

# Leeds Lung Health Check – Protocols, QA & Optimisation

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# Lung Cancer in Yorkshire

Lung Ca. rate in Yorkshire  
78.8/100,000 vs. 66.6 in  
England

Largest cause of premature  
death in Leeds

Leeds West and South & East  
CCGs in 4 highest for  
incidence and mortality rates



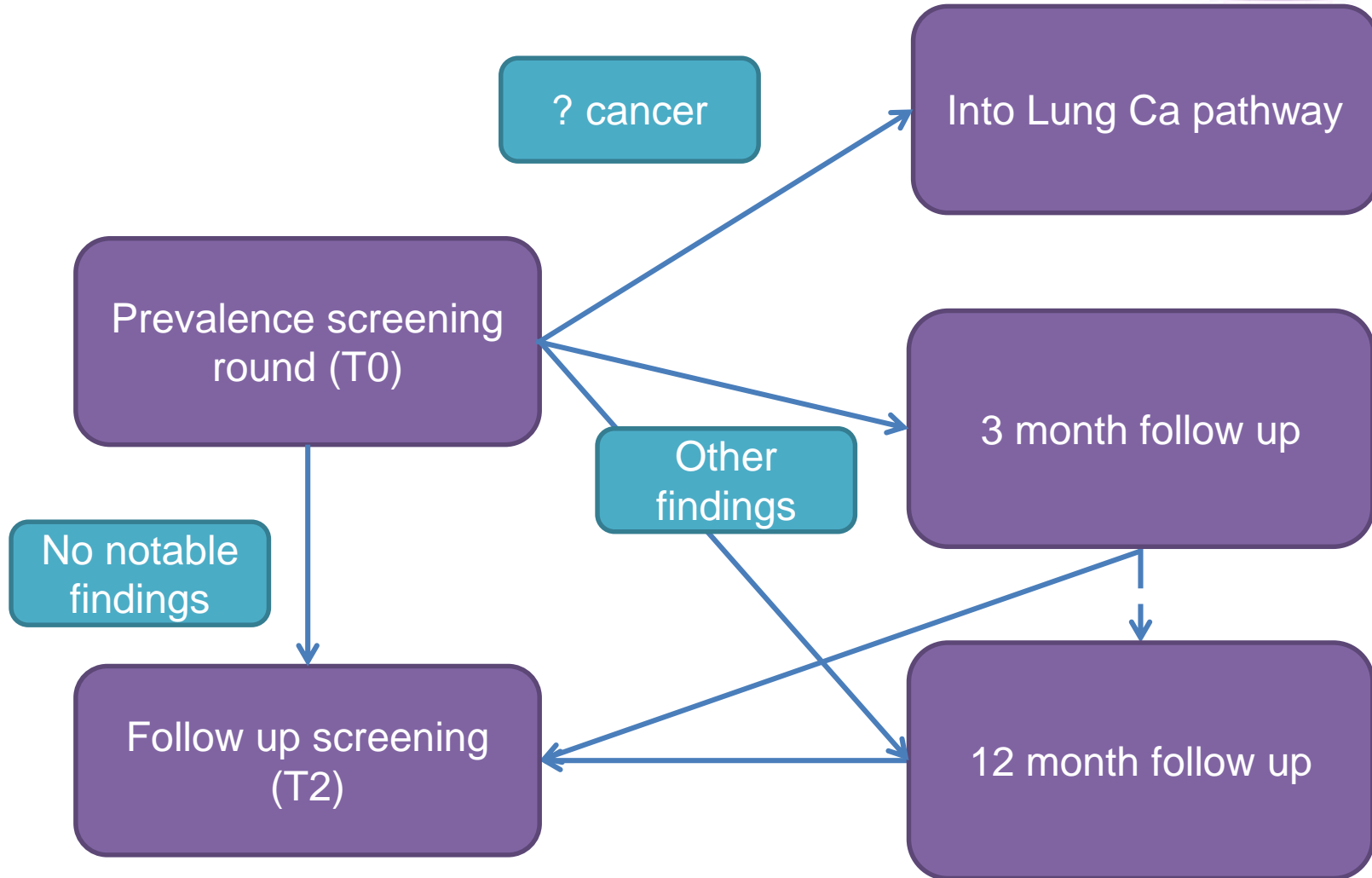
# Yorkshire Lung Screening Trial

55 – 80 year olds – ever  
smokers

1:1 randomisation –  
screening : no screening

## Screening arm:

- Two Lung Health Checks (inc. CT screens) at 2 yr interval
- Community based screening – mobile CT
- Surveillance program for identified nodules etc.
- Additional 5<sup>th</sup> year surveillance
- Estimate ~7000 persons having biennial screening





# LEEDS LUNG HEALTH CHECK



# Mobile CT

- Provided by Alliance Medical
- Canon Aquilion PRIME SP
- LTH acting as MPE for Trial



# Scan protocols

## AML proposed scan protocols

	<50 kg		50 – 80 kg		>80 kg	
kV	100		120		135	
mA	70		70		70	
Tube Rotation (s)	0.5		0.5		0.5	
Sure Exposure (AEC)?	No		No		No	
AIDR 3D?	No		No		No	
Beam Collimation	0.5 x 80		0.5 x 80		0.5 x 80	
Reconstructed Slice (mm)	2.0 / 1.0		2.0 / 1.0		2.0 / 1.0	
Speed / Pitch	0.813	65.0	0.813	65.0	0.813	65.0
Algorithm / Filter	FC18 (Soft Tissue) / FC51 (Lung)					





