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# Longitudinal Partial Psoas Muscle Volume Loss and Outcomes After Yttrium-90 Radioembolization in Hepatocellular Carcinoma

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## Simple Summary

Patients with liver cancer can lose skeletal muscle mass during treatment, which can adversely affect their overall health status, treatment tolerance and clinical outcomes. We investigated whether changes in skeletal muscle volume measured on routine computed tomography scans were associated with treatment response and disease progression. This retrospective study included 28 patients with intermediate-stage hepatocellular carcinoma treated with yttrium-90 radioembolization, which delivers radiation directly to liver tumors. We measured part of both psoas muscles on routine CT examinations for cancer assessment and follow-up. Patients whose muscle volume decreased had a lower response rate at three months and were less likely to remain alive without disease progression at two years. These preliminary findings suggest that monitoring muscle volume on existing scans may provide useful information alongside standard tumor assessment, without additional imaging or radiation exposure. Larger prospective studies are needed to confirm these results.

## Abstract

**Background/Objectives**: Dynamic skeletal muscle loss may provide clinically relevant information beyond baseline sarcopenia status in patients with cancer. We investigated whether longitudinal changes in CT-derived partial psoas muscle volume (PMV) were associated with radiological response and progression-free survival (PFS) in patients with intermediate-stage hepatocellular carcinoma (HCC) treated with yttrium-90 transarterial radioembolization (TARE). **Methods**: This retrospective single-center study included 28 patients with BCLC-B HCC treated with yttrium-90 TARE. Bilateral psoas muscles were segmented on CT from the inferior endplate of L1 to the inferior plate of L3 at baseline and during follow-up. Longitudinal change was expressed as percentage variation from baseline. Decreased PMV was considered an imaging-based marker of sarcopenia (Muscle loss group, n = 10, 35.7%), whereas stable or increased PMV indicated muscle preservation

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(Muscle preservation group, n = 18, 64.3%). **Results**: Median baseline PMV was 79.2 $cm^3$. At 3 months, objective response was observed in 100% of patients with preserved/increased PMV compared with 60% of patients with decreased PMV ($p = 0.01$). At 6 months, objective response rates were 66.7% and 40.0%, respectively ($p = 0.243$). At 24 months, estimated PFS was 53.9% in the preserved/increased PMV group and 20.0% in the decreased PMV group ($p = 0.04$). **Conclusions**: Longitudinal decline in CT-derived partial PMV, interpreted as an imaging-based manifestation of sarcopenia, was associated with poorer early radiological response and shorter PFS after yttrium-90 TARE. Longitudinal partial PMV assessment may therefore represent a feasible imaging approach for monitoring muscle volume changes during post-TARE follow-up and may complement conventional imaging-based assessment of treatment response and prognosis.

**Keywords:** hepatocellular carcinoma; sarcopenia; trans-arterial therapy; radioembolization; Yttrium-90; psoas muscle; computed tomography

## 1. Introduction

Hepatocellular carcinoma (HCC) is the sixth most common malignancy and the third leading cause of cancer-related death worldwide, accounting for more than 800,000 deaths annually [1].

Sarcopenia is a progressive skeletal muscle disorder associated with adverse outcomes in oncologic patients and has emerged as one of the most powerful prognostic biomarkers in oncology. Beyond its traditional definition as age-related muscle loss, sarcopenia is now recognized as a complex syndrome resulting from the interaction between cancer-associated inflammation, metabolic dysregulation, malnutrition, hormonal alterations, and reduced physical activity. The revised European Working Group on Sarcopenia in Older People (EWGSOP2) consensus identified low muscle quantity and quality as central determinants of adverse outcomes, emphasizing sarcopenia as a biological marker of reduced physiological reserve rather than merely a nutritional condition [2].

