world class expertise local care

Royal Free London NHS Foundation Trust NHS

# Optimisation of Toshiba Aquilion ONE Volume Imaging


Jane Edwards, RPRSG

Royal Free London NHS Foundation Trust

Dr Mufudzi Maviki,

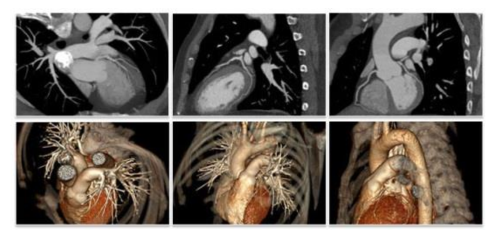
Plymouth Hospitals NHS Trust

# Background

- In 2011/12 Radiology at RFH was redeveloped – including the installation of three new CT scanners
- Pre 2011 we had a 4 slice GE scanner and a 64 slice Philips scanner
- We now have:
  - 2 Toshiba Aquilion ONE scanners (CT1 & CT3)
  - 1 GE HD 750 (CT2)

# Volume Scanning with Aquilion ONE Scanners

- 320 detector rows of 0.5mm
- Capable of 16cm data acquisition in a single rotation
- CT3 is used as a dedicated cardiac scanner
- Volume imaging is routinely used at RFH for cardiac, sinuses and MSK imaging (hips, knees, ankles, hands)
- Also for routine brain scanning for agitated/uncooperative patients



# Volume Brains Scans

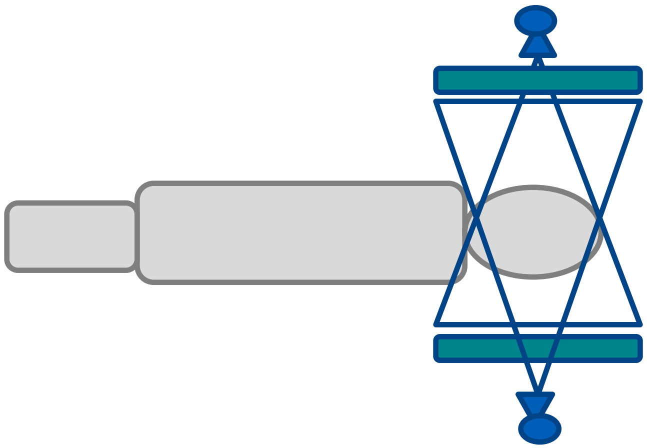
- From the start the radiologists were unhappy with the image quality
- Some of this may be due to unfamiliarity with the scanner
- We had discussions with Toshiba and some improvements were made
- Radiologists still saw room for improvement with the imaging

# What were the issues

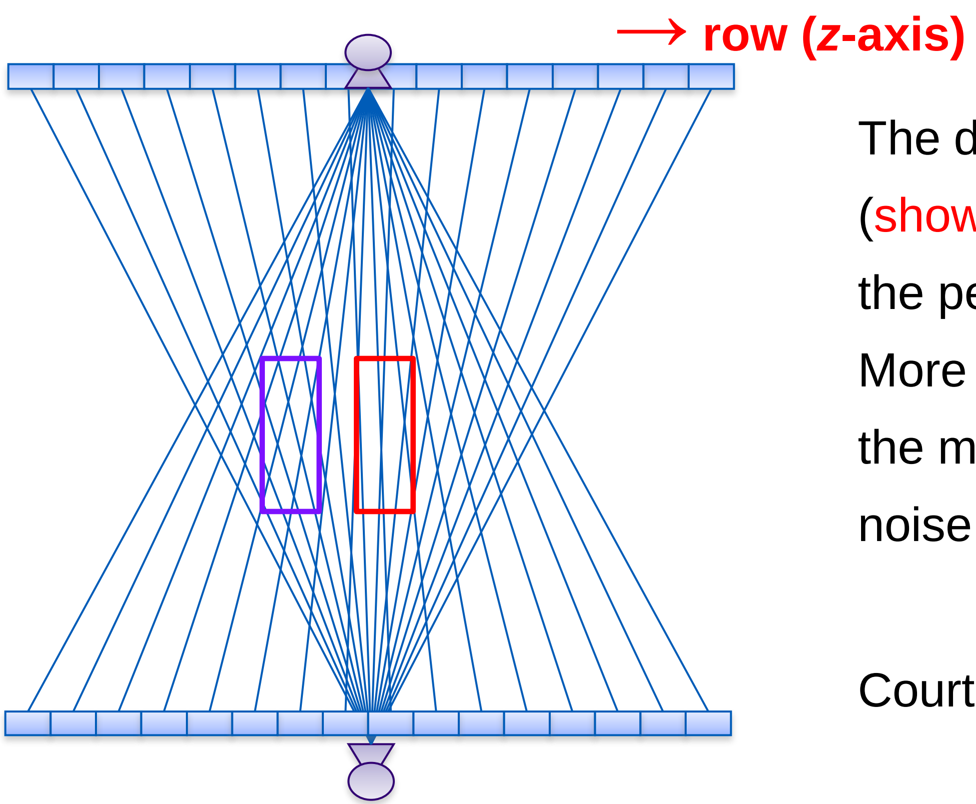
- Lots of artefact – can be mistaken as clinical findings
- Images with high levels of noise
- Decreased grey-white matter contrast
- Decreased resolution (when compared to helical scans)

