Detection of Pulmonary Nodules by Ultra-short TE Sequences in Oncology Patients using a PET/MR System

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Purpose: The recent introduction of hybrid PET/MR systems has raised the possibility of combined whole body PET and MR imaging for evaluation of oncology patients; however, feasibility of clinical PET/MR imaging has been traditionally limited by poor MR evaluation the lung parenchyma due to rapid signal decay, low tissue proton density and substantial respiratory/cardiac motion. Several approaches, including zero TE (ZTE) techniques[1], FSPGR[2,3], and FSE[4] have been utilized to minimize susceptibility and motion artifacts for pulmonary nodule evaluation. Recently, a free-breathing 3D radial ultra-short TE (UTE) technique has been described for evaluation of structural lung disease (e.g. pulmonary fibrosis)[5]; however, the utility of this sequence for pulmonary nodule evaluation has not yet been investigated. We hypothesized that, given its high spatial resolution and motion minimizing properties, a free-breathing 3D UTE-based technique would be feasible and sensitive for the evaluation of pulmonary nodules in oncology patients.

Methods: Five patients with known pulmonary nodules undergoing clinical PET/CT were enrolled. (3 male, average age 57.8 ± 11.8 y). Primary malignancy was breast carcinoma for two patients, melanoma for two patients, and papillary thyroid cancer for one patient. PET/MR imaging of the thorax was performed on a 3.0 T PET/MR system (investigational only; GE Healthcare, Waukesha, WI) following clinical PET/CT, using the clinically administered fluorodeoxyglucose (FDG) dose. PET/CT (slice thickness 1.25mm) was considered the gold-standard for the determination of nodule presence, size, location and FDG-avidity. Nodules were grouped into categories by short-axis diameter: < 4 mm, ≥4 – <6 mm, ≥6 – <8 mm, ≥8 – <10 mm, ≥10mm. Fissural or pleural nodules and nodules measuring ≤ 2 mm on CT were not included in analysis. Two short echo time (TE) sequences of the lung were performed for each patient: 1) 3D UTE sequence –TE 80 us, TR 2.5 ms, flip angle 4°, 1.25mm isotropic resolution, adaptive bellows gating with efficiency of 40%, scan time ≈ 5:00; 2) ZTE - TE 0 ms, TR 2.2 ms, flip angle 4°, 1.5 mm isotropic resolution, conventional bellows gating with efficiency of 40%, scan time ≈ 4:30. Means ± SD are reported for continuous variables and frequencies for categorical data. Proportions were compared using z-tests and Fisher's exact tests.

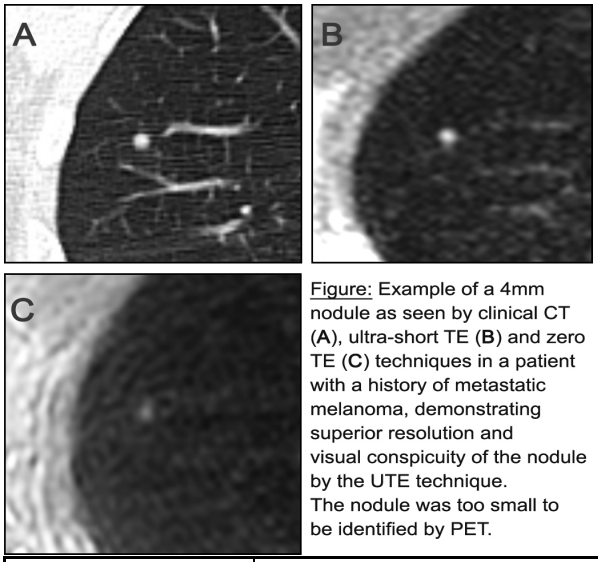

Figure: Example of a 4mm nodule as seen by clinical CT (**A**), ultra-short TE (**B**) and zero TE (**C**) techniques in a patient with a history of metastatic melanoma, demonstrating superior resolution and visual conspicuity of the nodule by the UTE technique. The nodule was too small to be identified by PET.

	Sensitivity for Nodule Detection by Size	
	UTE	ZTE
Overall (n=71)	75%	42%
< 4mm (n=9)	22%	0%
4 - 6mm (n=24)	71%	42%
6 - 8mm (n=17)	82%	47%
8 - 10mm (n=10)	90%	40%
>10 mm (n=11)	100%	73%

Results: A total of 71 nodules were detected by CT, with mean diameter of 6.3 ± 2.8 mm (range: 3-17mm). The frequency of nodules by size category was: 9 nodules <4 mm (13%), 24 nodules 4 – 6 mm (34%), 17 nodules 6 – 8 mm (24%), 10 nodules 8 – 10 mm (14%), 11 nodules ≥ 10mm (15%). Sensitivity for nodule detection was 75% overall for UTE and 42% overall for ZTE. Sensitivity of nodule detection by size is tabulated in the adjacent figure. Nodules in the central lung (<2cm from hilar structures) were more likely to be missed by ZTE compared with the mid or peripheral lung (80% vs. 46% missed, p<0.01); there were no differences in detection by location for UTE. Nodules were more likely to be seen by UTE and ZTE sequences if they were PET-avid versus PET negative (100% vs. 63%, p=0.027 for UTE and 83% vs. 33%, p=0.002 for ZTE). Correlation between nodule measurements by CT versus those by UTE and ZTE techniques were excellent (Pearson's coefficients of 0.95 and 0.96 respectively).

Discussion: The UTE sequence showed moderate sensitivity for nodule detection overall (75%), which was higher than overall sensitivity of the ZTE sequence (42%, p<0.001). Sensitivity for larger nodules (≥8mm) was excellent for UTE (95%) but was much lower for ZTE (51%). When considering smaller nodules (4-6mm), sensitivity was moderate for UTE (71%) but quite poor for ZTE (42%). The ZTE sequence particularly struggled in the central lung (detection rate of 20%), but the UTE sequence showed no significant change in detection rate by nodule location. All PET-avid nodules were identified by UTE, however, only 63% were identified by ZTE. These differences are likely due to improved adaptive respiratory gating and a higher spatial resolution of UTE compared to ZTE.

Conclusion: Free-breathing 3D UTE sequences performed well for the detection of pulmonary nodules ≥4mm in size in our small preliminary cohort and outperformed ZTE sequences at all sizes. UTE may be a viable alternative approach to evaluating patients with pulmonary nodules in the future, although continued refinement is warranted.

References:

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