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Study design of a randomised, placebo-controlled trial of nintedanib in children and adolescents with fibrosing interstitial lung disease

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Early View

Study protocol

Study design of a randomised, placebo-controlled trial of nintedanib in children and adolescents with fibrosing interstitial lung disease

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Title: Study design of a randomised, placebo-controlled trial of nintedanib in children and adolescents with fibrosing interstitial lung disease

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Take home message: We describe the design of InPedILD™, a study of 24 weeks' nintedanib or placebo on top of standard of care, followed by variable duration open-label nintedanib in children with interstitial lung disease (ClinicalTrials.gov: NCT04093024)

#PedILD (244/256 characters, including spaces)

Abstract

Introduction: Childhood interstitial lung disease (chILD) comprises >200 rare respiratory disorders, with no currently approved therapies and variable prognosis. Nintedanib reduces the rate of forced vital capacity (FVC) decline in adults with progressive fibrosing ILDs. We present the design of a multicentre, prospective, double-blind, randomised, placebo-controlled clinical trial of nintedanib in patients with fibrosing chILD (1199-0337 or InPedILD™; ClinicalTrials.gov: NCT04093024).

Methods and analysis: Male or female children and adolescents aged 6–17 years (≥ 30 ; including ≥ 20 adolescents aged 12–17 years) with clinically significant fibrosing ILD will be randomised 2:1 to receive oral nintedanib or placebo on top of standard of care for 24 weeks (double-blind), followed by variable duration nintedanib (open-label). Nintedanib dosing will be based on body weight-dependent allometric scaling, with single-step dose reductions permitted to manage adverse events. Eligible patients will have evidence of fibrosis on high-resolution computed tomography (within 12 months of their first screening visit), FVC $\geq 25\%$ predicted, and clinically significant disease (Fan score of ≥ 3 or evidence of clinical progression over time). Patients with underlying chronic liver disease, significant pulmonary arterial hypertension, cardiovascular disease, or increased bleeding risk are ineligible. The primary endpoints are pharmacokinetics and the proportion of patients with treatment-emergent adverse events at Week 24. Secondary endpoints include change in FVC% predicted from baseline, Pediatric Quality of Life Questionnaire™, oxygen saturation, and 6-minute walk distance at Weeks 24 and 52. Additional efficacy and safety endpoints will be collected to explore long-term effects. #PedILD. #InPedILD.

Keywords: interstitial lung disease in children; pulmonary fibrosis, nintedanib, childhood interstitial lung disease, chILD, parenchymal lung diseases (6/6)

Introduction

Childhood interstitial lung disease (chILD) comprises >200 rare heterogeneous respiratory disorders that can affect infants, children and adolescents [1, 2]. The prevalence (1.5–3.8 cases per million [3-5]) and incidence (1.3 cases per million children [6]) of chILD may vary across different studies/analyses [1] depending on study design. chILD includes disorders that occur in adults as well as those unique to children, such as neuroendocrine cell hyperplasia of infancy and diseases attributed to genetic conditions and developmental processes [7]. Fibrosing forms of interstitial lung disease (ILD) involve an injurious process that can occur in both children and adults [1, 8]. It is not clear, however, whether the mechanism of fibrosis in the adult lung is similar to fibrosis in children who have ongoing alveolarisation [1].

Though fibrosing ILD in children has not been extensively studied and characterised, underlying conditions or contributing factors include surfactant dysfunction disorders such as mutations in *SFTPC*, *ABCA3* and *NKX2.1*, connective tissue disease-related ILD, and radiation- or drug-induced fibrosis [1, 7, 9]. Similar to adults, subgroups of patients with fibrosing chILD exhibit a progressive phenotype characterised by worsening symptoms, lung function decline and increased morbidity [1, 10]. There are no approved therapies for ILD treatment in children and, based on anecdotal evidence, the current standard of care comprises the empiric use of systemic steroids, other (steroid-sparing) immunosuppressants, hydroxychloroquine or azithromycin [1, 11, 12].

The tyrosine kinase inhibitor nintedanib potently blocks receptor and non-receptor tyrosine kinases that are implicated in the initiation and progression of pulmonary fibrosis, such as vascular endothelial growth factor (VEGF) receptors, platelet-derived growth factor receptors, fibroblast growth factor receptor kinase activity and Src family tyrosine kinases (e.g. Lck, Lyn and Flt-3) [13-15]. The antifibrotic effects of nintedanib have been demonstrated in various animal models of lung fibrosis resembling features of idiopathic

pulmonary fibrosis (IPF) [16, 17], as well as in systemic sclerosis-associated ILD (SSc-ILD) [18] and rheumatoid arthritis-associated ILD [19]. Nintedanib treatment also decreased lung inflammation, granuloma formation and fibrosis in an animal model of silica-induced lung fibrosis [20] and reduced airway inflammation and remodelling following chronic allergic stimulation in ovalbumin-sensitised mice [21]. In animal models, nintedanib had an effect on tooth development and epiphyseal growth [22].

