

Quantitative QA: The hard part

Dr Tim Wood

Radiation Protection and Diagnostic Imaging Physicist
Castle Hill Hospital

Quantitative Image Quality Testing - experiences, problems and results

5th June 2013

UCL Institute of Child Health, London



Great Staff - Great Care - Great Future

Hull and East Yorkshire Hospitals

NHS Trust



What does IPEM Report 32 Part VII say?

- ‘...Quantitative analysis has a strong background and has been used extensively...’
- ‘...It has been shown to be **reproducible** and **sensitive** to changes in a **clinical service** and therefore can be suitable for QC...’
- ‘...In digital imaging, degradation of the image quality can be partially hidden by the image processing applied to the images and so changes may not be apparent to the user. **It is important that useful and consistent testing of digital systems is undertaken...**’

The hard part?

(or most time consuming)

$$F(u) = \frac{1}{N} \sum_0^{N-1} g(x) e^{\left(\frac{-2\pi i u x}{N}\right)}$$

$$DQE(u, v) = \frac{SNR_{OUT}^2(u, v)}{SNR_{IN}^2(u, v)}$$

$$NEQ(u, v) = \frac{MTF^2(u)}{NNPS(u)}$$

$$PV_{\log} = a \ln(K) + b \Rightarrow K = \exp\left[\frac{(PV - b)}{a}\right]$$

$$DQE(u) = \frac{MTF^2(u)}{K_a \cdot SNR_{in_Q}^2 \cdot NNPS(u)}$$

$$DQE(u) = \frac{MTF^2(u)}{Q \cdot NNPS(u)} = \frac{NPS_{\Delta Q}(u, v)}{Q^2}$$

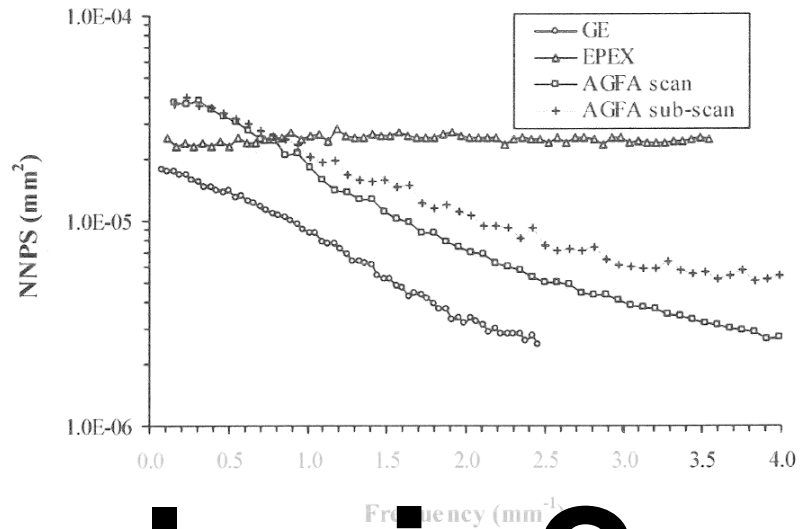
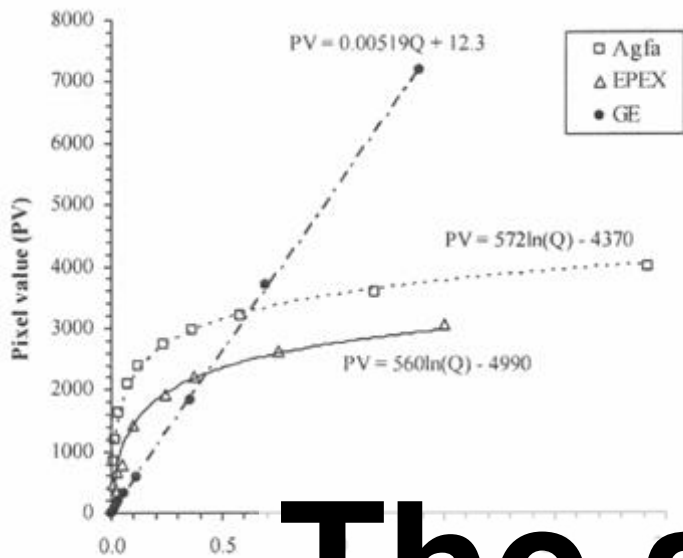
The theory?

$$NPS_{\Delta Q}(u_n, v_k) = \frac{\lim_{N_x \cdot N_y \rightarrow \infty}}{\lim_{M \rightarrow \infty}} \frac{1}{M} N_x \cdot \Delta x \cdot N_y \cdot \Delta y \sum_{m=1}^M |FT_{n,k} \{I_{lin}(x, y) - S(x, y)\}|^2$$

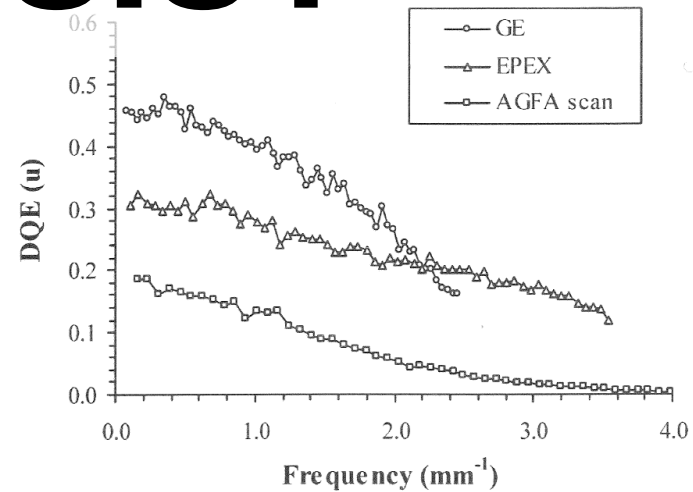
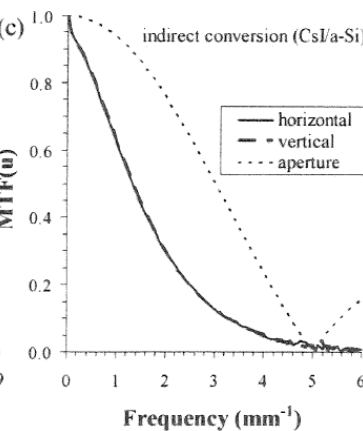
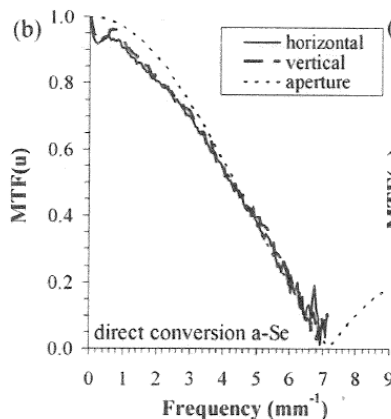
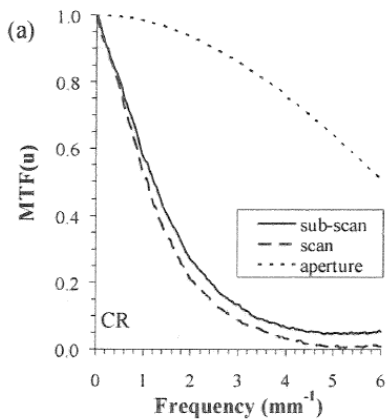
$$PV_{power} = aK^b + c \Rightarrow K = \left[\frac{(PV - c)}{a}\right]^{\frac{1}{b}}$$

