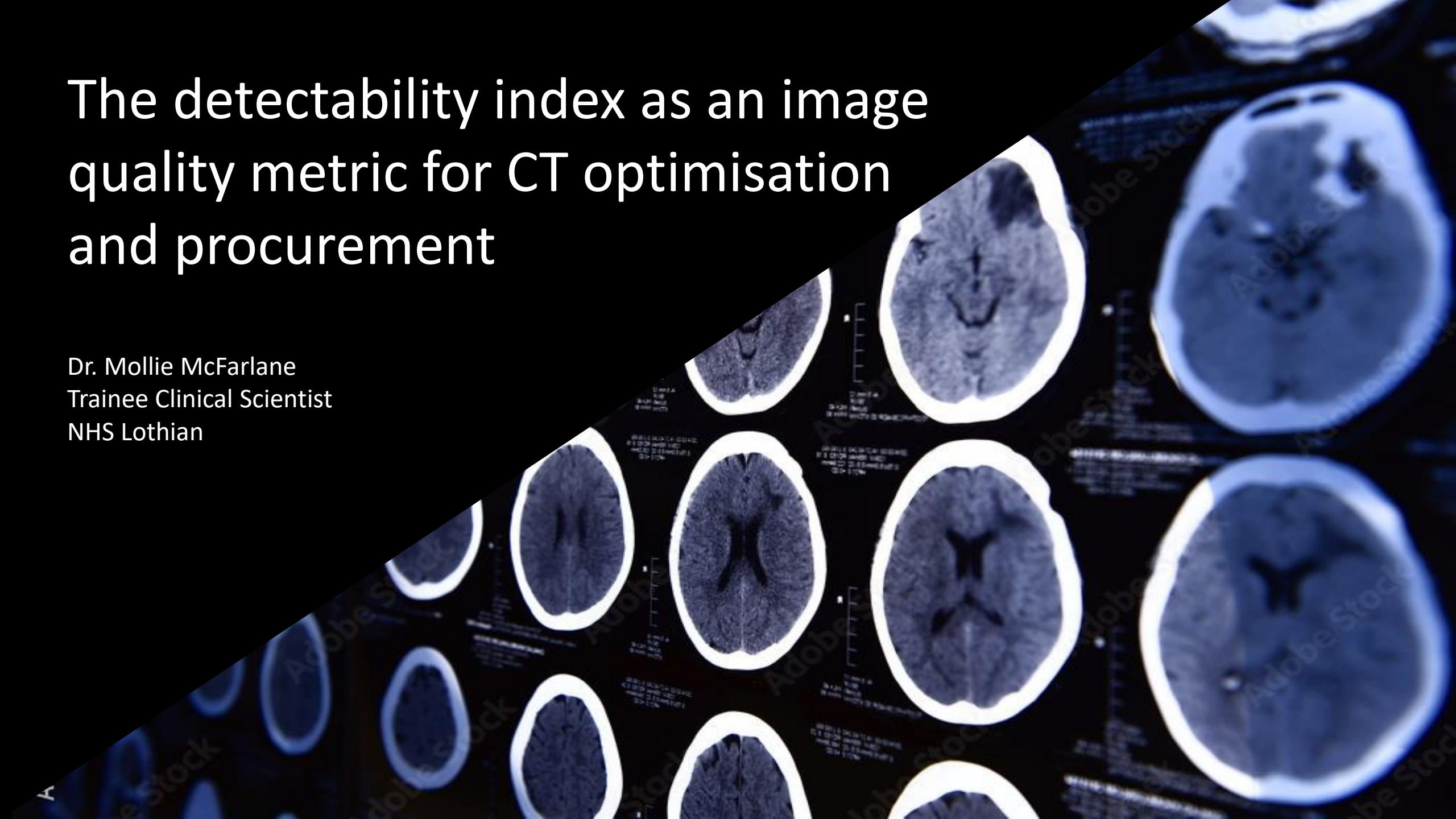


The detectability index as an image quality metric for CT optimisation and procurement