The benefits of nintedanib have been investigated in several fibrosing ILDs in adults, including IPF [23], SSc-ILD [24] and other progressive fibrosing ILDs (also described as chronic fibrosing ILDs with a progressive phenotype) [25]. Nintedanib is approved for the treatment of IPF, SSc-ILD and chronic fibrosing ILDs with a progressive phenotype in several countries [26, 27]. Across the clinical trial programme in adults, nintedanib is associated with a consistent and clinically meaningful slowing of the progressive decline in lung function as measured by forced vital capacity (FVC) over 52 weeks [23-25]. The most commonly reported adverse events (AEs) have been gastrointestinal disorders, including diarrhoea, which were mostly mild or of moderate intensity and amenable to treatment [23-25]. Liver enzymes were also elevated in the nintedanib arms versus placebo [23-25].

To date, there have been no clinical trials of antifibrotic agents in chILD. Based on its mode of action, preclinical effects in animal models of ILD, and clinical benefit in various progressive fibrosing ILDs in adults, the use of nintedanib treatment for children and adolescents with fibrosing ILD is compelling. Although it is not currently feasible to conduct a fully powered clinical trial of efficacy in this patient population, a clinical study evaluating the pharmacokinetics (PK) and safety of nintedanib in children and adolescents (6–17 years old) with clinically significant fibrosing ILD was designed. The primary objective of this randomised, placebo-controlled clinical trial (1199-0337 or InPedILD™; ClinicalTrials.gov: NCT04093024) is to inform the dosing and safety of nintedanib in this patient population. Efficacy assessment is also planned to explore the potential clinical benefit of nintedanib treatment in fibrosing chILD.

Methods

Trial design

This study is a multicentre, multinational, prospective, randomised, placebo-controlled clinical trial of nintedanib on top of standard of care for 24 weeks (double-blind), followed by variable duration nintedanib (open-label) in children and adolescents with clinically significant fibrosing ILD. Patient recruitment is expected in ~24 countries and 70 sites (~1 patient screened per site).

Patients will undergo a 4-week screening period (Visit 1 to Visit 2). At Visit 2, patients meeting the eligibility criteria will be randomised to enter the study treatment period (comprising Part A and Part B) (Figure 1). During Part A, patients will be randomised (2:1) to receive blinded treatment (nintedanib or placebo) for 24 weeks. Patients will receive either oral nintedanib or placebo (twice daily [BID]) on top of standard of care, with starting doses (50mg, 75mg, 100mg or 150mg BID) based on patient weight using allometric scaling. Following completion of Part A (Visit 6), patients will receive open-label nintedanib (Part B) and will remain on treatment until the end of the study or discontinuation (variable from patient to patient).

The study will end when ≥ 30 patients (including ≥ 20 adolescents aged 12–17 years) have completed PK sampling at 26 weeks or have prematurely discontinued the trial. Patients who complete the per protocol treatment period will be offered participation in a separate open-label extension trial, if supported by the benefit–risk assessment performed at the end of the double-blind period. Following the treatment period or after early treatment discontinuation, patients will enter a 4-week follow-up period, unless they roll over into the open-label extension trial.

Participants

Eligible children and adolescents (aged 6–17 years) will have clinically significant fibrosing ILD with fibrosis on lung biopsy or high-resolution computed tomography (HRCT) based on central review by an independent reviewer. Due to the lack of published guidelines validating imaging features of fibrosis in children, imaging criteria established by expert consensus will be used to confirm eligibility and ensure consistency (Figure 2; Supplementary Methods).

Table 1 details eligibility criteria. Patients with underlying chronic liver disease [28], clinically significant pulmonary arterial hypertension [29], cardiovascular disease [30] or increased risk of bleeding [31] are ineligible. Patients who have previously received nintedanib or another investigational therapy (within 1 month or 5 half-lives) are ineligible. Potential diagnoses likely associated with lung fibrosis include, but are not limited to: surfactant protein deficiency (*SFTPC*, *ABCA3*, *NKX2.1* mutations); chronic hypersensitivity pneumonitis; toxic, radiation- and drug-induced pneumonitis; post-haematopoietic stem cell transplant fibrosis; and connective tissue disease-related disorders such as juvenile rheumatoid arthritis, juvenile idiopathic arthritis, SSc, dermatomyositis/polymyositis, mixed connective tissue disease or sarcoidosis.

To match the systemic exposure reached in adult IPF, nintedanib doses (administered as soft capsules BID) will be based on body weight-dependent allometric scaling (scaling of adult clearance using an exponent of 0.75, consistent with the exponent estimated in population PK analyses in adults). A population mean nintedanib exposure of 80% to 125% compared with adult patients with IPF treated with 150mg BID was targeted for the determination of planned doses by body weight in the paediatric population (Supplementary Table 1).

Dose reductions are permitted for drug-related AEs without prior interruption, i.e. immediately stepping down from one dose to the next dose. If the reduced dose is well tolerated, re-escalation is possible within 4 weeks following dose reduction in cases where

AEs are considered drug related, or within 8 weeks in cases where AEs are not considered drug related. In cases of persistent AEs observed at the reduced dose, or severe effects at the starting dose, permanent treatment discontinuation should be considered. Temporary treatment interruption will be allowed to manage AEs. Dose reduction and re-increase are permitted on multiple occasions.

