Performance of 3 CT Scanners: Results from a 4 year period

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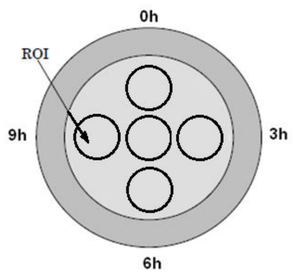
ECMP - Copenhagen, 23-25 August 2018

Purpose: The main role of medical physicist in CT is to implement a quality control program that will ensure consistency and optimal operation of the equipment and if possible predicts early detection of system troubles. Here we present the results of a 4 years period quality control routine test performed on **3 CT scanners** - Toshiba Aquilion 16 (**T**), Ge HiSpeed Lx/i (**G**) and Siemens Somaton Sensation Open (**S**) - with the aim of assuring compliance of the monitored parameters with baseline values and detect system performance malfunctioning problems. The test, obtained in 15 minute from an acquisition of the CATPHAN 600 (ϕ = 16 cm) phantom sections, was repeated weekly in the first year and twice a month thereafter since no significant fluctuations were observed.

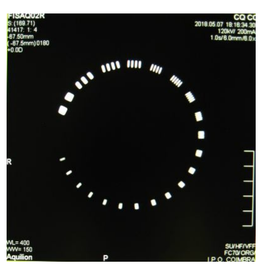
Methods:

Baseline values were established using the average of 10 images in sequential mode 120kV, 200mAs(T), 300mAs(G) and 280mAs(S), collimation: 1x6mm(T) 1x5mm(S&G), FOV=240mm, $CTDI_w \approx 45.4 \pm 0.5$mGy, kernel FC70(T), STND(G), H40s(S) and Surface Dose: 33mGy(T); 31mGy(G); 36mGy(S). Tolerances were set based on IEC, European Standards and phantom Catphan 600 manufacturer requirements. Routine values were obtained from single acquisitions of sections 1, 3b, 4 and 5 of CATPHAN 600. The performance indicators evaluated include:

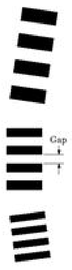
Noise Index, **SD** (the standard deviation of the HU measured in a central ROI of 28cm^2 - 40% of phantom S5 useful radius); **Uniformity index**, **UI** (maximum difference on the average HU measured in 4 periphery ROI's relative to a central ROI each with 10cm^2 - 24% of useful radius); **Artifacts:** visual observation of a spiral acquisition of S5 of catphan.



Section 5, Z= -160

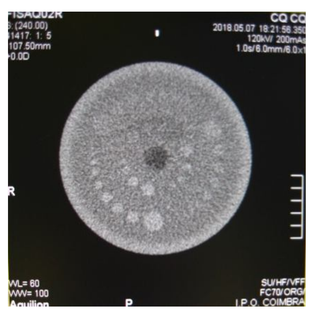


Line Pair/cm	Gap Size
1	0.500 cm
2	0.250 cm
3	0.167 cm
4	0.125 cm
5	0.100 cm
6	0.083 cm
7	0.071 cm
8	0.063 cm
9	0.056 cm
10	0.050 cm

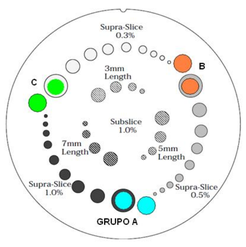


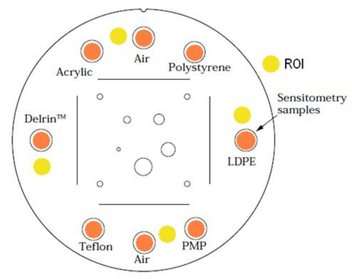
Spatial Resolution index, RI (zoomed visualization of the last visible group of a pattern of lp/mm using constant WW, WL in S3b of Catphan 600);

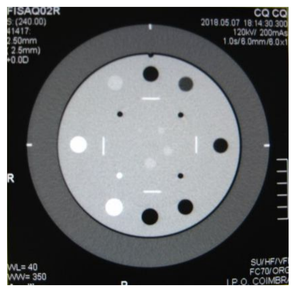
Low Contrast Resolution Index, CD (diameter * % contrast for each target - 3 groups of different sized low contrast targets A-10HU, B-5HU, C-3HU - 2 images averaged – Contrast detail detectability, **CDD** given by (mm*%) for Group C of S4 of Catphan 600);



Section 4, Z= -110







Section 1, Z=0

HU linearity index, HU_I (linear regression coefficient r^2>0.98 of straight line plot of HU versus linear attenuation coefficient - average HU in 45 mm^2 ROI's of S1 of Catphan - 8 target materials from -1000 up to 1000 HU.

