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Update on IPEM Evidence-based QA Working Party: CT

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Evidence-based QA Working Party

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Aims

- Primary: To assess the effectiveness of tests recommended by IPEM report 91 in terms of patient safety with consideration given to failure rates and the consequence of each failure.

- Secondary: To provide typical ranges of results to guide commissioning tests, and to support future decisions on appropriate tolerances.

Fluoroscopy, General, Dental, CR/DR, Display device, CT workstreams

Evidence-based QA Working Party

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Papers published by working party to date in Physics in Medicine and Biology as topical reports:

- Honey et al 2019; An evidence and risk assessment based analysis of the efficacy of tube and generator quality assurance tests on general x-ray units

- Worral et al 2021; An evidence and risk assessment based analysis of the efficacy of quality assurance tests on fluoroscopy units—part I; dosimetry and safety

- Shaw et al 2020; An evidence and risk assessment based analysis of the efficacy of quality assurance tests on fluoroscopy units—part II; image quality

CT subteam

Gareth Iball

Leeds Teaching Hospitals NHS Trust

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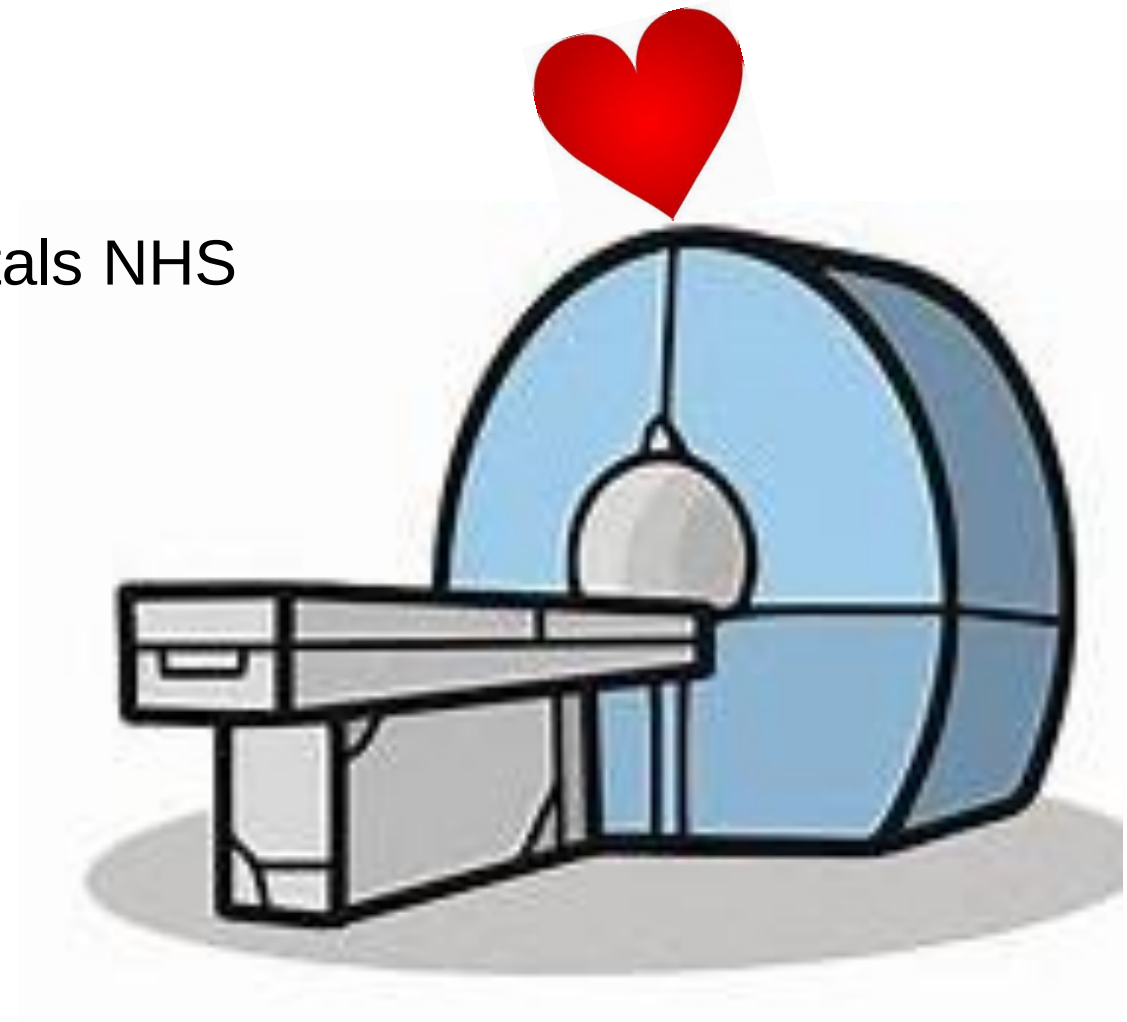