Ethical approval and patient consent

Trial initiation will occur at a site following review and approval by the respective institutional review board/independent ethics committee and competent authority according to national and international regulations. The trial will be conducted in accordance with the principles of the Declaration of Helsinki, International Conference on Harmonisation Guidelines, relevant sponsor standard operating procedures, and other relevant guidelines. Written informed consent and assent, where applicable, in accordance with the International Conference on Harmonisation Guidelines - Good Clinical Practice and local legislation, are required prior to trial participation.

Randomisation and masking

Eligible patients will be randomised to treatment groups according to a randomisation plan in a 2:1 ratio (nintedanib:placebo) at Visit 2 (i.e. the start of Part A) via Interactive Response Technology stratified by age group (6–<12 years; 12–<18 years). Access to the codes will be controlled and documented. Validated randomisation software will be used.

Endpoints

The primary endpoints are PK (area under the plasma concentration–time curve at steady state [$AUC_{T,ss}$] based on sampling at steady state [Weeks 2 and 26] just before drug administration, and 1, 2, 3, 4, 6 and 8 hours post dose) and the number (%) of patients with treatment-emergent AEs at Week 24 (Table 2).

Secondary endpoints include change in FVC% predicted from baseline, Pediatric Quality of Life Questionnaire™ (PedsQL™), oxygen saturation (SpO₂), and 6-minute walk distance at Week 24 and Week 52 (Table 2). Additional efficacy and safety endpoints will be collected to explore potential long-term effects (Table 2).

Key assessments

Figure 3 shows key assessments. A complete physical examination and electrocardiogram will be performed at specific time points throughout the study. Potential bone toxicity will be monitored using serial assessment of leg length, height and imaging of growth plates in those patients with open physes. A routine dental examination with imaging will be carried out to monitor potential dental toxicity.

AEs will be coded using the Medical Dictionary for Drug Regulatory Activities, and all AEs with an onset between start of treatment and 28 days after the last dose of trial medication will be assigned to the on-treatment period for evaluation. For the primary safety analysis, treatment-emergent AEs during the double-blind period until Week 24 (Part A) will be included. A separate analysis over the whole trial period including all treatment-emergent AEs will be performed. All treated patients will be included in the safety analysis.

While the study is not powered to detect treatment differences in efficacy outcomes like changes in FVC% predicted from baseline, efficacy assessments are planned to elucidate disease course and potential trends for treatment effect. FVC will be assessed using standardised spirometry equipment (ERT SpiroSphere®) [32], with predicted values calculated according to the Global Lung Initiative [33]. SpO₂ will be measured with room air at rest by standard pulse oximetry (earlobe or forehead). Exercise capacity will be assessed using the 6-minute walk test. Health-related quality of life will be assessed using PedsQL™ [34]. Time to first acute exacerbation (details provided in the Supplementary Methods), respiratory-related hospitalisation and time to death (all-cause mortality) will be documented.

Additional assessments

Serum biomarker samples will be collected and submitted to the central laboratory (Visits 2, 5, 6, 8 and 9 only). In selected sites, patients will have the option to participate in a longitudinal HRCT sub-study. HRCT scans will be performed at baseline, 52 weeks and 100 weeks, to identify potential predictors of progression, evaluate the association between HRCT-derived imaging and clinical parameters, and investigate computer-aided analysis for the characterisation and monitoring of chILD.

Statistical analysis

Target sample size is based on the sample size estimation for the evaluation of the primary endpoint of PK and trial feasibility evaluation. For the primary evaluation of PK, the clearance parameter needs to be estimated with adequate precision. Assuming variability of the clearance parameter is comparable between children and adults, at least 20 patients with available PK measurements per age group (6–<12 years; 12–<18 years) are needed to achieve at least 80% probability (loosely referred to as power in this context [35]) of having the 95% confidence interval of nintedanib CL/F_{ss} and with this $AUC_{T,ss}$ within 60% and 140% of the geometric mean estimate, calculated as described by Wang et al. [35]. PK assessment will be performed using non-compartmental analyses and population PK analyses exploring relevant covariates on PK (age and body weight).

An external safety monitoring committee will advise the study team and may recommend intermediate checks in those patients who switch from placebo to nintedanib at the end of the initial 24 weeks of treatment. An independent disease review committee will evaluate inclusion criteria of all screened participants, retrospectively, while an independent adjudication committee will review all fatal cases and adjudicate all deaths to either cardiac, respiratory or other causes, and review all AEs categorised as major adverse cardiovascular events.

Safety analyses will be descriptive. As this is an exploratory study, with no confirmatory testing, analysis of secondary endpoints will be descriptive and no adjustment for multiple testing will be performed. Continuous endpoints will be analysed using a mixed model with repeated measurements. Time-to-event endpoints will be displayed descriptively using the Kaplan–Meier method. Categorical endpoints, safety and tolerability will be displayed descriptively in frequency tables.

Discussion

This is the first randomised controlled trial of an antifibrotic agent in chILD, a group of disorders that are currently managed with limited, mainly supportive treatments [1]. Results will inform both the dose-exposure and safety profile of nintedanib in children aged ≥ 6 years.