# How come?

- Using a wide collimation means lots of scatter – higher noise and decreased contrast
- It's a cone beam

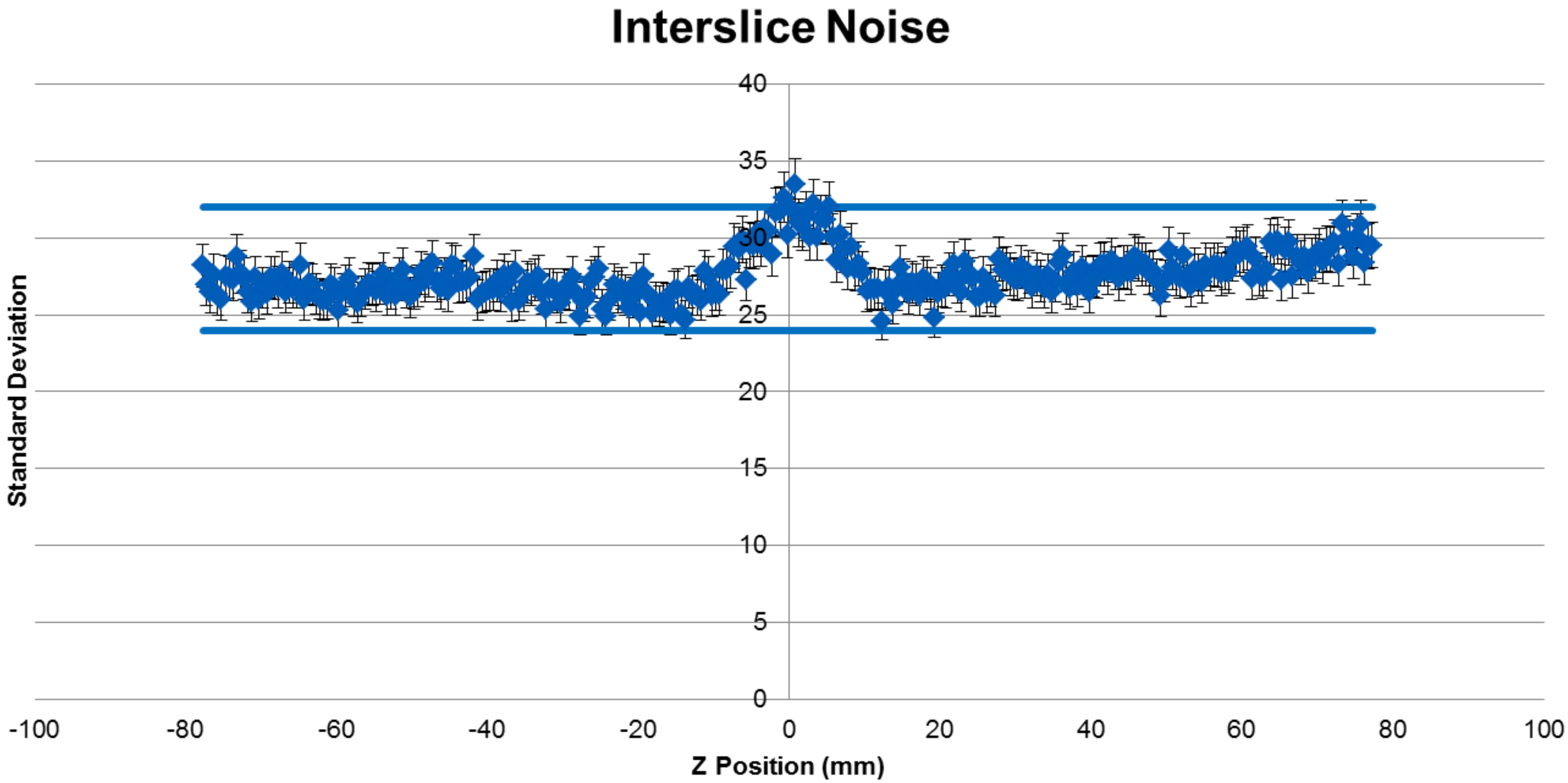


# ConeXact




The data density near the mid-plane (shown by red) is sparse compared to the periphery (shown by purple). More data gives better noise. Then, the mid-plane relatively has a worse noise than the others.

