# Optimization of the Non-Contrast CT Chest-Abdomen-Pelvis Protocol to Reduce Radiation Dose and Improve Acquisition Efficiency: One-Pass Versus Two-Pass

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## Background

The CT CAP W/O CONT protocol (Computed tomography for chest, abdomen, and pelvis without contrast) is routinely scanned in patients for assessment of systemic disease, oncologic surveillance and staging. Traditionally, this protocol is performed with a **Two-pass** protocol (chest then abdomen/pelvis with different noise indexes (NI=22.6(chest) and 19.5(abd./plvs.), which due to its overlapping scan regions has concerns of radiation dose and acquisition efficiency.

We hypothesize using a **One-pass** continuous acquisition with unified noise index (NI=19.5(chest-abd.-plvs.) will have equivalent image quality as Two-pass acquisition while improving efficiency and reducing radiation dose to patients.

This study compares whole body effective dose, organ-specific dose, and acquisition time between these two protocols.

## Methods

The patient data was taken from 672 patients who underwent either the One-Pass (54 patients, 81.0 ± 23.8 kg) or Two-Pass (54 patients, 85.7 ± 24.8 kg) CT CAP W/O CONT protocols within the Froedtert & MCW health network on 14 different GE and Siemens scanners CT scanners.

Whole body Effective dose (ICRP103, mSv) and Dose Length Product (DLP, mGy*cm) were obtained from patient dose reports. Scan Acquisition time was obtained from patient CT DICOM headers. Effective doses (mSv) to 26 different organs were estimated for groups of same-sex patients at a time with similar masses (Male-One-Pass: 10 patients, 95.1 ± 11.5 kg; Male-Two-Pass: 10 patients, 95.2 ± 23.1 kg; Female-One-Pass: 10 patients, 77.6 ± 13.0 kg; Female-Two-Pass: 10 patients, 77.9 ± 9.5 kg) using Radimetrics' built-in Monte Carlo simulation engine.

Two-Sample Welch's t-test with non-equal variance was used to analyze all One-Pass vs Two-Pass data.

## Results

For all patients, there was a significant DLP reduction (357.4 ± 275.2 mGy-cm, p = 0.0004), significant whole body effective dose reduction (10.0 ± 7.0 mSv, p = 0.000004), and significant acquisition time reduction (4.7 ± 3.1 sec, p = 0.003). These results are shown in figure 2.

For the organ dose simulations, there were significant dose reductions (ranging from 5.6 to 15.3 mSv, p ≤ 0.05) in 9 abdominal organs, and significant dose increases (ranging from 0.1 to 13.0 mSv, p ≤ 0.05) in 6 organs (5 head/neck organs, 1 pelvic). These results are shown in figure 3.

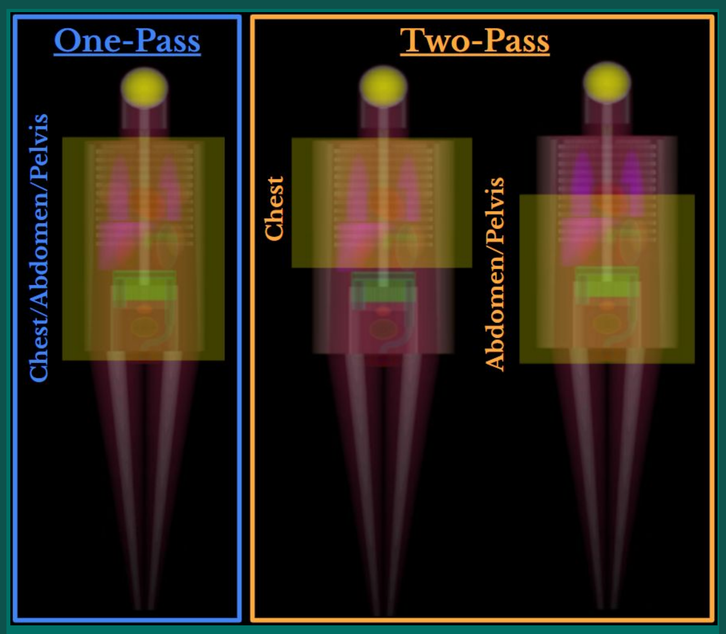


**Figure 1** A visualization of the different scan ranges between One-pass and Two-pass scans. These were obtained using a virtual phantom in Radimetrics simulation engine. Note the overlap and slight additional scan length present in the Two-pass scan.