Development of this study protocol required international collaboration to create a clinical trial framework in a disease area with no previous clinical trials. Unique challenges with the trial design include uncertainty regarding: 1) the prevalence of fibrotic ILD in children; 2) numbers of patients who will meet specific eligibility criteria; 3) the natural history of fibrosing ILD in children; 4) variable chILD clinical practice patterns worldwide; 5) limitations in validation of outcome measures; 6) considerations of safety and efficacy assessments when performing a study in children with ongoing lung and somatic growth. These factors impacted the approach to the study protocol as intense resource allocation was required to prepare for the implementation and standardisation of sites across a large number of countries due to the low prevalence of fibrotic ILD in children.

Similar to trials in adult fibrosing ILD [36, 37], a basket approach is being used to group children and adolescents according to demonstrated evidence of lung fibrosis and clinical disease severity, irrespective of the underlying clinical diagnosis. Hence, a major limitation of this study is the heterogeneous study population, especially in evaluating efficacy outcomes including lung function. An extensive characterisation of the patient population is needed given the differences in physiology, risk and outcome of ILD between adults and children.

Nintedanib inhibits several growth factors that are implicated in the development of IPF and other fibrosing ILDs [13-15] but may be important for lung development, e.g. VEGF [38]. Although most alveolarisation occurs by age 2 years [39], lung function increases throughout childhood and adolescence, and it is unclear how nintedanib may affect this process. Based on limited evidence to support the potential benefit versus risk of nintedanib in the growing lung and possible additional risks, including tooth development and the difficulty with assessing eligibility criteria, patients aged <6 years will be excluded from this study.

The minimum target of 30 patients and treatment duration of 24 weeks allow for adequate assessment of both systemic exposure and the tolerability profile of nintedanib in the target population. The planned dosing regimen aims to achieve nintedanib exposures in paediatric patients “similar” to those in adults (exposure-matching). The same dose/exposure across different ILDs was effective, supporting the use of the same exposure in chILD. This approach was chosen based on preclinical evidence that demonstrated antifibrotic activity of nintedanib at similar doses in several animal models of lung fibrosis [15]. Prediction of AEs and estimation of treatment effects are complicated by limited data on the natural history of chILD. A placebo group may allow exploratory evaluation of the natural course of lung function and assessment of the background of AEs in this patient population.

Nonetheless, evaluating potential clinical benefit in this paediatric subset is challenging. As children grow, increases in lung volume result in increased FVC, and there is the potential that FVC will increase in children with fibrosing ILD treated with nintedanib. This is in comparison with trials of fibrosing ILD in adults, where efficacy was demonstrated based on a decrease in FVC decline [25]. The benefits of improving lung structure and helping to achieve maximum lung function prior to reaching 18–21 years of age (before lung function decline begins) may have critical effects on morbidity and mortality. To support the extrapolation of the nintedanib treatment effect from adults to children, an assessment of whether data from clinical trials with nintedanib in adults can be used for the evaluation of the treatment effect in this paediatric trial (e.g. by incorporating the treatment effect of

nintedanib in adult patients with ILDs as prior information using a Bayesian approach) is planned.

While the safety profile in chILD is presumed to be similar to that observed in the adult studies of IPF, SSc-ILD and progressive fibrosing ILDs [23-25], there are no data on nintedanib use in children. To maintain patient safety, AE monitoring includes guidelines for management of diarrhoea and liver function test abnormalities, imaging and clinic exams to monitor potential bone and dental toxicity, as well as an unblinded safety monitoring committee. Preclinical data [22] and clinical data from other VEGF inhibitors suggest that any potential effects on bones will be reversible with drug discontinuation. The dental toxicity noted in previous rodent studies of nintedanib has not been replicated in primate models [22], nor seen with other VEGF inhibitors in children. However, dental monitoring will be implemented to allow for early detection of any potential effects. The placebo arm will assist in the interpretation of any unexpected findings (positive or negative) in this paediatric population.

Given the high unmet medical need, lack of therapeutic options and the potential for a robust assessment of efficacy, this study design has required new thinking around the definitions and outcome measures of pulmonary fibrosis in children. In addition to providing data about the use and safety of nintedanib in children and adolescents with fibrosing ILD, the results of this trial will contribute to our understanding of the natural history and characterisation of lung impairment. The experience gained from this study will inform future interventional studies of rare paediatric diseases.

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Conflicts of interest

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MG has received personal fees from Boehringer Ingelheim (during the context of the study) and grant funding from Boehringer Ingelheim (outside of the submitted work).

GD declares consulting fees paid to Seattle Children's Hospital from Boehringer Ingelheim (during the context of the study).

DW serves in an advisory role for Boehringer Ingelheim on the evaluation of nintedanib as a potential treatment for chILD and has received reimbursement for travel and consultation in this role.

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Data availability

To ensure independent interpretation of clinical study results, Boehringer Ingelheim grants all external authors access to all relevant material, including participant-level clinical study data, and relevant material as needed by them to fulfil their role and obligations as authors under the ICMJE criteria.

Furthermore, clinical study documents (e.g. study report, study protocol, statistical analysis plan) and participant clinical study data are available to be shared after publication of the primary manuscript in a peer-reviewed journal and if regulatory activities are complete and other criteria met per the BI Policy on Transparency and Publication of Clinical Study Data: <https://trials.boehringer-ingelheim.com/>.

