**Progress report:** Development of assessment and predictive metrics for quantitative imaging in chest CT
**Subaward No:** HHSN268201000050C (4a)
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**Reporting Period:** months 4-6

**Executive Summary for months 1-6:**

Thus far the project has achieved the development of a robust modeling framework to predict volumetric performance of a CT scanner from its basic performance characteristics of 2D resolution and noise. Methods have also been developed to measure those characteristics using a newly-designed phantom that accounts for the influence of patient size, mA modulation, and feature contrast. Ongoing work includes extension of the model to 3D, new task and volumetric operators, and the design of standard methods to ascertain quantitative conformance.

**Publications:**

1. Chen B, Richard S, Barnhart H, Colsher J, Amurao M, Samei E. Quantitative CT: technique dependency of volume assessment for pulmonary nodules. *Physics in Medicine and Biology* 57: 1335–1348, 2012.

2. Chen B, Richard S, Samei E. Relevance of MTF and NPS in quantitative CT: towards developing a predictable model of quantitative performance. SPIE International Symposium on Medical Imaging, San Diego, CA, February 2012, *Proc. SPIE Medical Imaging*, 2012.

**Presentations/Abstracts:**

1. Richard S, Chen B, Samei E, et al. A novel method for predicting the performance of lung nodule volume estimation in CT via ACR phantom measurements. Proceedings of the Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, Dec. 2011, *RSNA'11 Proc, 2011.*

**Deliverables (months 4-6):**

1. *Deployment of a framework for drawing a correspondence between simple figure of merits (FOM) and quantitative imaging performance in CT.*

   The definition of the framework has been modified since our last report in two aspects since last report: 1) While previous task function ($W_{task}$) was iteratively trained from existing precision measurements, a new task function was derived purely mathematically based on nodule edge characteristics (Figure 1). This modification eliminated the dependence of e' calculations on data available for

training, enabling a universal comparison of the quantitative precision across all possible protocols.

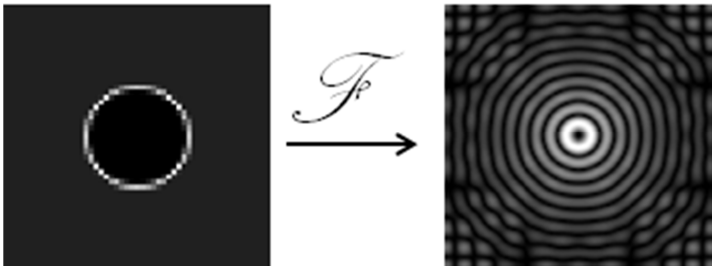

*Figure 1：A new task function (right) was derived purely mathematically from the edge characteristics of the nodule (left).*

2) Previous ideal observer model was replaced by a more realistic non-prewhitening model, calculated as

$$e'^2 = \frac{\left(\int |W_{task}(u)|^2 \, TTF^2(u) u du\right)^2}{\int NPS(u) |W_{task}(u)|^2 \, TTF^2(u) u du}. \quad (1)$$

With these two modifications, the e' still strongly correlates with the precision of volume quantification ($R^2 = 0.92$), as shown in Figure 2. Notice that the two outliers marked by arrows are precisions of FBP and MBIR at only 3% of clinical dose level, which are less clinically relevant. With the two outliers removed, the $R^2$ further increases to 0.98.