Methodology

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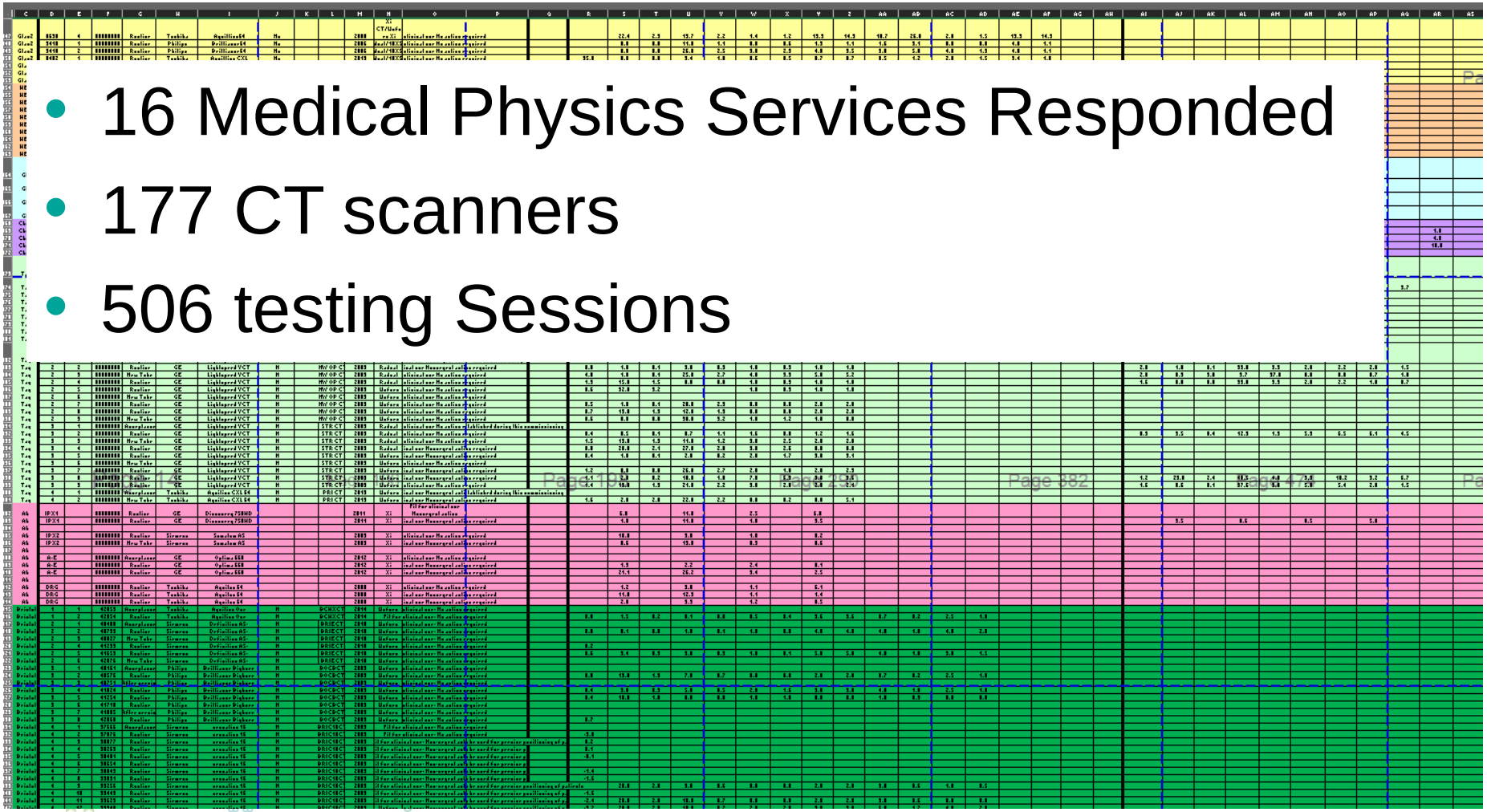
- Data collection
  - Excel template send out on jiscmail
- Assessment of efficacy using risk assessment methodology
  - Based on failure rate and consequences of failure

Excel template

- First section asked which tests the centre carries out and frequency
- Second section summary test results
  - Mechanical tests
  - CTDI in air
  - CTDI in phantom
  - Image noise & uniformity
  - CT number, resolution, slice thickness
  - Additionally, AEC (not IPEM 91)

