

INTRODUCTION

Rhenium (¹⁸⁶Re) obisbameda (¹⁸⁶RNL), a next generation radiotherapeutic, is BMEDA-chelated ¹⁸⁶Re encapsulated in liposomal nanoparticles. ¹⁸⁶Re is a beta-emitting therapeutic radionuclide with a 90-hour half-life, ~2 mm tissue path length, and optimal 137 keV γ -decay that allows real-time imaging of in vivo drug distribution by SPECT/CT.

Leptomeningeal metastasis (LM) is a devastating cancer of the CSF and membranes surrounding the brain and spinal cord, diagnosed in approximately 5-15% of all cancer patients. Typical treatment strategies include optimal systemic therapy for the primary disease, as well as neuroaxis-directed therapy, which may include intrathecal chemotherapy or radiotherapy. External Beam Radiation Therapy (EBRT) is limited to ~30-50 Gray (Gy) over multiple fractions to limit toxicity including myelopathy and marrow suppression given the dose to the brain, spinal cord, and surrounding tissues. With treatment, median overall survival is 2-6 months; without treatment, 4-6 weeks.

Durable, localized treatment with beta emitters has the potential to dramatically widen the therapeutic window, increase the delivered dose, avoid normal tissue exposure, and extend survival in patients with LM. ¹⁸⁶RNL uses **Direct Targeted Delivery**, which deposits high doses of radiation non-systemically and locoregionally to achieve thorough tumor coverage and retention with high absorbed radiation doses. For LM, ¹⁸⁶RNL is infused via Ommaya reservoir (intraventricular catheter) (**Figure 1**).

