**Transplant Date: July 20, 2021**

**Protocol Number:** AMI-018-006

**Study Number:** AMI-018-006-120

**Title of Study:** Transplantation with PHH lot DJW using a new blended NTBC cycle tests to evaluate engraftment and early pHH expansion and survival at ≥ 70 days post-transplant plus compare 1X vs 2X Ad:uPA dose concentration for liver pre-conditioning.

**Primary Investigators:** Lisa Wilson

**Number of Animals:** 40. **Species:** Rat. **Strain:** SD FRG. **Gender:** Male & Female. **Age or weight range: 5-**6 weeks

**Purpose**:

In IACUC protocol AMI-018-006, the focus of the set of experiments is to utilize the immunodeficient rat model of hereditary tyrosinemia type 1 (HT1) - which are deficient in the enzyme fumarylacetoacetate hydrolase (FAH) – as the model for expanding human hepatocytes. Hepatocytes that are FAH+ have a selective growth advantage over FAH- hepatocyte; therefore, we hypothesize that FAH+ human hepatocytes will grow and repopulate the FAH-KO rat liver. Proof-of-concept has already been demonstrated in the mouse model of HT1 (see Azuma et al. 2007 PMID: 17664939).

Studies are under way to improve the health and survival of transplanted FRG rats out to 90-125 days post-transplant while maintaining robust expansion of the transplanted primary human hepatocytes. In previous NTBC cycles there was an abrupt transition from NTBC at ≥ 1mg/L NTBC to 0.05-0 mg/L within the first 28 days of the cycle leading to a high mortality rate. We believe this mortality is due to a hypersensitivity to NTBC withdrawal (≤ 0.05mg/L) which leads to rapid apoptosis of the rat hepatocytes causing acute liver failure. Data from the most recent NTBC cycles in Phase 1 and 2, at -28- and -50-days post-transplant respectively, using the 0.4mg/L > 0.05mg/L NTBC (Cycles 4 and 11) allow for rat hepatocytes to enter senescence (0.4mg/L) prior to the very low NTBC concentration(0.05mg/L) where selective pressure is applied for the human hepatocytes to expand. Using this cycle has improved survival in the first 50-days post-transplant from ≤ 20% in seen from Jun 2020 – Sep 2020 to ≥ 80% from Oct 2020 – Apr 2021.

To date, we have not been able to improve survival at ≥ 70 days post-transplant. Data from evaluation of blood and tissue at the end of each Phase using Cycle 11, indicates that injury to kidneys and liver is occurring as early as 28 days post-transplant leading to a progression of chronic health issues. We hypothesize the lack of improvement is from insufficient NTBC to clear the toxic metabolites that provide the animals with a “rest” period. In studies -115, -116 and -117 we modified Phase 3 and 4 to use a blended cycle to include higher doses of NTBC, 2mg/L for 3 days> 0.4mg/L for 4 days to induce senescence before going to the low dose, 0.05mg/L for 14 days that applies selective pressure on the pHH to expand. At the end of each phase of the NTBC cycle animals will be selected for euthanasia and samples collected to evaluate the health of the animals.

Another variable that could be contributing to the low survival rate is the dose of Ad:uPA for pre-conditioning the mice. Ad:uPA is used to induce liver injury leading to the release of HGF to promote hepatocyte regeneration. Due to significant changes in the survival and repopulation indexes in transplanted FRGN mice and FRG rats in 2020, studies were initiated to evaluate the standard 1X Ad:uPA, 5E+7pfu/g of bw, vs 2X Ad:uPA, 1E+8puf/g of bw on survival and repopulation. The data from these studies indicated the 2X Ad:uPA, compared to the 1X Ad:uPA, improved the initial engraftment of the transplanted hepatocytes leading to significant improvements in survival and pHH replacement indexes. Therefore it was decided to use the 2X Ad:uPA for pre-conditioning of FRG rats. Starting with study AMI-018-006-095, 2/17/21, all FRG rats entered into transplantation studies have been pre-conditioned with the 2X Ad:uPA dose.