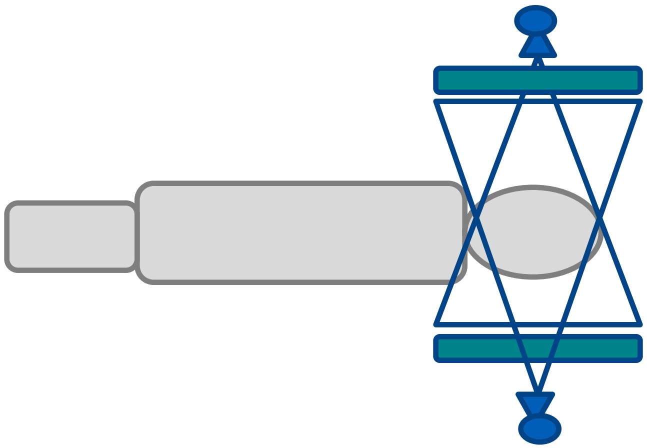
Courtesy of Toshiba Medical Systems



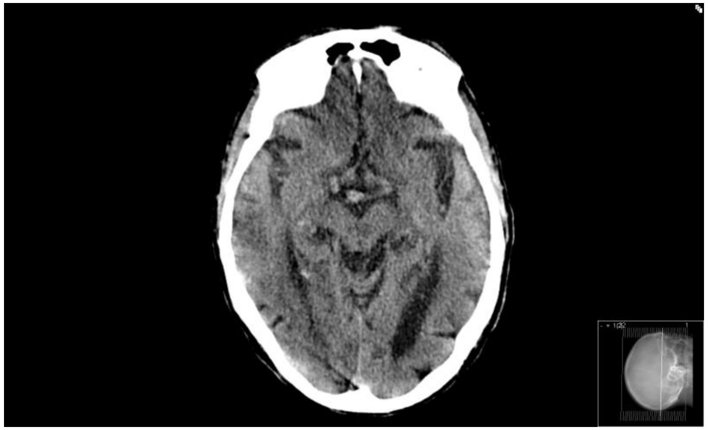
Interslice Noise
Standard Deviation
40
35
30
25
20
15
10
5
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
Z Position (mm)

# How come?

- Using a wide collimation means lots of scatter – higher noise and decreased contrast
- It’s a cone beam
- The patients often move



# The images we started with



# Plan of action

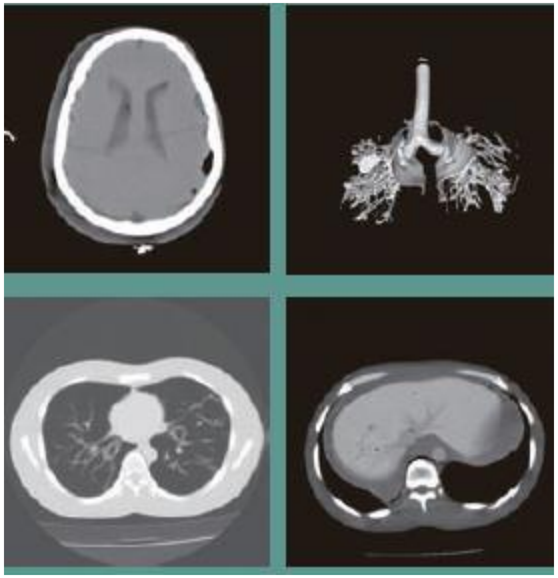
- We reviewed our protocol

| | RFH Standard |
|---|---|
| Scan Type | Volume |
| Rotation Time (s) | 0.5 |
| Detector Configuration | 320 x 0.5 |
| Pitch Factor | N/A |
| kV | 120 |
| mA | 500 |
| $^{SURE}$Exposure | No |
| Scan FOV | 240mm (s) |
| CTDIvol (mGy) | 54.0 |

- We asked some other centres with Aquilion ONE Scanners

# How we assessed image quality

- We got Terry involved….