In cancer patients, accumulating evidence indicates that skeletal muscle depletion is independently associated with increased treatment toxicity, postoperative complications, reduced quality of life, shorter progression-free survival, and increased mortality [3]. In a landmark systematic review and meta-analysis including more than 7800 oncologic patients, it was demonstrated that Computed Tomography (CT)-defined sarcopenia was consistently associated with inferior overall survival across multiple tumor types [4]. Similarly, Caan et al., in a cohort of more than 3200 patients, showed that low skeletal muscle mass was strongly associated with cancer mortality independently of body mass index, establishing body composition as a major determinant of oncologic outcomes [5].

The prognostic significance of sarcopenia appears particularly relevant in patients with HCC, where tumor progression develops in the context of chronic liver disease and cirrhosis, both conditions intrinsically associated with muscle wasting. Various meta-analyses confirmed that sarcopenia significantly increases the risk of mortality and recurrence in patients with HCC regardless of treatment modality, highlighting the importance of integrating body composition assessment into routine clinical evaluation [6,7]. A recent review has further summarized the adverse impact of sarcopenia across HCC treatment settings [8], and a meta-analysis of transcatheter liver-directed therapies associated low skeletal muscle mass with poorer outcomes, including in patients treated with TARE [9].

CT has become the reference standard for opportunistic evaluation of skeletal muscle because it is routinely performed in oncologic practice and enables quantitative body composition analysis without additional examinations or radiation exposure. Traditionally, muscle assessment has relied on two-dimensional measurements obtained from a single axial image at the third lumbar vertebra (L3), including the skeletal muscle index (SMI) and psoas muscle index (PMI). However, growing evidence suggests that single-slice measurements incompletely represent total skeletal muscle mass and may be affected by anatomical variability, slice-selection bias, and regional muscle asymmetry. Psoas cross-sectional area correlates poorly with total skeletal muscle area at L3 [10], and the psoas muscle alone at L3 has not been confirmed as a reliable assessment of low skeletal muscle mass [11]. The feasibility of quantifying body composition opportunistically from CT images acquired during routine cancer care was established in earlier methodological work [12].

Three-dimensional CT volumetry may provide a more comprehensive assessment of muscle bulk and has been proposed as an alternative to two-dimensional measurements [13]. This approach may be particularly useful in interventional oncology, where repeated CT examinations are routinely available for treatment response assessment.

Transarterial radioembolization (TARE) with yttrium-90 microspheres is an established locoregional treatment within multidisciplinary HCC management [14]. Outcomes after TARE are usually assessed using radiological response, liver function, tumor markers, and dosimetric parameters; however, these measures provide limited information on changes in the patient's physical condition during follow-up.

Current BCLC recommendations emphasize individualized management according to tumor burden, liver function, and patient-related factors [15]. In a multicenter study of patients with HCC undergoing TARE, low baseline skeletal muscle mass was associated with inferior long-term survival [16].

Patients undergoing TARE routinely undergo multiple follow-up CT examinations, creating a unique opportunity for longitudinal body composition assessment. However, follow-up CT protocols are often limited to the upper abdomen and may not consistently include the coverage required for conventional complete L3 assessment [17].

In this study, both psoas muscles were segmented over a standardized interval from the inferior margin of L1 to the inferior margin of L3. The resulting partial psoas muscle volume (PMV) represents a regional measurement that can be repeated on baseline and follow-up examinations.

The percentage change in PMV, relative to the pretreatment baseline (ΔPMV), was calculated to quantify intra-individual changes. Negative ΔPMV indicated a reduction in L1–L3 psoas volume, whereas stable or positive values reflected muscle preservation or an increase in muscle volume, respectively. ΔPMV is neither an anthropometrically normalized index nor a surrogate for whole-body. In the present study, longitudinal PMV loss was therefore interpreted as an imaging-based indicator of the development or progression of sarcopenia.

In a previous pilot study involving patients with HCC treated with holmium-166 TARE, a decline in two-dimensional psoas measurement was associated with an unfavorable radiological response at 3 months [18].

