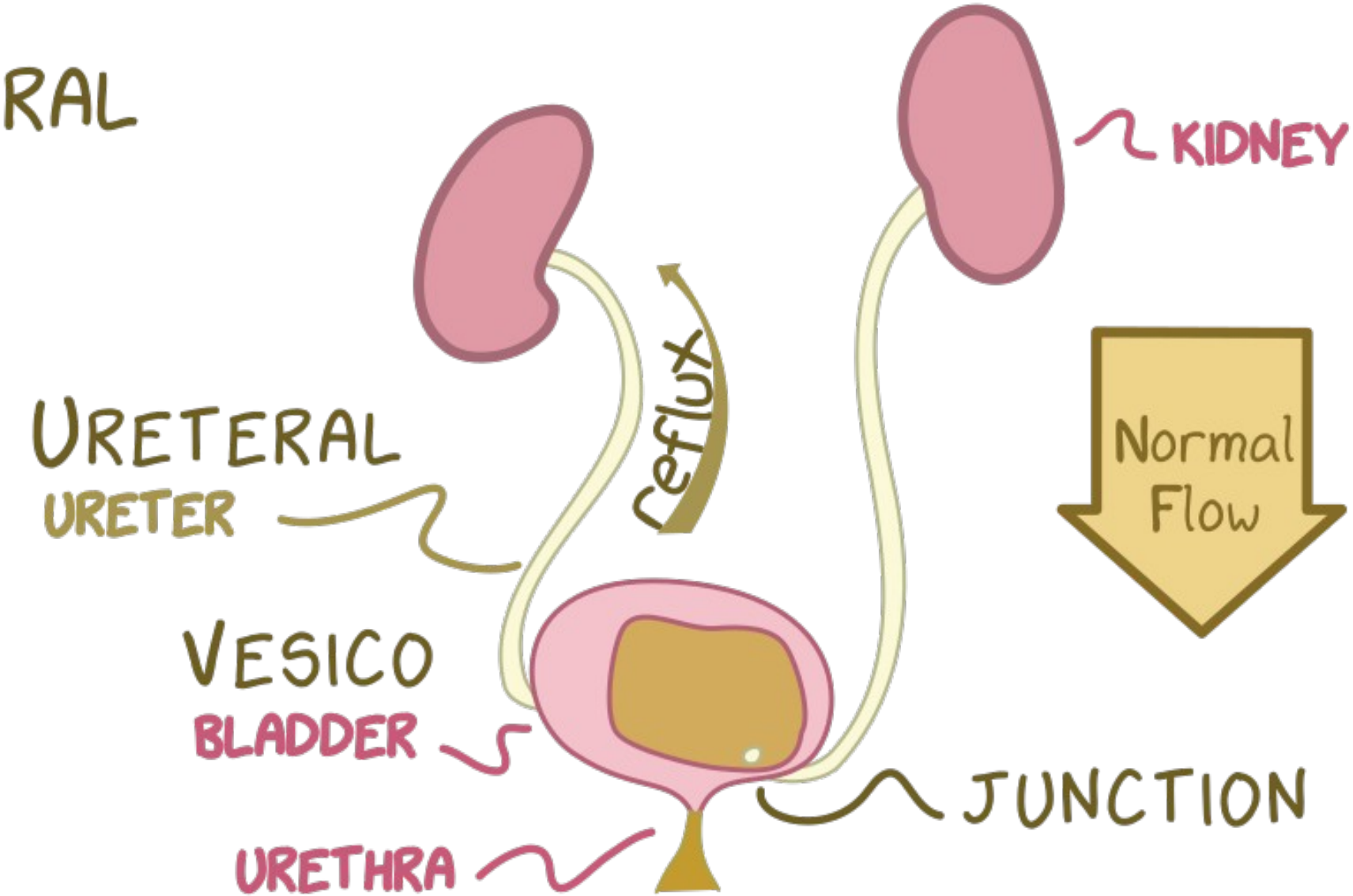
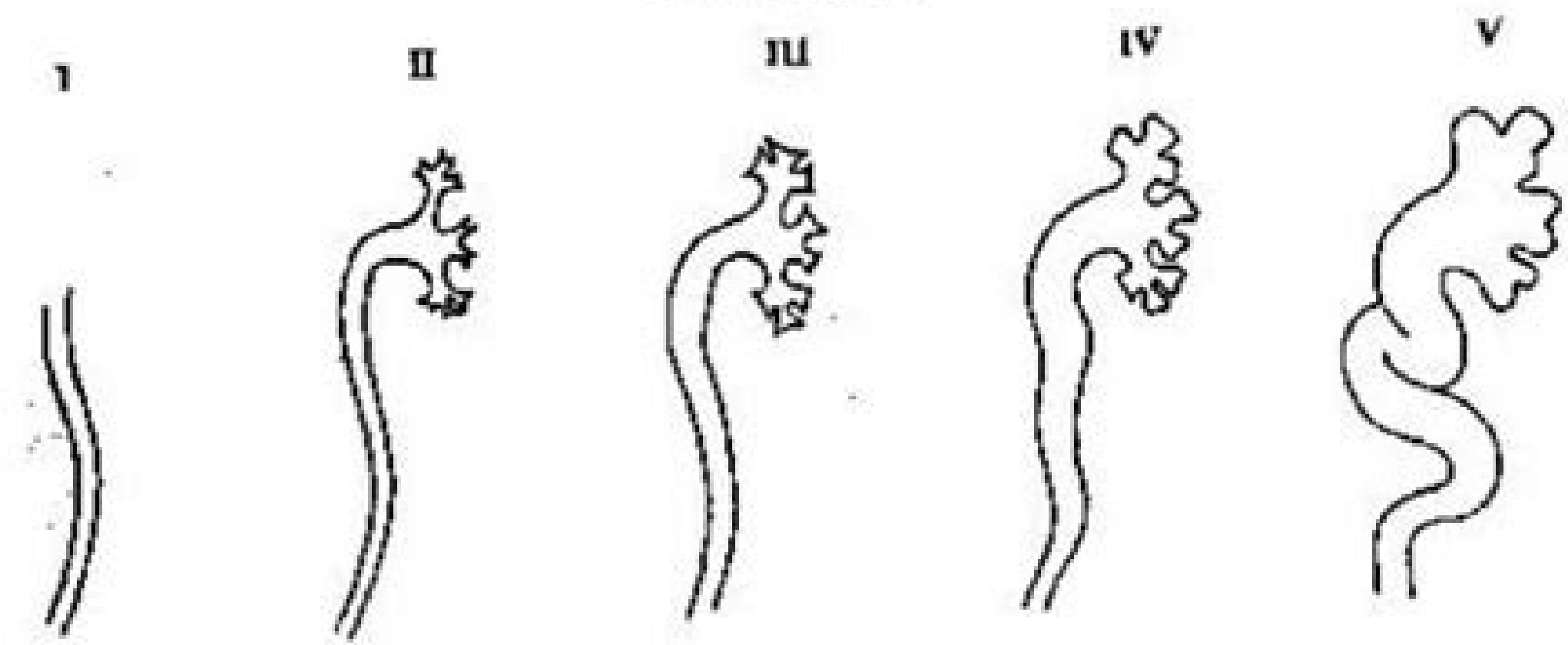
Vesicoureteral Reflux Imaged in an Animal Model Using EIT