# First attempt

- First we tried the AAPM suggested protocol
- http://www.aapm.org/pubs/CTProtocols/

ADULT HEAD – ROUTINE (HELICAL) (selected TOSHIBA scanners) (Back to INDEX)

**SCANOGRAM**: Lateral and AP.

| TOSHIBA | Aq32 | Aq64 | AqPremium | AqONE | AqONE |
|---|---|---|---|---|---|
| Scan Type | Helical | Helical | Helical | Helical | Volume |
| Rotation Time (s) | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| Detector Configuration | 32 x 0.5 | 32 x 0.5 | 32 x 0.5 | 32 x 0.5 | 320 x 0.5 |
| CT Pitch Factor | Detail (0.656) | Detail (0.656) | Detail (0.656) | Detail (0.656) | N/A |
| Speed (mm/rot) | 10.5 | 10.5 | 10.5 | 10.5 | 160 |
| kV | 120 | 120 | 120 | 120 | 135 |
| mA | 280 | 280 | 220 | 220 | 300 |
| SUREExposure | No | No | No | No | No |
| Scan FOV | 240mm (S) | 240mm (S) | 240mm (S) | 240mm (S) | 240mm (S) |
| Breath-hold | -- | -- | -- | -- | -- |
| Prep Delay (s) | -- | -- | -- | -- | -- |
| CTDI-vol (mGy) | 71.5 | 71.5 | 55.7 | 55.7 | 60.0 |
| **RECON 1** | | | | | |
| Type | Axial | Axial | Axial | Axial | Axial |
| Start | Base of skull | Base of skull | Base of skull | Base of skull | Base of |
| End | Vertex | Vertex | Vertex | Vertex | Vertex |
| SUREIQ* | Head Brain | Head Brain | Head Brain | Head Brain | Head Brain |
| Thickness (mm) | 5 | 5 | 5 | 5 | 5 |
| Interval (mm) | 5 | 5 | 5 | 5 | 5 |
| DFOV (mm) | Patient | Patient | Patient | Patient | Patient |
| **VOLUME** | | | | | |
| Type | Axial | Axial | Axial | Axial | Axial |
| Start | Base of skull | Base of skull | Base of skull | Base of skull | Base of |
| End | Vertex | Vertex | Vertex | Vertex | Vertex |
| SUREIQ* | Head Brain | Head Brain | Head Brain | Head Brain | Head Brain |
| Image Thickness (mm) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Reconstruction Interval (mm) | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| DFOV (mm) | Patient | Patient | Patient | Patient | Patient |

# Protocols

| | AAPM Suggested | RFH Standard |
|---|---|---|
| **Scan Type** | Volume | Volume |
| **Rotation Time (s)** | 0.75 | 0.5 |
| **Detector Configuration** | 320 x 0.5 | 320 x 0.5 |
| **Pitch Factor** | N/A | N/A |
| **kV** | 135 | 120 |
| **mA** | 300 | 500 |
| **$^{SURE}$Exposure** | No | No |
| **Scan FOV** | 240mm (s) | 240mm (s) |
| **CTDIvol (mGy)** | 60.0 | 54.0 |