## AAPM scan protocols

“Set of reasonable scan protocols developed by AAPM Working Group”

<https://aapm.org/pubs/CTProtocols/documents/LungCancerScreeningCT.pdf>

V5.1 September 2019

Suggested protocols for most current scanners

Missing detail – no info on recon kernel for Canon scanners

**Scanogram:** PA and LAT dual Scanogram; scan from top of shoulder through mid-liver.

CANON	Aq RXL	Aq Lightning (16 Rows)	Aq Lightning (80 Rows)	Aq PRIME (40 Rows)	Aq PRIME (80 Rows)
Scan Type	Helical	Helical	Helical	Helical	Helical
Rotation Time (s)	0.5	0.75	0.75	0.35	0.35
Detector Configuration	16 x 0.5 mm	16 x 1.0 mm	80 x 0.5 (mm)	40 x 0.5 mm	80 x 0.5 mm
Pitch	Fast (1.434)	Fast (1.438)	Standard (0.813)	Standard (0.825)	Standard (0.813)
kV	120	120	120	120	120
Minimum & Maximum mA	Min mA = 20 / Max mA = 110	Min mA = 10 / Max mA = 300	Min mA = 10 / Max mA = 300	Min mA = 20 / Max mA = 120	Min mA = 20 / Max mA = 120
SUREIQ Setting	Body Std Axial (5 mm Target Slice)	Body Std Axial (5 mm Target Slice)	Body Std Axial (5 mm Target Slice)	Body Std Axial (5 mm Target Slice)	Body Std Axial (5 mm Target Slice)
SUREExposure	ON	ON	ON	ON	ON
*SD	25*	20*	20*	25*	25*
**CTDIvol	1.8			1,8	1.8

\* Create a new SureExp setting using Body Std Axial SureIQ with 5 mm Target Slice and the given SD, min and max mA values.

\*\* For standard sized patient, defined as 5'7", 155 pounds. Do not adjust the SD as patient size varies. SureExposure modulates mA automatically based on patient size.

**Recon 1 – Axial Soft Tissue**

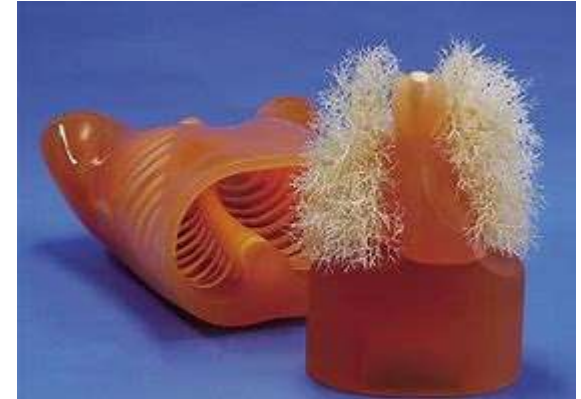
Type	Axial	Axial	Axial	Axial	Axial
SUREIQ Setting	Body Std Axial	Body Std Axial	Body Std Axial	Body Std Axial	Body Std Axial
AIDR 3D	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD
Thickness (mm)	1	1	1	1	1
Interval (mm)	1	1	1	1	1

**Recon 2 – Axial Lung**

Type	Axial	Axial	Axial	Axial	Axial
SUREIQ Setting	Lung Std Axial	Lung Std Axial	Lung Std Axial	Lung Std Axial	Lung Std Axial
AIDR 3D	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD	AIDR 3D STD
Thickness (mm)	1	1	1	1	1
Interval (mm)	1	1	1	1	1

## Lungman to the rescue! – Trial – 7 days...

- Scan Lungman on existing and AAPM protocols
  - With and without body plates
- Radiologist image review
  - Only one question:
  - Are images suitable for Trial?