Prior to providing access, documents will be examined, and, if necessary, redacted and the data will be de-identified, to protect the personal data of study participants and personnel, and to respect the boundaries of the informed consent of the study participants.

Clinical Study Reports and Related Clinical Documents can also be requested via the link <https://trials.boehringer-ingelheim.com/>.

All requests will be governed by a Document Sharing Agreement.

Bona fide, qualified scientific and medical researchers may request access to de-identified, analysable participant clinical study data with corresponding documentation describing the structure and content of the datasets. Upon approval, and governed by a Data Sharing Agreement, data are shared in a secured data-access system for a limited period of 1 year, which may be extended upon request.

Researchers should use the <https://trials.boehringer-ingelheim.com/> link to request access to study data.

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Table 1: Full inclusion and exclusion criteria

Inclusion criteria

Male or female children and adolescents aged 6–17 years old at Visit 2

Written informed consent and assent (where applicable) prior to admission to the trial

Female subjects of childbearing potential must confirm that sexual abstinence is standard practice and will be continued until 3 months after last drug intake, or agree to use a highly effective method of birth control from 28 days prior to initiation of study treatment, during treatment and until 3 months after last drug intake

Evidence of fibrosing ILD* on HRCT within 12 months of Visit 1 as assessed by the investigator and confirmed by central review

FVC% predicted $\geq 25\%$ at Visit 2[†]

Clinically significant disease at Visit 2, as assessed by the investigator based on any of the following:

- Fan score ≥ 3 [10], or
- Documented evidence of clinical progression over time based on either:
 - 5–10% relative decline in FVC% predicted accompanied by worsening symptoms, or
 - a $\geq 10\%$ relative decline in FVC% predicted, or
 - increased fibrosis on HRCT, or
 - other measures of clinical worsening attributed to progressive lung disease (e.g. increased oxygen requirement, decreased diffusion capacity)

Exclusion criteria

AST and/or ALT $> 1.5 \times$ ULN at Visit 1[‡]

Bilirubin $> 1.5 \times$ ULN at Visit 1[‡]

Creatinine clearance < 30 mL/min calculated by Schwartz formula at Visit 1[‡]

Patients with underlying chronic liver disease (Child Pugh A, B or C hepatic impairment) at Visit 1

Previous treatment with nintedanib

Other investigational therapy received within 1 month or 5 half-lives (whichever is shorter but ≥ 1 week) prior to Visit 2

Significant PAH defined by any of the following:

- Previous clinical or echocardiographic evidence of significant right heart failure
- History of right heart catheterisation showing a cardiac index ≤ 2 l/min/m²
- PAH requiring parenteral therapy with epoprostenol/treprostinil

Other clinically significant pulmonary abnormalities (investigator-assessed)

Cardiovascular diseases (any of the following):

- Severe hypertension (uncontrolled with treatment), within 6 months of Visit 1.
Uncontrolled hypertension is defined as:
 - Children aged 6– ≤ 12 years: ≥ 95 th percentile + 12 mm Hg or $\geq 140/90$ mm Hg (whichever is lower) (systolic or diastolic blood pressure equal to or greater than the calculated target value)
 - In adolescents aged 13–17 years: systolic blood pressure ≥ 140 mm Hg or diastolic blood pressure ≥ 90 mm Hg
- Myocardial infarction within 6 months of Visit 1
- Unstable cardiac angina within 6 months of Visit 1

Bleeding risk, defined as any of the following:

- Known genetic predisposition to bleeding
- Patients who require:
 - Fibrinolysis, full-dose therapeutic anticoagulation (e.g. vitamin K antagonists, direct thrombin inhibitors, heparin, hirudin)
 - High-dose antiplatelet therapy^s
- History of haemorrhagic CNS event within 12 months of Visit 1
- Any of the following within 3 months of Visit 1:
 - Haemoptysis or haematuria
 - Active GI bleeding or GI ulcers
 - Major injury or surgery (investigator-assessed)
- Any of the following coagulation parameters at Visit 1:
 - INR > 2
 - Prolongation of PT by > 1.5 x ULN
 - Prolongation of aPTT by > 1.5 x ULN

History of thrombotic event (including stroke and transient ischaemic attack) within 12

months of Visit 1

Known hypersensitivity to the trial medication or its components (i.e. soya lecithin)

Documented allergy to peanut or soya

Other disease that may interfere with testing procedures or in the judgement of the investigator may interfere with trial participation or may put the patient at risk when participating in this trial

Life expectancy for any concomitant disease other than ILD <2.5 years (investigator-assessed)

Female patients who are pregnant, nursing, or who plan to become pregnant while in the trial

Patients not able or willing to adhere to trial procedures, including intake of study medication

Patients with any diagnosed growth disorder such as growth hormone deficiency or any genetic disorder that is associated with short stature (e.g. Turner syndrome, Noonan syndrome, Russell–Silver syndrome) and/or treatment with growth hormone therapy within 6 months before Visit 2[¶]

Patients <13.5 kg of weight at Visit 1 (same threshold for male and female patients)

* Clinically significant fibrosing ILD will be confirmed based on documented evidence of fibrosing features on HRCT or lung biopsy, as defined in the *Participants* section of the **Methods**.