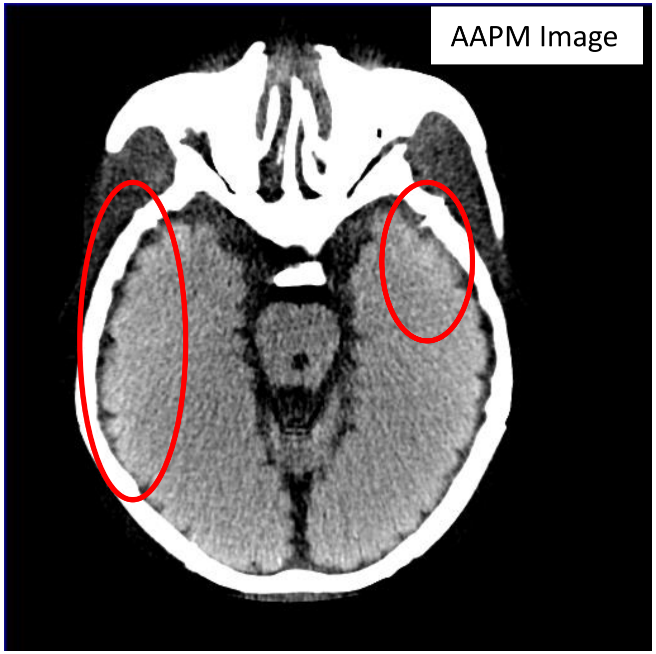
**RECON 1**

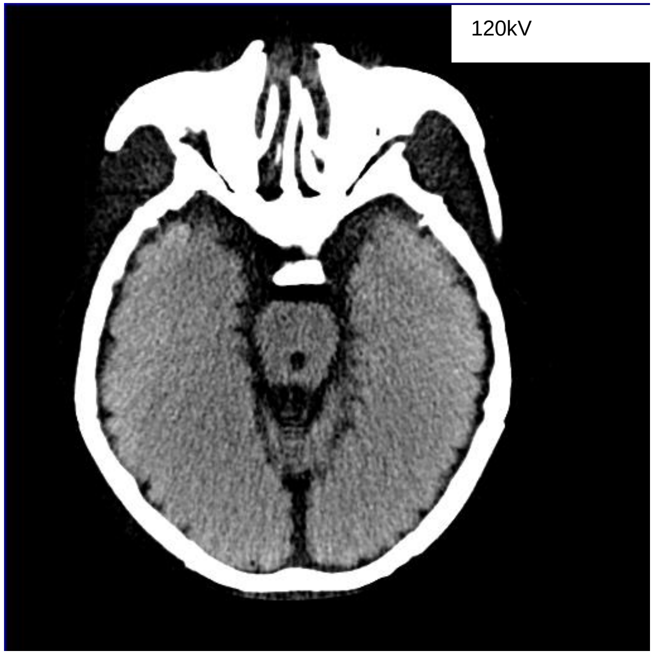
| Type | Axial | Axial |
|---|---|---|
| **Start** | Base of skull | Base of skull |
| **End** | Vertex | Vertex |
| **$^{SURE}$IQ** | Head Brain | Head Brain |
| **Image Thickness (mm)** | 5 | 5 |
| **Reconstruction Interval (mm)** | 5 | 5 |

**VOLUME RECON**

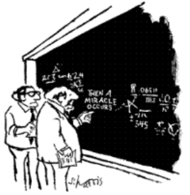
| Type | Axial | Axial |
|---|---|---|
| **Start** | Base of skull | Base of skull |
| **End** | Vertex | Vertex |
| **$^{SURE}$IQ** | Head Brain | Head Brain |
| **Image Thickness (mm)** | 0.5 | 0.5 |
| **Reconstruction Interval (mm)** | 0.25 | 0.5 |

# AAPM Protocol Image



# Plan of action



"I think you should be more explicit here in step two."

- We tried acquiring images with different:
  - kVs
  - Reconstruction Algorithms
  - Reconstructed Slice Thickness
  - Iterative Reconstruction Levels

# Plan of action

- We also compared to the helical protocol…..

| | RFH Standard |
|---|---|
| Scan Type | Helical |
| Rotation Time (s) | 0.75 |
| Detector Configuration | 0.5 x 32 |
| Pitch Factor | Detail (0.656) |
| kV | 120 |
| mA | Auto (Max = 230) |
| $^{SURE}$Exposure | Standard (SD=2) |
| Scan FOV | 240mm (s) |
| CTDIvol (mGy) | 45.0 |

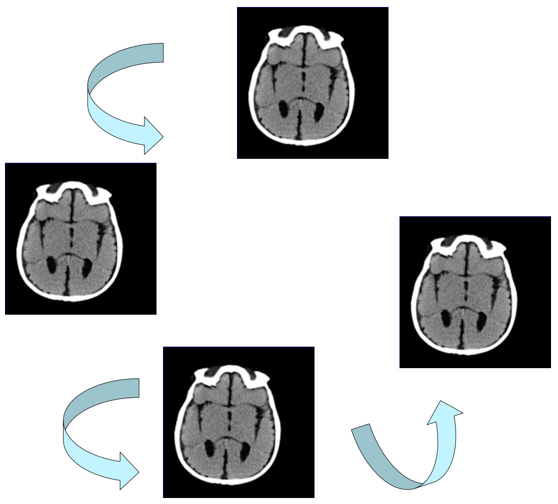
- Helical scans are fine focus, volumes are broad focus
- Determined by the output power of your protocol

# Method

- Weekly optimisation session on CT3
- Constant CTDI across all images – only one parameter was varied at one time
- 'Standard' volume image was included in all imaging sets as a reference
- CNR and SNR measurements performed by physics
- Phantom images anonymised and independently scored by two radiologists

# Method

- Regular feedback between physics and radiologists
- The winning image each week was used as a starting point for the next round of optimisation



# Analysis


"Now that desk looks better. Everything's squared away, yessir, squaaaaaared away."

