DOSE REDUCTION OF IRRADIATION IN PATIENTS WITH BREAST CANCER: VALUES OF THE SINGLE-PHASE THORACO-ABDOMINO-PELVIC CT SCAN

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Abstract. Breast cancer follow-up frequently relies on repeated thoraco-abdomino-pelvic (TAP) computed tomography (CT) scan, exposing patients to cumulative radiation doses. This prospective, single-center study, conducted at CHU "Sourô Sanou" (Bobo-Dioulasso, Burkina Faso) in 47 patients followed for histologically confirmed breast cancer, evaluated the dosimetric and diagnostic value of a single-phase (portal-phase) TAP CT scan protocol compared with each patient's standard multiphasic reference examination. The single-phase protocol gave an average effective dose of 15.53 ± 2.10 mSv, compared to 26.84 ± 6.40 mSv for the standard protocol, which corresponds to a dose reduction of 42.13 % ($P < 0.001$), with no patient exceeding the 20 mSv alert threshold. The image quality was rated satisfactory or excellent in over 95 % of the exams by two reviewers, with good to almost perfect agreement between observers, especially for liver metastases (*kappa* = 0.81), the main metastatic site in this group (40.42 % of metastatic cases). These results support adopting a single-phase portal protocol as the standard follow-up strategy for breast cancer, in line with the ALARA (As Low As Reasonably Achievable) principle, while preserving diagnostic performance.

Key words: optimization, radiation, breast cancer, CT scan, Burkina Faso.

INTRODUCTION

Breast cancer is a major public health problem because of its high incidence, prevalence, and mortality. In Burkina Faso, with a population of 23 million people, according to the Global Cancer Observatory 2022 (GLOBOCAN) 1,372 new cases of breast cancer were reported, representing 15.3 % of cancer cases among women,

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with 818 deaths [6]. The very large majority of breast-cancer-related deaths are due to metastases, particularly bone, pulmonary, hepatic, and cerebral metastases [7]. Furthermore, breast cancer remains a heterogeneous disease with marked clinical and biological heterogeneity, leading to individualized therapeutic decisions based on molecular and clinical characteristics. Despite the successful implementation of early breast cancer detection campaigns, up to one in three patients will develop metastases [9]. From a dosimetric standpoint, a breast cancer patient is potentially exposed to multiple irradiations throughout the care pathway, ranging from diagnostic procedures (mammography, CT), to surveillance procedures (CT, nuclear medicine), to therapeutic procedures (radiotherapy and nuclear medicine) [4]. Certain follow-up protocols recommend up to 16 thoraco-abdomino-pelvic CT scans (TAP CT) over three to five years, as suggested by the National Comprehensive Cancer Network [4]. It is within this context that the optimization of procedures and the reduction of cumulative doses in cancer patients remains a major issue in medical radiation protection, given that the risks of radiation induced cancers are not negligible [16].

While TAP CT scan is recommended by most learned societies for the initial stage of breast cancer, many cancer centers rely solely on portal-phase acquisition for follow-up. Numerous studies have demonstrated the non-inferiority of this approach compared with the conventional approach in most patients. Although the benefits of this single-phase approach are notable both in terms of radiation protection and cost, it has not yet been implemented in Burkina Faso. The use of a single-phase (monophasic) TAP CT scan protocol constitutes a major strategy for optimizing radiation protection in patients followed for breast cancer, consisting of a single image acquisition (generally at the portal, venous phase) after contrast agent injection, in contrast to multiphasic protocols that involve multiple X-ray passes. We therefore set out to compare the diagnostic performance (detection of recurrences or metastases) of a single-phase protocol with the standard protocol, the dosimetric gain and diagnostic performance being the two studied parameters.

MATERIALS AND METHODS

TYPE, FRAMEWORK, AND STUDY PERIOD

This work was a prospective, single center study conducted at CHU ”Sourô Sanou” in Bobo-Dioulasso, over an 18-month period from June 1, 2024, to December 31, 2025. Sampling was exhaustive, including all patients meeting the selection criteria during the study period.