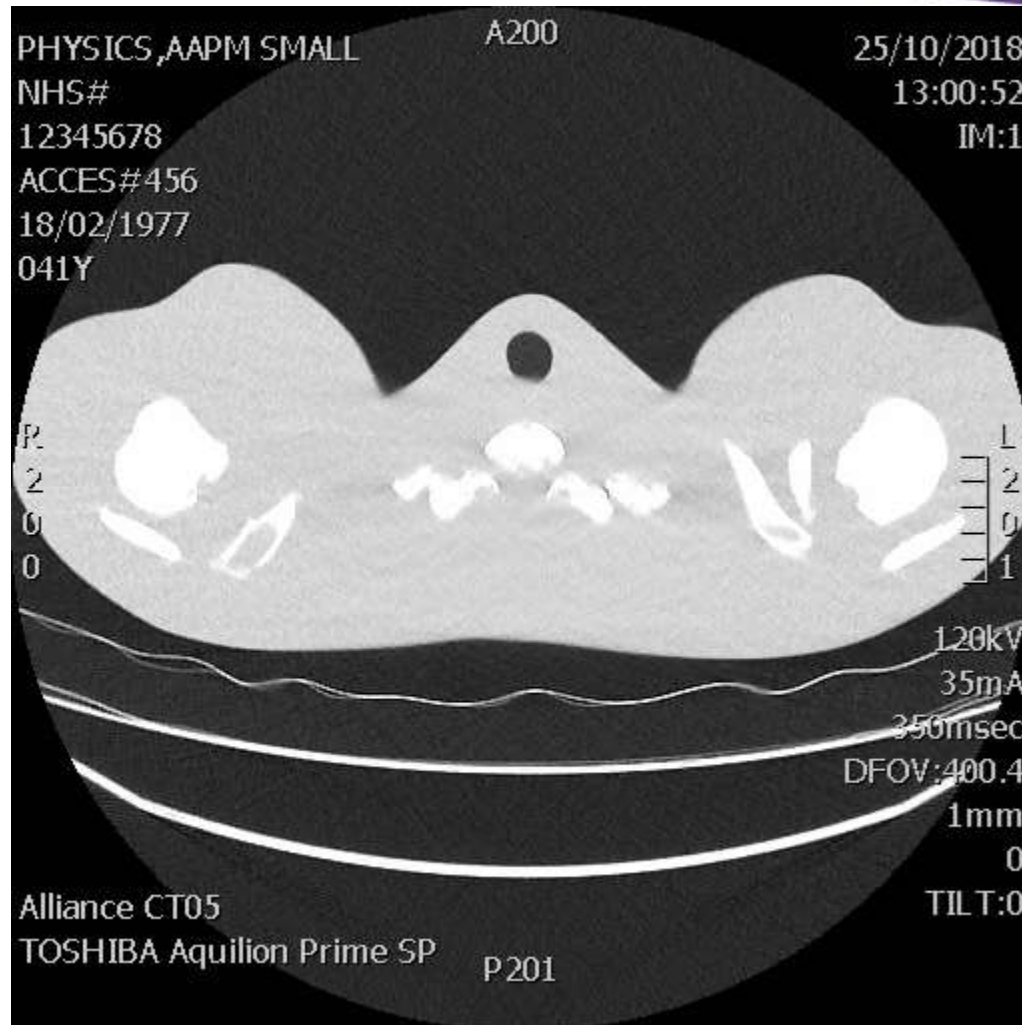


Lungman ~55kg equivalent

## Resulting doses

	Lungman	Lungman + body covers
Protocol	CTDIvol (mGy) / DLP (mGycm)	CTDIvol (mGy) / DLP (mGycm)
AML <50kg	1.2 / 40.9	-
AML 50-80kg	2.2 / 74.8	-
AML >80kg	3.2 / 106.8	3.2 / 104.9
AAPM	0.6 / 20.3	1.3 / 44.9

AAPM protocols look more sensible from a dose perspective



Radiologists happy with images from AAPM protocol – all phantom sizes

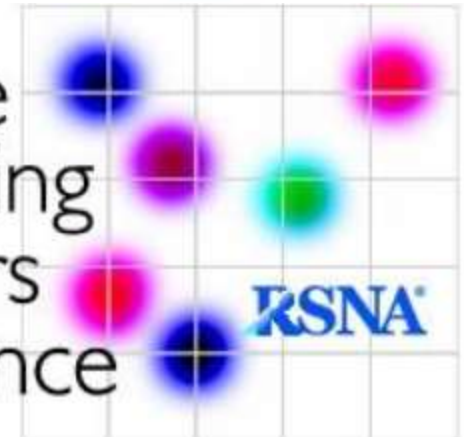
# RSNA QIBA

Quantitative Imaging Biomarkers Alliance

***QIBA Mission: Improve the value and practicality of quantitative imaging biomarkers by reducing variability across devices, sites, patients, and time***

[qibawiki.rsna.org](http://qibawiki.rsna.org)

Quantitative  
Imaging  
Biomarkers  
Alliance



## QIBA Profile:

**Small Lung Nodule Volume Assessment and  
Monitoring in Low Dose CT Screening**

## Image Quality Markers

**Edge enhancement –**  
shall not exceed 5%

### **3D resolution -**

A 3D PSF sigma ellipsoid  
volume of less than or  
equal to  $1.5\text{mm}^3$

**Spatial warping –**  
3D image acquisition  
results in Spatial warping of  
less than 0.3mm Root  
Mean Square Error

### **3D resolution aspect ratio**

-  
A Z PSF sigma less than  
two times larger than the in-  
plane PSF sigma

**HU bias –**  
CT HU value deviation of  
less than 35 HU for Air and  
Acrylic materials

### **Noise –**

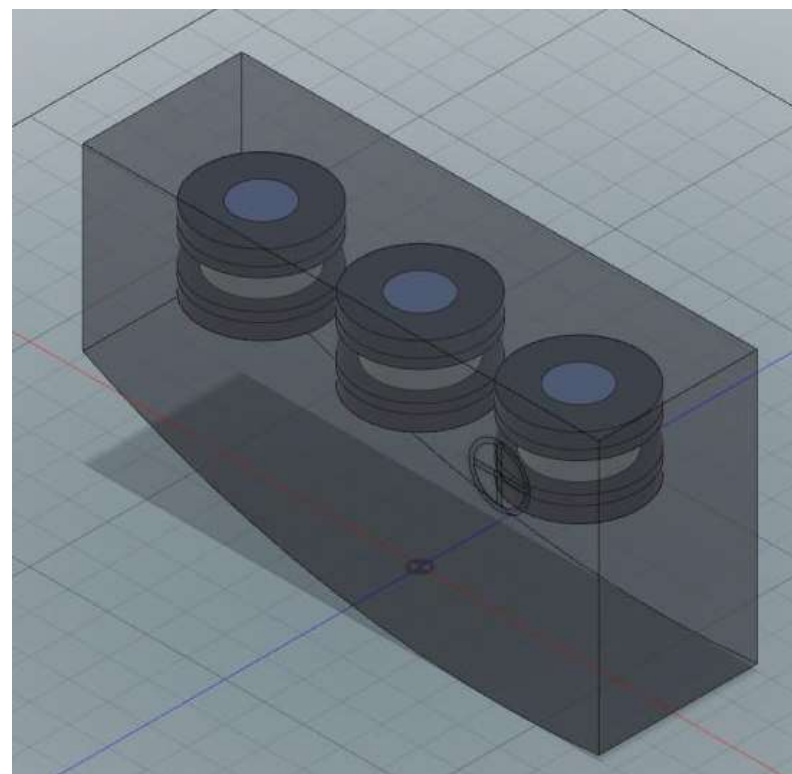
a standard deviation that is  
 $\leq 50$  HU for homogeneous  
Air and Acrylic materials