$$F(u) = \frac{1}{N} \sum_0^{N-1} g(x) e^{\left(\frac{-2\pi i u x}{N}\right)}$$

$$NPS(u, v) = NPS_Q(u, v) + NPS_{SQ}(u, v) + NPS_e(u, v) + NPS_{fp}(u, v)$$



The analysis?



IPEM Report 32 Part VII

- *‘Digital imaging does have some advantages, **if suitably processed images can be transferred to external media...**’*

The hard part?

(or most time consuming)

Getting unprocessed images off the system!

Typical vendor response:

'You're the first person to ask for that'...

DISCLAIMER: This is a broad generalisation from my experience with a limited range of equipment and in no way guarantees the experience you will have when trying this for the first time i.e. you never know, you may be the lucky one!

So what can be done?

- It may be obvious for your new shiny X-ray system, and you can just get on and do it
 - Unlikely
- Engineers/apps specialist might be able to show you
 - Can often depend on the individual you get...
- Share information through meetings like this
 - And hope your new system is being talked about on the day...
- Phone a friend
 - Find out who else has one and ask what they do...
- Share this information in a more co-ordinated way on a national scale
 - More on this later...

So what are the problems we face?

- X-ray imaging systems are not designed for Physicists and their strange ways!
- Clinical application always takes precedence (obviously)
- However, getting at the basic information you need is not always obvious or easy, and often the engineers who install the systems (i.e. the people the Physicist normally has to deal with when commissioning) don't know how to get at these bits either!
- And now, for a typical (real) scenario...

Setting up a quantitative QA programme:

A real ‘experience’

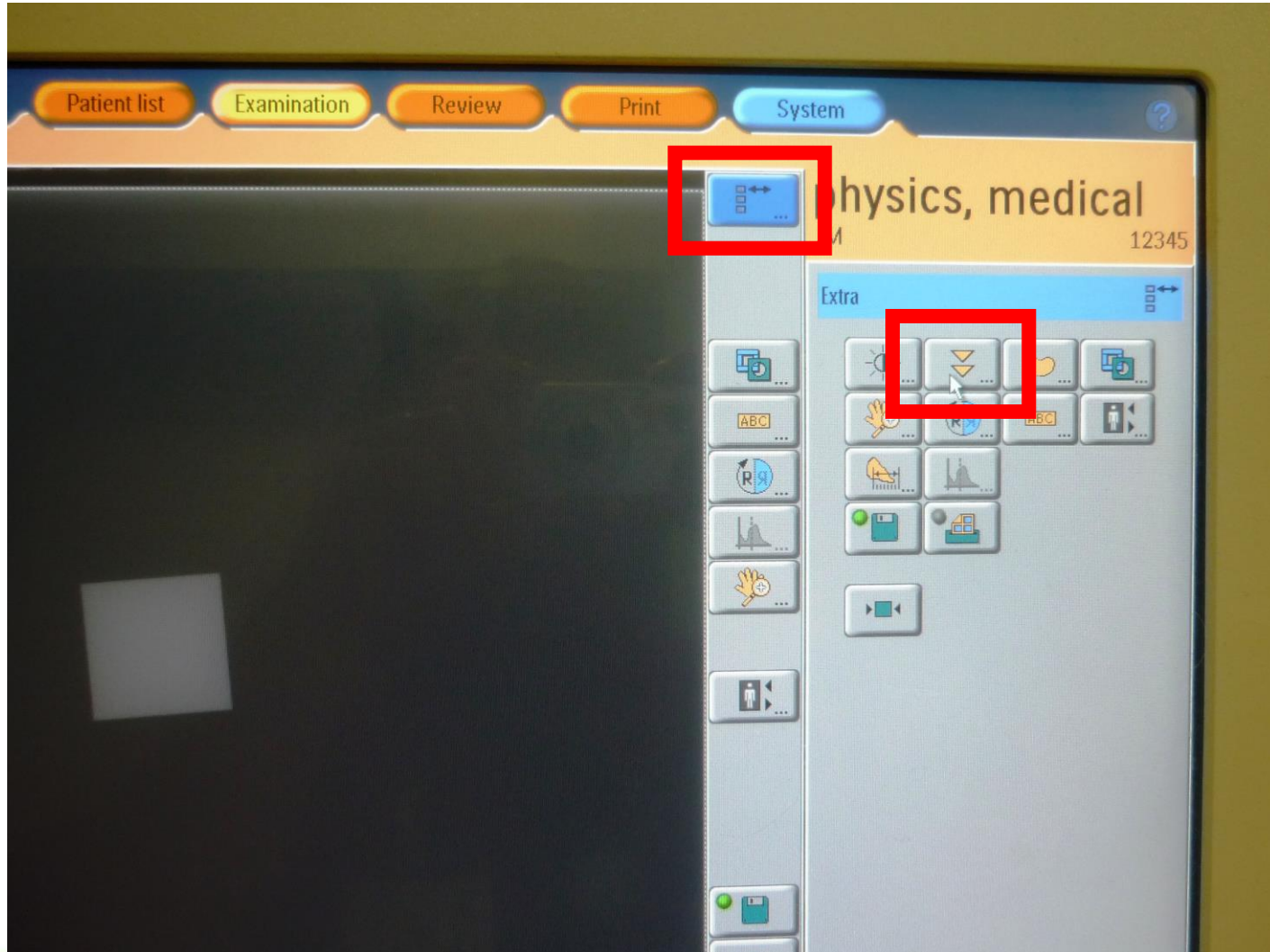
Setting up a quantitative QA programme

- New DR room installed Oct 2011
 - First one of its type in the Trust
- Had all the kit and analysis tools required for testing in accordance with IPEM Report 32 Part VII
- Asked the installation Engineer about accessing unprocessed images, getting them off the system, etc
 - **Told it was not possible**
 - Could not even show us how to draw ROIs on the images!
- Consulted second engineer that was on site to set-up a new DR mobile (same interface, wireless detector, etc)
 - Also said it was not possible (*'but you could on the previous version of the software'...*)
- Apps Specialist also not aware of how you could do this (or even why we were making such a fuss)