STUDY POPULATION

Inclusion criteria

- Patients followed for histologically confirmed breast cancer, with an initial work up including a standard (multiphasic) TAP CT scan and immunohistochemical tumor characterization;
- patients referred for a CAP CT for post-therapeutic follow-up, according to the single-phase portal phase protocol.

Exclusion criteria

- Contraindication to iodinated contrast medium injection (severe renal failure, history of severe allergy to iodinated contrast media);
- pregnancy;
- incomplete clinical or radiological file (absence of a reference TAP CT scan, missing dosimetric data).

EQUIPMENT

The study was carried out on a 64-slice CT scanner (SIEMENS©).

Acquisition parameters were as follows: voltage, 120 kV; current, automatic modulation (mAs) according to patient morphology.

INJECTION PROTOCOL (SINGLE-PHASE)

The objective was to obtain optimal parenchymal (liver, kidneys) and vascular enhancement in a single pass. Iodinated contrast medium was injected intravenously using an automatic injector, at a dose of 1.5 to 2 mL/kg, at a flow rate of 3 to 4 mL/s. Acquisition was performed at the portal phase, 70 to 80 seconds after the start of injection.

COLLECTION OF DOSIMETRIC INDICATORS

The dose length product (*DLP*) and the volumetric CT Dose Index (*CTDIvol*) were automatically extracted from the dose report generated by the CT console for each examination.

EVALUATION METHOD

Dosimetric evaluation

DLP (mGy·cm) and *CTDIvol* (mGy) were recorded for each patient from the dose report. Effective dose (*E*), expressed in milli sieverts (mSv), was calculated as:

$$E\ (\text{mSv}) = DLP\ (\text{mGy}\cdot\text{cm}) \times k \quad (1)$$

where k is the conversion coefficient specific to the anatomical region explored (chest, abdomen, pelvis), expressed in $\text{mSv}\cdot\text{mGy}^{-1}\cdot\text{cm}^{-1}$ [10].

The effective dose of the single-phase protocol was compared with that of each patient's standard (multiphasic) reference TAP CT scan, and the mean percentage dose reduction was calculated as:

$$Reduction\ (\%) = [(E\ \text{standard} - E\ \text{single-phase})/E\ \text{standard}] \times 100 \quad (2)$$

Diagnostic performance evaluation

Subjective criteria: an independent, blinded double reading was performed by two senior radiologists, using a four-point Likert scale ranging from excellent quality to non-diagnostic image.

Objective criteria: the signal to noise ratio (*SNR*) was calculated as:

$$SNR = SI/SD \quad (3)$$

where *SI* is the mean signal intensity (Hounsfield units) measured in a hepatic region of interest (ROI), and *SD* is the standard deviation of the signal in that ROI (noise).

The contrast to noise ratio (*CNR*) was calculated as:

$$CNR = (SI\ organ - SI\ reference)/SD\ reference \quad (4)$$

where *SI organ* is the mean intensity in the hepatic ROI, *SI reference* is the mean intensity in a subcutaneous fat reference ROI, and *SD reference* is the standard deviation of noise in that reference ROI.

The ability to detect secondary lesions (hepatic, lymph node, pulmonary, bone) was compared between the single-phase protocol and each patient's available standard reference TAP CT scan, used as the comparison examination.

STATISTICAL ANALYSIS

The data was recorded using Excel (Microsoft Excel 2016) and analyzed using SPSS 20 (SPSS, Chicago, IL, USA). Quantitative variables were expressed as mean ± standard deviation (or median, depending on distribution), and qualitative

variables as numbers and percentages. Doses (*DLP, CTDIvol,* effective dose) were compared between the single phase and standard protocols using Student's paired t-test, with each patient serving as their own control. Inter-observer agreement for the subjective image quality assessment was analyzed using Cohen's Kappa coefficient. A statistical significance threshold of $P < 0.05$ was retained for all tests.