## Accumetra CTLX1 phantom

- Three modules placed at 0mm, 102mm, and 204mm from isocentre
- Each module is hollow cylinder of Delrin
- Air region inside and outside cylinder
- Teflon cylinder and Acrylic cylinder above and below Delrin respectively

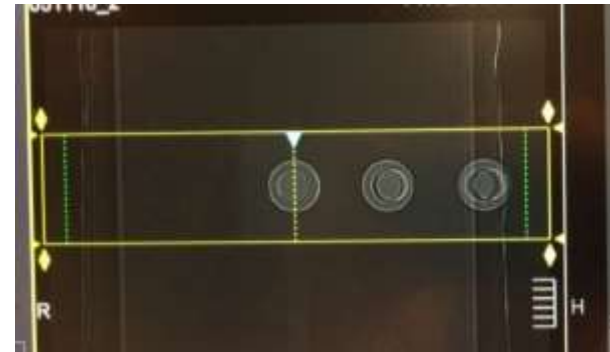
Unique phantom looks at performance across imaged field



Leeds is first site in the world to use this phantom on a mobile CT scanner

## CTLX1 scanning – Trial -7 days...

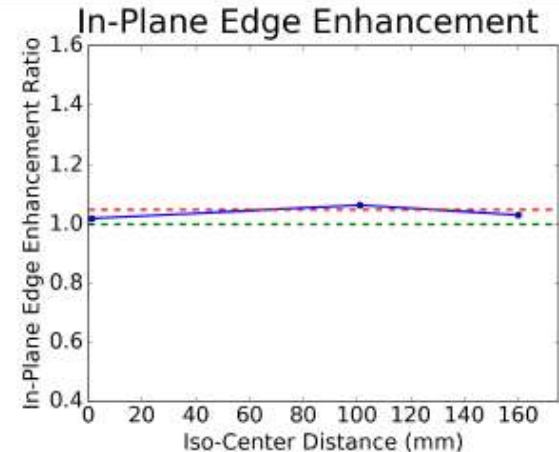
- Scanned on AML & AAPM protocols
- Online analysis of images
  - Failed on all protocols



## (1) Edge Enhancement



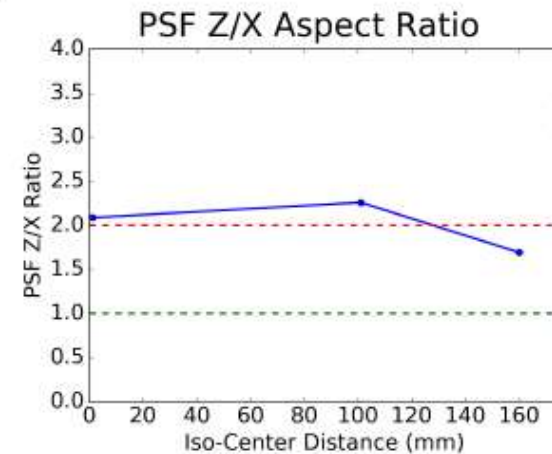
In-plane edge enhancement can significantly modify the HU values of objects in CT images and cause problems with quantitative measurement algorithms. We quantitatively tested your levels of edge enhancement at three distances from iso-center and found at least one value that exceeds QIBA CT SLN Profile specifications.



## (4) 3D Resolution Aspect Ratio



Quantitative measurement algorithms work better with uniform resolution along all three CT imaging dimensions. We quantitatively tested your PSF Sigma Z/X aspect ratio at three distances from iso-center and found at least one value that exceeds QIBA CT SLN Profile specifications.