Dr. Mollie McFarlane
Trainee Clinical Scientist
NHS Lothian



The Detectability Index

Imaging task

Model human visual system

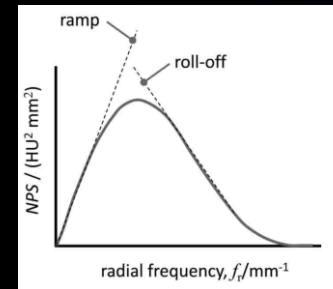
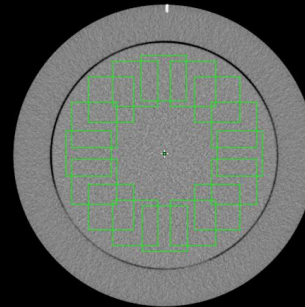
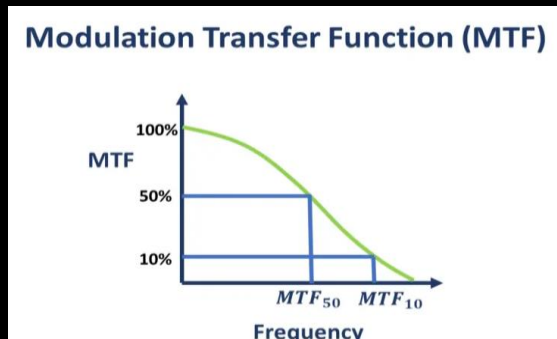
$$\text{Detectability index } (d'^2) = \frac{\left[\int_0^f |W(f)|^2 \times TTF^2 \times E^2(f) df \right]^2}{\int_0^f |W(f)|^2 \times TTF^2 \times E^2(f) \times NPS(f) df}$$

Resolution

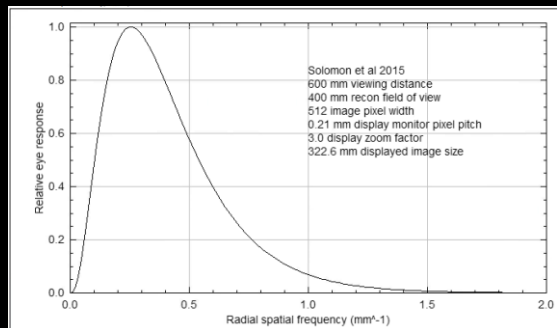
Noise

Task transfer function (TTF)

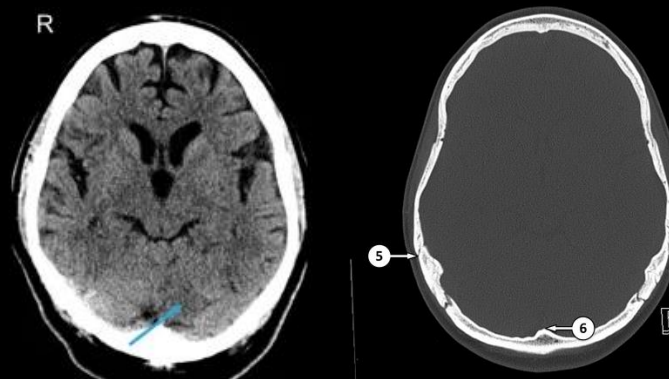
Noise power spectrum (NPS)



Model observers



Task-based metrics



The Detectability Index

Imaging
task

Model human
visual system

$$\text{Detectability index } (d'^2) = \frac{\left[\int_0^f |W(f)|^2 \times TTF^2 \times E^2(f) df \right]^2}{\int_0^f |W(f)|^2 \times TTF^2 \times E^2(f) \times NPS(f) df}$$

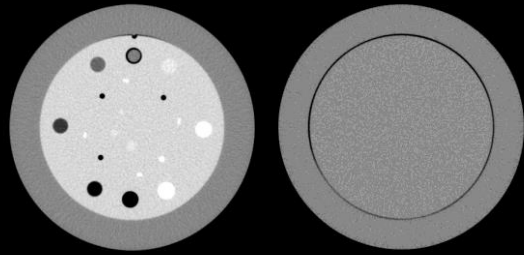
Resolution Noise

The detectability index:

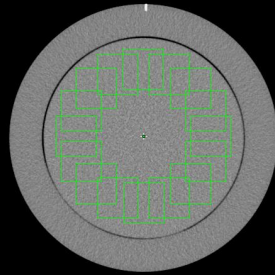
- Considers the imaging task, noise texture, image resolution and the response of the human eye
- Correlates strongly with human observers (more so than CNR) [3]
- Can be measured using pre-existing software on common CT phantoms (such as the Catphan)