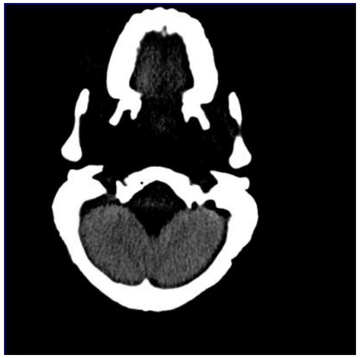
- CNR and SNR analysis performed at several points in each series
- Grey matter, brainstem, ventricles and CSF spaces used as reference points
- Analysis preformed with IQ Works to ensure consistent placement of ROIs
- Phantom images ranked by radiologists and reasons for decisions collated

# Results – Changing kV

| | | CNR | |
|---|---|---|---|
| kV | CTDI (mGy) | Ventricle vs Grey Matter | CSF Spaces vs Grey Matter |
| 80 | 49.6 | 6.59 | 2.68 |
| 100 | 51.6 | 6.73 | 2.75 |
| 120 | 51.4 | 7.30 | 2.61 |
| 135 | 54.7 | 5.78 | 2.52 |

| | | CNR |
|---|---|---|
| kV | CTDI (mGy) | Brainstem vs Grey Matter |
| 80 | 49.6 | 0.36 |
| 100 | 51.6 | 1.18 |
| 120 | 51.4 | 1.24 |
| 135 | 54.7 | 1.34 |

| | | CNR | |
|---|---|---|---|
| kV | CTDI (mGy) | Ventricle vs Grey Matter | CSF Spaces vs Grey Matter |
| 80 | 49.6 | 3.68 | 4.84 |
| 100 | 51.6 | 4.11 | 4.21 |
| 120 | 51.4 | 3.92 | 4.43 |
| 135 | 54.7 | 3.78 | 4.05 |



# Results – Recon Algorithm

6) For the head
(with BHC processing)*5

Smooth ↕ Sharp: FC20, FC21, FC22, FC23, FC24, FC25, FC26*7

*7: Contrast enhancement

(7) For the head
(with BHC processing)*6

Smooth ↕ Sharp: FC62, FC63, FC64, FC65, FC66, FC67, FC68*7

The image quality of *6 is sharper than that of *5.

*7: Contrast enhancement

(8) For the head
(without BHC processing)

Smooth ↕ Sharp: FC41, FC42, FC43, FC44

| | CNR | |
|---|---|---|
| Recon Algorithm | Ventricle vs Grey Matter | CSF Spaces vs Grey Matter |
| FC62 | 6.03 | 2.50 |
| FC64 | 4.84 | 3.51 |
| FC67 | 4.35 | 2.94 |
| FC68 | 7.30 | 2.61 |

# What the radiologists thought

Visual Image quality Assessment

Imaging set 1: Filter FC62.

| | 80KV | 100KV | 135KV |
|---|---|---|---|
| Doctor A | **3** | **1** | **2** |
| Doctor B | **3** | **1** | **2** |

Comments: 80kv images too dark within posterior fossa and vertex. 135 kv too bright with glare. 100kv ok compromise, a little in the dark post fossa.

Imaging set 2: Filter FC62

| | 80 | 100 | 120 | 135 |
|---|---|---|---|---|
| Doctor A | **4** | **2** | **1** | **3** |
| Doctor B | **4** | **2** | **1** | **3** |

Imaging set 3: Filter FC64

| | 80 | 100 | 120 | 135 |
|---|---|---|---|---|
| Doctor A | **4** | **2** | **1** | **3** |
| Doctor B | **4** | **1** | **2** | **3** |

Comments: Too much posterior fossa artifact on all images.

Imaging set 4: Filter FC67.

| | 100 | 120 | 135 |
|---|---|---|---|
| Doctor A | **3** | **1** | **2** |
| Doctor B | **3** | **1** | **2** |

Artefact at the orbits and anterior cranial fossa.

120 KV

| | FC62 | FC64 | FC67 |
|---|---|---|---|
| Post Fossa | 2 | 3 | 1 |
| Basal Ganglia | 2 | 3 | 1 |
| Superior cortex | 2 | 3 | 1 |

FC67 had sharper images, more aesthetically pleasing. FC64 has too much artifact.