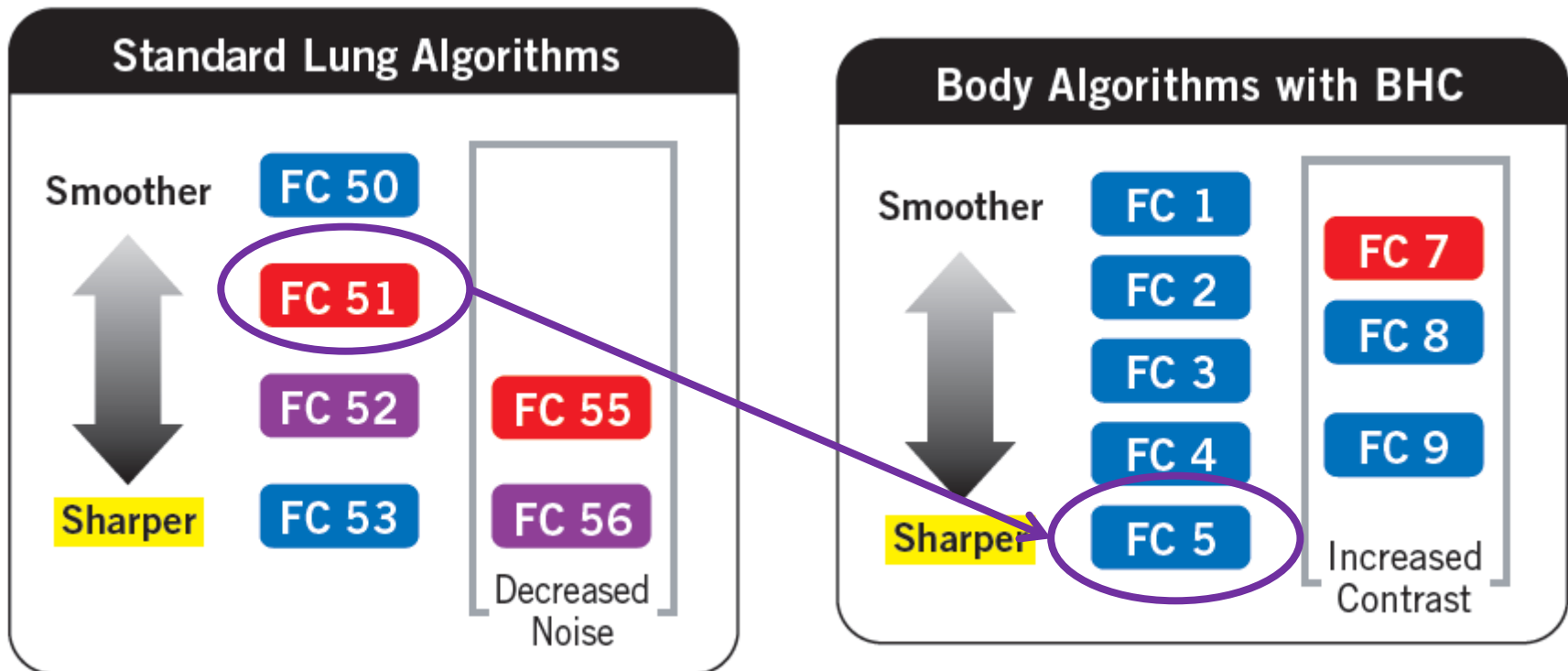




**DON'T PANIC**

## Protocol edit

- Advice from Canon & Accumetra re: recon kernel for lung recon.



## Protocol edit – Trial -1 day...

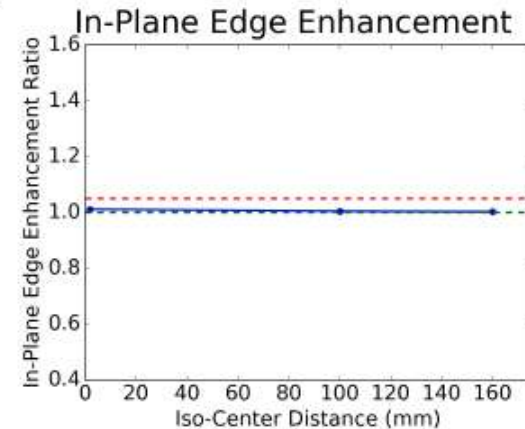
- Return to scanner day before Trial starts
- Amend scan protocol (FC 5)
- Re-scan Lungman
  - Images to Radiologist
  - Are images ok for the trial?
- Re-scan CTLX1
  - Upload for analysis



## [Lastminute.com](http://Lastminute.com)



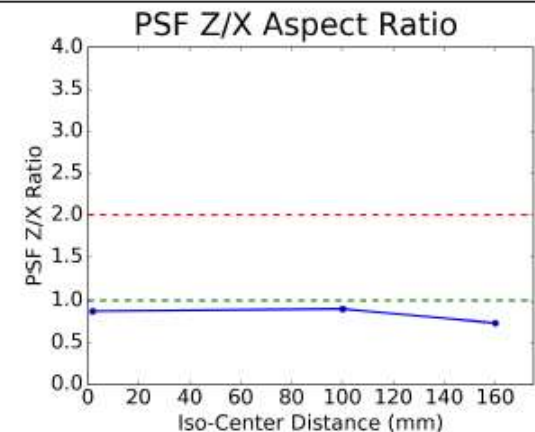
In-plane edge enhancement can significantly modify the HU values of objects in CT images and cause problems with quantitative measurement algorithms. We quantitatively tested your levels of edge enhancement at three distances from iso-center and found the values to be within QIBA CT SLN Profile specifications.



### (4) 3D Resolution Aspect Ratio



Quantitative measurement algorithms work better with uniform resolution along all three CT imaging dimensions. We quantitatively tested the Z/X PSF aspect ratio of your imaging system at three distances from iso-center and found the values to be within QIBA CT SLN Profile specifications.