Data

- 16 Medical Physics Services Responded
- 177 CT scanners
- 506 testing Sessions



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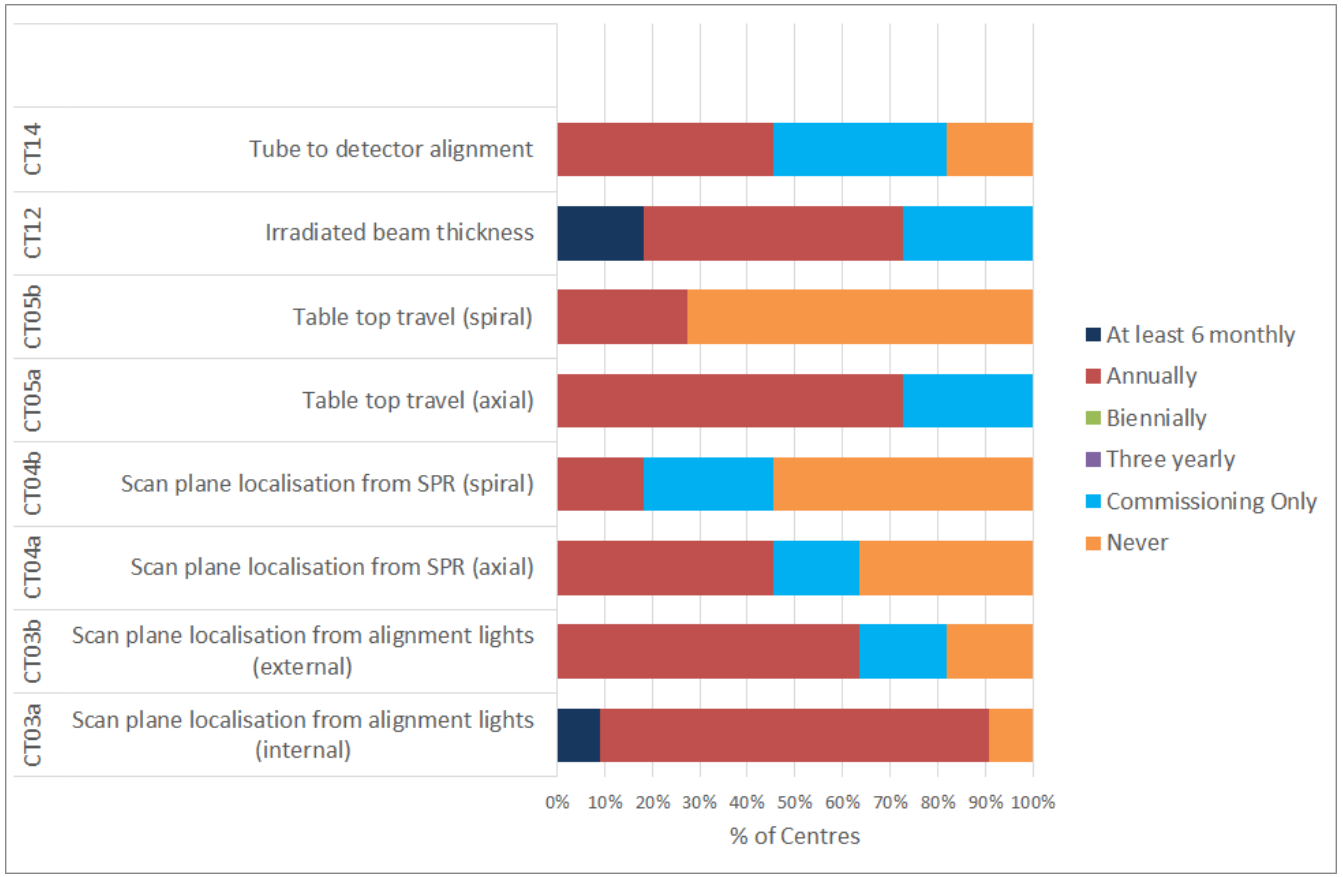
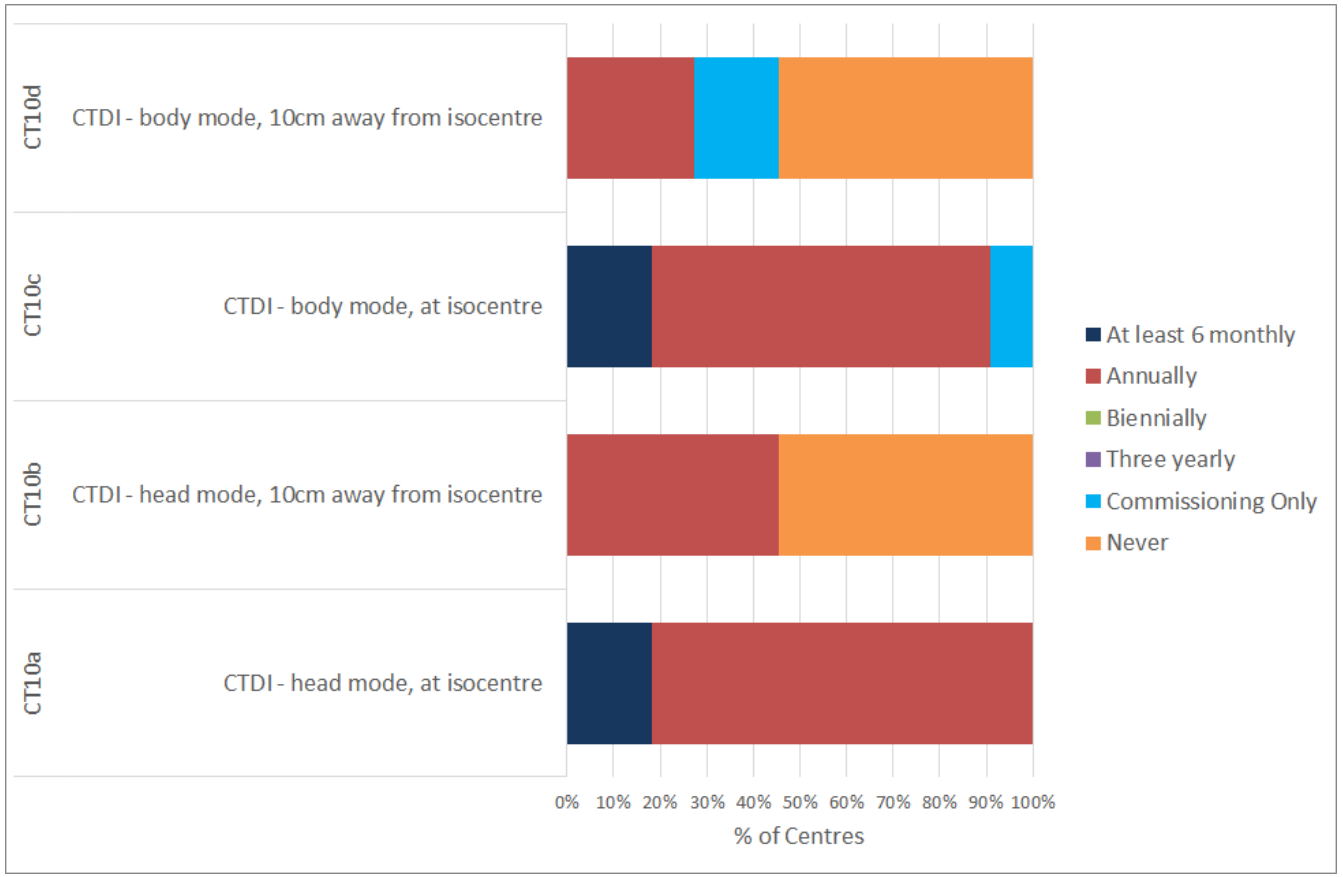
Testing Frequency