Alistair Boyle[1,2], Hari Om Aggrawal[1] and Sarah Loughney[1]
[1] Kite Medical, Galway, Ireland
[2] Carleton University, Ottawa, Canada

VESICOURETERAL REFLUX (VUR)



Grades of VUR



from https://www.gaurology.com/wp-content/uploads/Grades_of_reflux_495x210.jpg

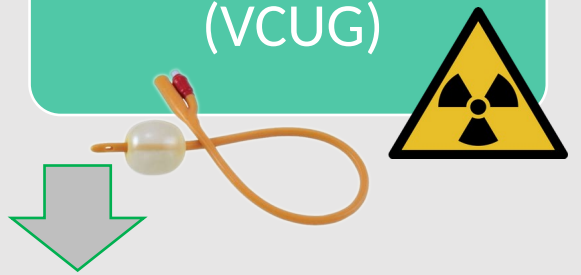
Current Diagnostic and Treatment Pathway

Febrile Urinary Tract Infection #2

Ultrasound

Sensitivity to VUR = 0.44

Voiding Cystourethrogram (VCUG)

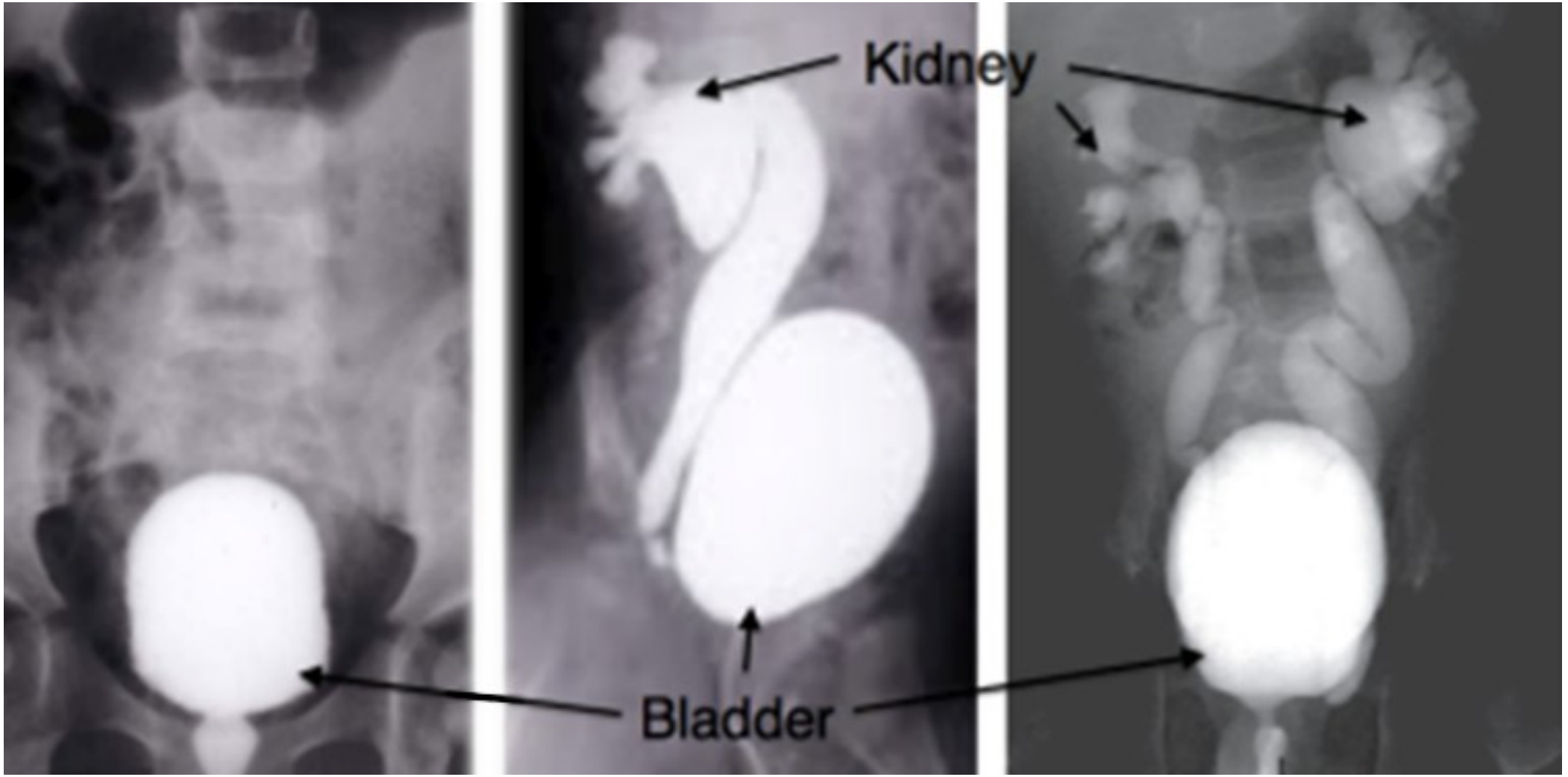


Prophylactic Antibiotics

Monitoring to Age 5-12

Surgery?