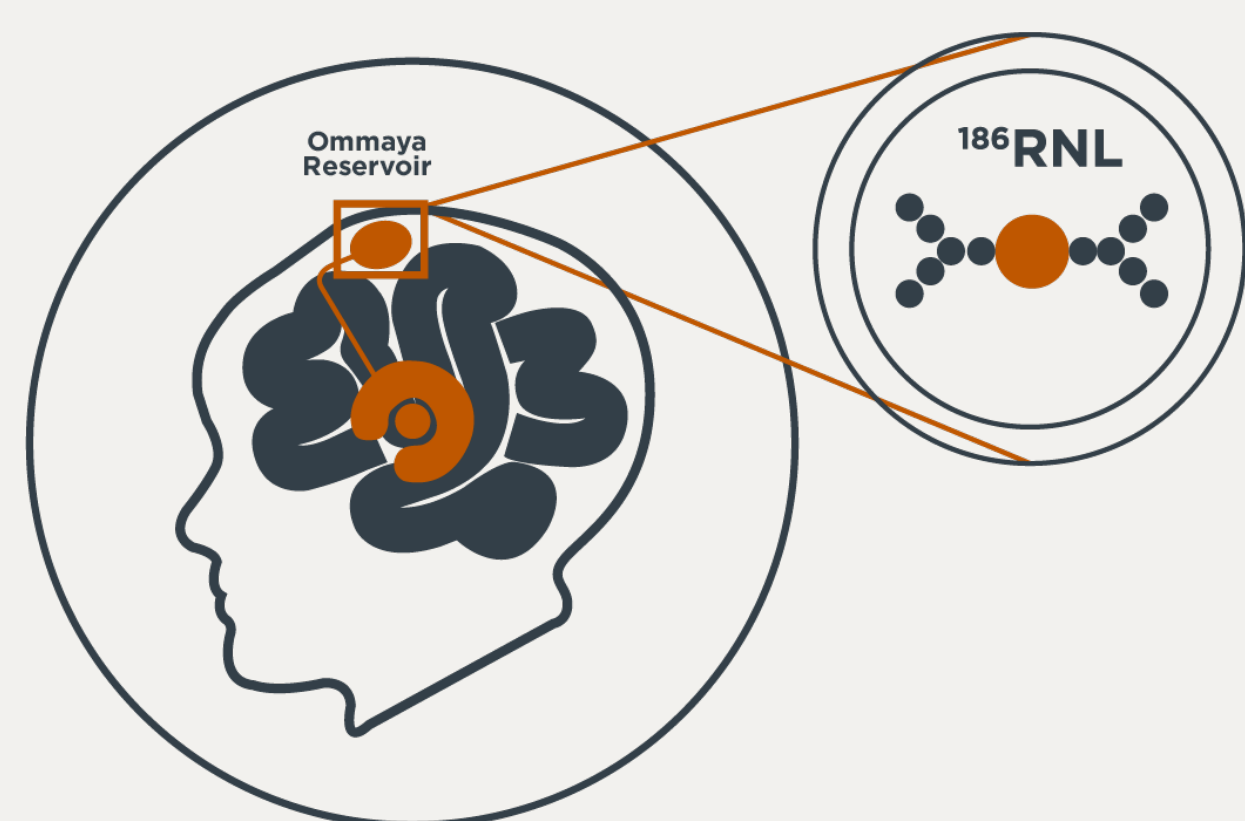


Figure 1. ¹⁸⁶RNL is BMEDA-chelated ¹⁸⁶Re encapsulated in nanoliposomes. For the treatment of LM, it is directly delivered to the CSF via intraventricular catheter (Ommaya reservoir).

STUDY DESIGN

ReSPECT-LM is a multi-center, sequential cohort, open-label, dose-escalation, Phase 1 clinical trial to evaluate the safety and tolerability of a single dose of ¹⁸⁶RNL given by the intraventricular route (Ommaya reservoir) in adult patients with LM from any primary cancer. The **primary objective of the Phase 1 study** is to determine a maximum tolerated dose (MTD)/maximum feasible dose (MFD) over 7 cohorts utilizing a modified 3+3 Fibonacci design (**Table 1**).

Cohort	Infused Volume (mL)	Total ¹⁸⁶ RNL Activity (mCi)	Concentration (mCi/mL)	Increase	Status
1	5	6.6	1.32	N/A	Complete
2	5	13.2	2.64	100%	Complete
3	5	26.4	5.28	100%	Complete
4	5	44.10	8.82	67%	Complete
5	5	66.14	13.23	50%	Enrolling
6	5	87.97	17.59	33%	Pending
7	5	109.96	21.99	25%	Pending

Table 1. ReSPECT-LM dose escalation schema for cohorts 1-7. Cohort 5 is currently enrolling.

The starting dose level of 6.6 mCi (cohort 1) was based on results of preclinical studies. Patients included on study are at least 18 years of age, have proven and documented LM (EANO-ESMO Clinical Practice Guidelines Type 1 and 2, except for 2D), Karnofsky performance status of 60-100, and standard organ function. As noted above, patients with any primary cancer are included. Patients with obstructive or symptomatic communicating hydrocephalus, ventriculo-peritoneal or ventriculo-atrial shunts without programmable valves, contraindications to placement of Ommaya reservoir, any prior radiation dose to the spinal cord or whole brain radiation therapy, or standard concomitant illnesses are excluded from the study.

Because 10-70% of subjects with LM have some sort of CSF flow abnormality, all study participants require a diagnostic CSF flow study using Indium-111 diethylenetriaminepentaacetic acid (¹¹¹In-DTPA) or low dose (1 mCi) ¹⁸⁶RNL following screening and 48-96 hours prior to ¹⁸⁶RNL infusion. Failure of the radionuclide to appear in a given CSF compartment is operationally defined as CSF flow block and the patient subsequently classified as a screen fail.

Patients are given supersaturated potassium iodide (SSKI) prior to treatment. ¹⁸⁶RNL is delivered intraventricularly through an Ommaya reservoir (5 mL, 1mL/min infusion). Whole Body Planar is completed at end of infusion (EOI) and 3.5-, 24-, 48-, and 168-hours post-infusion. SPECT/CT imaging is completed 45-minutes and 24-hours after EOI.