Which tests are centres carrying out and how often?

Mechanical Tests



CTDI in Air


CT10d
CTDI - body mode, 10cm away from isocentre
CT10c
CTDI - body mode, at isocentre
CT10b
CTDI - head mode, 10cm away from isocentre
CT10a
CTDI - head mode, at isocentre
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
% of Centres
At least 6 monthly
Annually
Biennially
Three yearly
Commissioning Only
Never

CTDI in Phantom

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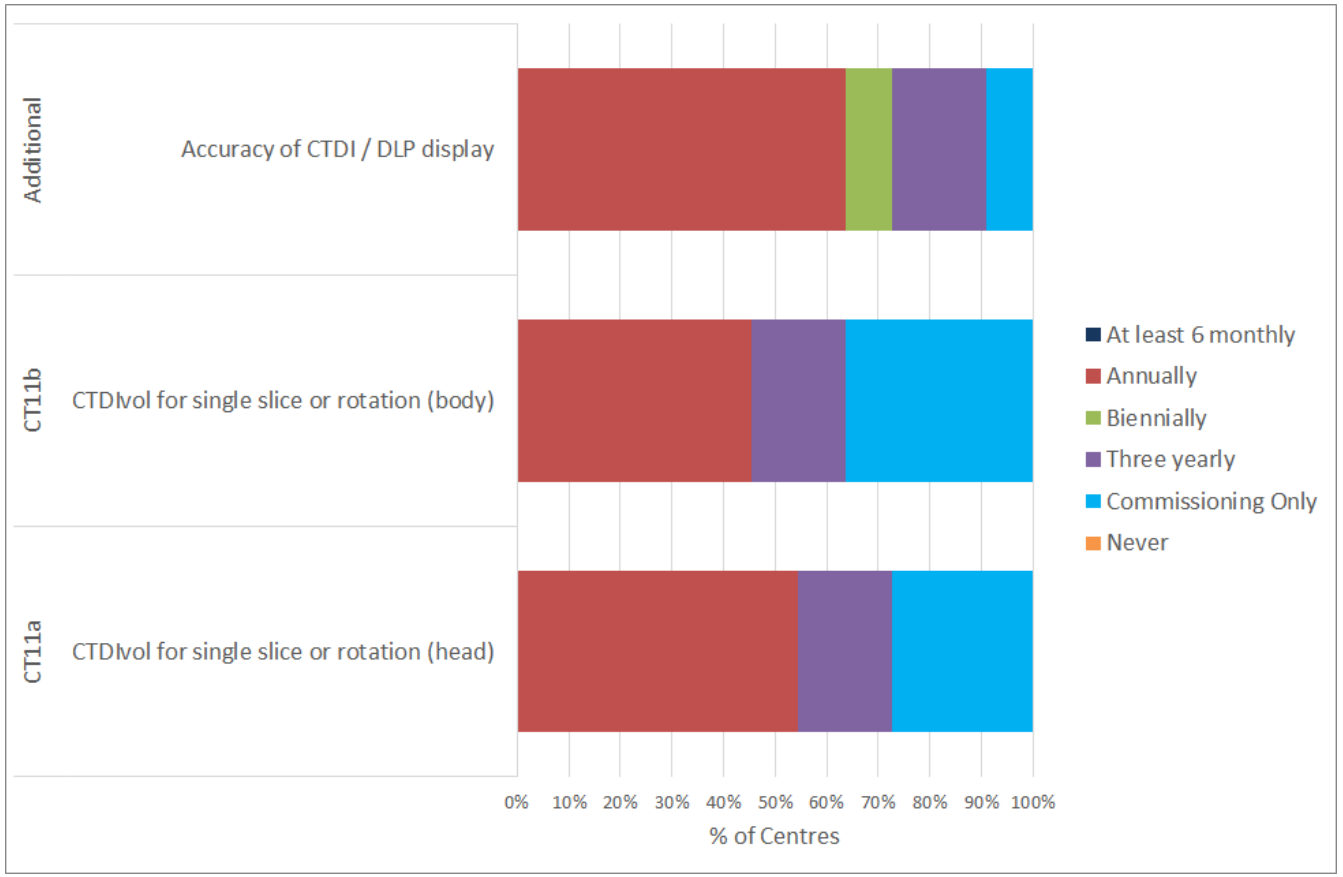
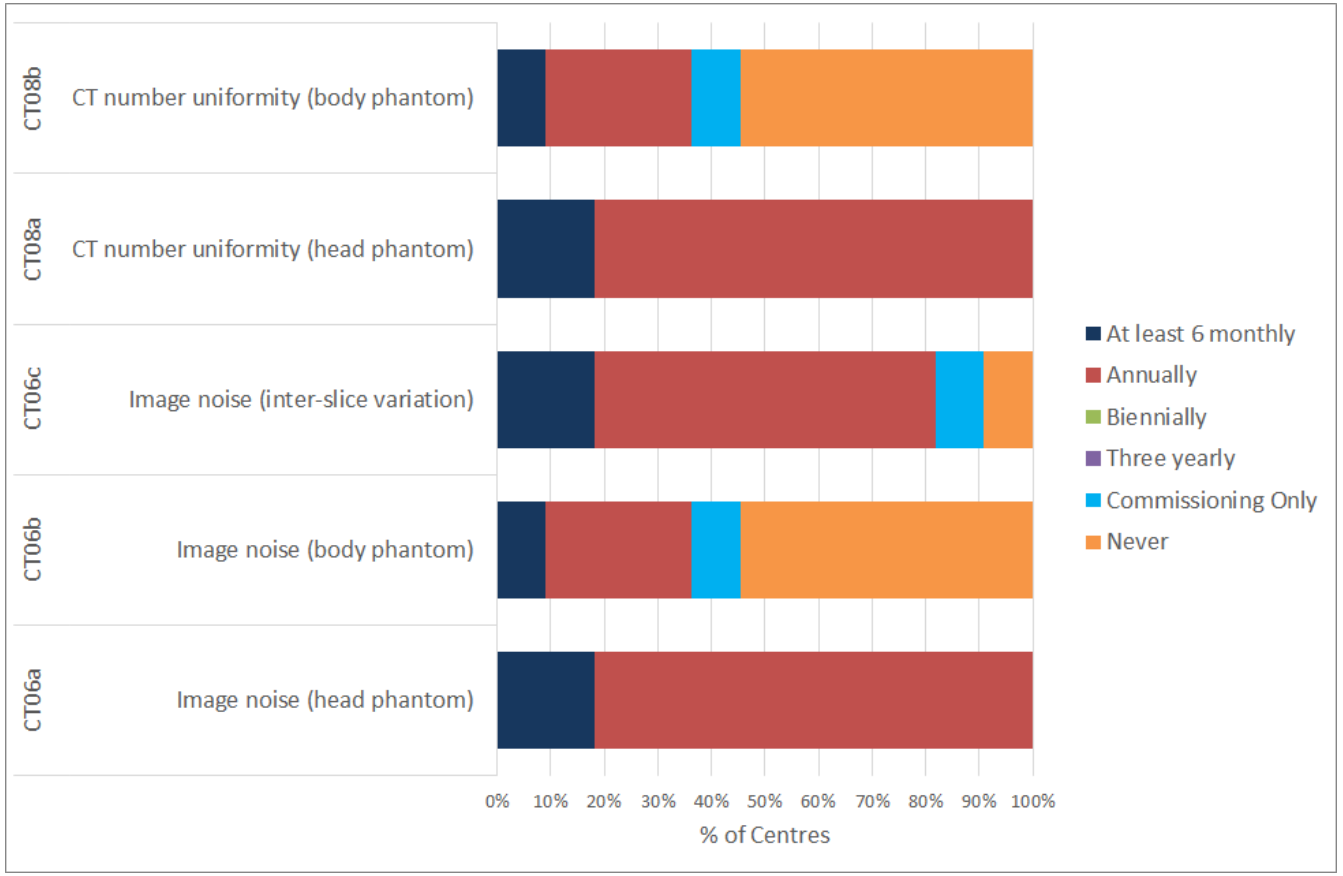
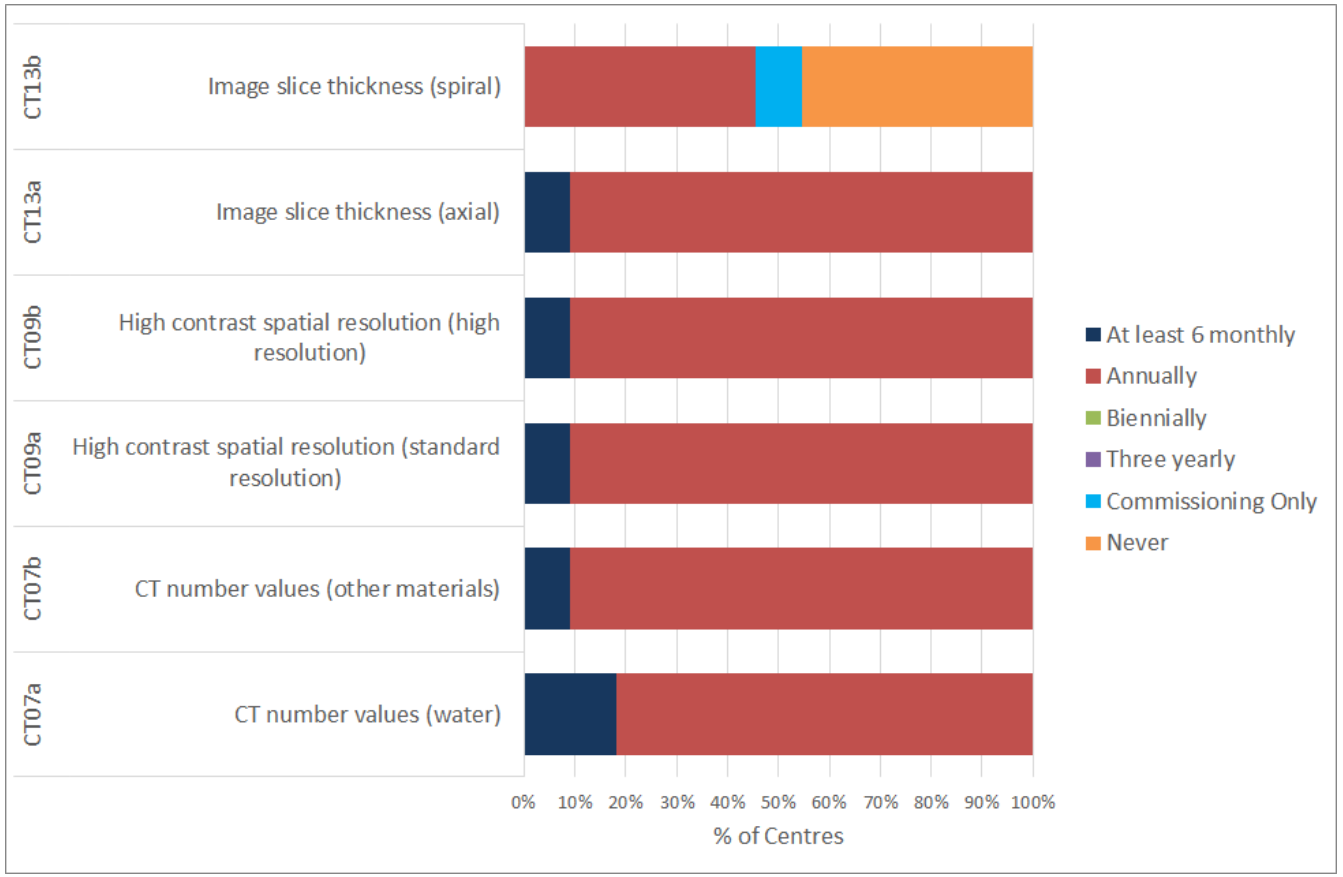