Results and Discussion:

Table 1 presents the baseline values for the 3 CT units:

Routine results:

Noise index:

σ(T)=5.36 ± 2%

σ(G)=2.87 ± 4%;

σ(S)=4.01 ± 6%;

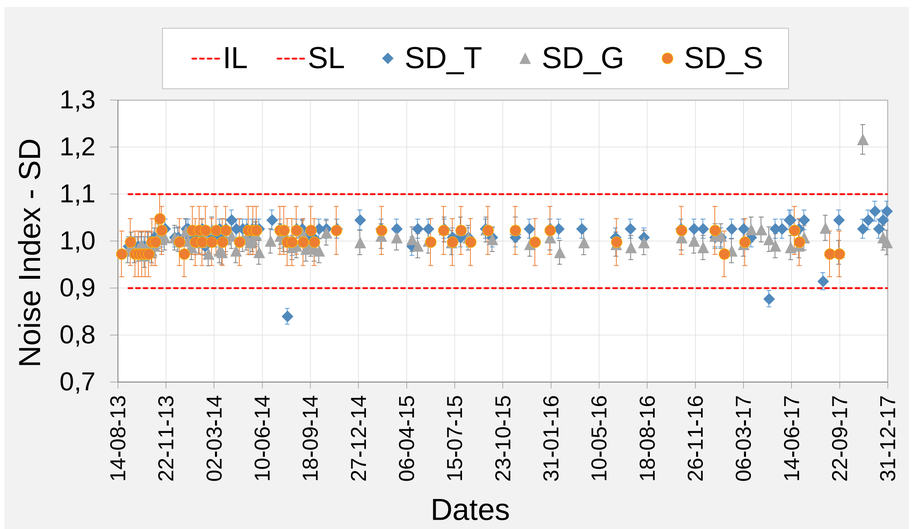
SD maximum deviations:

8.6%(T);

3.1%(G);

4.7%(S);

QC INDEX	CT_TOSHIBA (T)	CT_GE (G)	CT_SIEMENS (S)
NOISE, SD	5,36 ± 0,10	2,87 ± 0,15	4,0 ± 0,2
Tolerance	15% (± 0,80 HU)	(± 0,43 HU)	(± 0,6 HU)
UI	9,53 ± 0,38	7,10 ± 0,23	12,7 ± 0,4
Max diff <	16%(1,5 HU)	21% (1,5 HU)	12%(1,5 HU)
ARTIFACTS	No artifacts	No artifacts	No artifacts
RI	9 lp/cm	7 lp/cm	8 lp/cm
CDD	1,35 mm*%	1,48 mm*%	1,17 mm*%
Tolerance	0,6 mm*% SD @ 24 mGy	– –	– –
HU_I	R^2=0,997	R^2=0,9	R^2=0,9
Tolerance	R^2>0,980	R^2>0,980	R^2>0,980



outliers (>10%):

two (12.3;16.0%(T));

one 21.6%(G);

zero(S).

Artifacts: Uniformity and noise evaluation test did not detect artifacts. Artifacts were identified after clinical complain.

Results (cont):.

Uniformity index:

HU=9.53 ± 6%(T);

HU=7.1 ± 4%(GE);

HU=12.7 ± 4%(S);

UI max. diff. dev.:

14.7%(T);

14.5%(G);

12.6%(S);

outliers (>15%):

six(16.7;15.7%(T))

one 24.2%(G);

zero(S)

RI (lp/cm):

9(T); 7(G); 8(S);

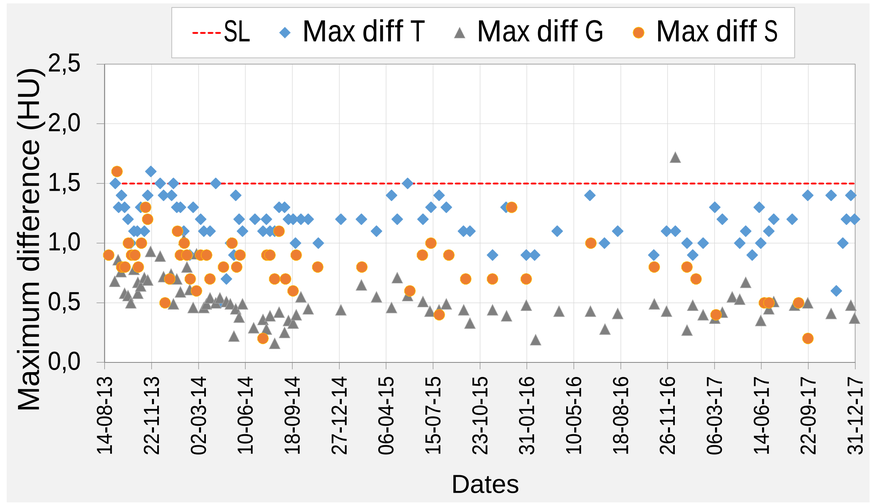
CCD (mm*%):