ETHICAL CONSIDERATIONS

Informed oral consent was obtained from each patient prior to inclusion. Data anonymity and confidentiality were guaranteed.

RESULTS

CHARACTERISTICS OF THE STUDY POPULATION

The study included 47 patients with histologically confirmed breast cancer, referred for a follow-up TAP CT scan examination at the Department of Medical Imaging of CHU "Sourô Sanou" in Bobo-Dioulasso.

The mean age was 49.71 ± 11.00 years. The mean body mass index (*BMI*) was 25.6 ± 4.1 kg/m². Eleven patients (23.4 %) had a family history of breast cancer. The disease involved the left breast ($n = 24$), the right breast ($n = 21$), and both breasts ($n = 2$). T4 breast lesions according to the UICC cTNM classification were found in 30 patients (63.82 % of cases) (Table 1). On immunohistochemistry, the triple negative subtype accounted for nearly half of cases ($n = 23$). Hepatic metastases were the most frequent ($n = 19$). More than half of the patients had undergone surgery ($n = 32$) or chemotherapy ($n = 28$). Table 1 summarizes the general, clinical, and therapeutic characteristics of the studied population.

Table 1

Characteristics of the studied population

General data	**Value**	**Range**
Age (years)	49.71 ± 11.3	34 – 71
Weight (kg)	67.2 ± 11.5	44 – 95
Height (cm)	162 ± 6	150 – 178
BMI (kg/m²)	25.6 ± 4.1	18.2 – 38.4

Tumor size	***n***	**Percentage**

T0	1	2.13
T1	3	6.39
T2	4	8.51
T3	9	19.14
T4	30	63.82

Histology on biopsy	***n***	**Percentage**
Non-specific infiltrating carcinoma	42	89.36
Lobular carcinoma	3	6.38
Carcinoma *in situ*	2	4.25

Immunohistochemistry	***n***	**Percentage**
Triple-negative	23	48.93
Hormone-dependent	20	42.55
HER2 positive	4	8.51

Metastases	***n***	**Percentage**
Liver	19	40.42
Multiple sites	6	12.76
Lungs	5	10.63
Bone	4	8.51

Treatment	***n***	**Percentage**
Surgery	32	68.08
Chemotherapy	28	59.57
Radiotherapy	6	12.76

DOSIMETRIC RESULTS

CTDIvol and *DLP* values

The mean *CTDIvol* measured over the entire TAP CT scan exploration was 9.8 ± 1.9 mGy. The median chest *CTDIvol* was 9.0 mGy. The median abdominal and pelvic values were 11.1 and 8.7 mGy, respectively. The median total *DLP* was 1,012.5 mGy·cm. Table 2 shows the values of the two dosimetric indicators on single-phase CAP CT.

Table 2

Dosimetric indicators measured during the portal-phase CAP CT

Parameters	Minimum	Maximum	Median	Mean ± SD
Chest *CTDIvol* (mGy)	5.1	13.7	9.0	9.2 ± 1.8
Abdominal *CTDIvol* (mGy)	6.2	16.8	11.1	11.4 ± 2.1
Pelvic *CTDIvol* (mGy)	4.6	12.7	8.7	8.8 ± 1.8
Mean *CTDIvol* (mGy)	5.3	14.4	9.6	9.8 ± 1.9
Chest *DLP* (mGy·cm)	210	520	340	352 ± 62
Abdominal *DLP* (mGy·cm)	290	680	530	528 ± 88
Pelvic *DLP* (mGy·cm)	154	177.75	142.5	144 ± 21
Total *DLP* (mGy·cm)	654	1,377.75	1,012.5	1,024 ± 14
Effective dose (mSv)	9.93	19.23	15.63	15.53 ± 2.10

