Study Protocol

Prospective evaluation of immunological, molecular-genetic, image-based and microbial analyses to characterize tumor response and control in patients with unresectable stage III NSCLC treated with concurrent chemoradiotherapy followed by consolidation therapy with durvalumab (PRECISION): protocol for a prospective longitudinal biomarker study

Lukas Käsmann1,2,3, Julian Taugner1, Chukwuka Eze1, Alexander Nieto1, Carolyn Pelikan1,4, Benedikt Flörsch1, Saskia Kenndoff1, Thomas P. Hofer1, Elfriede Nössner4, Christian Schulz5, Marcus Unterrainer6, Amanda Tufman7, Frederick Klauschen3,8, Andreas Jung3,8, Jens Neumann3,8, Jörg Kümbrink3,8, Niels Reinmuth9, Peter Bartenstein10, Claus Belka1,2,3, Farkhad Manapov1,2,3

1Department of Radiation Oncology, University Hospital, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany; 2Comprehensive Pneumology Center Munich (CPC-M), the German Center for Lung Research (DZL), Munich, Germany; 3German Cancer Consortium (DKTK), Partner Site Munich, Munich, Germany; 4Immuoanalytics Research Group Tissue Control of Immunocytes, Helmholtz Center Munich, Munich, Germany; 5Department of Medicine II, University Hospital, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany; 6Department of Radiology, University Hospital, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany; 7Respiratory Medicine and Thoracic Oncology, Internal Medicine V, Ludwig-Maximilians-University (LMU) of Munich and Thoracic Oncology Centre, the German Center for Lung Research (DZL), Munich, Germany; 8Institute of Pathology, Faculty of Medicine, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany; 9Asklepios Lung Clinic, Munich-Gauting, Gauting, Germany; 10Department of Nuclear Medicine, University Hospital, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany

Contributions: (I) Conception and design: F Manapov, L Käsmann; (II) Administrative support: C Belka, F Manapov; (III) Provision of study materials or patients: A Tufman, F Klauschen, A Jung, J Neumann, J Kümbrink, N Reinmuth, P Bartenstein, M Unterrainer; (IV) Collection and assembly of data: L Käsmann, J Taugner, C Eze, A Nieto, C Pelikan, B Flörsch, S Kenndoff, M Unterrainer; (V) Data analysis and interpretation: L Käsmann, J Taugner, E Nössner, C Schulz, F Manapov; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Lukas Käsmann, MD. Department of Radiation Oncology, University Hospital, Ludwig-Maximilians-University (LMU) of Munich, Munich, Germany. Email: Lukas.Kaesmann@med.uni-muenchen.de.

Background: Concurrent platinum-based chemoradiotherapy (CRT) followed by durvalumab maintenance treatment represents the new standard of care in unresectable stage III non-small cell lung cancer (NSCLC). In this prospective hypothesis-generating single-center study, we aim to identify a framework of prognostic and predictive biomarkers by longitudinal characterization of tumor- and patient (host)-related parameters over all phases of multimodal treatment.

Methods: This study will enroll 40 patients (≥18 years, Eastern Cooperative Oncology Group performance status (ECOG PS) 0–2, with a diagnosis of PD-L1 positive (≥1%), inoperable stage III NSCLC) with an indication for CRT followed by maintenance treatment with durvalumab according to European Medicines Agency (EMA) approval. Comprehensive analysis will include peripheral blood cellular and humoral immunophenotyping and circulating tumor DNA as well as gut/saliva microbiota analyses. Additional morphological analysis with 18F-FDG-PET/computed tomography (CT) before, 6 weeks, 6 and 12 months after the end of CRT is included. Statistical analysis using multiple testing will be used to examine the impact of different parameters on progression-free survival (PFS) and overall survival (OS) as well as tumor response and response duration.

