderate renal impairment than in patients with normal renal function. PK data are insufficient for patients with severe renal impairment (individual eGFR  $< 30$  mL/min) or end-stage kidney disease.

### Other intrinsic factors

The following population characteristics have no clinically significant effect on luspatercept AUC or clearance: sex and race (Asian vs. White).

The following baseline disease characteristics had no clinically significant effect on luspatercept clearance: serum erythropoietin level (2.4 – 1680 U/L for  $\beta$ -thalassaemia patients and 7.80 – 2920 U/L for MDS patients), RBC transfusion burden (0 – 43.4 units/24 weeks), MDS ring sideroblasts,  $\beta$ -thalassaemia genotype ( $\beta 0/\beta 0$  vs. non- $\beta 0/\beta 0$ ) and splenectomy.

The volume of distribution and clearance of luspatercept increased with increase of body weight (33 – 124 kg), supporting the body weight-based dosing regimen.

## **5.3 Preclinical safety data**

### Single and repeat-dose toxicity

Following repeated administration of luspatercept in rats, toxicities included: membranoproliferative glomerulonephritis; congestion, necrosis and/or mineralisation of the adrenal glands; hepatocellular vacuolation and necrosis; mineralisation of the glandular stomach; and decreased heart and lung weights with no associated histology findings. A clinical observation of swollen hindlimbs/feet was noted in several studies in rats and rabbits (including juvenile and reproductive toxicity studies). In one juvenile rat, this correlated histopathologically with new bone formation, fibrosis, and inflammation. Membranoproliferative glomerulonephritis was also seen in monkeys. Additional toxicities in monkeys included: vascular degeneration and inflammatory infiltrates in the choroid

plexus.

For the 6-month toxicity study, the longest duration study in monkeys, the no-observed-adverse-effect level (NOAEL) was 0.3 mg/kg (0.3-fold of clinical exposure at 1.75 mg/kg every 3 weeks). A NOAEL was not identified in rats and the lowest-observed-adverse-effect-level (LOAEL) in the rat 3-month study was 1 mg/kg (0.9-fold of clinical exposure at 1.75 mg/kg every 3 weeks).

#### Carcinogenesis and mutagenesis

Neither carcinogenicity nor mutagenicity studies with luspatercept have been conducted.

Haematological malignancies were observed in 3 out of 44 rats examined in the highest dose group (10 mg/kg) in the definitive juvenile toxicity study. The occurrence of these tumours in young animals is unusual and the relationship to luspatercept therapy cannot be ruled out. At the 10 mg/kg dose, at which tumours were observed, the exposure represents an exposure multiple of approximately 4 times the estimated exposure at a clinical dose of 1.75 mg/kg every three weeks.

No other proliferative or pre-neoplastic lesions, attributable to luspatercept, have been observed in any species in other non-clinical safety studies conducted with luspatercept, including the 6-month study in monkeys.

#### Fertility

In a fertility study in rats, administration of luspatercept to females at doses higher than the currently recommended highest human dose reduced the average number of corpora lutea, implantations and viable embryos. No such effects were observed when exposure in animals was at 1.5 times the clinical exposure. Effects on fertility in female rats were reversible after a 14-week recovery period.

Administration of luspatercept to male rats at doses higher than the currently recommended highest human dose had no adverse effect on male reproductive organs or on their ability to mate and produce viable embryos. The highest dose tested in male rats yielded an exposure approximately 7 times the clinical exposure.

#### Embryo-foetal development (EFD)

Embryo-foetal developmental toxicology studies (range-finding and definitive studies) were conducted in pregnant rats and rabbits. In the definitive studies, doses of up to 30 mg/kg or 40 mg/kg every week were administered twice during the period of organogenesis. Luspatercept was a selective developmental toxicant (dam not affected; foetus affected) in the rat and a maternal and foetal developmental toxicant (dam and foetus affected) in the rabbit. Embryofetal effects were seen in both species and included reductions in numbers of live foetuses and foetal body weights, increases in resorptions, post-implantation loss and skeletal variations and, in rabbit foetuses, malformations of the ribs and vertebrae. In both species, effects of luspatercept were observed in the EFD studies at the lowest dose tested, 5 mg/kg, which corresponds to an estimated exposure in rats and rabbits of approximately 2.7 and 5.5 times greater, respectively, than the estimated clinical exposure.

#### Pre- and post-natal development

In a pre- and post-natal development study, with dose levels of 3, 10, or 30 mg/kg administered once every 2 weeks from gestational day (GD) 6 through post-natal day (PND) 20, adverse findings at all doses consisted of lower F<sub>1</sub> pup body weights in both sexes at birth, throughout lactation, and post weaning (PND 28); lower body weights during the early pre-mating period (Weeks 1 and 2) in the F<sub>1</sub> females (adverse only at the 30 mg/kg/dose) and lower body weights in F<sub>1</sub> males during the pre-mating, pairing and post-mating periods; and microscopic kidney findings in F<sub>1</sub> pups. Additionally, non-adverse findings included delayed male sexual maturation at the 10 and 30 mg/kg/dose. The delay in growth and the adverse kidney findings, in the F<sub>1</sub> generation, precluded the determination of a NOAEL for F<sub>1</sub> general and developmental toxicity. However, there was no effect on behavioural indices, fertility or reproductive parameters at any dose level in either sex, therefore the NOAEL for behavioural assessments, fertility and reproductive function in the F<sub>1</sub> animals was considered to be the 30 mg/kg/dose. Luspatercept is transferred through the placenta of pregnant rats and rabbits and is excreted into the milk of lactating rats.