Excellent Compassionate Respectful

Noise and Uniformity



CT Number, Resolution and Slice Thickness



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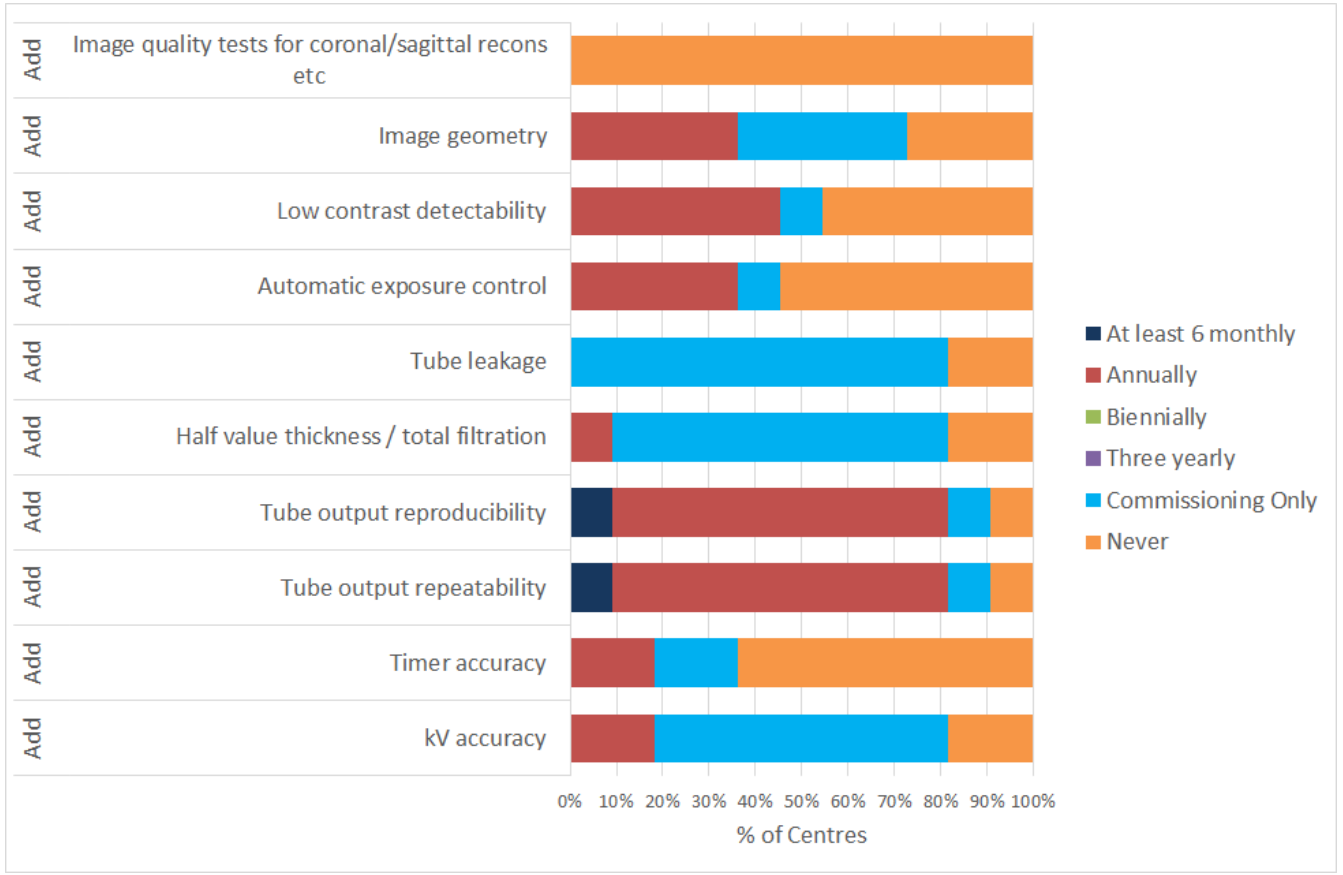
Excellent Compassionate Respectful

Additional Tests



Testing Frequency

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- Quite a bit of variation in how frequently tests are being carried out
  - Some tests 6 monthly at some centres and never in others
- General agreement that CT number, resolution and slice thickness conducted at least annually
- Noise and uniformity in head phantom mostly measured annually, about half of centres using body phantom
- All centres doing some combination of CTDI in air and in phantom at least annually, as expected
  - About a quarter only doing in phantom at commissioning
  - About half measuring CTDI in air off-centre

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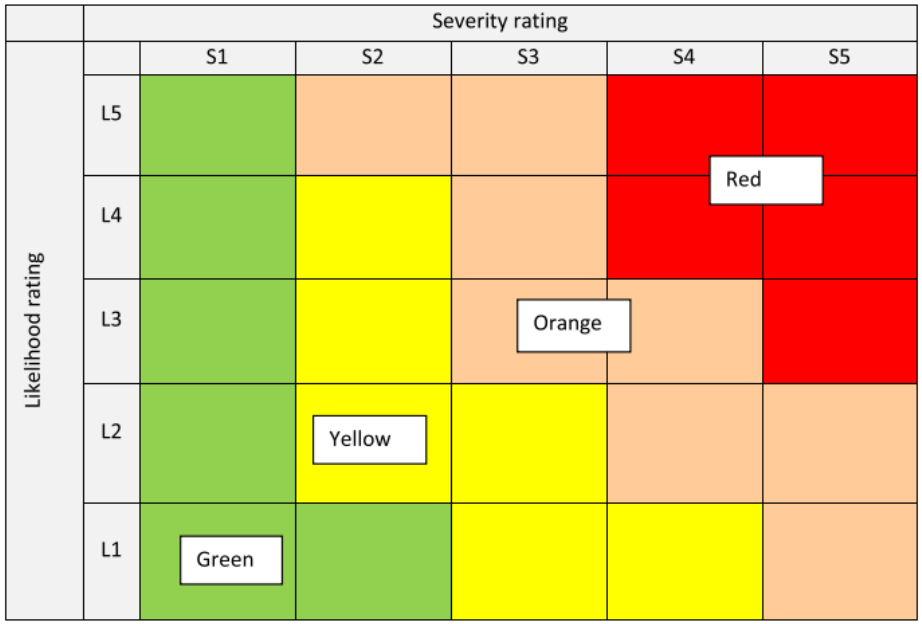
Risk Analysis

How effective are the tests? Are they worth keeping?