## Lastminute.com

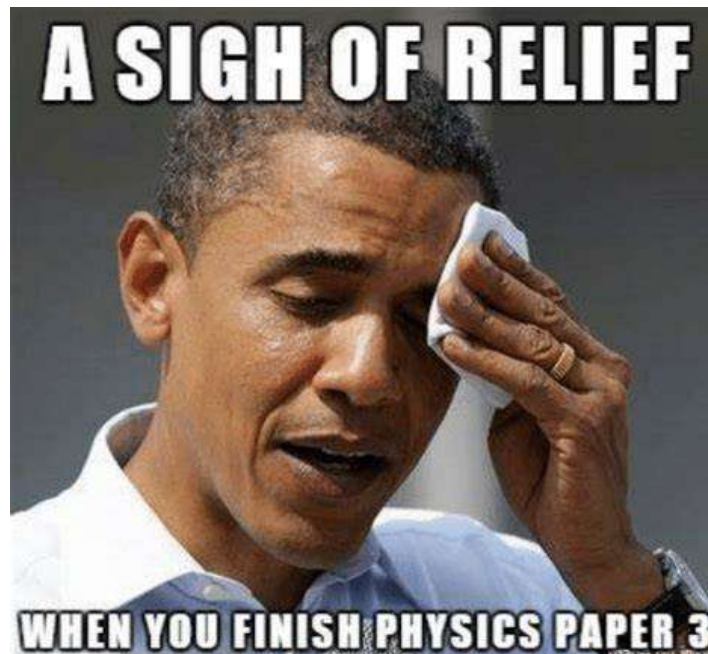
### Conformance Assessment Status

The required number of CTLX1 phantom modules were found (3).

The DICOM slice thickness is within acceptable limits for this analysis ( $\leq 1.25\text{mm}$ ).

The DICOM slice spacing is within acceptable limits for this analysis ( $\leq$  slice thickness).

All QIBA CT SLN Profile automated conformance checks have passed for this CT scanner and image acquisition protocol.





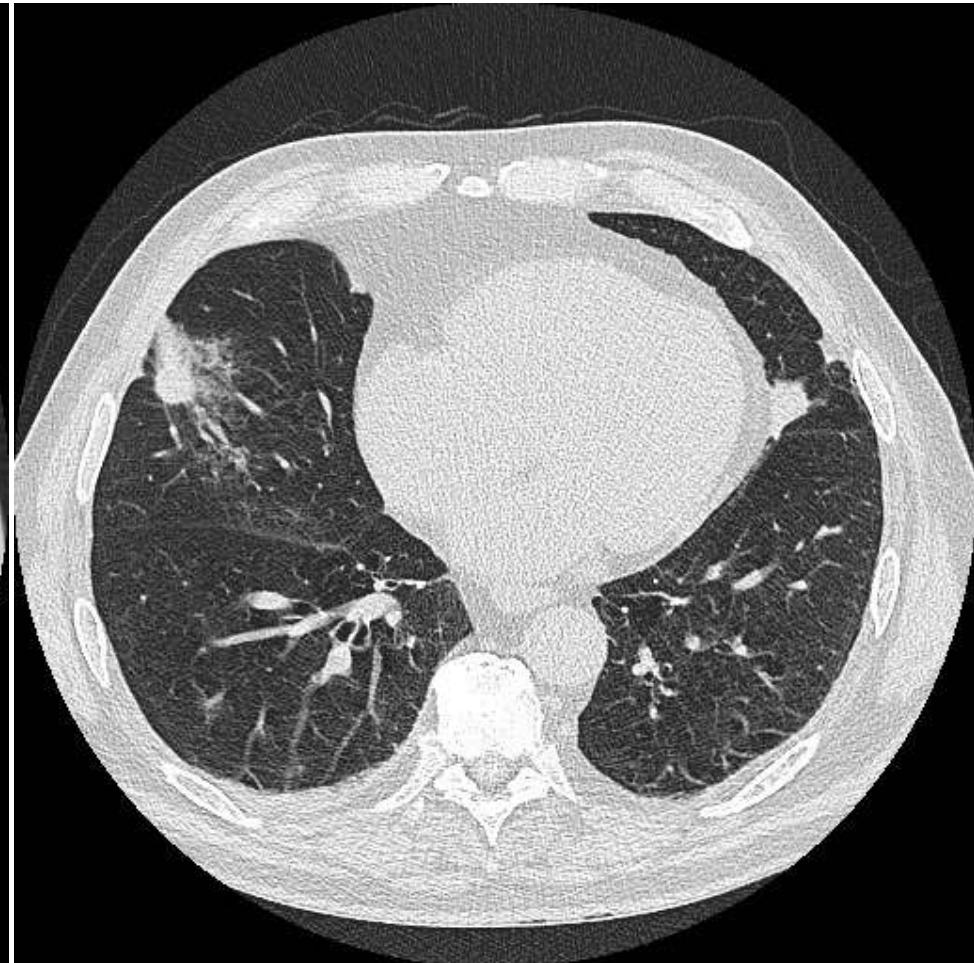
[Lastminute.com](https://www.lastminute.com)

Radiologists happy with IQ

Images quite different from normal HRCT

Trial image – Canon Prime  
SP

Follow up HRCT image – GE  
Revolution GSI



## Trial so far

Trial started 6<sup>th</sup> Nov 2018

3048 patient scans to date

Rounds 1 – 8

2018 patient scans

31 confirmed cancers  
(others being followed up)