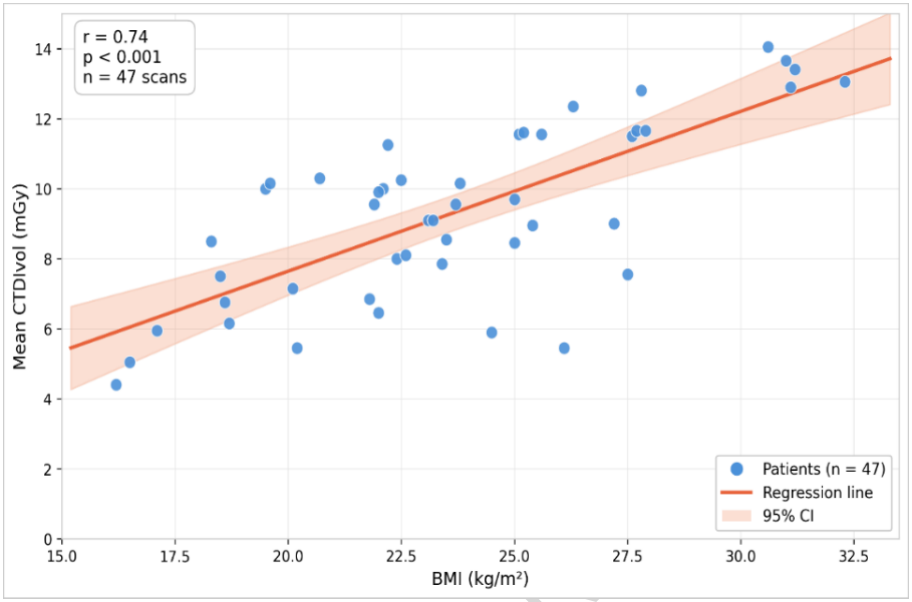

Fig. 1. Correlation between *BMI* and *CTDIvol*.

Overall, the estimated mean effective dose was 15.53 ± 2.10 mSv, with a median of 15.63 mSv. No patient exceeded the 20 mSv threshold commonly used as an alert level in adult oncology follow up protocols.

A significant positive correlation between *BMI* and mean *CTDIvol* was demonstrated ($r = 0.74$; $P < 0.001$), as shown in Figure 1.

Comparison with the reference standard protocol

All patients included in the study had previously undergone a TAP CT scan during initial staging. This examination, performed under conventional conditions, was considered the reference CT. Table 3 compares dosimetric data between single-phase and standard TAP CT scan.

Table 3

Comparison of dosimetric parameters in single phase *versus* standard CT

IMAGE QUALITY EVALUATION

Quantitative evaluation

Densitometric analysis of the regions of interest (ROI) revealed: a mean hepatic enhancement (Fig. 2) in the portal phase of 117 ± 13 HU (segment V), within the optimal range of 100 – 140 HU characteristic of this phase for the detection of isodense or hypodense hepatic metastases, which represent the vast majority of secondary hepatic locations in breast cancer; a mean signal to noise ratio (*SNR*) of 8.9, and a liver/aorta contrast to noise ratio (*CNR*) of 5.8, both acceptable for breast cancer follow-up imaging; and a mean aortic vascular enhancement of 287 ± 28 HU and a portal enhancement of 200 ± 18 HU.

Parameters	Single-phase CT	Standard CT	Dose reduction	*P* value
Mean *CTDIvol* (mGy)	9.8 ± 1.9	16.7 ± 4.7	38.93 %	< 0.001
Total *DLP* (mGy.cm)	1,024 ± 140	1,769 ± 361	42.11 %	< 0.001
Effective dose (mSv)	15.53 ± 2.10	26.84 ± 6.40	42.13 %	< 0.001