Discussion: This protocol describes the methodology of a comprehensive biomarker study in order to identify a framework of prognostic and predictive markers for unresectable stage III NSCLC in a real-world setting.
**Introduction**

In PD-L1 positive (≥1%), unresectable stage III non-small cell lung cancer (NSCLC), concurrent platinum-based chemoradiotherapy (CRT) followed by maintenance treatment with the PD-L1 inhibitor durvalumab represents the new standard of care with approval of the European Medicines Agency (EMA) based on the promising results of the PACIFIC study (1-6). However, prognostic and predictive markers for this novel tri-modal treatment approach remain unclear. Historically, aspects such as patients’ general condition, pulmonary function as well as tumor volume, extent of the tumor invasion and lymph node involvement have been of crucial importance for prognosis and treatment efficacy (7-9). Due to the introduction of immune check-point inhibition in contemporary cancer treatment, the state of the host’s immunity and microbiome has become more relevant for treatment efficacy and prognosis (10-12).

In order to identify a framework of prognostic and predictive biomarkers in unresectable stage III NSCLC, we will perform a non-interventional explorative biomarker study with longitudinal comprehensive characterization of the patient (host) and tumor as well as their longitudinal changes during the course of tri-modal therapy. This study will provide invaluable information on the immunological, molecular-genetic, morphological and microbial parameters in patients with unresectable stage III NSCLC treated with durvalumab maintenance for 12 months after concurrent CRT. The following article was written in accordance with the SPIRIT reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-21-1010/rc).

**Methods**

The study protocol and informed consent documents were approved by the ethics committee of the Ludwig-Maximilians-University of Munich (approval number: 20-0502), and informed consent will be obtained from all patients. All procedures performed in this study will be in accordance with the Declaration of Helsinki (as revised in 2013) and adhere to Good Clinical Practice guidelines.
bronchodilation): FEV1 ≥1.0 L and/or DLCO-SB ≥40% predicted;
• A maximum of two cycles of induction chemotherapy are permissible before the start of CRT.

Exclusion criteria:
• Simultaneous participation in another clinical trial;
• Mixed histology of small-cell lung cancer and NSCLC;
• Brain metastases confirmed by a contrast enhanced cranial MRI;
• Prior receipt of immunotherapy or an investigational medicinal product;
• Previous exposure to an anti-PD-1 or anti-PD-L1 antibody;
• Pneumonitis ≥ grade 2 as a result of prior CRT;
• Patients with a non-active disease in the last 5 years can be included, but only after consultation with the responsible investigator of the study or his representative;
• Primary immunodeficiencies in previous history
• Prior interstitial lung disease (ILD);
• Previous organ transplantation with subsequent therapeutic immunosuppression.

After consent and enrollment, blood samples will be collected during clinical routine 5–10 days before the start of CRT and subjected to immunophenotyping of peripheral blood mono-nuclear cells (PBMC), to genetic testing using the Oncomine Pan-Cancer Cell free Assay (Life Technologies, Carlsbad, CA, USA) next generation sequencing (NGS) as well as the detection of mutations in short circulating tumor total nucleic acid (ctTNA: ctDNA and ctRNA). At the same time of blood sampling, saliva and stool sample for microbiome analyses will be collected.

During treatment, a comprehensive characterization including immunophenotyping of PBMC, ctDNA as well as gut/saliva microbiome analyses will be performed.

Immunophenotyping will be performed using a set of eligible markers (CD3, CD4, CD8, CD19, CD20, CD14, CD16, slan, HLA-DR) to quantify the major blood cell lineages like T-cells, B-cells, NK-cells, and monocytes including their subpopulations in absolute numbers and frequencies. Further marker panels (e.g., FoxP3, Ki67, CD25, CX3CR1, CD38) are used to assess immunocyte subpopulations like T naive, Treg, Teff, Tmem, Texh that are relevant in immune response, regulation, and killing.

Bacterial assemblages will be analyzed using high-throughput sequencing based on 16S rRNA profiles to selectively identify the transcriptionally active bacteria. RNA from saliva and faecal samples will be extracted using the RNeasy kit (Qiagen, Mississauga, ON, Canada). After DNA digestion, first-strand cDNA will be synthesized using Superscript IV First-Strand Synthesis System (Invitrogen, Carlsbad, CA, USA) and random primers. Amplicon libraries will be generated as described before in detail (13,14).

Sample collection will be repeated mid-treatment (at the 15 fraction mark), at the end of CRT and 3, 6 and 12 months after the end of thoracic irradiation (see Figure 1).