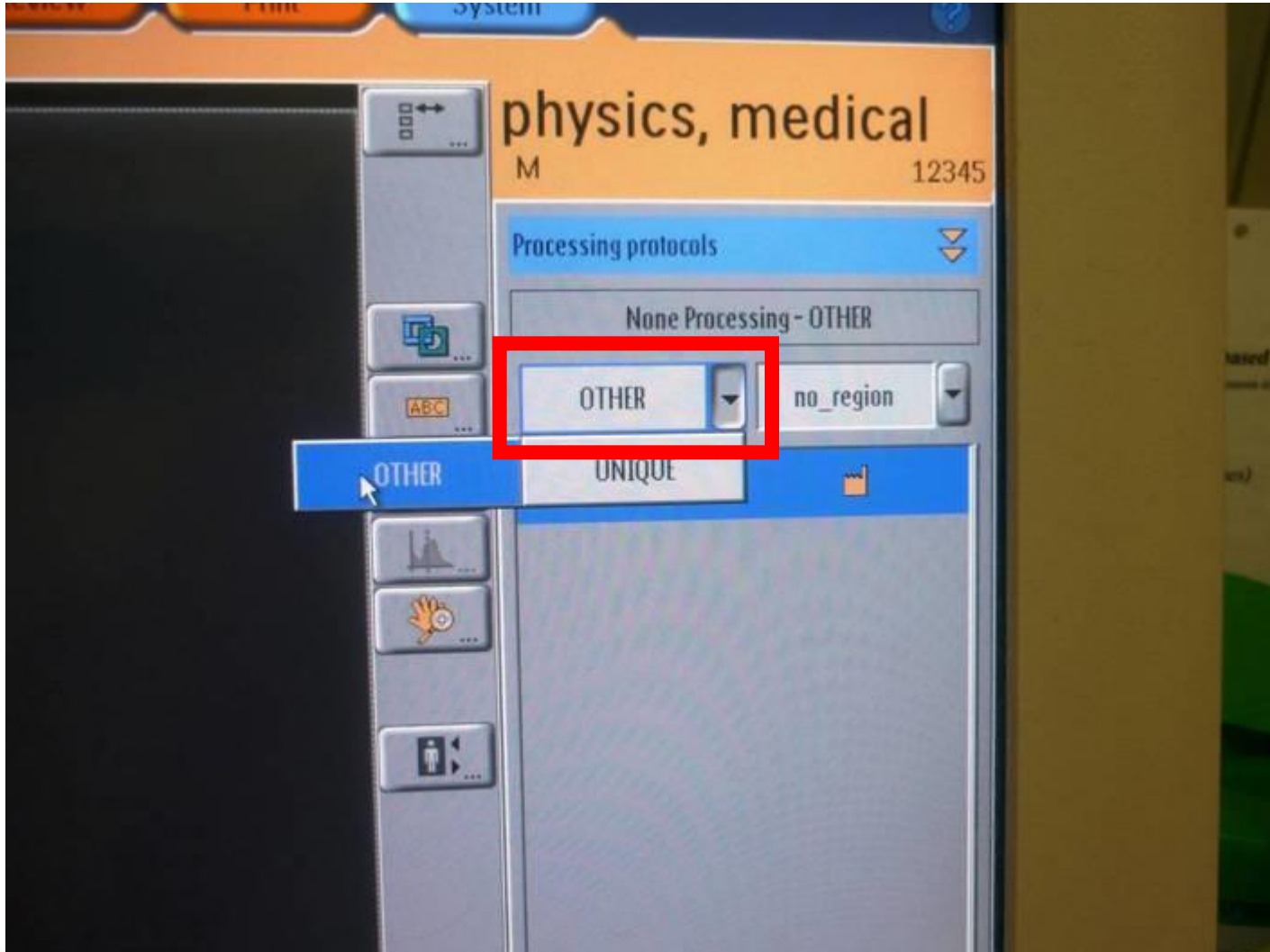
So what did we do?

- Requirements of IPEM Report 32 Part VII highlighted to senior Engineer, who promised to take it further
- Several months passed, and a number of repeated emails later...
- No progress!
- A further couple of months passed when our MTO happened to meet a different Apps Specialist who was on site demonstrating a new mobile flat panel fluoroscopy system
 - She knew what we were after, and how we could get at it
 - Also made arrangements for setting up an extra DICOM node for us to get images off the system (in the same way as we do for CR QA)
 - We still didn't know how to draw ROIs on the image...