Ca. detection rate at least 1.5%

c.f. ~0.9% in Breast Screening in  
2015/16

## Demographics

11 rounds completed – 3048 scans

54%:46% M:F ratio

	Age (yr)	Weight (kg)	Height (cm)	BMI (kg/m <sup>2</sup> )
Min	55.0	35.0	101.5	15.6
Mean	68.1	79.2	165.8	28.6
Median	68.0	77.5	166.0	28.0
Max	83.0	184.0	196.0	78.6

BMI range	Percentage
Underweight	0.6
Normal Weight	26.4
Overweight	38.2
Obesity	22.9
Severe Obesity	11.7

# Patient doses

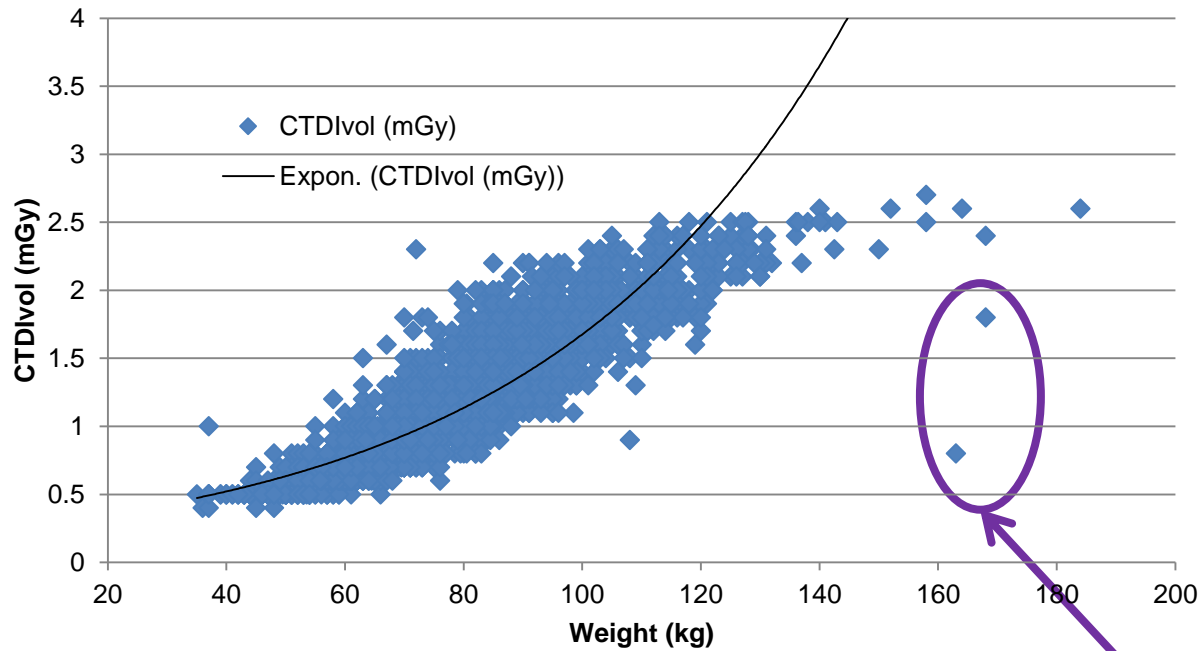
	CTDIvol (mGy)	DLP (mGycm)	Effective dose (mSv)	Scan length (cm)
<b>Min</b>	0.40	15.80	0.43	28.2
<b>Mean</b>	1.20	44.95	1.21	37.4
<b>Median</b>	1.10	42.70	1.15	37.4
<b>Max</b>	2.70	115.0	3.11	49.2