18F-FDG-PET/computed tomography (CT) will be performed 5–10 days before start of radiotherapy (RT), 6 weeks, 12, and 24 months after the end of CRT. Patients with asymptomatic disease progression will be assessed according to our internal standard operating procedure (SOP) with CT of the chest and abdomen every 3 months and every 6 months an MRI of the brain. In patients with symptomatic disease, imaging modality will depend on physician’s choice followed by the internal SOP.

Lung function will be assessed before the start of, at the end and 6 weeks as well as 3, 6 and 12, 18, 24 months after CRT.

Histopathological examination and NGS will be performed at the accredited Institute of Pathology (Faculty of Medicine, LMU of Munich, Munich, Germany).

Follow-up until 5 years after the end of chemoradiation will be performed by the Department of Radiation Oncology at the University Hospital Munich (LMU) according to the clinical SOPs as well as treatment-related side effects according to Common Terminology Criteria for Adverse Events (CTCAE) version 5.

Study objectives

The primary objective is to identify early immunological and morphological biomarkers and their dynamic changes to predict progression-free survival (PFS) at 12 and 24 months [according to the Response Evaluation Criteria in Solid Tumors (RECIST), version 1.1, and PERCIST as assessed by means of blinded independent central review]. PFS is defined as the time from end of CRT to the date of the first documented event of tumor progression or death in the absence of disease progression.

The secondary objective is to identify predictive biomarkers for PFS at 6 and 18 months after CRT. PFS will be assessed by the investigators according to RECIST 1.1 and PERCIST. Overall response rate, local and distant tumor control (response duration) at 6 weeks, 6, 12, 18 and
24 months from the end of CRT according to PERCIST and RECIST criteria will be correlated with potential biomarkers.

**Statistical analysis**

In this prospective explorative study, 40 patients will be enrolled between December 2020 and September 2022 based on previous single-center experience and published historical data:

- 20 patients will be progression-free at 24 months after the start of CRT (50% PFS rate);
- 12 patients will develop multiple distant metastases, including brain (30% rate);
- 3 patients will develop a single metachronous distant metastasis, including brain (7.5% rate);
- 10 patients will develop a loco-regional recurrence (25% rate) at 24 months after completion of CRT.

Five cancer-related deaths are anticipated until end of follow-up period (24 months after start of CRT). A 5% drop-out rate was estimated.

With a sample size of 40 patients, an explorative biomarker study using multiple testing is justified to evaluate predictive and prognostic biomarker by the scarcity of quality samples, capacity and costs of molecular techniques. A further confirmation step is planned in an external validation cohort.

**Discussion**

Implementation of maintenance treatment with the PD-L1 inhibitor durvalumab in unresectable stage III NSCLC with at least stable disease after completion of concurrent CRT has led to a marked improvement in patient prognosis and established a new standard approach for this heterogeneous disease. According to the PACIFIC trial and reported real-world data, this novel tri-modal approach has led to a significant increase in local-regional control, PFS and overall survival (OS) (5,14).

Despite the unprecedented historical improvement of long-term outcome, a significant number of patients will develop recurrent disease. Importantly, there is a paucity of data regarding salvage treatment options. Comprehensive analysis of recurrence predictors, including clinical factors and biomarker candidates are pertinent.

Additionally, further intensification of this tri-modal approach with application of immune checkpoint inhibition and CRT simultaneously followed by the established maintenance treatment is also the subject of several ongoing studies (15,16).

In the face of the achieved progress in this field, underlying mechanisms explaining the durable positive effect of durvalumab maintenance treatment on local and distant tumor control after CRT are still unclear (3,17,18). Hence, the ongoing trials should be focused on deciphering...
these synergistic effects.

PRECISION is a single-center explorative biomarker study designed to generate a framework of specific tumor- and patient (host)-associated parameters with significant impact on the processes of tumor clearance during CRT and establishment of long-lasting antitumor immune response during the durvalumab maintenance phase of multimodal treatment.

The strength of this study is a comprehensive and longitudinal biological material collection and analysis. Analyses will be performed at six time points: three time points during CRT and three during the maintenance treatment phase, respectively. This study will also evaluate the dynamic changes of the tumor- and patient (host)-related parameters across the treatment time. The association of the detected cfDNA/ctDNA levels/variant frequencies with objective tumor response based on the RECIST and PERCIST criteria and pattern of failure (loco-regional vs. distant) may add new relevant data for patient follow-up. Correlation of the dynamic changes of PBMCs with acute and subacute treatment-related toxicity, especially pneumonitis, should provide crucial knowledge for future studies to mitigate adverse effects.