Voiding Cystourethrogram (VCUG)



Grade V VUR

The Experiment

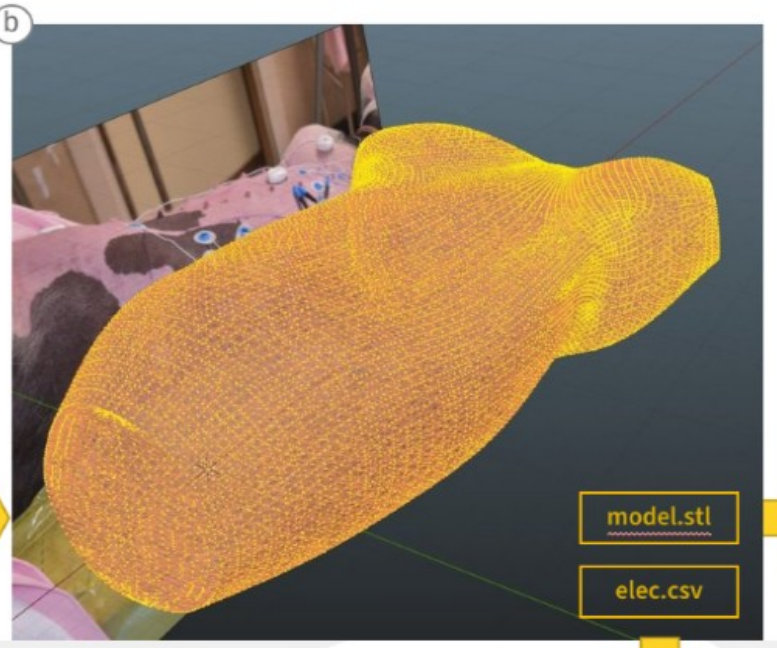
- A pre-clinical trial using a 32-electrode EIT system and inertial measurement units (IMU) was conducted in July 2021 on three pigs.
- The key features distinguishing this data from previous pre-clinical VUR experiments (Dunne *et al.* 2019) are:
  - **Stenting of the ureters**, rather than severing them, thereby including bladder filling effects in the data. A stent was positioned between the ureters and bladder, where previously a catheter directly infused solution into the ureters.
  - **Intentional movement** of the animal during data collection. Six IMUs (accelerometer, gyroscope, magnetometer) were used to directly measure the movement and to quantify the amount of movement at the skin surface around the kidney where electrodes were most densely placed.
  - **New EIT hardware and software**
  - **Electrode positions** optimised to detect VUR and to isolate nuisance conductivity parameters (Aggrawal *et al.* 2021) in a **3D arrangement** where previously a 2D ring of electrodes was used.

