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Comparison of CTDIw and Effective mAs as Predictors of Effective Dose in Thoracic CT Examinations: A Retrospective Analysis

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Abstract

This study compared the association between weighted computed tomography dose index (CTDIw) and effective milliampere-seconds (effective mAs) with the effective dose (ED) received by patients during thoracic computed tomography (CT) examinations. Retrospective data from breast cancer patients were obtained from The Cancer Imaging Archive (TCIA) and processed using IndoseCT software to extract CTDIw, effective mAs, and ED values. Descriptive statistics, scatter plots, and simple linear regression analyses were performed to evaluate the relationships between these parameters. The correlation between effective mAs and CTDIw was moderately strong ($R^2 = 0.6774$), consistent with the principle that higher tube current–time settings generally increase scanner-reported dose indices. CTDIw and ED showed a very strong correlation ($R^2 = 0.978$), reflecting the close link between standardized dose metrics and estimated patient dose. The correlation between effective mAs and ED ($R^2 = 0.7505$) was stronger than that between effective mAs and CTDIw, but still lower than the CTDIw–ED correlation. These results indicate that, in this dataset, CTDIw was a more consistent predictor of ED than effective mAs. While both parameters are relevant for dose assessment, CTDIw may be a more reliable reference for estimating ED in similar thoracic CT protocols. Although this analysis was limited to retrospective data from a specific patient group, the findings provide practical insights that can support protocol evaluation and dose optimization strategies. Further studies involving larger and more diverse datasets would be beneficial to confirm and extend these observations.

Keywords: CTDIw, effective mAs, effective dose, thoracic CT, radiation dose estimation, breast cancer.

1. Introduction

Radiation dose management in computed tomography (CT) is a critical component of patient safety, particularly in oncologic imaging where repeated examinations are often required. Thoracic CT imaging for breast cancer patients presents a unique challenge: while high-resolution images are essential for accurate staging, treatment planning, and follow-up, repeated exposure to ionizing radiation can increase both deterministic and stochastic risks, including secondary malignancies and tissue damage (Dudhe et al., 2024; Martin & Abuhaimed, 2024). For this reason, international guidelines such as those from the International Commission on Radiological Protection (ICRP) and the American Association of Physicists in Medicine (AAPM) emphasize dose optimization strategies that balance diagnostic image quality with the ALARA (As Low As Reasonably Achievable) principle (Vañó et al., 2017; Cho et al., 2018).

Scanner-based dose metrics, particularly effective milliampere-seconds (effective mAs) and the weighted computed tomography dose index (CTDIw), are frequently used to characterize radiation output in CT examinations. Effective mAs is defined as the tube current-time product (mAs) normalized to the pitch factor, reflecting the actual load on the X-ray tube during a helical scan. While it directly influences photon flux and consequently impacts patient dose, effective mAs is highly dependent on other scan parameters such as tube voltage (kVp), collimation width, and automatic exposure control (Azadbakht et al., 2021; Elkut & Shalbi, 2025). In contrast, CTDIw is a standardized phantom-based measure calculated from central and peripheral dose measurements to represent the average dose across the scan field, independent of patient size (American Association of Physicists in Medicine, 2008). By decoupling patient anatomy from scanner output, CTDIw serves as a stable and reproducible index for comparing scanner protocols across institutions (DePew et al., 2022; Devi et al., 2024).

Our earlier study (Nurhanivah, Ramdhani, & Bilqis, 2025) examined patient size metrics such as water-equivalent diameter (Dw) in breast cancer patients and identified significant correlations with body mass, highlighting the importance of patient-specific parameters in dose estimation. However, scanner-related factors, particularly effective mAs and CTDIw, have not yet been directly compared for their predictive value in estimating effective dose in this patient group. Previous study has suggested that CTDI-based metrics may outperform tube current metrics in predicting patient dose, especially under standardized protocols (Shirazu et al., 2017; Elzaki et al., 2025; Kesmezacar et al., 2025).