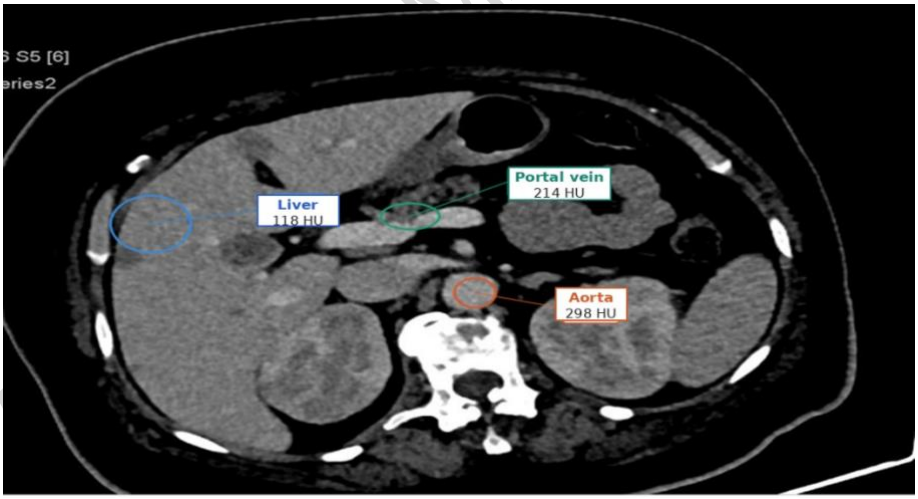

Fig. 2. Illustration of a densitometric analysis on a standard ROI.

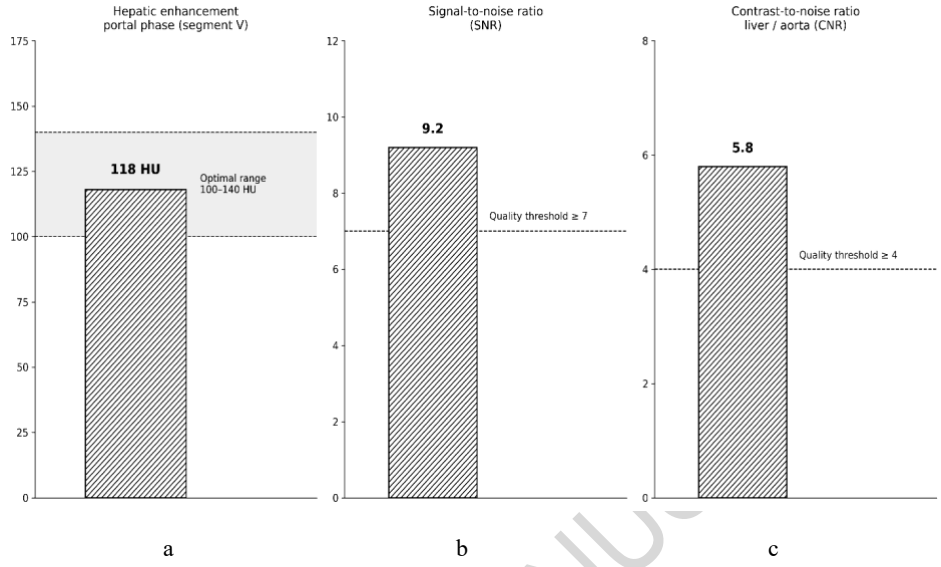

Fig. 3. Characterization of liver enhancement in the portal phase (a), signal-to-noise ratio (b), and contrast-to-noise ratio (c).

Qualitative evaluation

The blinded double reading, performed by two radiologists, covered all 47 examinations. Scores were assigned on a four points Likert scale. Overall image quality was rated satisfactory or excellent (score ≥ 3) in 97.9 % of cases for reader 1, and 95.7 % of cases for reader 2. Visualization of hepatic metastases obtained the highest scores (median 3.7 for reader 1; 3.6 for reader 2). Inter-observer agreement was good, with a Cohen's *kappa* coefficient of $k = 0.68$ (95 % *CI*: 0.58–0.78).

Table 4

Qualitative scores after blinded reading

Criteria	Median reader 1	Median reader 2	Inter-observer agreement
Image quality	3.3	3.2	0.68
Mediastinal lymph nodes	3.1	3.0	0.72
Hepatic metastases	3.7	3.6	0.81
Pulmonary metastases	3.2	3.1	0.70

Bone metastases	3.9	3.9	0.64
Artifacts (reverse score)	3.5	3.4	0.65

Two examinations (4.25 %) showed respiratory motion artifacts, with no diagnostic impact. These artifacts, inherent to the acquisition length in spiral technique, were recorded but did not alter the final diagnostic scoring. Of the 47 examinations performed according to the single-phase portal protocol, none required repeat acquisition or immediate additional examination due to diagnostic insufficiency.