Samples of the CSF are drawn via the Ommaya reservoir at various intervals to monitor radioactivity, estimate absorbed dose, and perform pharmacodynamic studies, such as determination of DNA damage markers, tumor cell count, and standard of care cytology analysis. Urine samples are collected at 0-24-hour and 24-48-hour intervals for radioactivity measurements. Likewise, blood samples are collected after ¹⁸⁶RNL infusion at various timepoints to estimate the absorbed dose to red marrow. Study subjects are routinely assessed by MRI (standard of care) until disease progression according to RANO criteria.

PATIENTS

17 patients were consented and screened between March 07, 2022 and September 18, 2023. 13 patients were treated with ¹⁸⁶RNL over 4 cohorts between March 16, 2022 and September 21, 2023 (1 withdrew consent and 3 were screen failures). Patients were treated over three study sites: UT Health San Antonio (7 patients), UT Southwestern (5 patients), and Northwestern (1 patient).

62% of patients were women and 77% were white. Patients ranged in age (at time of treatment) between 35 and 70 years old.

Patients of all primary tumors are included in the Phase 1 study. The majority of the patients had breast cancer as their primary tumor (46%); other primary tumors included Kaposi sarcoma (1), lung adenocarcinoma (2), non-small cell lung cancer (1), pineal parenchymal tumor of intermediate differentiation (1), small cell carcinoma of the oropharynx (1), and squamous cell carcinoma (1).

TUMOR CELL ENUMERATION

Exploratory endpoints included performing analysis on cerebral spinal fluid (CSF) pre- and post-administration of ¹⁸⁶RNL to evaluate pharmacodynamic (PD) markers of ¹⁸⁶RNL efficacy. For tumor cell enumeration, Biocept's CLIA validated CNSide assay was used. CSF tumor cells were captured using a biotinylated 10-antibody capture cocktail and immobilized in a streptavidin coated microfluidic channel. Cancer cells were identified with various immunocytochemistry markers (e.g., Cytokeratin, CD45) and cells were quantified via digital analysis of the microfluidic channels. Tumor cells were defined as DAPI positive, CD45 negative, Cytokeratin positive or negative, and Streptavidin positive. Figure 2 provides the percent change of tumor cell counts to predose at 24-hours, 48-hours, 28-days, and 56-days post infusion for 12/13 patients with reported data. Patients had up to 100% reduction in tumor cell count (max reduction at all time points measured), with an average of 59% reduction at Day 28 (compared to predose; range of 6% increase to 100% decrease).