† Predicted normal values will be calculated according to the Global Lung Initiative.

‡ Laboratory parameters from Visit 2 will only be available after randomisation and, if the result no longer satisfies the entry criteria, the investigator will decide whether the patient should remain on study drug. Abnormal laboratory parameters at Visit 1 are allowed to be re-tested (once) if it is thought that there was a measurement error or if they are a result of a temporary and reversible medical condition (once that condition has resolved).

§ Prophylactic low-dose heparin or heparin flush as needed for maintenance of an indwelling intravenous device, as well as prophylactic use of antiplatelet therapy, are not prohibited.

† Patients with short stature considered by the investigator to be due to glucocorticoid therapy may be included.

ALT, alanine aminotransferase; aPTT, activated partial thromboplastin time; AST, aspartate aminotransferase; CNS, central nervous system; GI, gastrointestinal; FVC, forced vital capacity; HRCT, high-resolution computed tomography; ILD, interstitial lung disease; INR, international normalised ratio; PAH, pulmonary arterial hypertension; PT, prothrombin time; ULN, upper limit of normal.

Table 2: Study endpoints

Primary endpoints:

Pharmacokinetics: $AUC_{\tau,ss}$ based on sampling at steady state (at Week 2 and Week 26)

Number (%) of patients with treatment-emergent AEs at Week 24

Secondary endpoints:

Number (%) of patients with treatment-emergent pathological findings of epiphyseal growth plate on imaging at Week 24 and Week 52*

Number (%) of patients with treatment-emergent pathological findings on dental examination or imaging at Week 24 and Week 52*

Number (%) of patients with treatment-emergent AEs over the whole trial

Change in height, sitting height, leg length from baseline at Week 24, Week 52*, Week 76* and Week 100*

Change in FVC% predicted from baseline at Week 24 and Week 52*

Absolute change from baseline in PedsQL™ at Week 24 and Week 52*

Change in SpO₂ on room air at rest from baseline at Week 24 and Week 52*

Change in 6-min walk distance from baseline at Week 24 and Week 52*

Patient acceptability based on the size of capsules at Week 24

Patient acceptability based on the number of capsules at Week 24

Time to first respiratory-related hospitalisation over the whole trial

Time to first acute ILD exacerbation or death over the whole trial

Time to death over the whole trial

Further endpoints

Number (%) of patients with increase/decrease in FVC% predicted (5–10%; >10%) at Week 24 and Week 52*

Number (%) of patients with ≥4.4-point increase in PedsQL™ from baseline at Week 24 and Week 52*

Number (%) of patients with >4% increase in SpO₂ on room air from baseline at Week 24 and Week 52*

Change in calculated Fan severity score from baseline at Week 24 and Week 52*

Change in HAZ score from baseline at Week 24 and Week 52*

Change in WAZ score from baseline at Week 24 and Week 52*

Slope of HAZ over whole trial

Slope of WAZ over whole trial

Number of missed school days due to the disease under study at Week 24

Absolute change from baseline in log-transformed CA-125 at Week 24 and Week 52

Pharmacokinetic endpoints at Visit 3 (Week 2) and Visit 7 (Week 26)

$C_{\max,ss}$

$t_{\max,ss}$

$t_{1/2,ss}$

CL/F_{ss}

Vz/F_{ss}

$C_{pre,ss}$

* 52 weeks, 76 weeks, and 100 weeks time points will not be available for all patients.

Other parameters may be calculated as deemed appropriate.

AE, adverse event; $AUC_{t,ss}$, area under the plasma concentration–time curve at steady state; CL/F_{ss} , apparent clearance of the analyte in the plasma at steady state following extravascular multiple dose administration; $C_{\max,ss}$, maximum measured concentration of the analyte in plasma at steady state; $C_{pre,ss}$, pre-dose concentration of the analyte in plasma at steady state immediately before administration of the next dose; FVC, forced vital capacity; HAZ; height-for-age z-score; ILD, interstitial lung disease; PedsQL™, Pediatric Quality of Life Questionnaire™; SpO_2 , oxygen saturation; $t_{1/2,ss}$, terminal half-life of the analyte in plasma at steady state; $t_{\max,ss}$, time from dosing to maximum measured concentration of the analyte in plasma at steady state; Vz/F_{ss} , apparent volume of distribution during the terminal phase λ_z at steady state following extravascular administration; WAZ, weight-for-age z-score.

Figure legends

Figure 1: Study design

EoT, end of treatment; FPE, first patient enrolled; FPI, first patient in; LPI, last patient in.

Figure 2: Inclusion criteria for fibrosing ILD

Evidence of fibrosing ILD will be confirmed by central review (lung biopsy and HRCT).

* Coexisting cystic abnormalities or ground-glass opacity are acceptable; however, coexisting multifocal non-fibrotic, non-dependent consolidations (e.g. organising pneumonia, infection) will not be permitted.

† With or without ground-glass opacification.

HRCT, high-resolution computed tomography; ILD, interstitial lung disease; NSIP, non-specific interstitial pneumonia; UIP, usual interstitial pneumonia.