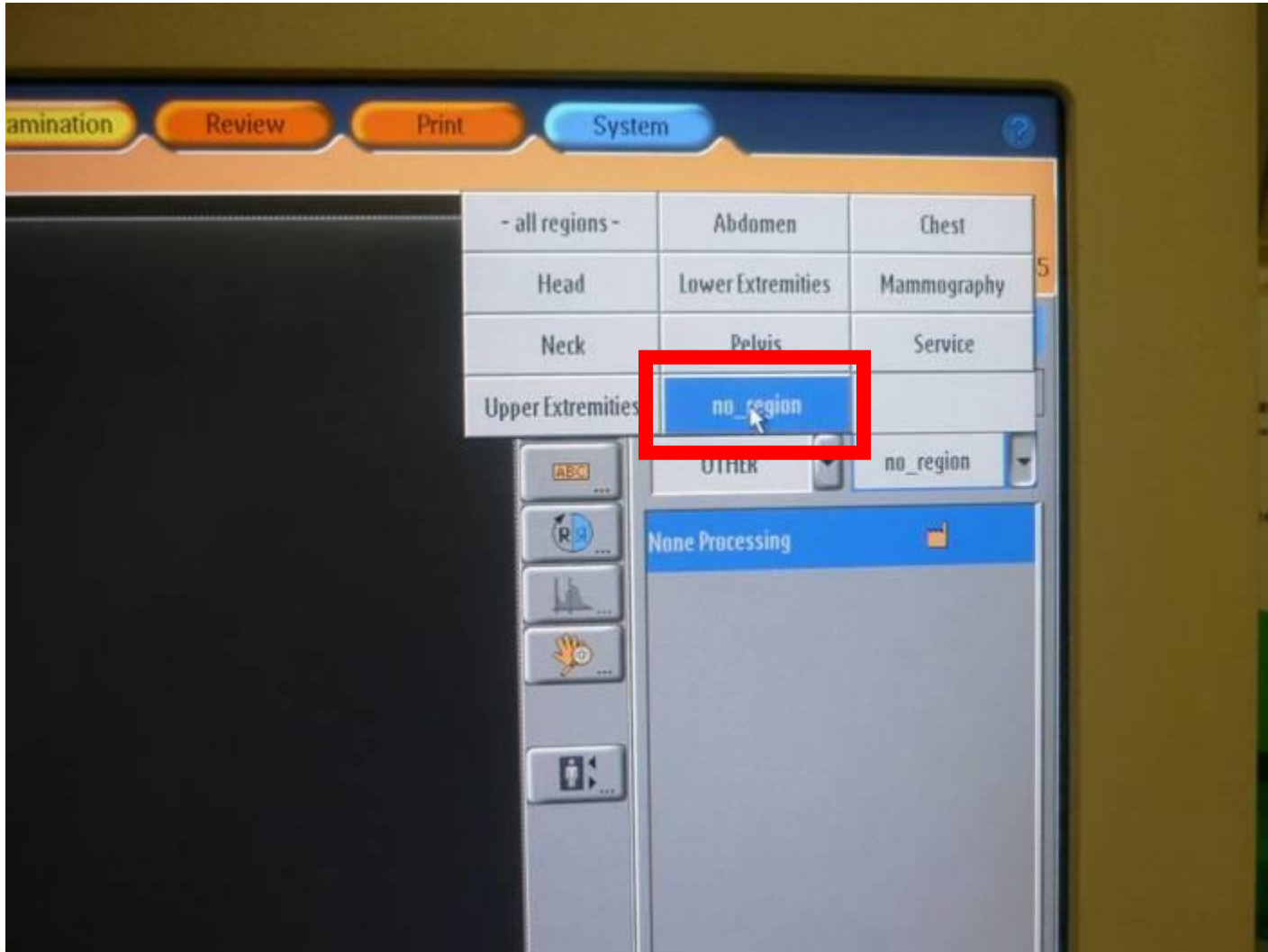
Accessing 'unprocessed' images



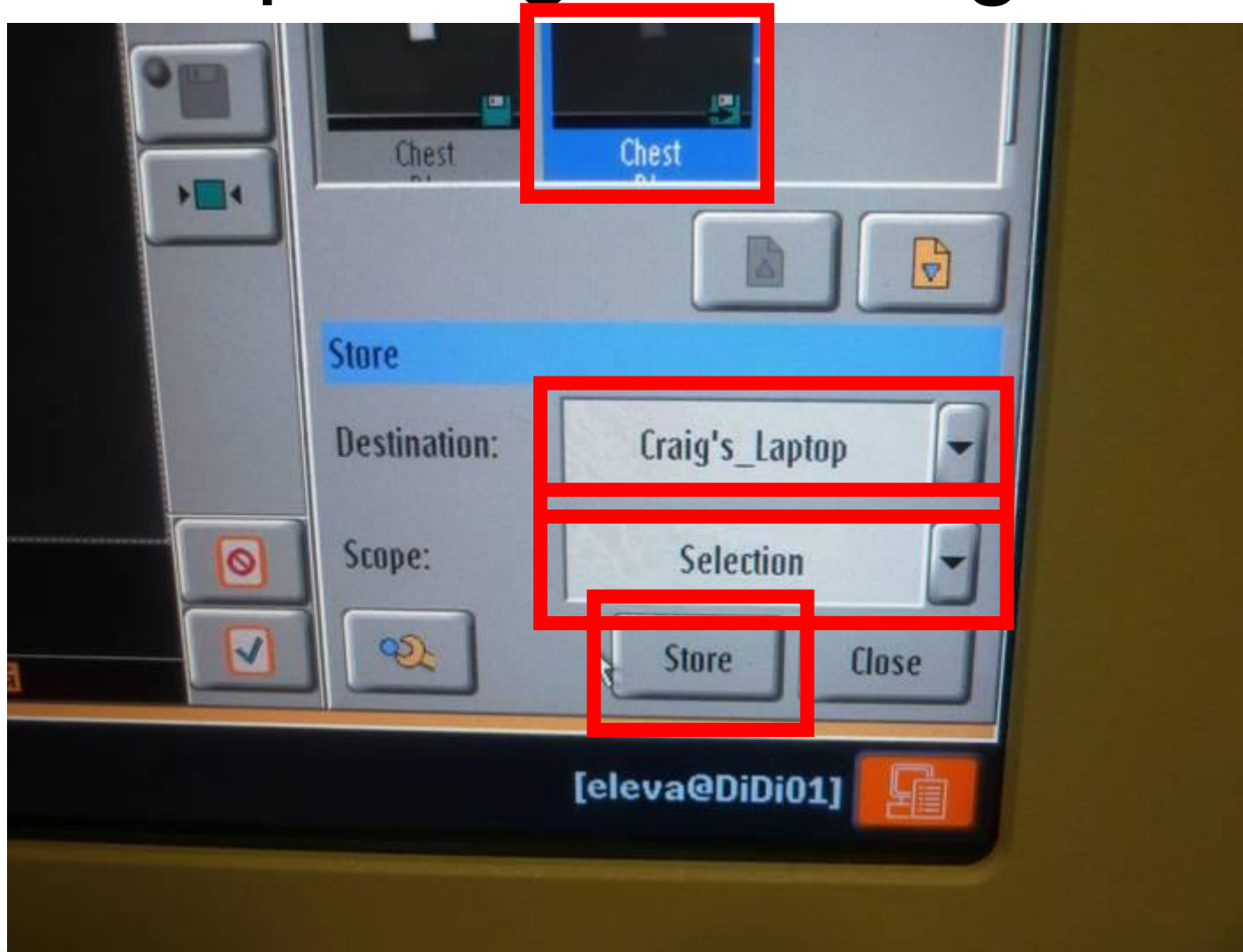
Accessing 'unprocessed' images



Accessing 'unprocessed' images



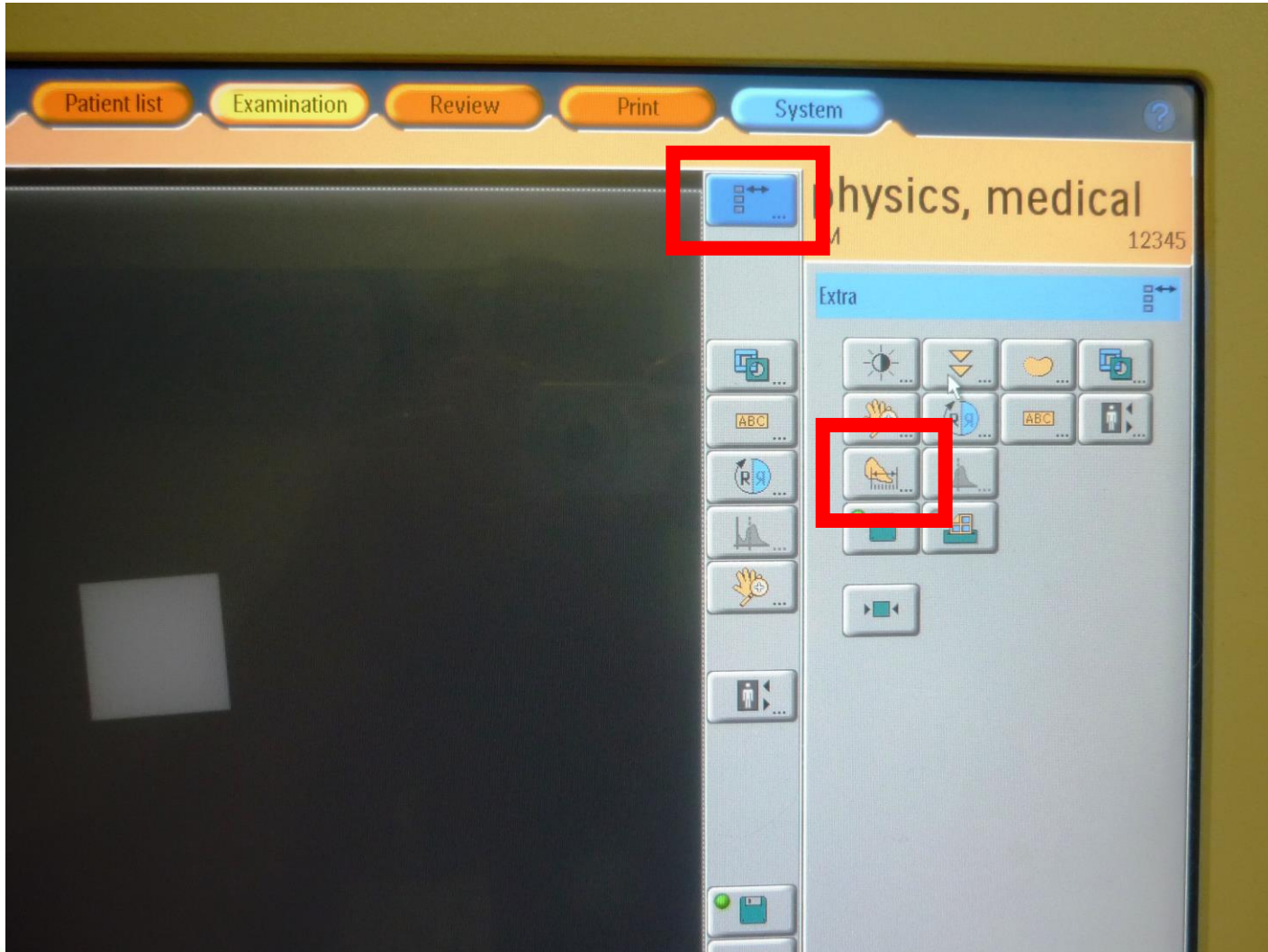
Exporting test images



And finally...

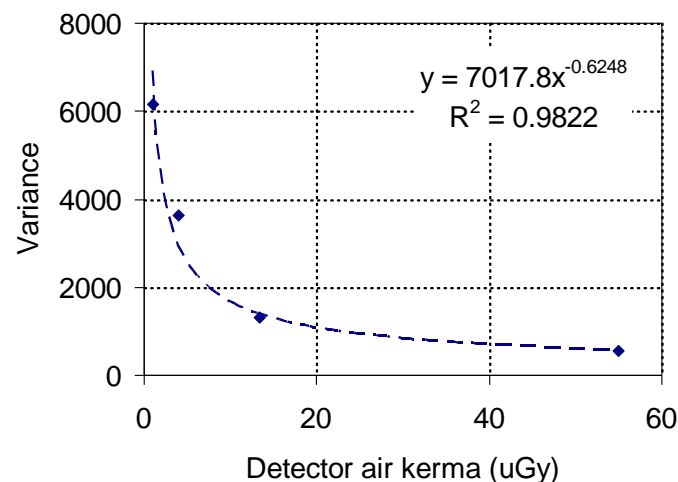
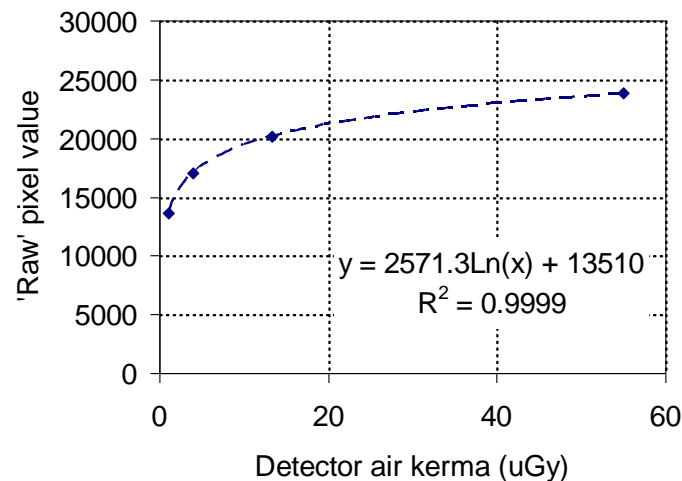
- Flat panel digital mammography system by same manufacturer installed in Dec 2012
- After a lot of initial head scratching by Engineer/Apps, were able to access raw images, get them off the system (via CD/DVD in this case), ***and draw ROIs on the images!***
 - Surprised how difficult this was given the well established (and nationally co-ordinated) requirements for breast screening – though we were the first to by this system in the UK!
- Same interface as DR room, so able to go back and access the same tools via a series of (not very obvious) icons