Previous studies found a mutual relationship between the gut microbiota and administered immunotherapy especially in malignant melanoma patients (19,20). Despite an unknown underlying mechanism, gut microbes may modulate adaptive immunity, either in a beneficial or harmful manner and might influence the efficacy and toxicity of immunotherapy via the microbiota and modulation of adaptive immunity. Our study contributes to a further understanding of the patient immune system and identify potential biomarkers. In order to confirm our results, a validation preferably in an external cohort is warranted and planned.

In summary, PRECISION will provide invaluable information regarding patient (host) systemic immune landscape and the cancer—patient (host) immune interplay at different phases of tri-modal treatment. The key challenge will be defining a specific framework of immunological, molecular-genetic and microbial parameters and their dynamic changes with specific impact on long-term tumor control and patient prognosis.

Acknowledgments

Figure 1 of this article has been reproduced from Käsmann et al. (15) and written permission from the copyright holder (Springer Nature) has been obtained in order to reproduce the material.

Funding: The Hospital of the LMU of Munich takes the sponsor role for this study. The study was supported by an unrestricted grant from AstraZeneca Germany.

Footnote

Reporting Checklist: The authors have completed the SPIRIT reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-21-1010/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-21-1010/coif). AJ receives honoraria, worked in consulting or advisory role and received expenses for travel and accommodation by Amgen, Astra Zeneca, Bayer Pharmaceuticals, BMS, Boehringer Ingelheim, Merck KGaA, Novartis, Qiagen, Roche Pharma and Takeda. AT serves in the advisory boards: Lilly, Pfizer, MSD, BMS, GSK, Celgene, Roche, Takeda, Boehringer Ingelheim, Amgen, AstraZeneca. Projects financed by AstraZeneca and Takeda. AT receives travel support from Pfizer and Amgen. CB receives grants or contracts from any entity but not related to this manuscript from Viewray, Brainlab and ELEKTA. CB receives honoraria from BMS, ROCHE, MERCK, AstraZeneca and Viewray. CB receives support for attending meetings and/or travel from BMS, ROCHE, MERCK, AstraZeneca and Viewray. CB receives BMS, ROCHE, MERCK, AstraZeneca and Viewray. CB serves in a fiduciary role in the ESTRO. CE receives grants or contracts from any entity but not related to this manuscript from German Cancer Aid. CE receives consulting fees from Novartis. CE receives support for attending meetings and/or travel from Novartis. CS has received lecture honoraria from Falk and Janssen. EN receives honoraria from AstraZeneca, Hexal, Ipsen, and Roche. EN serves in consulting or advisory board of Definiens and Visiopharm. EN receives research funding from Phio Pharmaceuticals (Inst). EN receives royalties or licenses from Medigne (Inst). FK is co-founder of the company ‘Aignostics GmbH’ and receives honoraria from BMS, Merck, Agilent, Novartis, Roche, Lilly, MSD. FM receives an unrestricted Research Institutional Grant from AstraZeneca. FM receives honoraria from AstraZeneca, Novartis, Roche, Lilly, Elekta and Brainlab. FM serves in the advisory board of AstraZeneca, Novartis. LK receives honoraria from AMGEN. NR reports receiving honoraria
for speaker activities and participation in advisory boards for AbbVie, AstraZeneca, Bristol-Myers Squibb, Boehringer Ingelheim, Merck Sharp & Dohme, Pfizer, Roche, and Takeda. The other authors have no conflicts of interest to declare.

**Ethical Statement:** The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This biomarker study will be conducted in accordance with the Declaration of Helsinki (as revised in 2013) and adhere to Good Clinical Practice guidelines. Prior to the initiation of the study, local Ethics Committee/Institutional review board approval (approval number: 20-0502) has been given, and informed consent will be obtained from all patients.

**Open Access Statement:** This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: https://creativecommons.org/licenses/by-nc-nd/4.0/.

**References**