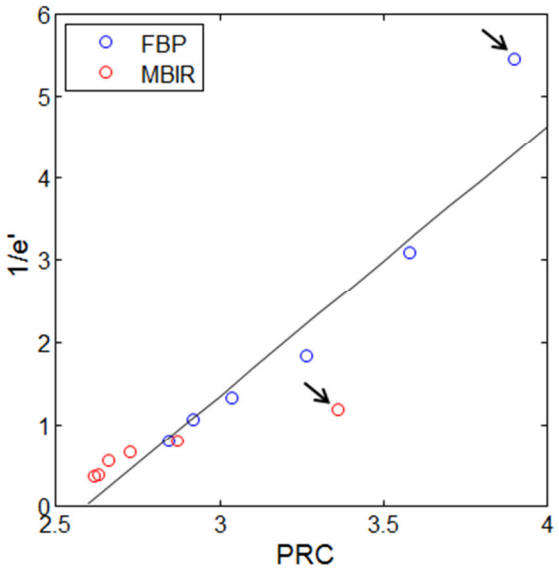


*Figure 2: The modified e' still strongly correlates with the precision of volume quantification (PRC) with an $R^2$ of 0.92. The two outliers marked by arrows are precisions of FBP and MBIR at only 3% of clinical dose level, which are less clinically relevant. With the two outliers removed, the $R^2$ further increases to 0.98.*

In addition, 3D TTF and NPS have been measured to better characterize the 3D nature of volume quantification (Figure 3). Stationarity (location) and variability (repeat) of TTF and NPS are being examined, which will be accounted for in future estimations of e' (Figure 4). Ongoing work also includes developing task functions for a variety of quantitative tasks.

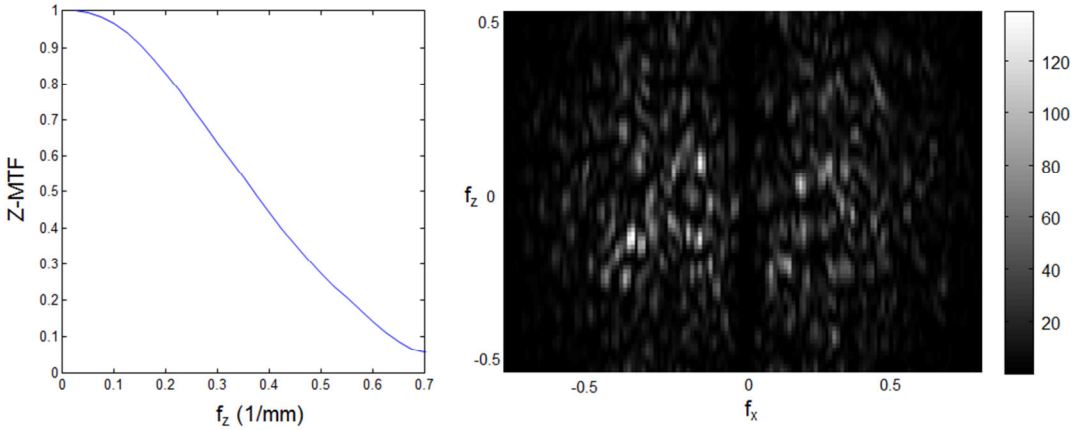


*Figure 3: TTF in z-direction (axial) and NPS in XoZ plane.*

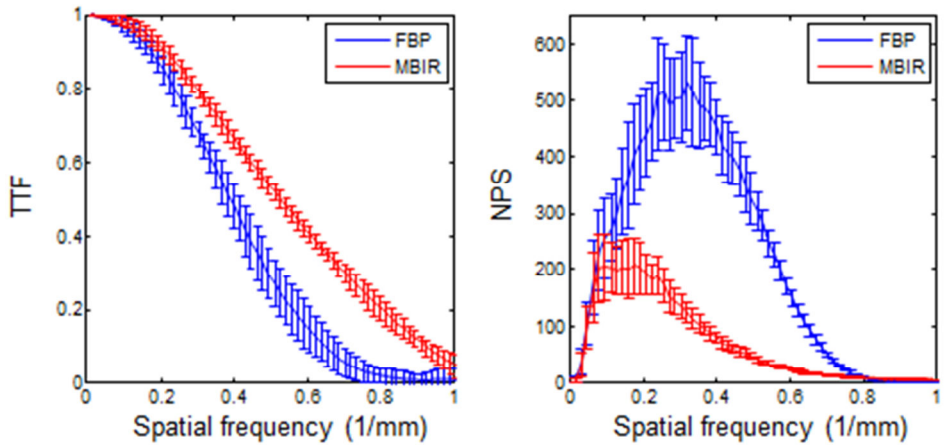


*Figure 4: The standard deviation of TTF and NPS measured across slices, represented in terms of error bar.*