- 120kV appears the best IQ
- FC67 or FC68 are the optimal algorithms

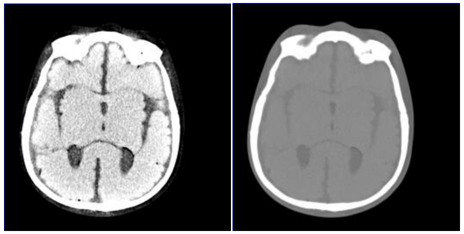
# Results – Other stuff

- The change in iterative reconstruction (AIDR Strong) gave the most pronounced improvement when reviewed by the radiologists
- The fine focus scan was a close second

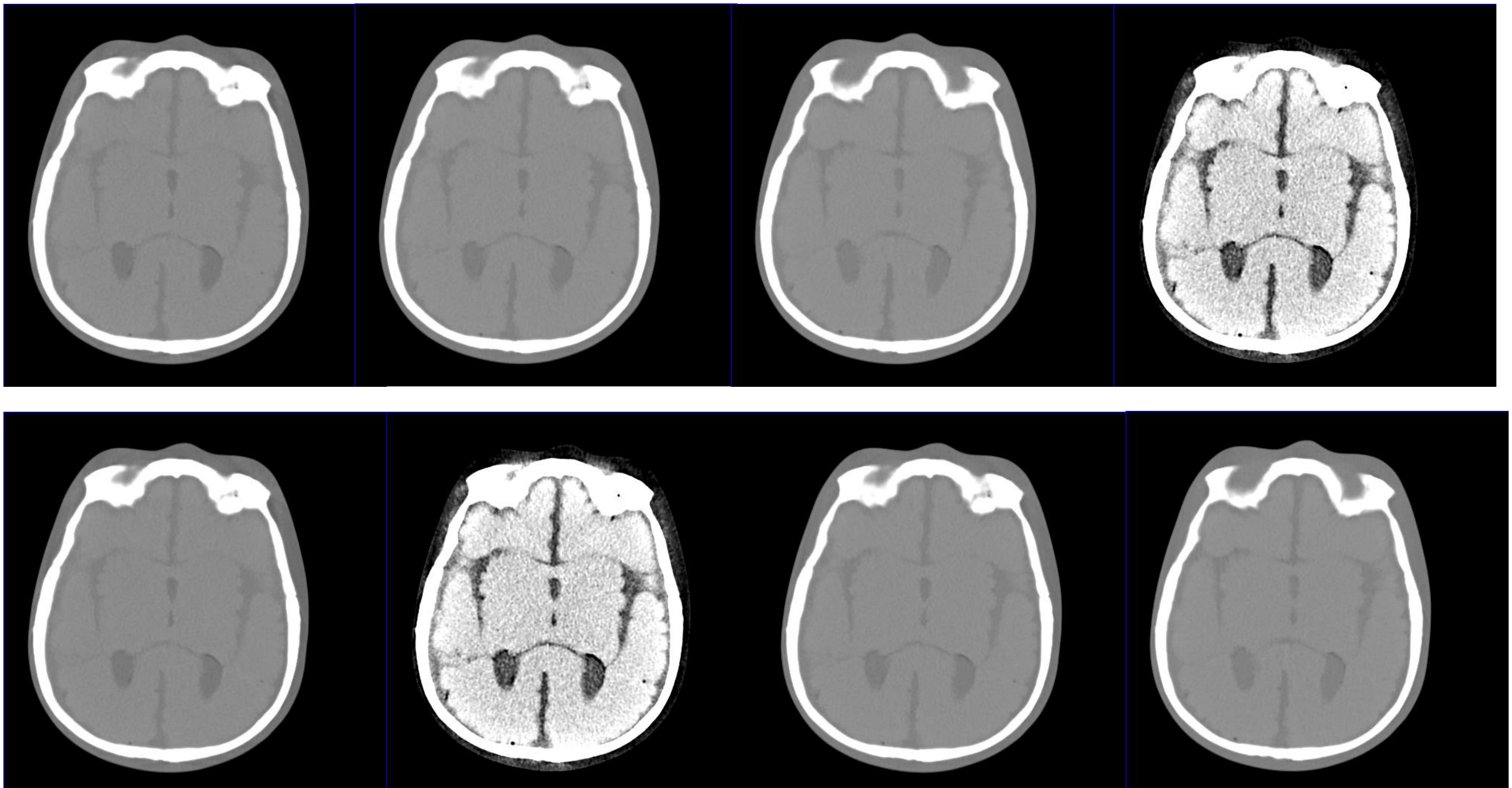
| | | CNR | |
|---|---|---|---|
| **Scan** | CTDI (mGy) | Ventricle vs Grey Matter | CSF Spaces vs Grey Matter |
| **Standard** | 49.6 | 7.30 | 2.61 |
| **Overlapping Acquisition** | 49.6 | 6.52 | 2.58 |
| **AIDR Strong** | 49.6 | 7.30 | 2.68 |
| **Fine Focus** | 49.6 | 6.73 | 2.82 |

# Psychology of Imaging

- Does the order in which images are presented have an effect on the outcome?
- Probably…..