ROIs

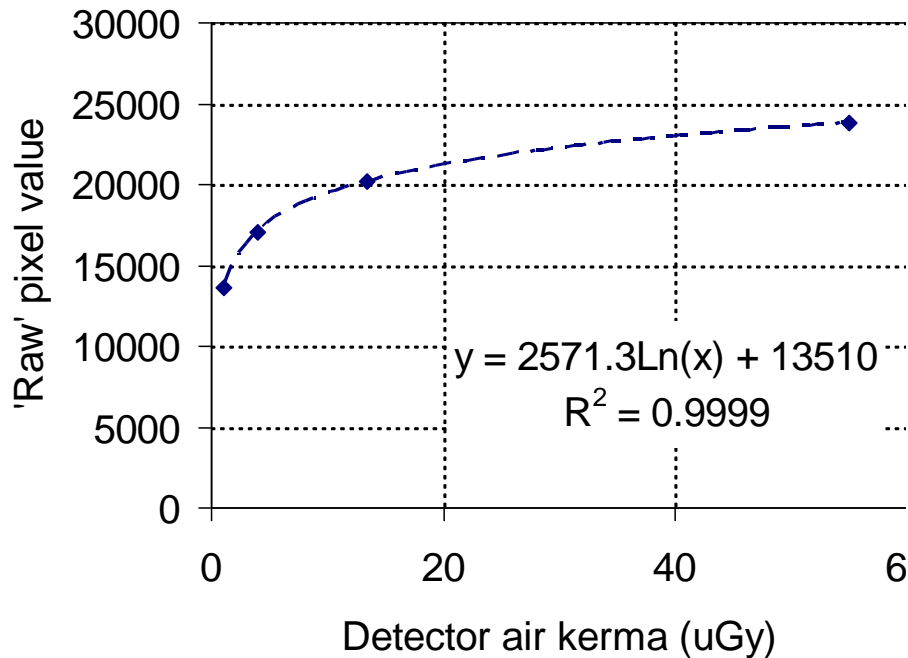


So in summary...

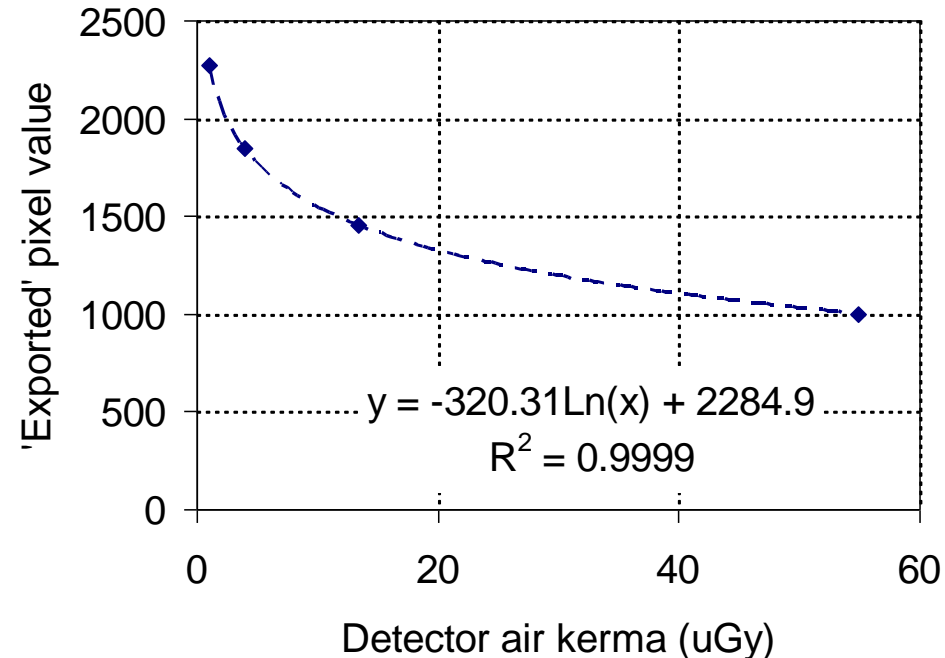
- Problems solved?
 - Not quite!
- STP not linear...
- And hence variance falls with dose
- STP is **different** between the displayed '**Raw**' values, and that measured on images exported from the system
- **Clearly the images are not completely unprocessed**
 - We **believe** it is just the LUT i.e. no sharpening, noise reduction, etc