Effective dose, derived from the dose-length product (DLP) and organ-specific conversion coefficients, represents the biologically weighted estimate of radiation detriment across different tissues (Al-Othman et al., 2022; Chu et al., 2023). In breast cancer imaging, where patients may undergo multiple thoracic CT examinations during diagnosis and follow up, it is useful to determine which scanner-based parameter, CTDIw or effective mAs, better predicts effective dose (WHO, 2016; Tawhari et al., 2025). This study aims to compare the correlation strength of CTDIw and effective mAs with effective dose in this patient group, and to examine the relationship between these two scanner parameters using a retrospective dataset. Findings from this comparison may support dose monitoring practices that align with broader radiation protection recommendations.

2. Materials and Methods

2.1. Study Design and Data Source

This study was an observational, cross-sectional analysis utilizing retrospective thoracic CT examination data from breast cancer patients. The dataset was obtained from The Cancer Imaging Archive (TCIA), a publicly accessible repository supported by the U.S. National Cancer Institute (NCI) and the University of Arkansas for Medical Sciences (UAMS). TCIA provides de-identified medical imaging data in Digital Imaging and Communications in Medicine (DICOM) format containing basic demographic information such as body mass, age, and gender. Ethical and privacy safeguards are ensured in compliance with HIPAA regulations, and all personal identifiers were removed prior to public release. The TCIA dataset is publicly accessible at https://www.cancerimagingarchive.net/access-data/.

Raw CT images and associated dose reports from TCIA were processed using the IndoseCT software to extract scanner-reported exposure parameters and calculate patient dose metrics. IndoseCT applies validated algorithms to derive standardized quantities, including weighted CT dose index (CTDIw), effective milliampere-seconds (effective mAs), and effective dose (ED). In this study, CTDIw and effective mAs served as predictor variables reflecting scanner radiation output and exposure settings, while effective dose represented the biologically relevant estimate of radiation absorbed by patients. This analysis builds upon our previous work that examined patient size metrics, such as water-equivalent diameter (Dw) and size-specific dose estimate (SSDE), using the same dataset (Nurhanivah, Ramdhani, & Bilqis, 2025).

2.2. Study Variables

This study analyzed three key parameters obtained from the IndoseCT output: effective milliampere-seconds (effective mAs, mAs), weighted computed tomography dose index (CTDIw, mGy), and effective dose (ED, mSv). Effective mAs is defined as the product of tube current (mA) and exposure time (s), adjusted for the pitch factor, representing the actual X-ray tube loading during the CT scan. CTDIw is a standardized dose metric (expressed in milligrays, mGy) calculated from measurements at central and peripheral positions within a standard phantom, following the methodology outlined in AAPM Report No. 96 (American Association of Physicists in Medicine, 2008). This parameter reflects the scanner's radiation output independent of patient size (DePew, 2022; Devi, 2024).

Effective dose (ED, in millisieverts, mSv) estimates the biologically relevant radiation dose absorbed by the patient, derived from the dose–length product (DLP, mGy·cm) and anatomical region-specific conversion coefficients as recommended in ICRP Publication 103 (International Commission on Radiological Protection, 2007) (Al-Othman, 2022; Chu, 2023; Elzaki, 2025). In this study, effective mAs and CTDIw were treated as predictor variables, while effective dose served as the outcome variable.

2.3. Statistical Analysis

Descriptive statistics (mean, standard deviation, and range) were used to summarize the study variables. Relationships between the predictor variables (effective mAs and CTDIw) and the outcome variable (effective dose) were assessed using scatter plots and simple linear regression analyses. Linear regression models were fitted separately for each predictor to quantify their associations with effective dose, with the coefficient of determination (R^2) used as the primary metric to compare predictive performance.

Pearson's correlation coefficient (r) was calculated to assess the strength and direction of linear relationships. In addition to these analyses, a scatter plot and correlation analysis between effective mAs and CTDIw were performed to evaluate the relationship between the two predictor variables. The assumptions of linear regression (normality of residuals, linearity, and homoscedasticity) were considered to ensure model validity. Statistical significance was set at $p < 0.05$.