<1.56(T);

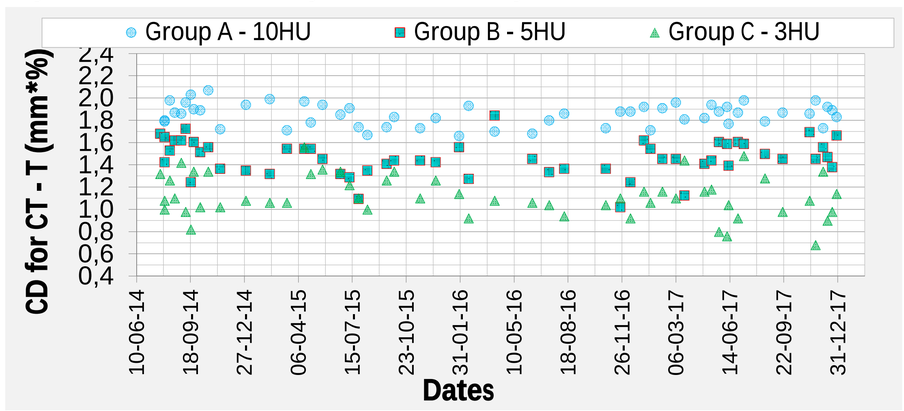
< 1.48(GE);

< 1.51(S).

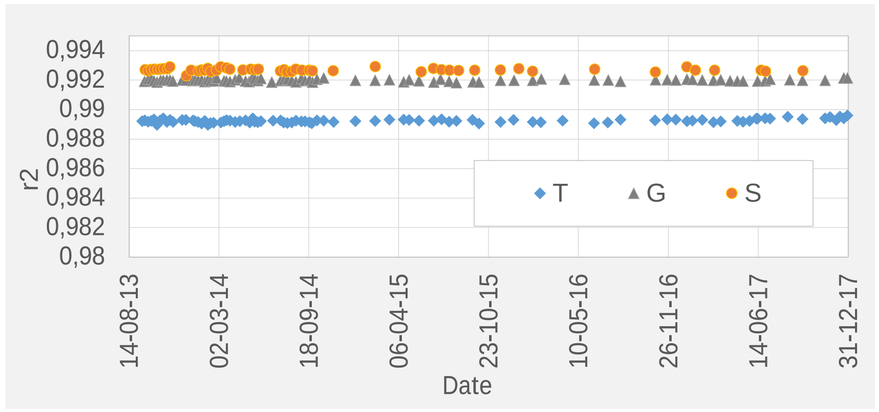
Graphic of CD for Toshiba



Artifacts: Only 2 times ring artifacts were visually observed in CT T and no relation was found with other parameters. Solution: calibration in air of the detector. One of the artifacts was caused by contrast in the x-ray tube assembly.



HU_I: R^2>0,989 (T); R^2>0,991 (G); R^2>0,992 (S);



All within manufacturer tolerance despite the 4 x-ray tube changes for Toshiba and 1 change for Siemens.

The customized Catphan 600 test proved to be a simplified but incomplete method for system performance consistency evaluation since it was unable to detect ring artifacts in T caused by faults in detector system calibration for the head protocol. The addition of a spiral acquisition in the uniform section, led to direct visualization and awareness of this type of artifacts but still does not enable the detection of artifacts in larger FOVs or in special collimation sets, depending on the CT scanner design.

Despite the use of the same $CTDI_w \approx 45$ mGy, a similar collimator settings and manufacturer standard reconstruction kernels, the 3 CT systems are not comparable: Toshiba MSCT has higher spatial resolution (higher noise) and worse low contrast resolution than Siemens MSCT for this settings.

All systems behaved very stable along the years.

Conclusion:

A CT quick routine QC was performed along a 4 year period, based in the images of S1 through S5 of Catphan 600 to evaluate noise, uniformity, CT number consistency, artifacts, SR, CDD, HU linearity and lasers accuracy. All monitored parameters were at all times largely within IEC tolerances despite the 4 x-ray tube changes in T and 1 change in S. Most of the malfunctioning troubles originated CT error messages with interlocks for the acquisitions. Major troubles with x-ray system and DAS power supply occurred suddenly instead of gradually, therefore undetected by QC. Few small parameter fluctuations were registered. In all cases the systems recovered from these fluctuations, without intervening in the equipment's. Artifacts detection and prevention require other QC approach such as specific air calibrations as part of daily warmup routines.