Cone Beam Computed Tomography (CBCT) Image Quality Assurance: Establishing a Quantitative Program

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INTRODUCTION

CBCT monthly image quality assurance (QA) is prescribed by TG-142, which recommends testing multiple image quality metrics. TG-142 suggests a tolerance of "baseline" for all metrics with the exception of geometric distortion. There is limited published data investigating how to establish tolerances across multiple machines of the same model or across multiple CBCT techniques used clinically.

AIMS

- Determine if machine-independent and/or technique-independent baselines can be generated
- Quantify the effect of re-calibrating a CBCT mode on image quality baselines
- Explore the impact of multiple CBCT acquisitions on monthly QA results

METHODS

CBCT acquisitions:

- Over 200 CBCTs were taken on five version 2.7 TrueBeam linear accelerators (labeled TB1-TB4 and Edge) over the course of fifteen months
- For one accelerator, CBCTs were taken both before and after completing a calibration of each CBCT mode. For the other accelerators, scans were only taken after calibration
- Catphan 604 phantom was scanned and analyzed for fifteen image quality metrics using the SunCheck Machine software:
  - Geometric distortion, spatial resolution, uniformity, contrast, noise, HU constancy (9 different densities), and slice thickness
  - ROIs used for analysis shown below

- Four CBCT techniques were investigated: Spotlight, Head, Pelvis, and Thorax

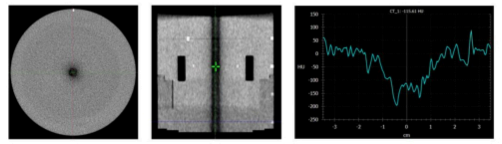
METHODS CONTINUED

Statistical Analysis:

- Two-way ANOVA tests of CBCTs taken after calibration used to determine if image quality metrics differed between machine and technique
- T-test used to quantify the effect of re-calibrating a CBCT mode on image quality baselines

Impact of CBCT Acquisition order on results:

- Before this study, a central dark artifact was seen on some monthly QA CBCT images, but was not seen during clinical use (see Figure below)



- Impact of taking multiple CBCT scans of different techniques in rapid succession on the artifact was characterized and a procedure was developed to eliminate the artifact from monthly QA scans

RESULTS

Image quality variability across machine and technique:

- Figure 1 shows the image quality parameters as a function of machine and technique
- A two-way ANOVA test showed that, for each parameter, there was at least one machine or one technique that was statistically different from the group (P<0.05)
- While differences between machines for a given image quality parameter were statistically significant, the range seen across machines was within the vendor specification for CBCT performance for all but the high-Z HU plugs measured with the Head technique

Impact of re-calibrating CBCT modes:

- Table 1 shows the difference between the expected value of each image quality metric between the pre- and post-calibration CBCTs
- Re-calibrating a CBCT mode caused statistically significant changes to some image quality metrics (P<0.05). Bolded items in Table 1 are statistically significant
- The largest change with calibration is seen with the high Z HU constancy plugs and the Head technique
- The magnitude of the change in each image quality parameter with calibration is consistent with the range in expected values of the image quality parameters across machines