3. Results and Discussion

The relationship between effective mAs and CTDIw (Figure 1) shows a coefficient of determination (R^2) of 0.6774, indicating a moderately strong positive correlation. This suggests that as effective mAs increases, CTDIw tends to increase as well, although the relationship is not perfectly linear. In the context of CT imaging, this trend aligns with the fact that higher mAs values contribute to a greater radiation output from the X-ray tube, thereby increasing the dose index received by the patient (Elkut, 2025). However, the moderate R^2 value implies that other scanning parameters such as tube voltage, pitch factor, and beam collimation also play a substantial role in determining CTDIw (Azadbakht, 2021). This observation highlights the need for dose optimization strategies that do not rely solely on mAs adjustment but also consider multi-parameter control for patient safety and image quality (Kesmezacar et al., 2025).

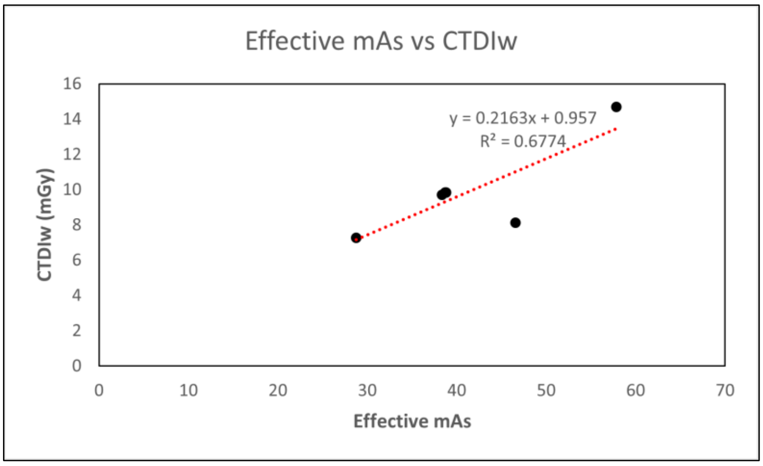

Figure 1: Scatter plot of Effective mAs versus CTDIw.

Building upon this relationship, the correlation between CTDIw and the effective dose (Figure 2) presents an R^2 value of 0.978, which reflects a near-perfect linear association. This high degree of correlation is expected, as CTDIw serves as a key surrogate measure for patient dose in CT examinations (Devi, 2024). From a physical standpoint, CTDIw quantifies the dose delivered to a standardized phantom, and effective dose extends this metric by incorporating tissue weighting factors that reflect the varying radiosensitivity of different organs (DePew, 2022; Martin, 2024). The strength of this relationship reinforces the validity of using CTDIw as a predictive parameter for estimating effective dose in similar scanning protocols, thereby supporting dose monitoring practices recommended in diagnostic radiology guidelines (AAPM, 2014; Cho et al., 2018).

From a radiation protection perspective, such a high R^2 supports the use of CTDIw in real-time dose monitoring systems to flag potentially high-dose scans before completion, allowing radiographers to intervene in accordance with the ALARA principle. Recent studies in thoracic CT have also highlighted the practicality of integrating CTDI-based triggers into automated quality control software, reducing cumulative population dose without compromising diagnostic quality (Chu et al., 2023; Tawhari et al., 2025).

Extending the analysis further, the relationship between effective mAs and effective dose (Figure 3) yields an R^2 of 0.7505, suggesting a stronger correlation than that observed in the effective mAs–CTDIw relationship, but still not as high as CTDIw–effective dose. This result can be explained by the fact that effective mAs, defined as the tube current–time product divided by the pitch factor, directly influences photon flux and, consequently, the total radiation output, which in turn impacts the patient's effective dose (Azadbakht, 2021). Variations in patient size, scan length, and automatic exposure control settings, however, can introduce deviations from a purely linear relationship (Lange, 2021). The moderately high R^2 indicates that while effective mAs adjustment is an effective means of dose modulation, it should be complemented with other optimization measures to maintain both image quality and radiation safety.