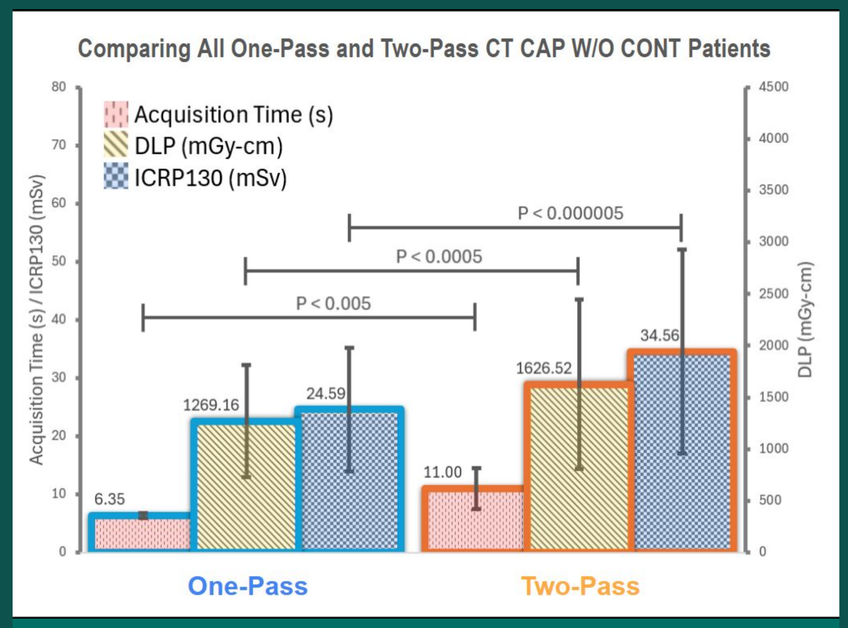


**Figure 2** Comparison of radiation dose and acquisition time for all patients who underwent either of the two protocols using Two-sample Welch's t-test with non-equal variance. For all parameters, One-pass was significantly less than Two-pass.

| Organ Dose (mSv) | Male | | Female | |
|---|---|---|---|---|
| Region | Difference | P Value | Difference | P Value |
| Kidneys | -15.3 | 0.015 | -9.6 | 0.022 |
| Stomach | -13.1 | 0.023 | -9.2 | 0.024 |
| Spleen | -12.5 | 0.024 | -9.8 | 0.018 |
| Liver | -11.9 | 0.030 | -8.9 | 0.028 |
| Gall Bladder | -11.4 | 0.025 | -7.2 | 0.037 |
| Adrenals | -9.7 | 0.036 | -7.5 | 0.033 |
| Pancreas | -9.5 | 0.034 | -7.4 | 0.027 |
| Urinary Bladder | -0.6 | 0.881 | -10.0 | 0.006 |
| Uterus | - | - | -5.6 | 0.048 |
| Thymus | 10.3 | 0.017 | 7.9 | 0.012 |
| Thyroid | 9.5 | 0.043 | 1.8 | 0.020 |
| Brain | 0.2 | 0.004 | 0.1 | 0.024 |
| Salivary Glands | 0.2 | 0.004 | 0.1 | 0.024 |
| Eye Lenses | 0.3 | 0.048 | 0.1 | 0.483 |
| Testicles | 13.0 | 0.012 | - | - |

**Figure 3** Comparison of simulated organ-specific radiation doses within small groups of 10 patients using Two-sample Welch's t-test with non-equal variance. Highlighted P-values are significant at a 0.05 level. The color denotes **significant dose reduction** and **significant dose increase** between One-pass vs Two-pass simulations. Non-significant organs were excluded for simplicity but 26 were tested. There is a trend that most abdominal organs experienced a dose reduction, and head and neck organs experienced a dose increase. The testicles break this trend.

## Conclusion

The One-pass CT CAP W/O CONT protocol achieved comparable image quality while significantly reducing DLP, effective dose, and scan time compared with the conventional Two-pass protocol.

Simulations showed significant large dose reduction for several abdominal organs. While it was accompanied by some significant dose increases for organs in the head and neck, these increases were smaller in comparison.

The simulated significant dose increase in the testicles could be a potential risk for male patients, but we believe this comes from the slight additional scan length present in the Two-Pass scan. This can clearly be seen in Figure 1.

Adoption of the One-pass protocol with a unified noise index has been a straightforward strategy to optimize radiation dose and improve scan efficiency in routine clinical imaging, particularly for patients requiring repeated examinations. It has already been implemented into MCW and Froedtert's current non-contrast CT chest–abdomen–pelvis protocols.

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