Procedure

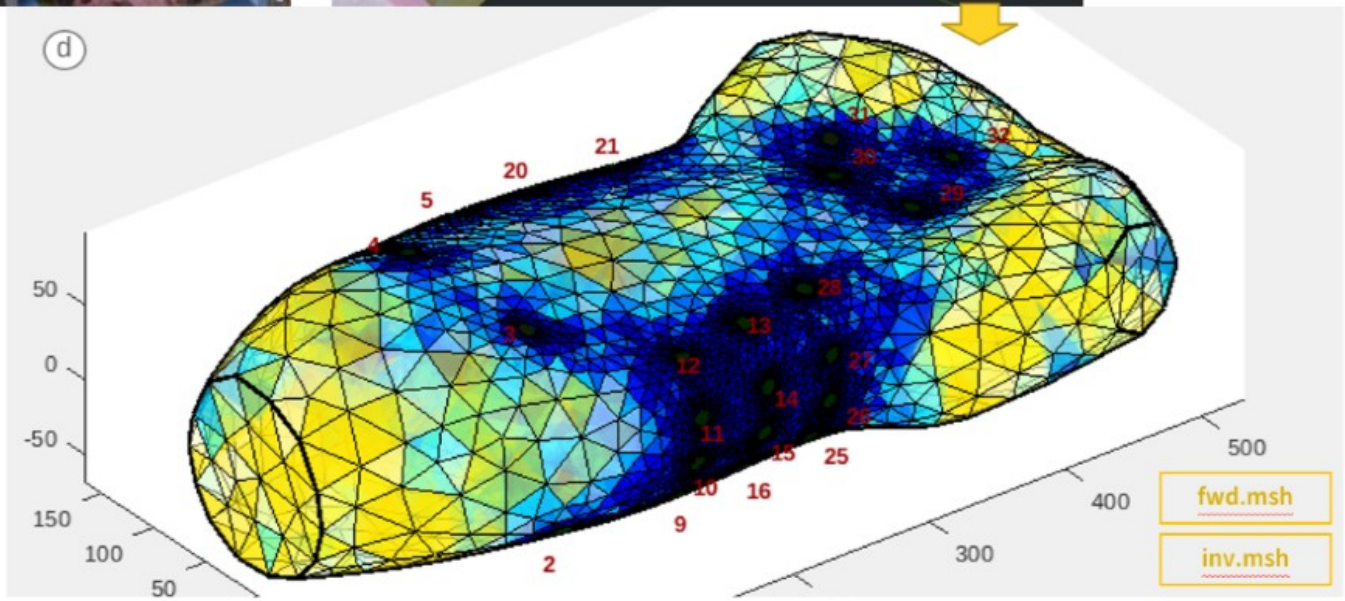
For three pigs the following procedure was completed:

1. The animal was anaesthetised and ventilated. Either one or both UVJ were stented. Placement of the stent was confirmed with CT or fluoroscopy.
2. Sensors were applied and calibrated.
3. **Up to 32 cycles of catheterized filling and draining** the bladder were completed while capturing measurements.

For the first and last cycles, x-ray contrast agent and fluoroscopy were used to confirm VUR. Otherwise, saline was used with conductivity values similar to urine. On alternating cycles, movement was modelled by manipulating the pig's left leg. Each stage of a cycle (empty, filling, filled, draining, back to empty again) was 30 to 90 seconds. Data was recorded continuously throughout the experiment.