2. *Table of strengths and weakness of current phantoms for assessing quantitative imaging performance.*

To characterize the FOM under a broader spectrum of clinical tasks, our Duke QA phantom now includes two more features:

1) A fourth section (37 cm diameter) in addition to the previous three sections (16, 23, and 30 cm diameter) to simulate larger patients.
2) To better capture the dependency of iterative reconstruction's TTF on object contrast, four new iodinated inserts (2.2, 4.3, 6.4, and 8.5 mg/cc) with low contrasts (25, 96, 164, and 224 HU @ 120 kVp) have been implemented into each section of the phantom.

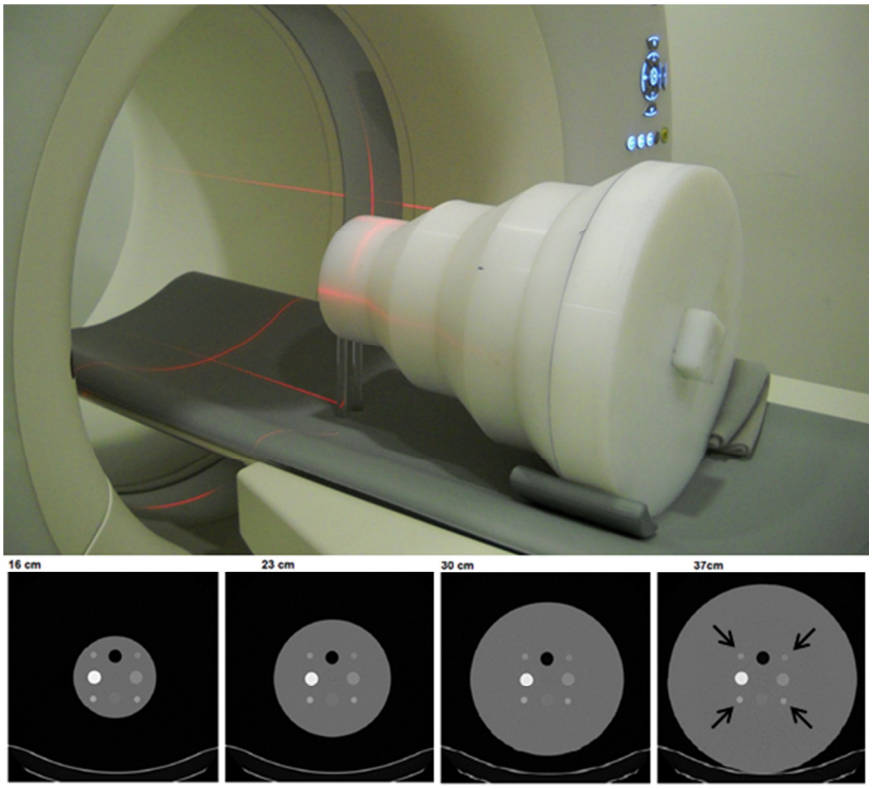


*Figure 5: The phantom developed at Duke for 3D FOM measurements now includes a fourth section to capture large patients. In addition, four iodinated inserts marked by arrows have been implemented to facilitate measurements of TTF for iodinated features.*

In addition, to investigate the cyclostationarity of TTF, future phantom might include inserts at different distances from the center. The comparison between phantoms is underway while the framework in Deliverable 1 is being finalized.

3. *Identify tolerances and threshold that CT quantification requires in terms of FOM measured on QA phantoms and recommend guidelines for compliance of quantitation techniques (software and hardware).*

   Initiated but this is still in early stages. This awaits the finalization of our e' model and QA phantom noted above.

**Work in the coming period** will focus on extending the current model to 3D and to a broader range of quantitative tasks. In addition, more phantom data will be acquired to investigate the stationarity and variability of TTF and NPS.