Overall, the progression of these findings from a moderate correlation between effective mAs and CTDIw to a near-perfect correlation between CTDIw and effective dose demonstrates the layered dependencies among CT scan parameters. These results highlight that CTDIw functions as a robust intermediary metric that links technical settings to patient dose, making it a valuable parameter for predictive modeling in radiation dose management (AAPM, 2014). Furthermore, accurate prediction of patient dose using CTDIw could facilitate the establishment of national dose registries and the development of evidence-based diagnostic reference levels (DRLs), which are essential tools for monitoring and optimizing population radiation exposure (WHO, 2016; Al-Othman et al., 2022). Such registries not only enhance institutional quality assurance but also contribute to broader public health strategies aimed at preventing cumulative radiation-related cancer risk in vulnerable populations, including recurrently imaged cancer patients (Kesmezacar et al., 2025; Elzaki et al., 2025).

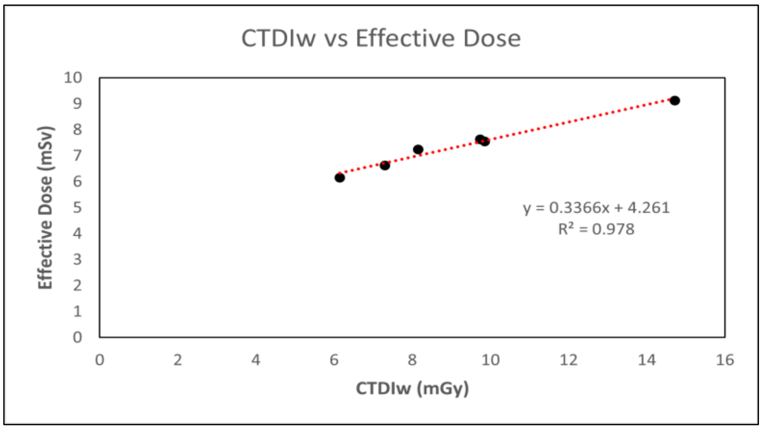

Figure 2: Scatter plot of CTDIw versus Effective Dose.

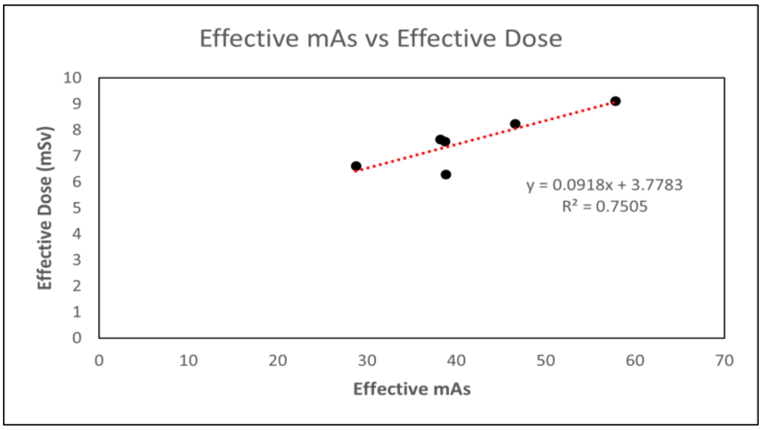

Figure 3: Scatter plot of Effective mAs versus Effective Dose.

4. Conclusion

In this retrospective analysis of thoracic CT examinations in breast cancer patients, both effective mAs and CTDIw were positively associated with patient dose, with CTDIw demonstrating greater predictive consistency within the study dataset. These findings indicate that CTDIw may serve as a more reliable parameter for estimating radiation dose in comparable CT protocols, while effective mAs still provides complementary information on scan settings. While the outcomes may provide useful guidance for dose monitoring and optimization in similar settings, they represent preliminary insights that would benefit from validation in larger and more varied patient populations. In this way, the study highlights the practical role of parameter selection in influencing patient exposure and underscores the potential contribution of dose monitoring to safer imaging practices. Continued research across broader clinical contexts is encouraged to reinforce these observations and support their gradual translation into more comprehensive strategies for radiation protection and public health.

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