'Raw' versus 'Exported' STP

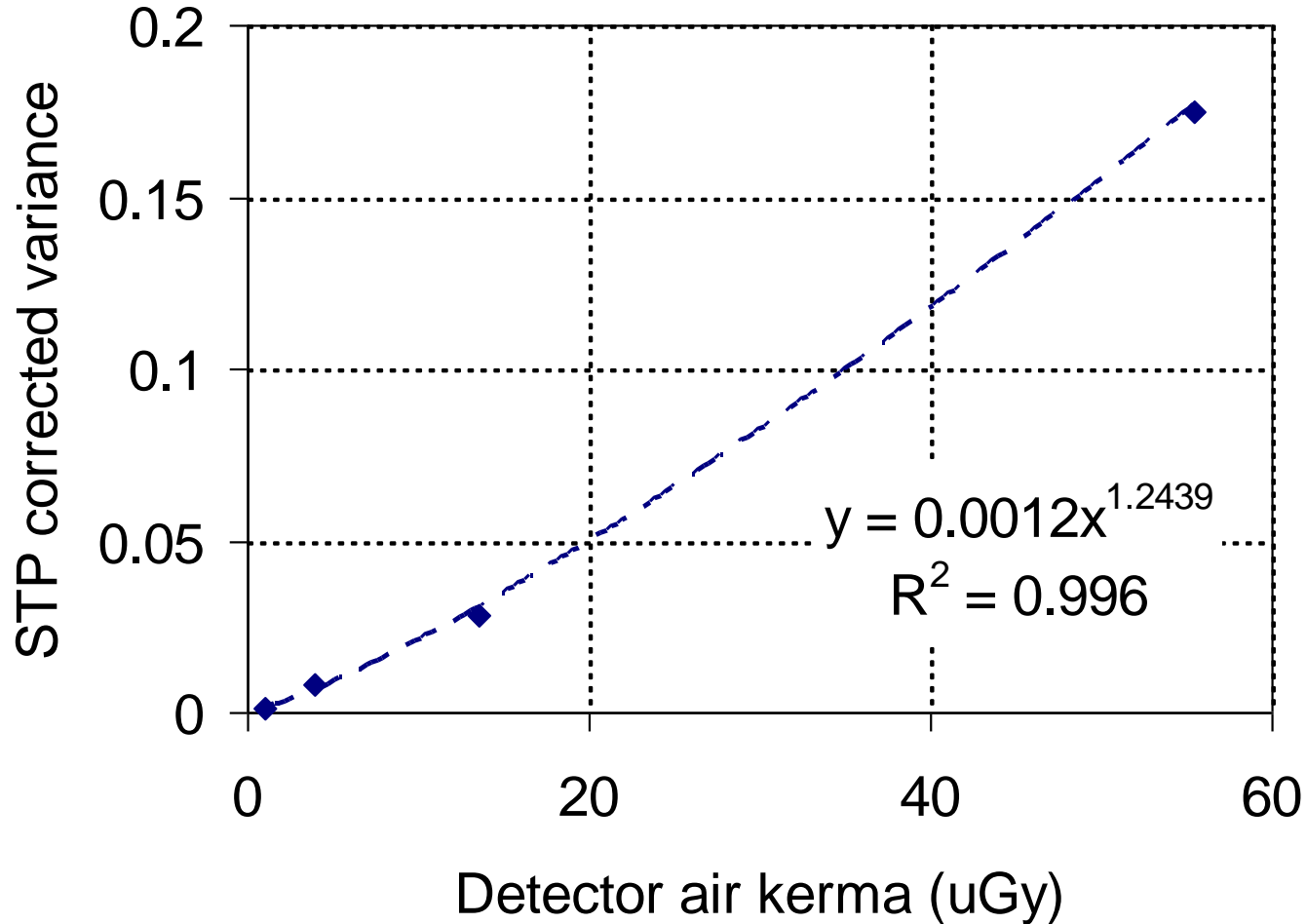


'Raw' pixel values from ROI on the system



'Exported' pixel values from ImageJ/IQWorks

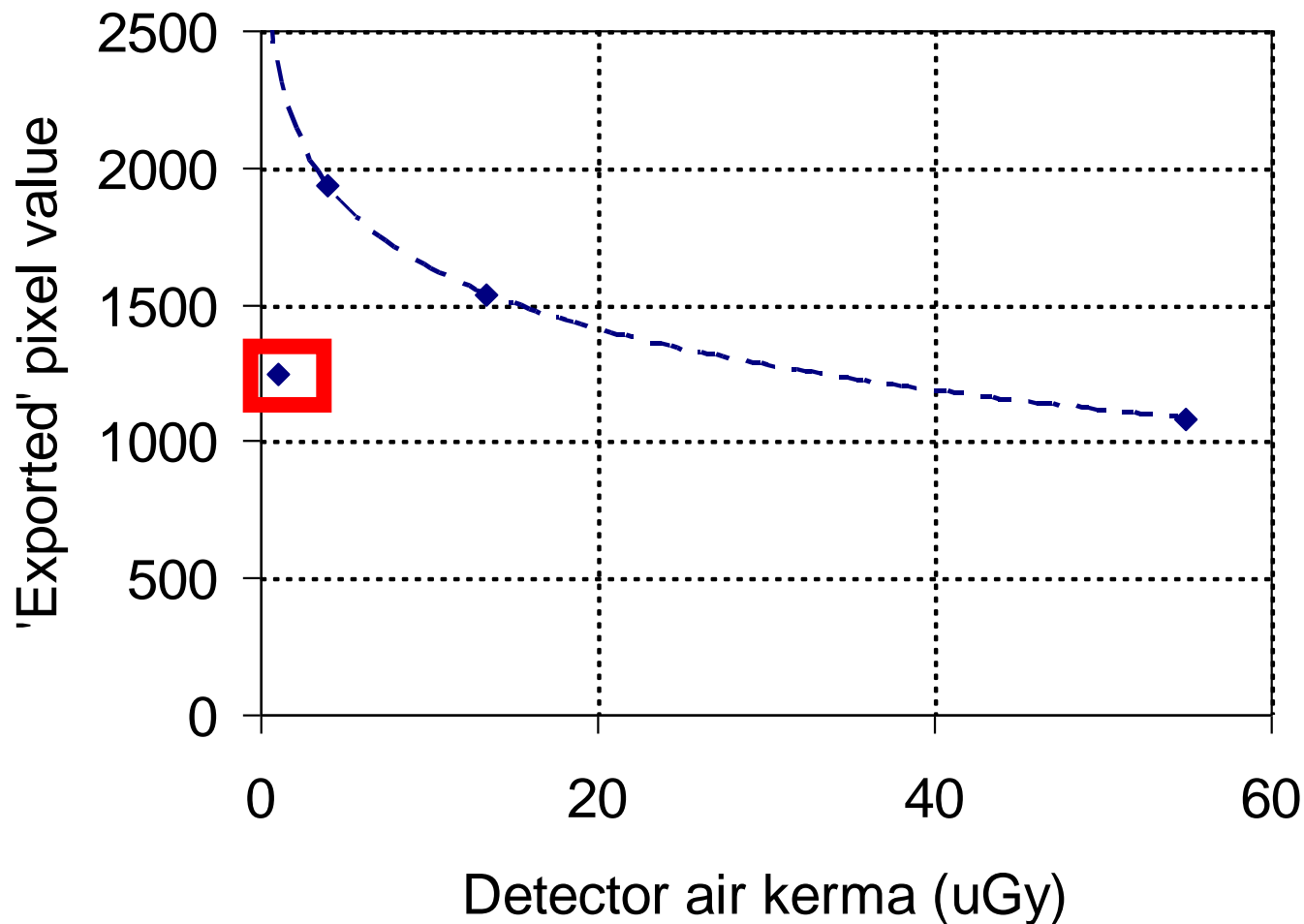
STP corrected variance



But beware of 'unique' features...

- This particular vendor uses brightness/contrast settings rather than conventional window/level
 - Actually, very tricky to use when looking for artefacts, etc
- Changes the 'processed' pixel values i.e. the images that quantitative QA is performed on
 - It changes the image LUT, rather than the range of pixel values displayed in the image!
 - If place an ROI on and change the brightness/contrast settings, 'Raw' values are constant but processed values change
- So, if you want to adjust image presentation (e.g. to look for artefacts), **ensure you export the image first, or reset the brightness/contrast settings before sending**

Brightness/contrast setting...



Flat field images

Accessing flat field unprocessed images

- For meaningful, consistent and comparable results, all image processing (apart from flat field correction) must be turned off
- May be as easy as selecting a factory set QA protocol
 - Mammography is the perfect example e.g. ‘QC raw’ on Siemens, ‘flat field conv’ on Hologic, etc
 - ‘System Diagnosis → Flat field 200’ on Agfa CR
- May require the user to set up a new protocol
 - Turn off all extra image processing in the various menus
 - Harder than you think as there can be **many** options, and they don’t all have an obvious on/off option
- May not actually be possible!
 - Some image processing may only be ‘minimised’
 - Some image processing may be hidden – you think you have turned it off, but then get some strange results!