$$E/DLP = 0.027\text{mSv/mGycm}$$

### CTDIvol vs. weight

$$y = 0.2395e^{0.0195x}$$

$$R^2 = 0.7786$$

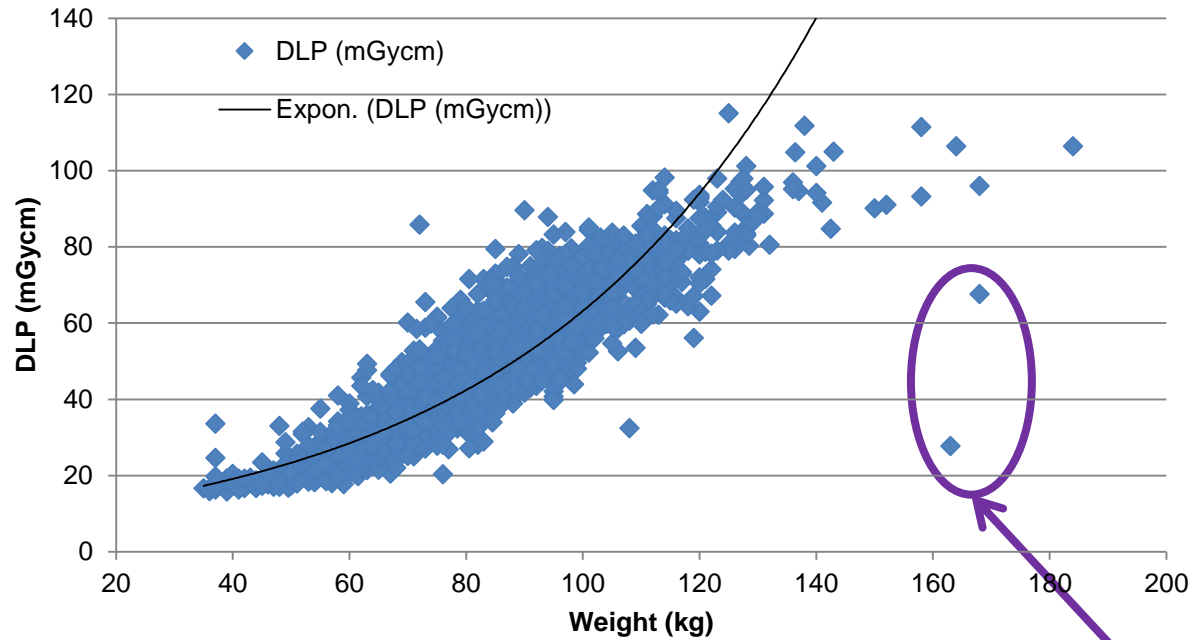


Suspect height entered instead of weight

# DLP vs. weight

$$y = 8.6236e^{0.0199x}$$

$$R^2 = 0.8061$$



Suspect height entered instead of weight

## Dose & image quality summary

- “Happy” with doses & quality
- Suspect we could lower dose
  - Never sought to optimise, just to get acceptable IQ and pass QIBA standard
  - Could look to do this for 2<sup>nd</sup> screen (T2)
    - Further Lungman scans
    - Repeat CTLX1 analysis



# What has gone wrong?

- Two CQC reportable incidents
  - Radiographers adjusted AEC for large patients
  - Received 3-4 times intended dose
- Scanner software upgrade
  - Protocol lost
    - Not backed up prior to upgrade
    - Had to be rebuilt on 1<sup>st</sup> morning of a screening visit

## Routine QA check

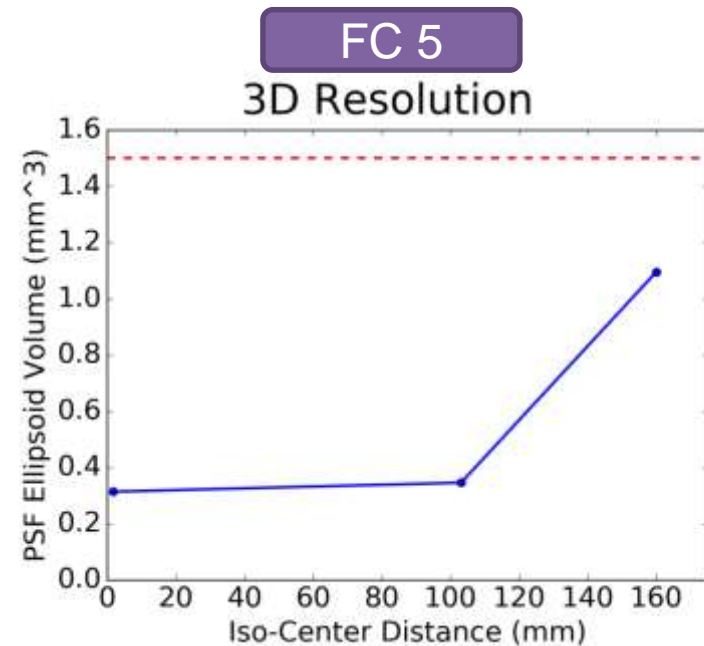
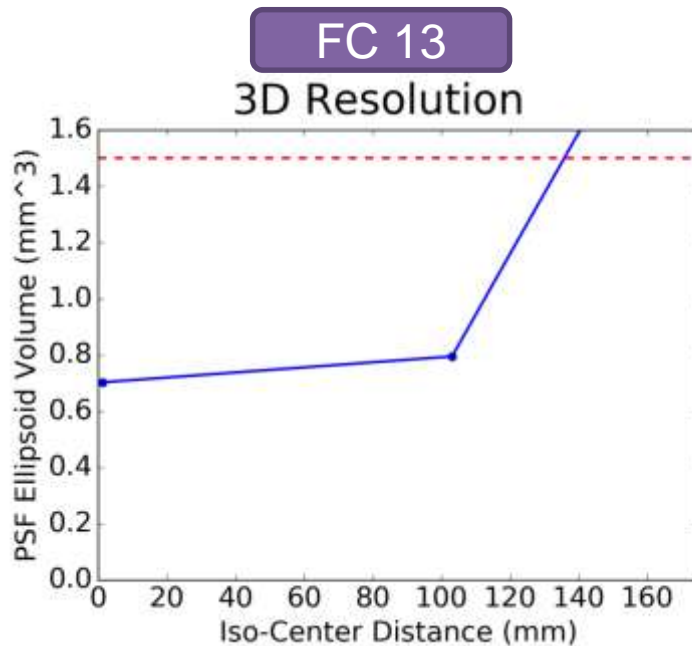
- CTLX1 scan performed on 1<sup>st</sup> morning of each screening round
- Check before any patients scanned
- Ideally upload and analyse images whilst still on site

## QA issues

- CTLX1 QA failed on 1<sup>st</sup> morning
  - Weekly air calibration not performed
  - Passed after calibration
    - Highlighted importance of weekly air calibration

# QA issues

- Wrong kernel
  - When protocol re-built, recon defaulted to FC 13, not FC 5



Some other unexplained variations in CTLX1 results – under investigation

## Summary

- Major lung screening trial in Leeds
- Set up specific clinical scan protocols
  - Further optimisation possible?
- Novel QA process in place
  - Company further developing phantom and analysis routines
- IMHO – National Lung Screening Programme likely to happen
  - Need to get Physicists together to set up standards as per Breast Screening Programme