#### Juvenile toxicity

In a study in juvenile rats, luspatercept was administered from postnatal day (PND) 7 to PND 91 at 0, 1, 3, or 10 mg/kg. Many of the findings seen in repeat-dose toxicity studies in adult rats were repeated in the juvenile rats. These findings included glomerulonephritis in the kidney, haemorrhage/congestion, necrosis and mineralization of the adrenal gland, mucosal mineralization in the stomach, lower heart weights, and swollen hindlimbs/feet. Luspatercept-related findings unique to juvenile rats included tubular atrophy/hypoplasia of the kidney inner medulla, delays in the mean age of sexual maturation in males, effects on reproductive performance (lower mating indices), and non- adverse decreases in bone mineral density in both male and female rats. The effects on reproductive performance were observed after a greater than 3-month recovery period, suggesting a permanent effect. Although reversibility of the tubular atrophy/hypoplasia was not examined, these effects are also considered to be irreversible. Adverse effects on the kidney and reproductive system were observed at clinically relevant exposure levels and seen at the lowest dose tested and, thus, a NOAEL was not established. In addition, haematological malignancies were observed in 3 out of 44 rats examined in the highest dose group (10 mg/kg). These findings are all considered potential risks in paediatric patients.

## **6. PHARMACEUTICAL PARTICULARS**

### **6.1 List of excipients**

Citric acid monohydrate (E330)  
Sodium citrate (E331)  
Polysorbate 80  
Sucrose  
Hydrochloric acid (for pH adjustment)  
Sodium hydroxide (for pH adjustment)

### **6.2 Incompatibilities**

This medicinal product must not be mixed with other medicinal products except those mentioned in section 6.6.

### **6.3 Shelf life**

Unopened vial  
5 years.

#### After reconstitution

When stored in the original container, chemical and physical in-use stability of the reconstituted medicinal product has been demonstrated for up to 8 hours at room temperature ( $\leq 25^{\circ}\text{C}$ ) or for up to 24 hours at  $2^{\circ}\text{C} - 8^{\circ}\text{C}$ .

From a microbiological point of view, the medicinal product should be used immediately. If not used immediately, in-use storage times and conditions prior to use are the responsibility of the user and should not be longer than 24 hours at  $2^{\circ}\text{C} - 8^{\circ}\text{C}$ .

Do not freeze the reconstituted solution.

### **6.4 Special precautions for storage**

Store in a refrigerator ( $2^{\circ}\text{C} - 8^{\circ}\text{C}$ ).

Do not freeze.

Store in the original carton in order to protect from light.

For storage conditions after reconstitution of the medicinal product, see section 6.3.

## 6.5 Nature and contents of container

### Reblozyl Powder for Solution for Injection 25 mg/vial

2R, 13mm Type I clear glass TopLyo vial with 13 mm Flurotec® coated, gray bromobutyl rubber stopper and sealed with 13 mm aluminum flip-off seal with yellow polypropylene button

### Reblozyl Powder for Solution for Injection 75 mg/vial

2R, 13mm Type I clear glass TopLyo vial with 13 mm Flurotec® coated, gray bromobutyl rubber stopper and sealed with 13 mm aluminum flip-off seal with orange polypropylene button

Pack size: 1 vial

## 6.6 Special precautions for disposal and other handling

Reblozyl must be reconstituted gently prior to administration. Aggressive shaking should be avoided.

### Reconstitution of the product

Reblozyl is supplied as a lyophilised powder for reconstitution before use. Only water for injections (WFI) should be used when reconstituting Reblozyl.

The appropriate number of Reblozyl vials should be reconstituted to achieve the desired dose. A syringe with appropriate graduations must be used for reconstitution to ensure accurate dosage.

The following steps should be followed for reconstitution:

1. Remove the coloured cap from the vial and wipe the top with an alcohol wipe.
2. Reblozyl Powder for Solution for Injection 25 mg/vial  
Add 0.68 mL WFI into the vial by means of a syringe with appropriate graduations with a needle directing the flow onto the lyophilised powder. Allow to stand for one minute. Each 25 mg single-dose vial will deliver at least 0.5 mL of 50 mg/mL luspatercept.  
  
Reblozyl Powder for Solution for Injection 75 mg/vial  
Add 1.6 mL WFI into the vial by means of a syringe with appropriate graduations with a needle directing the flow onto the lyophilised powder. Allow to stand for one minute. Each 75 mg single-dose vial will deliver at least 1.5 mL of 50 mg/mL luspatercept.
3. Discard the needle and syringe used for reconstitution. Do not use them for subcutaneous injection.
4. Gently swirl the vial in a circular motion for 30 seconds. Stop swirling and let the vial sit in an upright position for 30 seconds.
5. Inspect the vial for undissolved powder in the solution. If undissolved powder is observed, repeat step 4 until the powder is completely dissolved.
6. Invert the vial and gently swirl in an inverted position for 30 seconds. Bring the vial back to the upright position and let it sit for 30 seconds.
7. If needed, step 6 can be repeated up to seven more times to ensure complete reconstitution of material on the sides of the vial.
8. Visually inspect the reconstituted solution prior to administration. When properly mixed, Reblozyl reconstituted solution is a colourless to slightly yellow, clear to slightly opalescent solution which is free of visible foreign particulate matter. Do not use if undissolved product or foreign particulate matter is observed.
9. If the reconstituted solution is not used immediately, see section 6.3 for storage conditions.

Any unused medicinal product or waste material should be disposed of in accordance with local requirements.

**7.     MARKETING AUTHORISATION HOLDER**

Bristol-Myers Squibb (S) Pte Ltd  
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#20-01/09 Parkway Parade,  
Singapore 449269

**8.     DATE OF REVISION OF THE TEXT**

December 2025