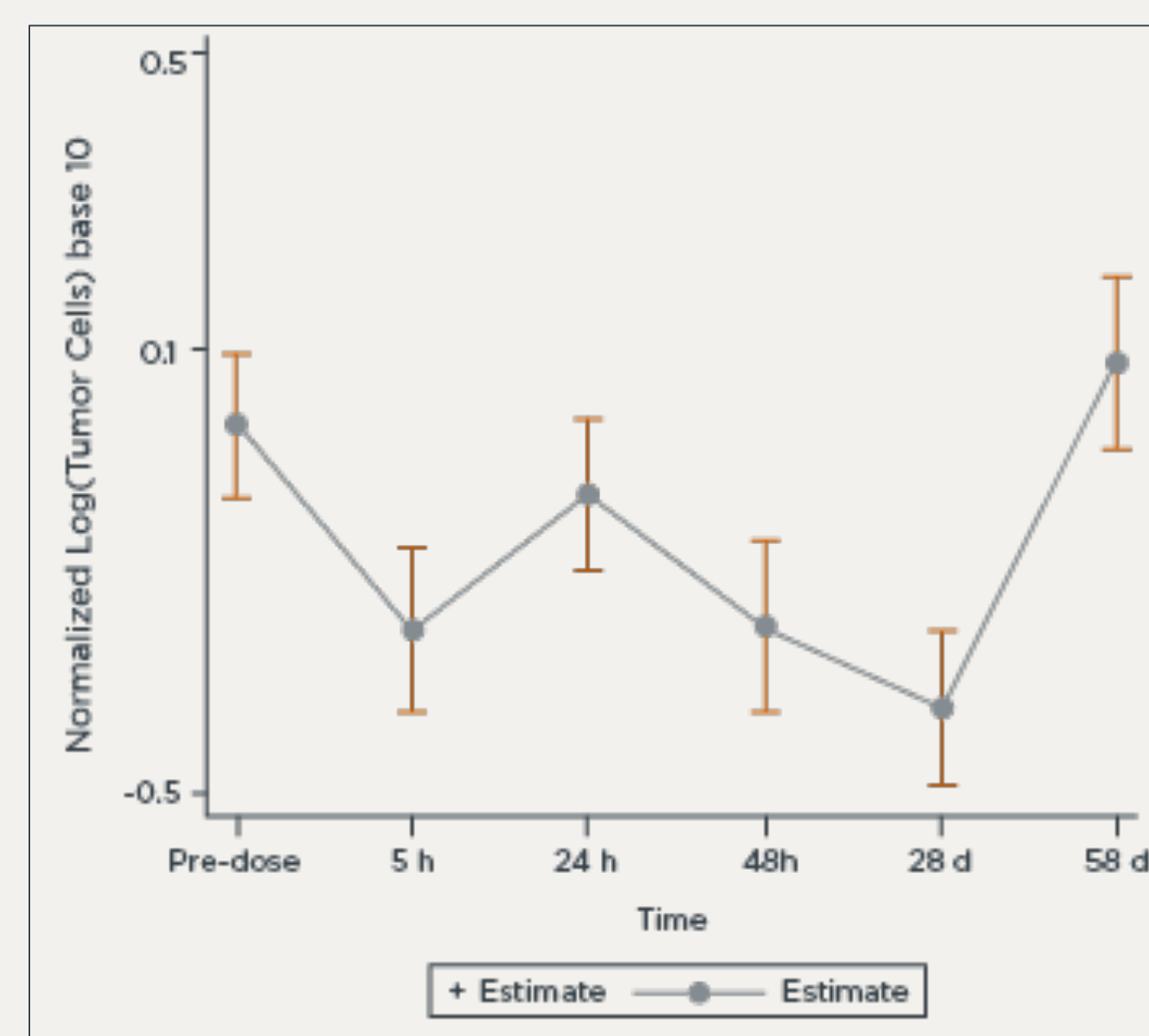


Figure 2. Normalized Log (tumor cells) by time for 10 evaluable patients.

IMAGING

Planar and tomographic (SPECT/CT) images were collected from all subjects using a dual-detector SPECT/CT camera. A sealed ¹⁸⁶Re radioactivity vial with known ¹⁸⁶Re radioactivity (~5% of injected radioactivity) was positioned next to each subject's head and well inside the image field of view at each time of image acquisition for in vivo radioactivity quantification. The planar and tomographic image acquisition uses low energy high resolution parallel-hole collimators (LEHR) with three energy windows setting: 1) Primary energy window: 137 keV (\pm 10%); 2) Low energy scattering window: 119 keV (\pm 3.5%); and 3) High energy scattering window: 156 keV (\pm 3.5%). Representative SPECT/CT images at the two acquisition time points (45-min post EOI and 24-hr post EOI) are shown in **Figure 3**.

Representative whole body planar imaging in **Figure 4** shows durable retention of ¹⁸⁶RNL out to 7 days.