Some specific examples...

- Siemens DR
 - Amplification = 1
 - LUT = 1
 - Gains all set to zero
 - Diamond view off
- Siemens Luminos dRF
 - As above, with noise reduction off
- Siemens Axiom Artis dFC / dBC
 - K-factor off
 - EVE off
 - DDO off
 - NAT filter off
- Siemens Artis Zee
 - Gain correction = 0
 - I-noise reduction off
 - Native Edge = 0
 - Gamma = gammalog
 - EE kernel = 3
 - DDO = 0
 - K-factor off
 - Eve off
 - Sigmoid window off

...and some more

- Fuji CR
 - QC TEST → SENSITIVITY
 - Fix S = 200, L = 1 or 2
- Agfa CR
 - Flat field 200
 - **Ensure set up export destination 'for processing'**
- Carestream CR/DR
 - Process under Pattern mode
- GE Precision Rxi
 - Edge level = 1
 - Gamma = LUT 1
- GE Optima 220 (mobile)
 - Outputs 'RAW' (for processing) and processed (for presentation) images
- Samsung DR
 - 'Raw test' under 'QA/Test'
 - Ensure apps set this up!
- Varian OBI
 - 'None' processing
- Varian TrueBeam
 - Use Service Mode, turn off gains, etc
 - 'None' in clinical mode still applies (weird) processing

Exporting test images

Getting images off the system

- There are generally three options available for getting images off;
 - Write the images directly to a CD/DVD/USB drive on the X-ray set
 - Send the images to PACS, and then retrieve them from there
 - Set up a 'Physics' DICOM node on the X-ray set and send them directly to that location

Direct writing to storage media

- ***If available***, this is often the easiest option
- But;
 - May conflict with some Trusts data protection policies
 - We have a dedicated USB hard-drive that has been signed off by the highest levels of management for transferring QA images ***only***
 - Originally had a finger print scanning, encrypted USB hard-drive (very expensive!) – BUT it didn't work on the X-ray systems!
 - Not all systems offer this as an option, even if made by the same vendor
 - e.g. 50% of our Philips DR equipment has a CD drive for writing data (mammography & fluoroscopy), but the DR room and mobile do not have this as an option

Direct writing to storage media

- Known to be possible on...
 - Siemens
 - Export to offline (USB or CD)
 - **Some** Philips
 - Send to CD in review window, then go to admin tab and burn DICOM CD (or DVD)
 - **Some** Fuji CR
 - USB drive
 - Samsung DR
 - USB drive if using 'admin' login
 - GE
 - Burn to CD
 - And maybe others...

Sending images via PACS

- Simply send the images to PACS (as would be done in normal clinical practice) and then get them off at an appropriate terminal e.g. burn to CD, etc
- All systems!
- **Issues:**
 - Not necessarily the most ‘convenient’ technique...
 - Image processing may be applied by the PACS system e.g. Fuji
 - Need to have appropriate access, and a method to get images off the terminal
 - Local terminal? CDs? Network drives?
 - May have to ask PACS team to do this for you
 - Can add extra delays to the process and impact workflow!

Setting up a DICOM node

- System specific in how you implement this, but should be possible for all systems (I assume)
- Need a computer running an appropriate PACS client/server that the imaging system can connect to
 - e.g. K-PACS (other PACS client/servers are available...)
- **Issues:**
 - Settings such as IP address *may* be hidden away from the user (only engineers have access). Hence, require fixed IP address to send to, and need to be able to grab this on the receiving computer
 - Some systems allow the IP address for the DICOM node to be changed e.g. Agfa CR. Hence, can use a dynamic IP address on receiving computer and change the setup of the imaging system
 - Some systems will export processed images by default e.g. Agfa CR. **Ensure the node is set up correctly to only send 'for processing'**

A better way forward?

- **Everybody reinventing the wheel is not an efficient use of our skills and resources**
- The new IPEM website allows us (and IPEM is willing) to host a range of useful information that can be shared amongst the DR community
- DRSIG also now have a group email address:
drsig@ipem.ac.uk
- The proposal:
 - **Users** send information on specific settings used on different systems to access the required information
 - Host this information on the IPEM website *via* DRSIG
 - Could also include example results, etc

And now for the plea for help!

If you have **any** details/information about how you access and export unprocessed images on **any** X-ray imaging system, and are willing to share the information, please send it to:

drsig@ipem.ac.uk

A final thought...

- Why are we still having issues accessing such basic features as (truly) raw images, and exporting them off the system?
- Shouldn't we (as a community) be pushing the vendors to make these features **easily** accessible to all?
 - It has been done in mammography, so why can't it be done in the wider DR community?
 - Ensure we can get truly unprocessed images from the systems
 - A range of options for exporting QA images easily (technique can often be Trust IT policy dependent)

Remember what IPEM Report 32 Part VII says...

- ‘...Quantitative analysis has a strong background and has been used extensively...’
- ‘...It has been shown to be **reproducible** and **sensitive** to changes in a **clinical service** and therefore can be suitable for QC...’
- ‘...In digital imaging, degradation of the image quality can be partially hidden by the image processing applied to the images and so changes may not be apparent to the user. **It is important that useful and consistent testing of digital systems is undertaken...**’

A final thought...

- Given that the benefits of quantitative QA are now well established (at least until the big debate!), surely it is in the manufacturers interests to be helpful in setting up the system appropriately
- Take a united stance so that we know we aren't the '**first person to ask**' and push the manufacturers to play ball!
- What is the best way to do this?...

Summary

- Often the most ‘basic’ aspect of the quantitative QA programme, i.e. exporting unprocessed images, can prove the most challenging!
 - Experience tends to be vendor/Engineer/Apps specific
- It is proposed that we set up a forum, via IPEM (DRSIG) that allows us to share information on how best to perform this task on as much equipment as possible
- This should help with gaining co-operation from vendors (we will know if it is possible!)
- Should we be pushing manufacturers harder to make these options more easily accessible?
 - **True unprocessed images**
 - **Easy export options**
 - **Simple QA options/protocols** available on systems **by default** i.e. not after a long period of negotiation!

Acknowledgements

- IPEM
 - DRSIG
- Craig Moore
- Ian Honey
- Laurence King
- Mark Worrall

Any questions?

tim.wood@hey.nhs.uk

drsig@ipem.ac.uk