Analysis Pipeline



1. Catphan images

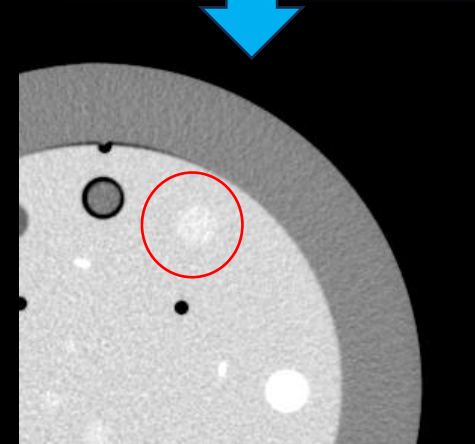


2. Noise power spectrum

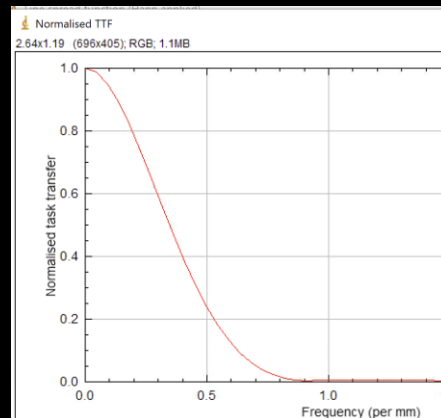


$$\rho = \frac{FOV \times R \times \pi}{D \times 180}$$

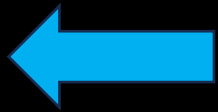
3. Eye model



4. Task



5. Task Transfer Function

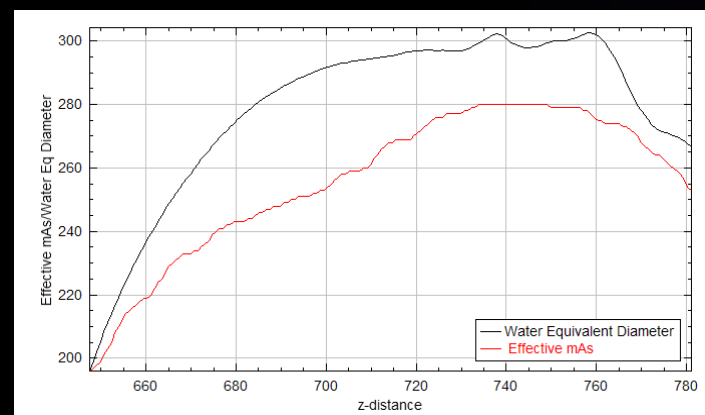
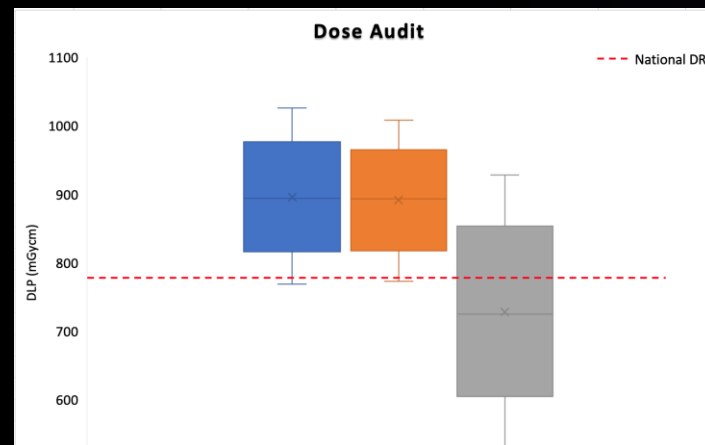


```
Log
File Edit Font
Detectability results
Reconstruction filter,J30s12
Detectability,728.86
Task diameter (mm),12.00
Contrast (HU),824.18
CNR,126.81
Noise (HU),6.50
TTF 50 (1/mm),0.35
TTF 10 (1/mm),0.63
TTF centre of mass (x),79.97
TTF centre of mass (y),159.13
Lower integration limit (1/mm),0
Upper integration limit (1/mm),1.16
Image pixel size (mm),0.43
TTF average stack used,No
TTF min stack index,N/A
TTF max stack index N/A
```

6. Output

Optimisation of Head Scans using d'

- Scanner within health board consistently delivering doses above NDRL
- Scanner does not use AECs – would switching these on affect image quality?
- Test this by lowering fixed mAs to value ~ equal to mean mAs when using AECs
- Measure d' before and after the change