DISCUSSION

POPULATION CHARACTERISTICS: A REFLECTION OF THE SUB-SAHARAN EPIDEMIOLOGICAL PROFILE

The typical patient profile in our study was 49 years old on average, with advanced neoplastic disease (T4: 63.82 %), an advanced stage that contrasts with the relatively young age compared with Western data. Several West African studies report a similar profile. Somé *et al.*, in a 2022 study in Bobo-Dioulasso, reported a mean age of 46.6 ± 12.1 years, with 76.9 % of cancers at stage T4 [15]. Ouedraogo *et al*., across the entire Burkinabè population, found a mean age of 48.1 ± 13.6 years in 2024 for all female cancers combined [12]. Parenté *et al*. found a relatively young mean age of 48 years in Benin in 2023, compared with the French average of 60 years [13].

In retrospective cohort studies, women with stage III and IV disease represented 77 % of breast cancer patients at Mulago Hospital in Uganda, 77 % of patients at the Butaro Cancer Center of Excellence in Rwanda, and 78 % of breast cancer patients at the Angolan Cancer Control Institute.

This late diagnosis pattern is a major determinant of the metastatic profile observed in our series. Our series also excluded patients without immunohistochemical results, given the fundamental role of immunohistochemistry in breast cancer management, although the treatment cost remains essential for molecular classification. As in African and Western data, our study confirms the predominance of the triple-negative subtype among black patients, which could be explained by genetic particularities that nevertheless remain to be characterized [1].

This molecular aggressiveness, combined with late diagnosis, likely explains the high frequency of hepatic metastases (40.42 % of metastatic cases) observed in our series, supporting the appropriateness of a follow-up strategy centered on the detection of hepatic metastases.

DOSIMETRIC REDUCTION: A PREDICTABLE RESULT WITHIN THE BREAST CANCER CARE PATHWAY

The number of acquisitions is one of the parameters that linearly explains the overall dose received during a potentially irradiating examination: the fewer the scans, the lower the irradiation, regardless of the influence of technical parameters. Predictably, a single portal acquisition substantially reduces overall radiation dose compared with a standard protocol that includes at least three scans.

The reduction in effective dose observed in our study (42.13 %) reflects the international trend toward simplifying oncology protocols. No current practice in Burkina Faso incorporates these data into CT acquisition protocols. An Australian study compared a standard protocol with a single portal-phase protocol in 111 patients and concluded that the latter approach significantly improved the visibility of pleural lesions ($P < 0.001$), improving chest assessment without loss of diagnostic confidence for the abdomen, while significantly reducing the delivered dose [2]. In the African context, a Moroccan study conducted at Hassan II Hospital in Agadir reported, for CAP CT, a mean effective dose of 11.72 ± 3.98 mSv and a mean *CTDIvo*l of 10.82 ± 2.53 mGy, with a mean *DLP* of 755.97 ± 251.52 mGy·cm [3]. Our single-phase protocol values (C*TDIvol* 9.8 mGy; *DLP* 1,024 mGy·cm) are broadly comparable in terms of *CTDIvol*, but our *DLP* and effective dose remain higher, which could be explained by a more extensive anatomical coverage (full CAP *versus* segment by segment comparison) or by differences in technical parameters (pitch, kV, reference mAs) between the two centers. The absence of any case exceeding the 20 mSv threshold in our series is meaningful in light of international standards: this value corresponds approximately to the cumulative dose of about two standard CAP CT scans, equivalent to seven to nine years of exposure to natural background radiation [3].

Given the need for repeated surveillance in oncology, the dosimetric savings achieved by adopting a single-phase portal protocol represent a potentially significant cumulative gain over the entire care pathway, fully aligning with the ALARA principle (as low as reasonably achievable) while maintaining diagnostic capability.