Figure 3: Key assessments

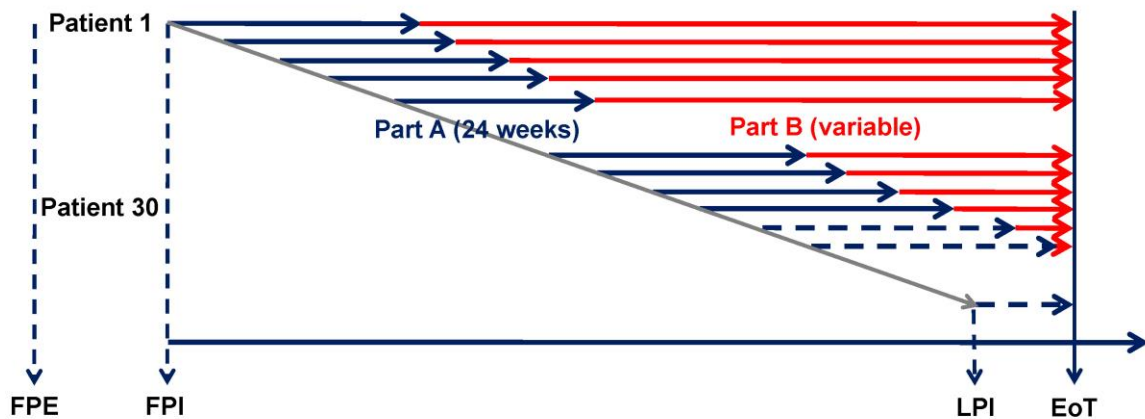
* Part A comprises Visit 2 (Week 0), Visit 3 (Week 2), Visit 4 (Week 6), Visit 5 (Week 12), and Visit 6 (Week 24). Laboratory tests can be performed between Visit 5 and 6 (Visit 5A) as needed.

† Part B starts at the end of Visit 6 and comprises Visit 7 (Week 26), Visit 8 (Week 36), Visit 9 (Week 52), Visit X (Week 64, then every 12 weeks until EoT), and EoT. Laboratory tests can be performed between each visit (Visit 7A, 8A, 9A and XA as needed).

‡ The primary endpoints are PK ($AUC_{t,ss}$) based on sampling at steady state (Weeks 2 and 26) and number (%) of patients with treatment-emergent adverse events (Week 24).

§ Clinically significant disease is assessed by the investigator based on any of the following: Fan score ≥ 3 or documented evidence of clinical progression over time (either 5–10% relative decline in FVC% predicted accompanied by worsening symptoms, or a $\geq 10\%$ relative decline in FVC% predicted, or increased fibrosis on HRCT, or other measures of clinical worsening attributed to progressive lung disease [e.g. increased oxygen requirement, decreased diffusion capacity]).

6MWT, 6-minute walk test; $AUC_{\tau,ss}$, area under the plasma concentration–time curve at steady state; DL_{CO} , diffusing capacity of the lung for carbon monoxide; ECG, electrocardiogram; EoT, end of treatment; FVC, forced vital capacity; HRCT, high-resolution computed tomography; ILD, interstitial lung disease; PedsQL™, Pediatric Quality of Life Questionnaire™; PK, pharmacokinetics; SpO_2 , oxygen saturation.



Lung biopsy

- Previous findings of fibrosis on lung biopsy:
 - NSIP (fibrosing)
 - UIP
 - Honeycomb lung
 - Evidence of interstitial fibrosis on a significant component
 - Evidence of lobular remodelling on a significant component

Yes

No

HRCT scan

- ≥1 of the following on 1 HRCT scan within 12 months of screening:*
- reticular abnormality
 - traction bronchiectasis
 - architectural distortion[†]
 - honeycombing

- ≥2 of the following on ≥2 HRCT scans; most recent within 12 months of screening:
- reticular abnormality
 - traction bronchiectasis
 - architectural distortion[†]
 - honeycombing
 - cystic abnormalities