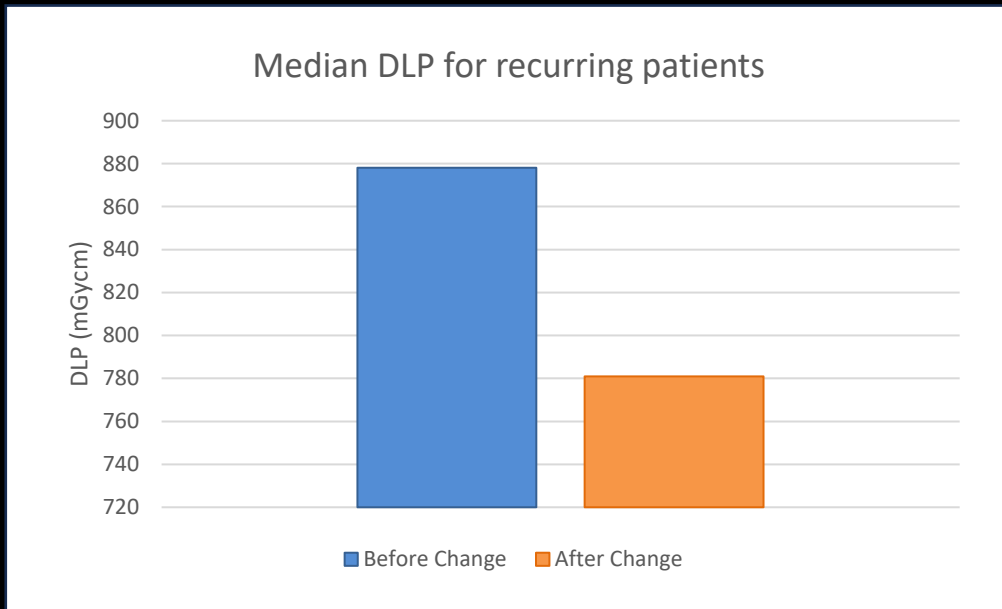


| Protocol | mAs | d' | DLP (mGycm) |
|--------------|-----|----------------|-------------|
| Original | 280 | 30.4 ± 2.3 | 953 |
| Dose-reduced | 260 | 32.2 ± 2.3 | 793 |

What now?

- AECs on ✓
- Radiologist-led IQ monitoring via VGC ✓
- Dose monitoring via patient scans...

| Visually sharp reproduction of the border between white and grey matter | | | | |
|---|---|--|---|--|
| Confident that the criteria is fulfilled | Somewhat confident that the criteria is fulfilled | Indecisive about whether the criteria is fulfilled | Somewhat confident that the criteria is NOT fulfilled | Confident that the criteria is NOT fulfilled |
| 0 | 5 | 5 | 0 | 0 |
| 1 | 0 | 0 | 5 | 4 |



| | Median DLP for recurring patients | Effective dose |
|---------------|-----------------------------------|----------------|
| Before Change | 878 mGy cm | 1.85 mSv |
| After Change | 781 mGy cm | 1.64 mSv |

11% dose reduction observed in patients who underwent head scans before and after the change in protocol

Procurement of new CT scanner

- 4 manufacturers scored on aspects including clinical, technical and support aspects
- Image quality worth 70 points out of total 1000
- Objective image quality score measured using d'
- Images acquired on manufacturer's head protocol at standardised CTDIvol and slice thickness
- Spice-CT used to sense-check the ranking provided by d'

| | | | | |
|----|---------------|--|----|---|
| 10 | Image quality | | 70 | <p>Product will be evaluated on image clarity and acquisition quality across a range of clinical uses based on site visits, tender response and images provided including but are not limited to the following:</p> <ul style="list-style-type: none"> Objective image quality score with CATPHAN Range of images provided Image quality with reduced intravenous contrast volume Features for optimising Image quality in obese patients. Minimum temporal resolution for perfusion Noise Artefact removal software – availability and functionality Motion correction options |
|----|---------------|--|----|---|

| Manufacturer | d' | MTF50 (Spice-CT) | Noise (Spice-CT) |
|--------------|------------|------------------|------------------|
| 1 | 52.8 ± 1.1 | 0.35 | 0.24 |
| 2 | 62.3 ± 1.2 | 0.35 | 0.31 |
| 3 | 70.4 ± 1.4 | 0.40 | 0.33 |
| 4 | 78.1 ± 1.6 | 0.37 | 0.23 |

Procurement of new CT scanner



"I'M SO GLAD WE USED THE DETECTABILITY INDEX!"

- KATE SEXTON, DEPARTMENT OF MEDICAL PHYSICS



Thank You!

Special thanks to:
Debbie Harries
Nick Weir
Kate Sexton
Lee Hampson
Katie Baker