Sustainable Diagnostics: A Comparative Analysis of Weightbearing CT, X-Ray, and Standard CT in Foot and Ankle Imaging

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INTRODUCTION: In the evolving landscape of musculoskeletal imaging, especially in foot and ankle diagnostics, selecting an imaging modality that sufficiently provides the information needed to guide clinical care (including diagnostic accuracy) while also ensuring safety, sustainability, and economic efficiency is paramount. With increasing awareness of healthcare's environmental impact and the ongoing value-based care transformation, imaging methods should be evaluated not only by their clinical utility, though this is critical, but also by their carbon footprint, radiation exposure, and true procedural costs. Time-Driven Activity-Based Costing (TDABC) is an accurate and granular approach to assess procedural costs by accounting for the actual time and resource utilization during the patient care cycle. This study aims to compare three commonly used imaging modalities—Weightbearing CT (WBCT), 3-view conventional x-rays, and standard lower extremity CT—in terms of carbon emissions, radiation dose, direct costs, and TDABC-calculated resource use, to provide a comprehensive evaluation that may factor into clinical and administrative decision-making.

METHODS:

Carbon emissions were estimated based on equipment power consumption (in kilowatts), average scan duration, and standard U.S. electricity carbon intensity values (0.25 kg CO_2e per kWh). Radiation dose values were drawn from existing published literature and industry-standard estimates for musculoskeletal imaging. Direct costs were sourced from publicly available data on outpatient imaging billing in the United States. TDABC analysis was conducted by calculating the estimated Capacity Cost Rate (CCR) for each resource (technologist, radiologist, equipment, and facility space) based on publicly available information and multiplying it by the estimated time, also pulled from publicly available information and previous studies, during the imaging process. Formulas used and sample calculations are provided in Figures 1 and 2. All numerical estimates for power usage, scan duration, and operational design were obtained from open-source databases, published scientific literature, and manufacturer/vendor websites.

RESULTS: Reported, calculated, and estimated cost burdens are outlined in Table 1. WBCT demonstrated the lowest carbon footprint and second lowest radiation exposure while standard CT had the highest carbon footprint and radiation dose. WBCT also incurred the lowest TDABC cost, driven in the calculations by minimal technician time, a streamlined scanning process, and low energy demand compared to the other two imaging modalities. Specifically when comparing WBCT with x-rays, WBCT requires less technologist and radiologist time and involves a single acquisition, whereas x-rays often require multiple positions and retakes. While WBCT equipment has a higher per-minute cost, its shorter usage time offsets this. Consequently, these small differences in variables between imaging modalities led to shifts in TDABC. Additionally, although conventional x-rays showed lower direct cost on average, their TDABC-adjusted value was higher due to the longer technician time and multiple views. Notably, standard CT showed the highest values across all categories of burden.

DISCUSSION AND CONCLUSION: This study uniquely presents a comprehensive comparison of foot and ankle imaging modalities by quantifying their environmental, safety, and financial dimensions. The results indicate that WBCT provides the most favorable profile—lowest carbon emission, decreased radiation dose compared to standard CTs, and significantly reduced procedural costs—while maintaining high diagnostic accuracy. These findings can support decision-makers in selecting imaging strategies that align with clinical efficacy, economic stewardship, and environmental responsibility. Ultimately, understanding these cost burdens unlocks opportunities within process improvement, care organization, reimbursement, and decision-making to combat the cost crisis within healthcare.

Imaging Modality (Foot and Ankle)	Carbon Emission (kg CO_2e)	Radiation Dose (mSv)	Direct Cost (USD)	TDABC Cost (USD)
Weightbearing CT (WBCT)	0.00485	4.2	$250–$500	$22–28
3-View X-rays	2.28	1.4	$100–$400	$47
Standard CT	9.00	25	$500–$3,000	$83

Table 1. Cost burdens (carbon emissions, radiation dose, direct costs, and calculated TDABC costs) by imaging modality

$$TDABC = Time\ spent\ on\ activity\ \times Capacity\ Cost\ Rate\ (cost\ per\ time\ unit\ of\ resource)$$

$$\text{where } Capacity\ Cost\ Rate = \frac{Total\ cost\ of\ capacity\ supplied}{Practical\ capacity\ (in\ time\ units)}$$

Figure 1. Calculation of TDABC

Figure 2. Sample TDABC Calculation for WBCT

*using estimates and reported times/costs from publicly available sources

Workflow Step	Estimated Time (min)
Patient check-in & setup	1.5
Patient positioning	1.5
Scan acquisition	1.5
Technologist post-processing	2.0
Total Technologist Time	**6.5**
Radiologist interpretation (optional)	2.0

Calculating CCR:

Resource	Cost/hour	CCR ($/min)	Source
Technologist	$45/hr	$0.75/min	BLS + Benefits
Radiologist	$180/hr	$3.00/min	ACR Data
Equipment	$100/hr	$1.67/min	Amortized Cost (5–7 years)
Room/Facility Use	$60/hr	$1.00/min	Overhead & Utilities

Component	Time (min)	CCR ($/min)	Cost ($)
A. Technologist Time	6.5	$0.75	$4.88
B. Equipment Use	6.5	$1.67	$10.86
C. Room/Facility Use	6.5	$1.00	$6.50
D. Radiologist Interpretation*	2.0	$3.00	$6.00

Calculating final TDABC:

Scenario	TDABC
Without Radiologist Review	$4.88 + $10.86 + $6.50 = **$22.24**
With Radiologist Review	$22.24 + $6.00 = **$28.24**