Hypothesis:

For study AMI-018-006-120 we propose repeating the same NTBC cycle used in AMI-018-006-119, introducing a blended cycle with the 2mg/L NTBC earlier post-transplant to prevent the kidney/liver injury and improve survival ≥ 70 days post-transplant. By repeating this cycle we have a larger number of animals for statistical analysis as well as confirming the effects of the cycle change. In addition, the animals will be divided into two groups, A and B, and dosed with either 1X or 2X concentration of Ad:uPA to evaluate engraftment, pHH expansion and survival when compared to the same NTBC cycle.

All FRG rats will be on 5LJ5

All FRG rats will begin on 16 mg/L NTBC + 820µg/mL Equisul in the drinking water

**Experiment Outline:**

N=40 FRG rats

Animals will be held for at least one week to acclimate following arrival.

Animals will be socially housed. On the rare case where one animal remains in a cage without a partner, additional cage enrichment (non-food) will be provided.

Animals will be divided into 2 groups, A and B, with equal number of males and females.

Using body weights collected the same day as preconditioning the rederived FRG rats from Envigo will be dosed with Ad-uPA 24h ± 2h prior to transplant and placed on the drinking water as specified in the NTBC cycling protocol located on the Ambys G-drive. On the day of transplant, the cryopreserved validated commercial PHH Lot will be prepared following the standard protocol used for transplantation.

**Day -1:** In the AM, ALL rats will be dosed with 1E8pfu/gram of body weight Ad-UPA by IV tail injection. Ad-uPA will be provided to the IVS team for tail vein dosing. The NTBC drinking water will be changed as indicated in the above chart.

|  |  |  |
| --- | --- | --- |
| **Group** | **# of FRG rats** | **Ad:uPA dose (pfu/g of BW** |
| A | 20 | 5E+7 pfu/g of body weight |
| B | 20 | 1E+8 pfu/g of body weight |

A picture containing timeline

Description automatically generated

**Day 0:** Hepatocytes (5 million per 100g of rat) will be prepared in hepatocyte media (2.5 million per 100 µl media). The volume of hepatocytes suspension determined by body weight will be in 1.5ml Eppendorf tubes and transferred on ice. Hepatocytes will remain on ice until time of injection. At time of injection, hepatocytes will be gently pipetted up/down x3 with P1000 pipet and sterile P1000 tip to get the cells in suspension (hepatocytes are large and will quickly pellet to the bottom of the tube). Hepatocytes will be drawn into a sterile 1cc syringe with a 27G needle and injected into the spleen via laparotomy method.

**Day 1 onwards:** Animals will be put on the short NTBC cycle as indicated above in the chart and as indicated in the NTBC water cycle sheet located on the Ambys’ G drive.

All animals post-transplant will be offered the nutritionally balanced **Supreme mini treats supplement** at the time of body weight collection as positive reinforcement (~1-2 pellets) and for supplementation of additional calories and vitamins at a dose of 6-8 pellets per animal.

The IVS team will record the date and quantity of supplement administration, and clinical observational scores.

**Day 28-92: Urine and Serum collection**

On the days indicated in the chart below, the PI or IVS Supervisor with randomly select 2 animals from Group A and 2 animals from Group B for procedures.

1. Using the standard urine collection method as much urine as possible will be collected from each animal and dispensed into 50µL aliquots before storing at -20C.
2. Induce a surgical plane of anesthesia with 3-5% isoflurane and collect ~500µL of whole blood via the retro-orbital vein. Isolate serum and place 210µL into sterile 1.5mL microfuge tubes before storing at -20C.
3. Recover animals and observe until conscious and righted in cage.

|  |  |  |  |
| --- | --- | --- | --- |
| Phase | Day of collection ± 1 days | Group A | Group B |
| 1 | August 16, 2021 | 1F, 1M | 1F, 1M |
| 2 | September 13, 2021 | 1F, 1M | 1F, 1M |
| 3 | October 4, 2021 | 1F, 1M | 1F, 1M |
| 4 | October 25, 2021 | 1F, 1M | 1F, 1M |

**Day 30 – 90**: All animals, collect 5µL whole blood for human albumin measurements via tail vein, tail or saphenous vein nick at the specified dates on the chart above and the NTBC water cycle sheet located on the Ambys’ G drive. **PI will communicate:**