model.stp

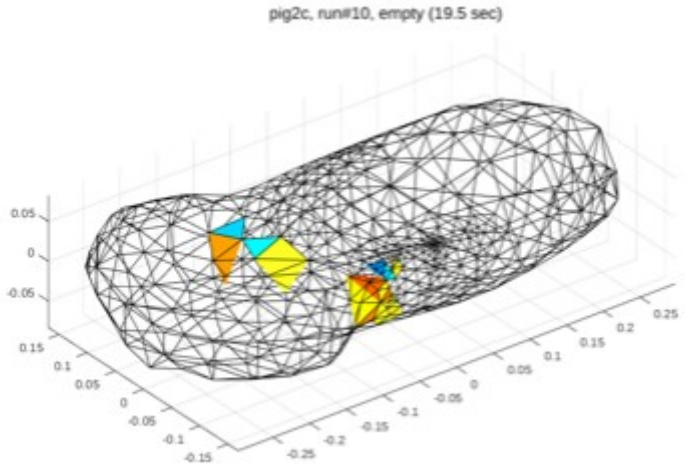


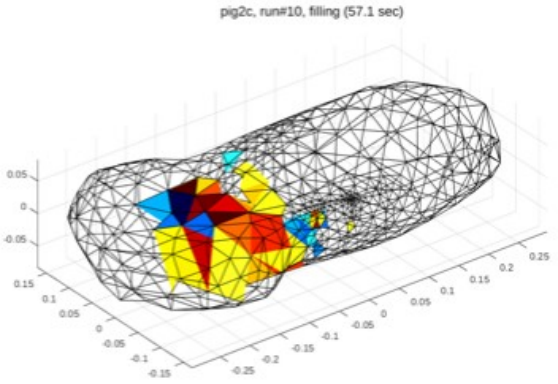
Adaptive Remeshing

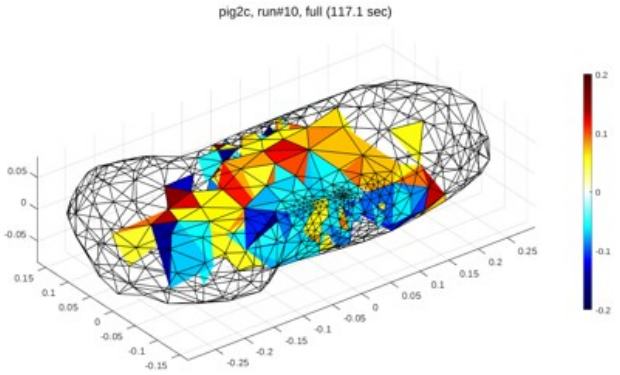
1. model.stp + elec.csv
2. initial mesh
3. simulate current density
4. remesh: fwd.msh + inv.msh