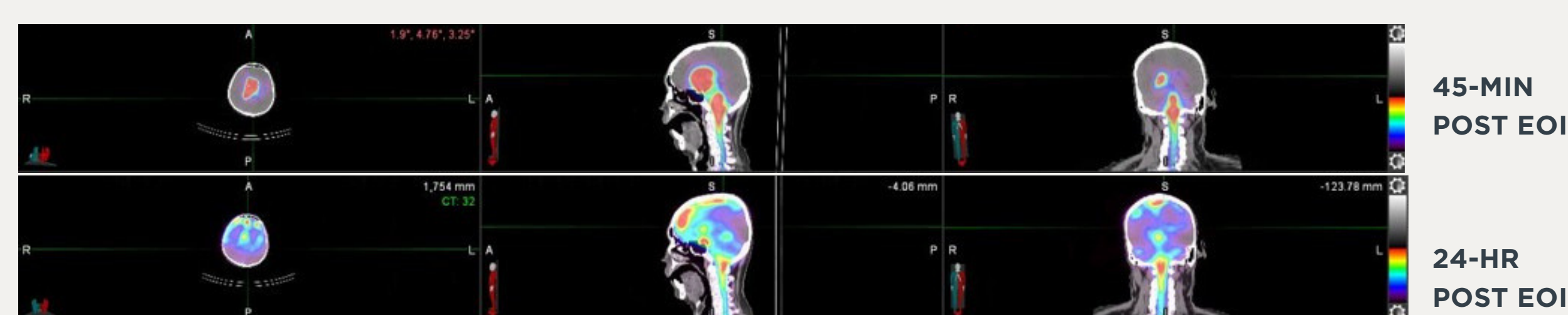


Figure 3. SPECT/CT of LM patient in cohort 2 (13.2 mCi injected activity) at 45-min and 24-hours post intraventricular ¹⁸⁶RNL infusion through the Ommaya reservoir.