RESULTS CONTINUED

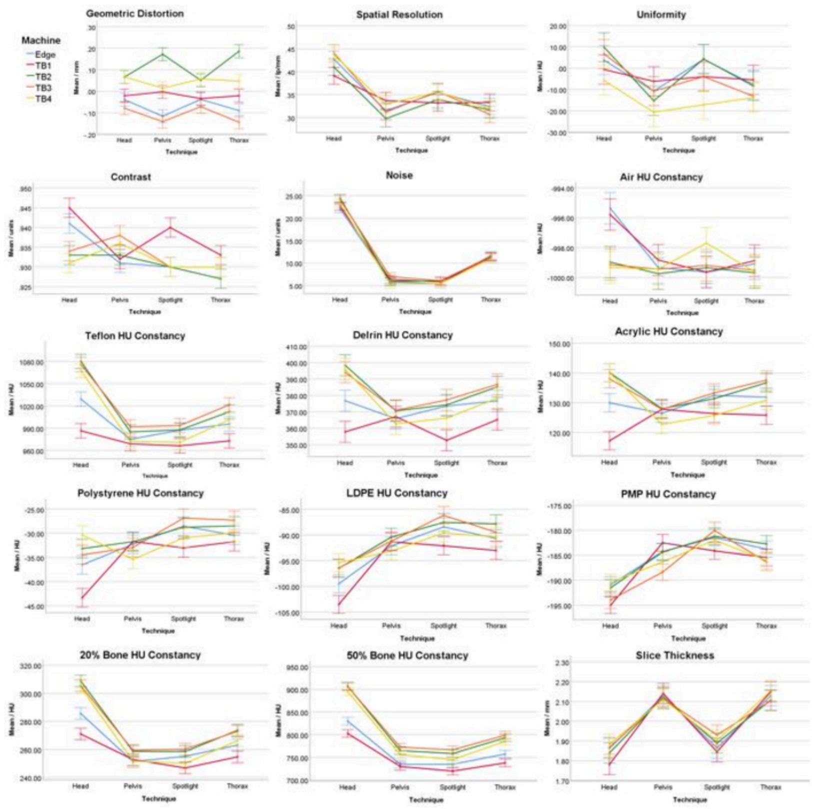


Figure 1: Image quality parameters as a function of machine and technique. Error bars represent the 95% confidence interval.

Table 1: Difference in mean between pre-calibration and post-calibration scans on a single TrueBeam machine. Items in bold are statistically significant (P<0.05)

Parameter	Head	Spotlight	Thorax	Pelvis
uniformity (HU)	**10.47**	**-12.95**	-10.10	-14.61
air (HU)	**-3.20**	**0.29**	**-0.47**	-1.23
teflon (HU)	**116.1**	8.10	**42.62**	**14.19**
delrin (HU)	**50.62**	4.57	**22.31**	**7.84**
acrylic (HU)	**31.67**	2.88	**17.63**	4.89
polystyrene (HU)	**15.39**	1.66	**10.14**	3.22
LDPE (HU)	**10.39**	1.78	**9.39**	3.04
PMP (HU)	4.05	2.10	**7.95**	2.45
20 % Bone (HU)	**39.82**	1.51	**20.02**	**7.44**
50% Bone (HU)	**93.39**	2.22	**34.12**	**10.07**

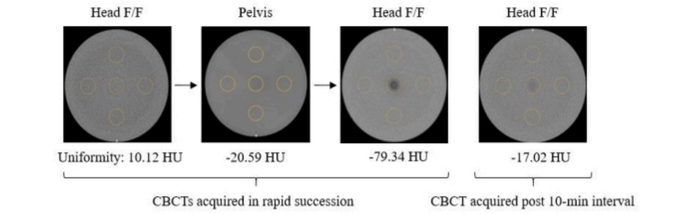


Figure 2: impact of rapidly acquiring CBCT scans on image uniformity

RESULTS CONTINUED

Impact of rapid acquisition of multiple CBCT modes:

- When CBCTS were taken in rapid succession, as may be done during monthly QA, a cylindrical artifact appeared that caused the measured uniformity to be out of manufacturer's tolerance
- The artifact disappeared when the number of CBCTs taken in succession was reduced
- Figure 2 shows the appearance of the central artifact as CBCT scans are acquired in rapid succession and then the reduction of this artifact after a pause in CBCT acquisition
- No artifacts were seen when back-to-back CBCT acquisitions were limited to two

CONCLUSIONS

- Image quality parameters are machine and technique specific and must be measured on each machine. Depending on the parameter and the desired tightness of the tolerance, it may be possible implement machine-independent baselines
- Re-calibration of a CBCT technique can introduce statistically significant changes to the expected baseline image quality parameters. These values should be measured post re-calibration to evaluate for changes
- To avoid introducing artifacts during monthly CBCT scans, no more than two CBCT scans should be taken in rapid succession

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REFERENCES

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For further information, contact Sameer Taneja at Sameer.Taneja@nyulangone.org. David Barbee discloses that Sun Nuclear Corporation paid for prior conference travel to speak about SNC products. This work is under review for publication in JACMP.