HA visit:

* Initial Issues:
  + RBC problem - Hb drop from 15-5 g/dL over first few hours; b/c no natural drainage point, pump suction tubing coming in from above
  + Settling of healthy RBCs as confirmed via peripheral blood smear; stagnation also = infection risk
  + Mixing solutions: tilting, pumps Gary suggested (elevated hemolysis as evidence through dark effluent dialysate color)
  + Mixing also further aerated the system; in addition to dropping of blood from VCS return, raw edge, IVC, etc.
  + Foam / perfusate interface = fibrinous substance formation; clogs filters (dialysis and oxygenator)
    - Also, souffle in pumps led to complete occlusion on one occasion
  + Needed a different blood reservoir to alleviate all these concerns
* New Blood Reservoir:
  + Cardiotomy reservoir - tapered to prevent settling, filter to get rid of debris, height difference b/t I/O to get rid of air
  + Want to bypass old reservoir and route to this, but need way to collect blood from liver raw edge (b/c we're doing segments - up to 50% of blood from the edge in some cases)
  + Enter the silicon rubber hammock - supports the liver (as having the liver sit on the metal grate you gave us / on the diaphragm w/movement leads to pressure necrosis especially around the periphery - cut and no bleed), but also has a magnet-based drain to collect raw edge bleeding and route to reservoir
  + Having drains in the same hammock (attached to posts on metal plate) as the liver = issues with the diaphragm and interfering with the drains; so new concept…
* Current Design:
  + Initial hammock for liver to rest; blood from raw edge drains off through pores in the hammock
  + Diaphragm below; adjustable height (get as close to liver as possible); is not something we had w/old design
  + Bottom hammock to capture all blood and route it to external reservoir
  + Claviens new paper: drain concept in the manner described above; also added cardiotomy reservoir
* To accommodate all this, we have our engineers design two spacers that replaced the initial spacer you all designed
  + Spacers also = increased height; before, chamber was short enough that w/diaphragmatic movement, the liver butted against the top water jacket
* Port where cannulas enters - fixes problem of each liver being variable / requiring cannulas to be in a different position; "rigid" concept with panels and ports didn't work well; also allows tubing to come in above the level of the liver
  + Negates the need for a deformable wire to be tied along cannulation tubing to allow for positional flexibility of cannulas
  + Does create a more open system however, which we’ve seen can lead to problems w/desiccation of liver surface, and thermoregulation
* Other thing we've discussed = suspension of liver by its triangular and falciform ligaments (US experiment - opens up collapsible veins)

**Design parameters:**

* Recapitulation of hammock and diaphragm to offload pressure, with funnel concept to collect all blood and route to external reservoir
  + Gary suggested using a sloped stainless steel pan to capture the blood; we would likely need to do testing with this to find the minimum height that can still provide the adequate slope to prevent settling
    - Funnel would be ideal; need walls to be sloped enough to prevent any stagnation / settling
    - Stainless steel pan has been used in other perfusion set ups
  + For hammock: stick with silicon rubber, or move to a silicon mesh? (see Porte et al. papers)
    - We want a balance of support + deformation
    - Our current hammock is 1/16” thick silicon rubber
  + Diaphragm design: multiple, alternatively inflating pieces?
    - Height must be adjustable to get the diaphragm as close as possible to the sagging liver; currently we use metal rods, perhaps we could have internal pegs in the reservoir to place these in? These would provide discrete locations for the pegs, though it would be better to have more continuous locations
    - Also need the ability to change the horizontal position of the diaphragm; add a sealable “access window” to allow the user to access the diaphragm, similar to the windows on the current reservoir
    - Whatever the new design, alleviate the current design’s flaws (many crevices for blood settling, flat edges where blood can pool, etc.)
* Integration of external reservoir is essential (filter capabilities)
* Cannulas coming in from above the level of the liver
  + Our current design of an open window works well for this, but it also creates an open system (heat loss / infection risk). Want to combine flexibility to change tubing location w/a closed system
    - Foam or silicon insert?
* Amenable to liver suspension / “hanging”
  + We will need to do more testing with this to see if its something we want in the final design
* Enough height to accommodate all of this
* Closed reservoir / jacketed; maintaining heat will be key, as will be keeping out infection (Heating - Permselect vs. CAPIOX; IV tubing warmer; other solutions?)
  + Any openings in the system (e.g. access windows) must be sealable
  + Pump that circulates warm, humidified air within the chamber?
  + Would like to move away from using clinical heater-oxygenators due to their propensity to fail; however, using just an IV tubing warmer doesn’t bring the organ anywhere close (only to 30C) to normothermia
  + Heating blankets around cardiotomy reservoir? Heated stainless steel tubing to run perfusate through? Rubber heaters to drape on top or underneath the liver?
  + Run an experiment where we eliminate the top/bottom water jackets (design our base and lid) to quantify heat loss from the reservoir without any heating in it?
* Closed system – desiccation issues
  + Based on US, liver was still well perfused, even in the periphery

**Other changes:**

* Second oxygenator - maintain portal saturation; titrating artery was too difficult; automate via CDI machine; Clavien did this in his new paper
* Major issues with hemolysis - precipitated our switch from Medtronic pump heads / drive to Rotaflow system; old cone design was bad