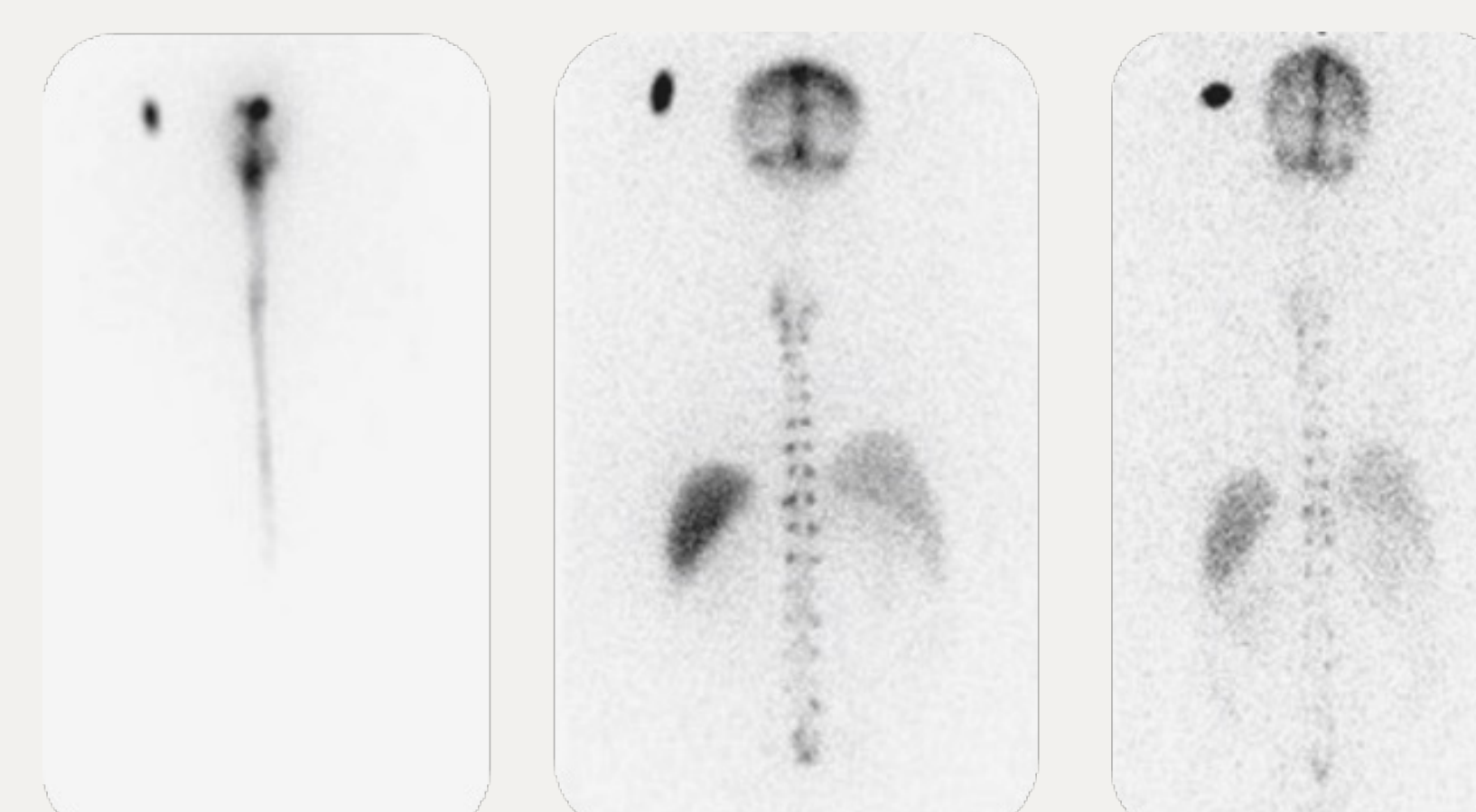


Figure 4. Whole body planar image of LM patient at 0.25-hours, 48-hours, and 7-days post intraventricular ¹⁸⁶RNL infusion through the Ommaya reservoir.

SAFETY

13 patients were treated over 4 cohorts, with one patient receiving a second treatment (retreatment protocol) under compassionate use. To date, we have had no DLTs and have not reached MTD/MFD. The majority of AEs were mild (Grade 1, 64.10%) or moderate (Grade 2, 27.35%) with only one AE of Grade 5 (systemic disease progression) with an attribution of unrelated to study drug. Only five SAEs were found, and all were not related or unlikely related to study drug except for one. The one possibly related SAE was also attributed to the patient's pre-existing condition.

ABSORBED DOSE

Table 2 reports the average absorbed dose of cranially located, subarachnoid cerebral spinal fluid for the ventricles and cranial subarachnoid (SA) space, ventricles (Lateral, 3rd, and 4th), and cranial subarachnoid space. Additionally, we measured the average absorbed dose in the spinal fluid, liver, and spleen. Organ doses remain low while absorbed dose to the CNS increased with administered dose.

Cohort	Liver Absorbed Dose (Gy)	Spleen Absorbed Dose (Gy)	Ventricles and Cranial Subarachnoid Space Absorbed Dose (Gy)	Ventricles (Lateral, 3rd, and 4th) Absorbed Dose (Gy)	Cranial Subarachnoid Space Absorbed Dose (Gy)	Spinal Fluid Absorbed Dose (Gy)
1	0.38	1.82	24.84	19.26	27.95	6.88
2	0.64	3.61	40.86	25.43	49.49	20.73
3	1.47	2.40	63.83	25.96	85.73	44.07
4	1.26	1.43	156.16	82.64	196.41	78.68

Table 2. Average absorbed doses over 13 patients treated with a single dose of ¹⁸⁶RNL.

OVERALL SURVIVAL

The median overall survival (OS) for n=10 patients (cohorts 1-3) was 10 months (95% CI 1-NA) with 5 alive and censored patients at the time of analysis (August 1, 2023) (**Figure 5**).