Risk Analysis: Colour Rating

- **Green**
  - Test may not be needed any longer
- **Yellow**
  - Perhaps reduce frequency of test
- **Orange**
  - Maintain frequency of test
- **Red**
  - Consider increasing frequency of test



Risk Analysis: Likelihood

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Likelihood rating	Remedial level exceeded frequency
1	<0.5%
2	>0.5% and <2.5%
3	>2.5% and <7%
4	>7% and <15%
5	>15%

Risk Analysis: Severity

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Severity Rating	Repeat Exposures Required	Effect On Image Quality	% Effect On Pop^{n} Dose	Max. Increase In Individual Patient Dose (mSv)	Increase to Individual Staff Dose As A Percentage Of Any Annual Dose Limit
1	None	Little/none	<2	0.1	0.5
2	Few if any	Small, unlikely to have much effect	2-5%	0.1-0.5	0.5-2.5
3	Likely to be a small number	Noticeable, but clinical IQ likely to still be acceptable	5-10%	0.5-2	2.5-10
4	Almost certain to cause a small number	Significant degradation in clinical image quality	10-25%	2-5	10-25
5	Will cause many repeats / will cause externally reportable repeat	Major degradation in image quality likely to seriously effect diagnosis	>25%	>5	>25

Mechanical Tests

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	Test ref	Tolerance	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
Scan plane - light alignment	CT03 - internal	+/-2mm	1.1	3.25	Yellow
	CT03 - external	+/-2mm	5.3	7.25	Yellow
Scan plane - SPR alignment	CT04 - axial	+/-2mm	4.8	3.08	Yellow
	CT04 - helical	+/-2mm	0	N/A	Green
Table top travel	CT05	+/-2mm	0	N/A	Green
Irradiated beam thickness	CT12 - >5mm	+/-20%	1.8	28.8	Orange
	CT12 - <5mm	+/-1mm	6.4	2.1	Green
Tube to detector alignment	CT14	+/-1mm	2.2	1.2	Yellow

CTDI

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	Test ref	Tolerance	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
CTDI (in air)	CT10	+/-15%	1.8	23.4	Orange
CTDI in phantom	CTDI	+/-15%	0.7	25.28	Orange
CTDI accuracy	Add	+/-20% - EU ref	5.3	33.7	Orange

Image noise and Uniformity

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	Test ref	Tolerance	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
Image noise	CT06 - interslice	+/-10%	22.5	20.04	Orange
	CT06	+/-10%	2.9	25.5	Orange
CT number uniformity	CT08 - head	10HU	1.7	11.68	Yellow
	CT08 - body	20HU	0	N/A	Green

CT number, Resolution, Image Slice Thickness

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	Test ref	Tolerance	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
CT number values	CT07	Water +/- 5HU	2.2	17.9	Yellow
		Other materials +/- 10HU	13.4	26	Red
High contrast spatial resolution	CT09 MTF	+/-20%	2.67	43.6	Orange
	CT09 Bar	+/-20%	0.37	26	Yellow
Image slice thickness	CT13 - >5mm	+/-20%	1.1	80.8	Yellow
	CT13 - <5mm	+/-1mm	0.9	6.9	Yellow

CT number by material

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	Nominal CT# HU	Tolerance	Tolerance as % of CT#	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
Water	0	+/- 5HU		2.2	17.9	Yellow
Air	-1000	+/- 10HU	1	18.6	13.0	Red
Teflon	990	+/- 10HU	1	38.9	11.1	Red
Acrylic	120	+/- 10HU	8	1.7	17.0	Yellow
LDPE	-100	+/- 10HU	10	4.7	17.0	Yellow
Other		+/- 10HU		7.1	25.1	Red
All non-water		+/- 10HU		13.4	26.0	Red

CT number by material

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	Nominal CT# HU	Tolerance	Tolerance as % of CT#	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
Air	-1000	100	10	0.0		Yellow
Teflon	990	99	10	0.4		Yellow
Acrylic	120	12	10	2.0		Orange
LDPE	-100	10	10	4.9		Orange
All non-water			10	3.1	24.9	Orange

AEC

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	Test ref	Tolerance	Failure rate (%)	3rd Quartile of values exceeding remedial level	Risk matrix result
AEC - CTDI	Add	+/-15% dose (Iball paper)	6.8	18.5	Orange
AEC - DLP	Add	+/-15% dose (Iball paper)	7.3	20.15	Red

Iball et al, J Appl Clin Med Phys, 2016 Jul 8;17(4):291-306

Summary

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- Data collected from physics departments in UK for CT QC tests recommended by IPEM Report 91
- Several tests had a lot of variation in testing frequency across the physics services
- Risk analysis method applied and results to be used to inform update of IPEM 91 test recommendations
- Need to carefully consider test tolerances when thinking about changing frequency of a test.

Next steps

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- Further statistical analysis
  - Check for statistically significant differences due to testing reason, age of scanner, manufacturer, physics centre, etc.
- Look into typical results to help with future tolerances
- Publish Topical Report in PMB

Thank you!

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- Thanks to the following for providing data for this project:
  - The Royal Marsden NHS Foundation Trust
  - NHS Greater Glasgow and Clyde
  - University Hospitals Birmingham NHS Foundation Trust
  - The Hillingdon Hospitals NHS Foundation Trust
  - Integrated Radiological Services Ltd
  - Royal Free London NHS Foundation Trust
  - Royal Berkshire NHS Foundation Trust
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  - NHS Tayside
  - University Hospitals Bristol
  - Leeds Teaching Hospitals NHS Trust
  - Northampton General Hospital NHS Trust
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