**Day 50 huAlb readout:** hAlbumin **≤ 250µg/mL** will be removed from study and euthanized.

**Day 70 huAlb readout:** hAlbumin **≤ 750µg/mL** will be removed from study and euthanized.

**Day 0-125:** Body weights and clinical scoring will be measured and documented up to three times each week.

**Day >125:** IVS to notify PI and Perfusion Team of any remaining animals.

**Animal care and welfare:**

Refer to **the document titled “VETERINARY CLINICAL CARE AND REPORTING FOR FRG RATS”** for the evaluation and documentation of clinical status and palliative treatments**.** In reference to the group A and B assignments above, animals will be supplemented based on their group assignments.

**Additional Veterinary Testing:**

For veterinary health and surveillance screening, the Attending Veterinarian may request aseptic sample collection of tissues in lieu of perfusion, under general anesthesia. Once all samples have been collected, the animal will be euthanized via exsanguination/vital organ removal.

**Humanized FRG rats for perfusion, hepatocyte isolation and human hepatocyte purification:**

At ≥ 71 days post-transplant with human albumin concentrations of ≥ 2,500µg/mL, animals may be offered to the Product Development team for optimization of processes involving liver perfusion (refer to the document titled “Perfusion Procedure Guideline: Portal Vein and Inferior Vena Cava Approaches), hepatocyte isolation, human hepatocyte purification and in vitro characterization.

Once the cannula has been inserted into the caudal vena cava or portal vein, secured and blood starts to fill the head, ≥ 500µL whole blood will be collected for sera isolation. Alternatively, the blood may be collected from the tail vein based on a 50µL aliquot of sera will be dispensed into a pre-labeled sterile 1.5 mL tube for Tyrosine and Succinylacetone quantitation. Remaining sera will be transferred to a second pre-labeled sterile 1.5mL tube. Both aliquots should be stored at -20C until shipped for analysis.

Principal Investigator: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Head of Pharmacology (or alternate): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Appendix A: Processing blood, urine and tissue samples**

Blood collection

* Using Isoflurane, anesthetize the animal to a surgical plane of anesthesia (Induction 4-5%, maintenance 2-3%). Confirm with a firm toe pinch on both hind feet.
* Using operating scissors or other appropriately sized scissors, cut through the skin and muscle to open the peritoneal cavity.
* Using gauze, sweep the intestines out of the body cavity to expose the inferior vena cava.
* Using 5 mL (rat) syringe and 25 G needle puncture the inferior vena cava and slowly withdraw 4mL of blood from rat. Be careful to not collapse the vein by creating too much vacuum pressure.

Serum:

* Dispense ≤ 2mL whole blood volume into 4mL serum separator tube and allow to clot for at least 1 hour at room temperature.
* Centrifuge at 10,000 rpm for 5 minutes.
* Dispense 220µL into 4 X 1.5 sterile mL tube, store at -80C

Plasma:

* Dispense ≥ 1mL of whole blood in a 4mLK2EDTA anticoagulation micro tube (do not overfill or blood will clot).
* Gently invert 3 times (do not shake) to facilitate complete mixing with anticoagulant.
* Centrifuge at 10,000 rpm for 5 minutes.
* Dispense 80µL into 4 X 1.5 sterile mL tube, store at -80C

Urine during Necropsy

* Following collection of blood, collect urine (if present) via cystocentesis. Urine to be placed in labeled freezer compatible tube and store at -20oC

Collection of Liver

* Using blunt tipped scissors (curved if possible) separate the liver from the diaphragm, blood vessels and connective tissue and remove the liver from the body cavity.
* Make 4-5, 1cm nicks across the liver to facilitate fixation.
* Place whole liver in bottle of 10% NBF.

Collection of the Kidney

* Remove the adrenal glands, located in the fat cranial to the kidneys.
* Dissect the kidneys away from the fat and cut at the juncture of the kidney with the renal artery and vein.
* Transect the left kidney (transverse section) with a scalpel blade or straight razor.
* Longitudinally bisect the right kidney at the midline.
* Place into a bottle with 10% NBF