Meets criteria for fibrosing ILD

Screening	Treatment		Follow up: EoT plus 28 days + 7
	Part A (randomised) [†]	Part B (open-label) [†]	
<p>Visit 1: –4 weeks</p> <ul style="list-style-type: none"> • Informed consent/assent • Demographic information and medical history • Physical examination and vital signs <ul style="list-style-type: none"> • Height (sitting/standing) • Weight • 12-lead ECG (at rest) • Laboratory tests • Review of inclusion/exclusion criteria • HRCT imaging sent for central review • Biopsy sent for central review (if required) • Lung function tests <ul style="list-style-type: none"> • SpO₂ (earlobe or forehead, room air, resting) • FVC • Concomitant therapy • Safety 	<p>Every visit</p> <ul style="list-style-type: none"> • Physical examination and vital signs • Weight • Laboratory tests • SpO₂ (earlobe or forehead, room air, resting) • FVC • ILD exacerbations • Hospitalisations (respiratory-related) • Safety[‡] • Concomitant therapy <p>Visit 2: 0 weeks</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • 12-lead ECG (at rest) (2 [if abnormal at Visit 1]) • Serum and plasma biomarkers • DL_{CO} • Fan severity score • Confirmation of clinically significant disease[§] • Review of inclusion/exclusion criteria • Randomisation • PedsQL™ • Bone imaging (if applicable) • Dental examination • Dental imaging • 6MWT <p>Visit 3: 2 weeks</p> <ul style="list-style-type: none"> • PK sampling[‡] <p>Visit 5: 12 weeks</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • Serum and plasma biomarkers • Bone imaging (if applicable) • Dental examination <p>Visit 6: 24 weeks</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • 12-lead ECG (at rest) • Serum and plasma biomarkers • PedsQL™ • Bone imaging (if applicable) • Dental examination • Dental imaging • 6MWT 	<p>Every visit</p> <ul style="list-style-type: none"> • Physical examination and vital signs • Laboratory tests • SpO₂ (earlobe or forehead, room air, resting) • FVC • ILD exacerbations • Hospitalisations (respiratory-related) • Safety • Concomitant therapy <p>Visit 7: 26 weeks</p> <ul style="list-style-type: none"> • PK sampling[‡] <p>Visit 8: 36 weeks</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • Weight • Serum and plasma biomarkers • Bone imaging (if applicable) • Dental examination <p>Visit 9: 52 weeks</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • Weight • 12-lead ECG (at rest) • Serum and plasma biomarkers • PedsQL™ • 6MWT • Bone imaging (if applicable) • Dental examination <p>Visit X: 64 weeks, then:</p> <ul style="list-style-type: none"> • Every 12 weeks until EoT <ul style="list-style-type: none"> • Height (standing/sitting) • Weight • Every 24 weeks until EoT <ul style="list-style-type: none"> • Leg length • 12-lead ECG (at rest) • Bone imaging (if applicable) • Dental examination • Every 48 weeks until EoT <ul style="list-style-type: none"> • Dental imaging <p>EoT</p> <ul style="list-style-type: none"> • Height (standing/sitting) • Leg length • Weight • 12-lead ECG (at rest) • Bone imaging (if applicable) • Dental examination • Dental imaging 	<ul style="list-style-type: none"> • Physical examination and vital signs <ul style="list-style-type: none"> • If clinically relevant changes: <ul style="list-style-type: none"> • Height (standing/sitting) • Weight • Laboratory tests (if clinically relevant changes) <ul style="list-style-type: none"> • Weight • ILD exacerbations • Safety • Concomitant therapy • Hospitalisations (respiratory-related) • Completion of patient participation

Supplementary materials

Title: Study design of a randomised, placebo-controlled trial of nintedanib in children and adolescents with fibrosing interstitial lung disease

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Methods

Inclusion criteria for fibrosing ILD

For patients with previous pathological findings of fibrosis on lung biopsy, confirmation of fibrosis on high-resolution computed tomography (HRCT) will be made if at least one of the following imaging criteria are met within 12 months of screening (Visit 1), as confirmed by central review: reticular abnormality or traction bronchiectasis or architectural distortion (with or without ground-glass opacification) or honeycombing. Coexisting cystic abnormalities or ground-glass opacities are acceptable; however, coexisting multifocal non-fibrotic, non-dependent consolidations (e.g. organising pneumonia, infection) will not be permitted.

Any of the following lung biopsy findings or diagnoses will be accepted as documentation of fibrosis, as confirmed by central review: non-specific interstitial pneumonia (fibrosing); usual interstitial pneumonia; evidence of interstitial fibrosis on a significant component of the lung biopsy (based on the opinion of the central reviewer); evidence of lobular remodelling on a significant component of the lung biopsy (based on the opinion of the central reviewer); or honeycomb lung. For patients without any documented lung biopsy or whose biopsy results do not meet the biopsy criteria for fibrosis listed above, at least two of the aforementioned imaging findings are required on at least two HRCT scans.

Definition of acute exacerbation in cILD

Acute exacerbation will be defined as a significant worsening of the patient's respiratory condition that necessitates a change in regular management, based on >2 of the following criteria over 4 weeks: increase in respiratory rate $\geq 20\%$ from baseline; increase in or development of dyspnoea; newly developing or increased abnormalities on chest imaging; onset/increase of oxygen demand to attain the individual baseline saturation (at rest and/or during exercise); need for an additional level of ventilatory support (in addition to oxygen); decrease in vital capacity $\geq 10\%$ from baseline in children able to perform the test; or reduced exercise tolerance in children able to perform the tests (includes desaturation) [12].

Supplementary Table 1: Dose assignment and dose reduction based on patient body weight

Body weight bin	Weight range (kg)	Dose (BID)	Capsule strength (number required)	Dose reduction allowances (BID)	Capsule strength (number required)
1	13.5* to <23.0	50 mg	25 mg (2)	25 mg	25 mg (1)
2	23.0 to <33.5	75 mg	25 mg (3)	50 mg	25 mg (2)
3	33.5 to <57.5	100 mg	100 mg (1) or 25 mg (4)	75 mg	25 mg (3)
4	≥57.5	150 mg	150 mg (1) or 25 mg (6)	100 mg	100 mg (1) or 25 mg (4)

* Patients <13.5 kg of weight will be excluded from the trial.

BID, twice daily.