Preliminary Evaluation of the QCkV-1 Phantom and CyberKnife® Digital Flat Panel Detector Imager Response

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PURPOSE

To evaluate the applicability of the QCkV-1 diagnostic imaging phantom (Standard Imaging, Middleton, WI) for trending analysis of the amorphous silicon flat panel imagers from the CyberKnife® Robotic Radiosurgery System (Accuray Incorporated) and to study their response over a period of time and under different conditions.

METHOD AND MATERIALS

- Data on CyberKnife Imagers was collected from different sites both within Accuray and outside for both G3 and G4 CyberKnife imager configurations:

1. G3: 45° short stand imagers 20 x 20 cm with 512 x 512 pixels.

2. G4: in-floor imagers 40 x 40 cm with 1024 x 1024 pixels.

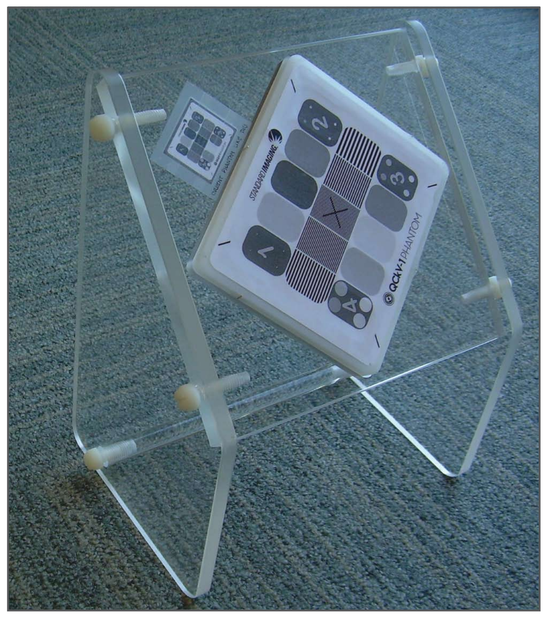
- QCkV-1 imaging phantom with PIPSpro™ software[1] was used to measure:

1. Contrast to Noise Ratio (CNR).

2. Spatial resolution using f_{30}, the frequency in line pairs/mm at 30% RMTF (Relative Modulation Transfer Function).

- QCkV-1 is designed for radiographic systems and measurements are done by placing it on the flat panel detector. This means that the absolute values of numbers such as f_{30} and CNR are not very meaningful, however they can be useful for trending analysis as well for relative measurements (under similar conditions).

- In our case, the phantom was placed at the imaging center by mounting it on an acrylic case at 45° to the treatment couch (so that the X-rays are incident normally upon it). It also has fiducials to enable precise and reproducible alignment.



- Raw unprocessed images were imported into PIPspro to obtain f_{30} and CNR trends.

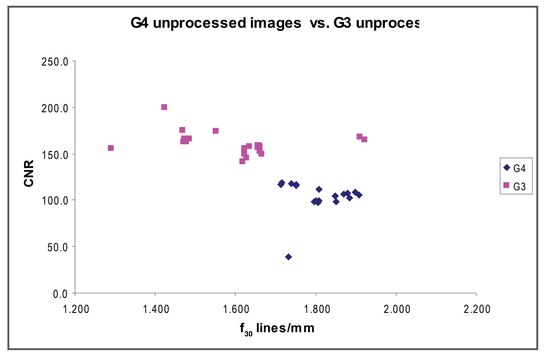
- Settings for X-ray tube and PIPSpro raw image import for the two CyberKnife configurations are summarized in this table:

Type	KV	mAs	Pixels	Pixel Size	Header Size (Bytes)	Dynamic Range
G3	70	10	512	0.4 mm	320	16-bit
G4	80	10	1024	0.4 mm	320	16-bit

- These settings were used for optimum values of f_{30} and CNR, these are not the typical settings used for patient tracking. In addition to above settings, KV = 120 and mAs = 2.5 and 3.5 respectively for G3 and G4 systems can also be used.

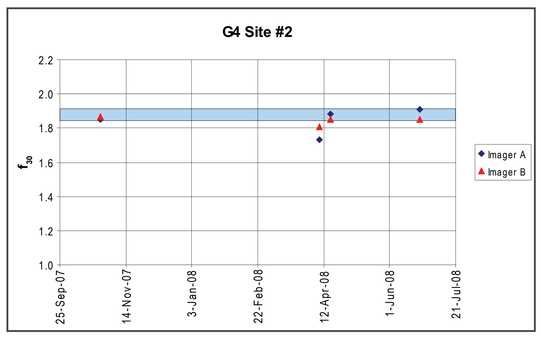
RESULTS

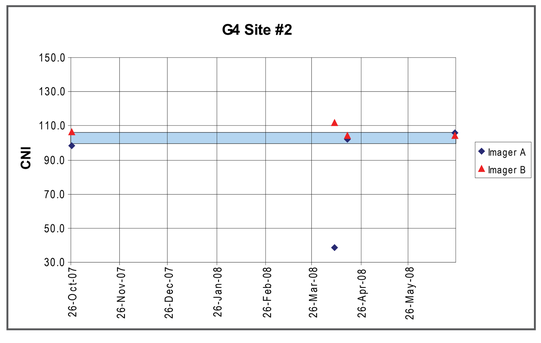
- Plot of f_{30} vs. CNR for a collection of several CyberKnife Systems:



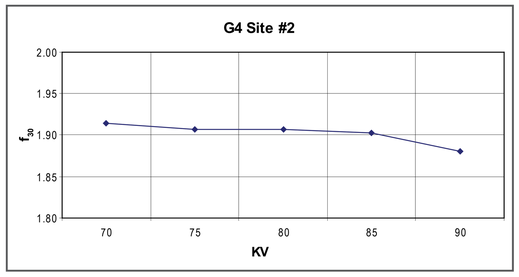
- The f_{30} & CNR values were found to be generally stable over the period of this study (~6 months).

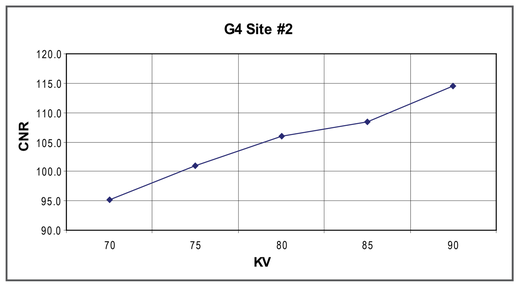
- In the case of one site which eventually required replacement of an aged imager which could no longer be used to track patient position as evidenced from results of phantom tracking tests, the bad detector clearly showed a discontinuity in the CNR value before and after the imagers were replaced. The plot below shows f_{30} and CNR with a tolerance band indicated by a shaded area.





- The X-ray KV was varied to study its effect on f_{30} and CNR:





- Further tests need to be done at X-ray settings typically used in CyberKnife treatments.

CONCLUSION

The QCkV-1 phantom, coupled with PIPSpro analysis can be used to study f_{30} and CNR trends. It can successfully measure changes in imager performance due to variations in X-ray kV. Further studies with longer term monitoring are required to evaluate the utility of QCkV-1 in understanding the relationship between these low-level measurements and overall performance of the system in terms of actual tracking.

Acknowledgements

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CONTACT

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References

1. R. Rajapakshe, K. Luchka and S. Shalev, A quality control test for electronic portal imaging devices. Med. Phys. 23 (7) 1237-1244, 1996.