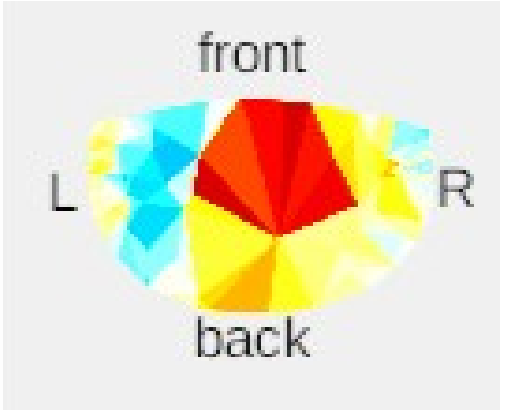
… repeat until tolerance

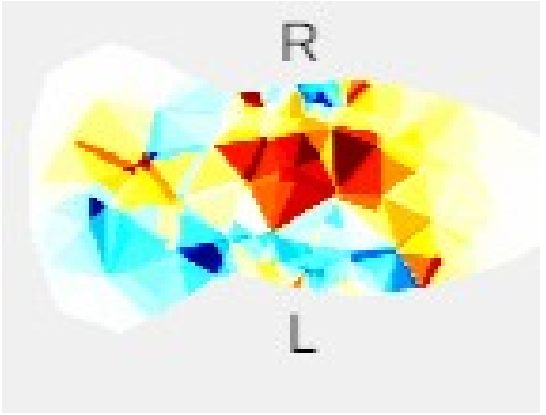
Bilateral VUR



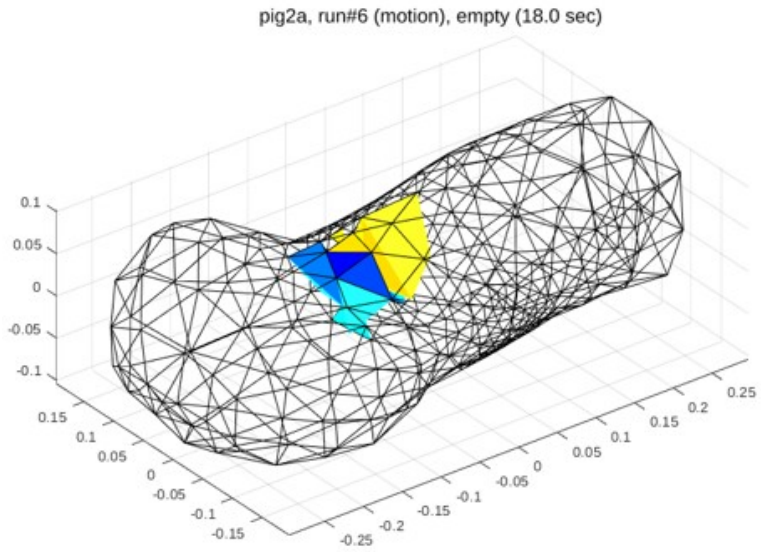


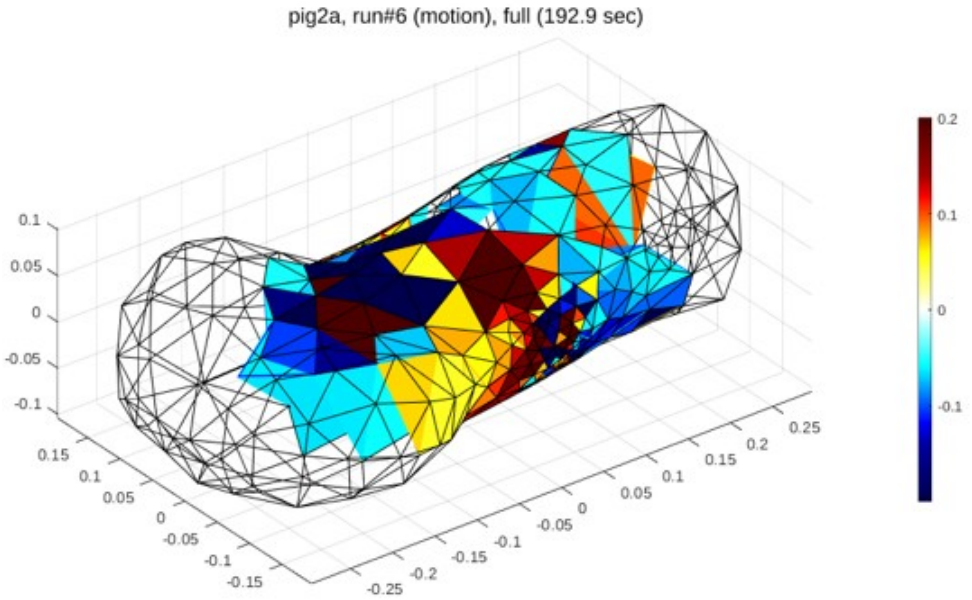


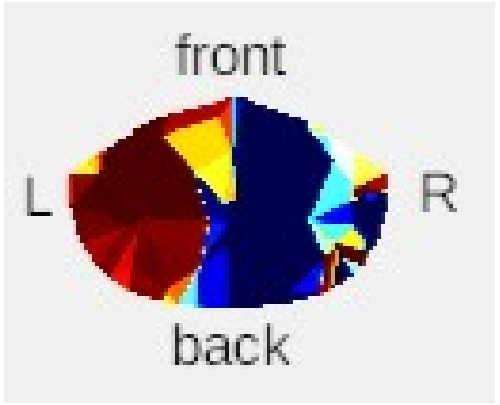


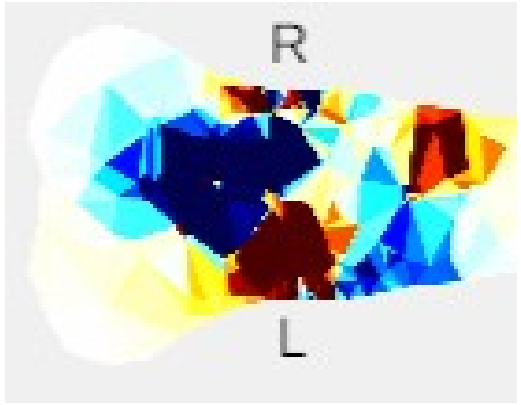


Unilateral VUR









Discussion & Conclusions

- Recreated approximately Grade II to III VUR
- 3D Models were built from multiple photographs. Fast methods for acquiring patient-specific models are important.
- Improved 3D EIT reconstructions using IMU data to track movement is a promising avenue for further work.
- Data from best 20 repetitions, suggests that VUR is detectable.*
- Where conductivity changes were not detected, the key issues were measurement noise due to either **movement** (typical bioimpedance/electrode movement effects) or **intermittent instrument noise**.

Thanks to the hardworking team at Kite Medical and HvV for making these experiments possible.

Thanks for your attention.

Contact me at alistair.boyle@kitemedical.ie

Kite medical