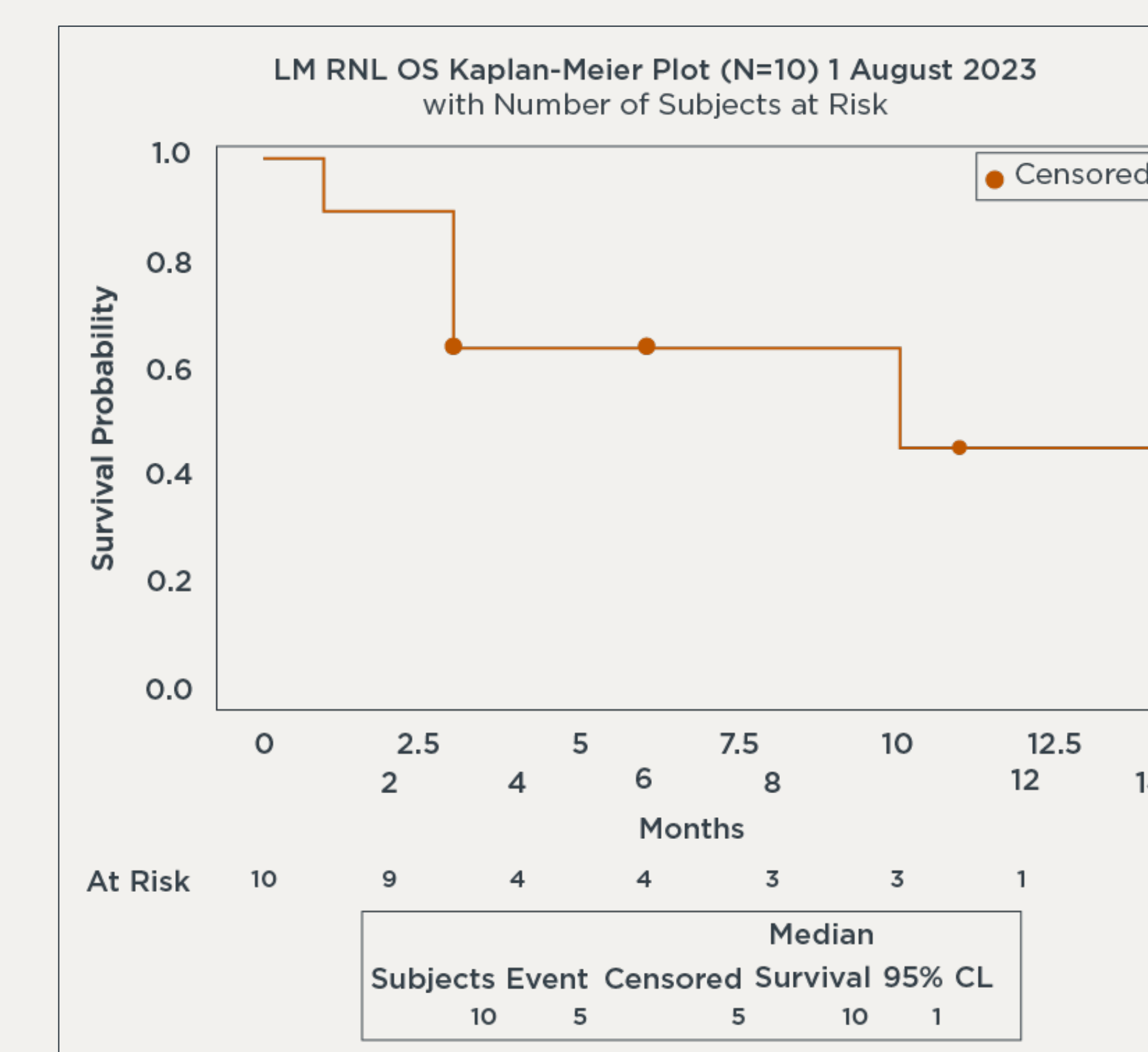


Figure 5. Kaplan-Meier analysis for 10 Phase 1 patients.

CONCLUSION

- + 13 patients with LM received a single intraventricular dose of ¹⁸⁶RNL between 6.6 and 44.10 mCi through indwelling Ommaya reservoir.
- + In all 13 patients, ¹⁸⁶RNL circulated throughout the CSF space by 1-hour following administration and persisted in the CSF for up to 7-days.
- + Variability was seen in the absorbed dose in CNS structures but there was a linear increase with increasing administered dose.
- + As expected with a nanoliposome formulation, overall organ radiation doses were low, with the liver, spleen, and bladder wall having the most prominent ¹⁸⁶RNL clearance but still significantly below any absorbed dose concerns for a critical organ.
- + No DLTs were observed and the MTD/MFD was not reached.
- + Most AEs were Grade 1 and 2.
- + CSF tumor cell enumeration decreased up to 91% following ¹⁸⁶RNL treatment.
- + 7/13 treated patients remain alive (at time of reporting) with a median OS of 10 months for patients in the first three cohorts (cohorts 1-3).
- + A continued dose escalation design to MTD/MFD (cohorts 5-7) is open and enrolling.
- + Multi-dose and retreatment protocols are in process.