DIAGNOSTIC PERFORMANCE OF SINGLE-PHASE CT IN LINE WITH THE ALARA APPROACH

Our study shows that diagnostic performance is preserved despite the elimination of the conventional phases, a finding extensively documented in the scientific literature. Single portal-phase imaging is now standardized in Western

cancer centers [11], based on the fact that hepatic metastases are little or not hypervascularized, making the portal phase alone sufficient in the vast majority of cases.

This point is essential for interpreting our results: unlike primarily hypervascular tumors (hepatocellular carcinoma, neuroendocrine tumors, certain renal cancers), breast cancer hepatic metastases are most often hypovascular or isodense, making them particularly well identifiable at the portal phase [5]. Our finding of a mean hepatic enhancement of 117 ± 13 HU confirms the diagnostic potential of hepatic lesions at the portal phase. Accordingly, the "hepatic metastases" criterion obtained both the best quality scores (median 3.7/4) and the best inter-observer agreement (*kappa* = 0.81) in our study.

Overall inter-observer agreement (*kappa* = 0.68; 95 % *CI*: 0.58 – 0.78) can be described as good according to the Landis and Koch scale (substantial agreement between 0.61 and 0.80), a satisfactory level for a diagnostic tool intended for routine clinical use. Agreement was even better (*kappa* = 0.81, near-perfect agreement) for the main metastatic target in our population.

Beyond the strict dosimetric benefit, eliminating the arterial and delayed phases from the follow-up protocol offers organizational advantages worth highlighting in the specific context of Bobo-Dioulasso: reduced scanner occupancy time (a critical parameter in a department with limited technical resources and high patient volume; only one scanner was operational during the collection period); and reduced volume of iodinated contrast medium used, with economic benefits and lower risk of nephrotoxicity. These two parameters can directly translate into a reduction in examination cost, a non-negligible consideration given that the overall cost of oncology care remains largely inaccessible in this context.

STUDY LIMITATIONS

Several methodological limitations should be discussed. Firstly, temporal comparability of the two protocols: the reference standard CT scan corresponds to the initial examination stage, performed at a different time from the follow-up single-phase CT scan; morphological variations (weight, general condition under treatment) or technical variations (evolution of machine parameters) between the two examinations cannot be entirely excluded and may have influenced the dosimetric comparison. Further statistical analyses correlating *BMI* variability between examinations with the dosimetric gain could address this limitation. Secondly, sample size: 47 patients constitute a relevant sample for a single-center pilot study but remain limited for drawing firm conclusions about underrepresented subgroups such as pulmonary and bone metastases. Thirdly, the single-center design limits the generalizability of the results.

CONCLUSION

Taken together, the results of our work support the adoption of the single-phase portal protocol as the standard follow-up protocol for breast cancer at CHU ”Sourô Sanou”, with the proposal of an algorithm for occasional recourse to a complementary phase in cases of an atypical hepatic lesion that cannot be characterized on single-phase imaging (suspicious hypervascular lesion, diagnostic uncertainty). A prospective, multicenter, nationwide study, including a larger sample size and longer-term clinical follow-up, would help consolidate these results before generalizing the recommendations to all hospital facilities in Burkina Faso.

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Informed consent. Free and informed consent was obtained from patients. All data collected was analyzed and presented anonymously.

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Conflicts of interest. The authors declare that they have no conflicts of interest to report regarding this study.

Ethical considerations. Ethical considerations and data confidentiality were respected. Permissions from the various hospital authorities were obtained in advance (N°MESRI/SG/UNB/INSSA/DPT-IM/2025-0016).

Data availability. The data are available in the collection database and in the hospital medical records and are accessible in accordance with ethics and confidentiality.

Declaration of generative AI and AI-assisted technologies in the writing process. Since we are in a French-speaking country (Burkina Faso), we used AI to translate certain parts into English so that the written English would be much more understandable.

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