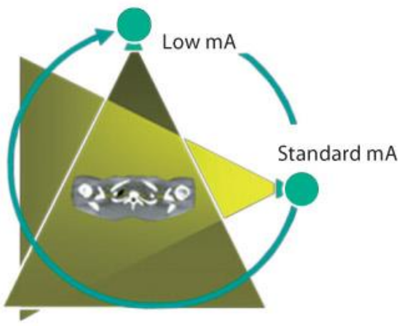


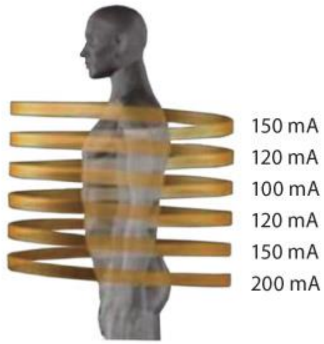
# Psychology of Imaging



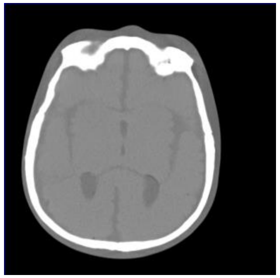
# Helical Image Quality

- We tried a similar strategy with the helical images
- The results were very different – what improves the volume scans does not apply to the helical scans




Toshiba Medical Systems



# Comparison

| Ranking | Changing kV | | Recon Algorithm | |
|---|---|---|---|---|
| | CNR Results | Radiologists Opinion | CNR Results | Radiologists Opinion |
| 1 | 80 | 120 | FC64 | FC67 |
| 2 | 100 | 100 | FC68 | FC68 |
| 3 | 135 | 135 | FC62 | FC62 |
| 4 | 120 | 80 | FC67 | FC64 |

# Conclusions

- Improved CNR doesn't mean better clinical image
- The clinical task is the more important measure of IQ
- The order images are displayed may influence your results
- Volume acquisitions have their uses for head imaging but may require higher doses than helical techniques
- The radiologist involved leaving before completion of the project affects what you can achieve!

# Further Work

Urgent Care Division, Directorate of Radiology and Nuclear Medicine

Royal Free London NHS
NHS Foundation Trust

## Change of CT Protocol Form

Scanner: CT 1 CT 2 CT 3 (highlight appropriate equipment)

| | |
|---|---|
| Scan protocol: | |
| Reason for change | |
| Requester | |

| Current Protocol | | Amended Protocol: | |
|---|---|---|---|
| kV | | kV | |
| mAs | | mAs | |
| Rotation Time (s) | | Rotation Time (s) | |
| Pitch | | Pitch | |
| Slice Thickness (mm) | | Slice Thickness (mm) | |
| Dose Modulation used? | | Dose Modulation used? | |
| Standard deviation (Tosh Only) | | Standard deviation (Tosh Only) | |

**Please contact Medical Physics (Ext: 33759) if any of the parameters above have been amended as this will have an effect on patient dose.**

| Current Protocol | | Amended Protocol: | |
|---|---|---|---|
| Effective Dose (mSv) | | Effective Dose (mSv) | |

Medical Physics: Optimisation advice and patient dose information supplied by

……………………………………………………. Date………………………

| Current Protocol | | Amended Protocol: | |
|---|---|---|---|
| Filter (Recon Algorithm) | | Filter (Recon Algorithm) | |
| Reconstruction and Storage changes | | Reconstruction and Storage changes | |
| Other | | Other | |

IRMER Practitioner: I agree to the above changes and justify any change in patient dose

……………………………………………………. Date………………………

Amendments agreed and changed By CT Superintendent

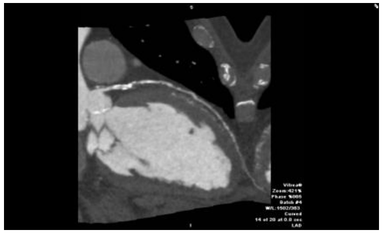
……………………………………………………. Date………………………

| | | |
|---|---|---|
| Change Of Protocol Formv2 | Authors: Dave Edwards & Jane Edwards | Date First Written: October 2012 |

- Change of Protocol to be completed
- Document to be produced outlining the changes we have made
- Continue with Volume imaging

# Further Work

- Assess helical image quality
- Move to looking at other volume imaging
- Extend the project to look at other body parts – cardiac, c-spines



Royal Free London NHS Foundation Trust

# Any questions