The present study builds upon these findings by using three-dimensional L1–L3 PMV measurements in patients treated with yttrium-90 TARE while assessing radiological response at 3 and 6 months and progression-free survival. We hypothesized that a reduction in PMV would be associated with less favorable radiological response and shorter progression-free survival (PFS).

Accordingly, the aim of the present study was to evaluate the association between longitudinal changes in CT-derived PMV and oncologic outcomes in patients with HCC treated with yttrium-90 radioembolization.

## 2. Materials and Methods

### 2.1. Study Design and Patient Population

This retrospective single-center study included 50 consecutive patients with BCLC-B HCC who underwent yttrium-90 TARE at the IRCCS Regina Elena National Cancer Institute, Rome, Italy, between January 2020 and December 2025. All cases were discussed by a multidisciplinary liver tumor board, and eligibility for TARE was established according to tumor extent, liver function, performance status, technical feasibility, previous treatments, and available therapeutic alternatives.

Inclusion criteria were: (1) HCC diagnosed histologically or according to accepted imaging criteria; (2) treatment with yttrium-90 TARE; (3) availability of a contrast-enhanced pretreatment CT; (4) contrast-enhanced CT follow-up at approximately 3 and 6 months; (5) complete visualization of both psoas muscles from the inferior margin of L1 to the inferior margin of L3 at all time points; (6) adequate image quality for volumetric segmentation and response assessment.

Exclusion criteria were unavailable or incomplete CT follow-up at 3 and/or 6 months, insufficient L1–L3 coverage, severe artifacts preventing reliable segmentation, previous surgery or anatomical alterations substantially affecting the psoas muscles, and incomplete clinical data. Twenty-two patients were excluded, mainly because follow-up imaging was unavailable or incomplete, leaving 28 patients for the final analysis.

Follow-up imaging was unavailable for some patients because subsequent examinations had been performed at their local referring institutions after TARE. All 28 patients included in the final analysis had evaluable CT examinations at both 3 and 6 months.

Clinical, laboratory, imaging, procedural, and dosimetric data were retrospectively retrieved from institutional records. Baseline variables included age, sex, body mass index, Eastern Cooperative Oncology Group performance status, liver function, tumor characteristics, tumor markers, previous oncologic treatments, and TARE-related parameters.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional ethics committee. All patients provided written informed consent for the procedure and for the use of anonymized clinical and imaging data for research purposes.

### 2.2. CT Acquisition Protocol

All baseline and follow-up CT examinations were performed on the same multidetector scanner (LightSpeed VCT, GE Medical Systems, Waukesha, WI, USA), using the institutional standard multiphasic liver CT protocol for HCC. Acquisition parameters included a tube voltage of 120 kV, a tube current of 300–500 mA, and a helical pitch of 0.5–0.7. Weight-adjusted iodinated contrast medium was administered intravenously at 2.0–3.0 mL/s, followed by a 40 mL saline flush. Late arterial-phase acquisition was initiated 18 s after the bolus-tracking trigger. Portal venous-phase images were acquired approximately 70 s after the start of contrast administration. Images were reconstructed using adaptive statistical iterative reconstruction (ASiR; GE Healthcare), with a standard soft-tissue kernel and a slice thickness of 2–5 mm. The specific ASiR blending percentage could not be confirmed from the available protocol information.

Arterial-phase images were used for mRECIST assessment, whereas portal venous-phase images were used for PMV quantification.

### *2.3. CT-Based PMV Assessment and ΔPMV Calculation*

Sarcopenia assessment was based on longitudinal CT-derived volumetric analysis of the psoas muscles. Because post-TARE surveillance was limited to the upper abdomen to reduce cumulative radiation exposure, complete evaluation of the entire psoas muscles and conventional complete L3 assessment were not consistently feasible. A standardized partial volume was therefore obtained by segmenting both psoas muscles from the inferior endplate of L1 to the inferior endplate of L3 (Figure 1).

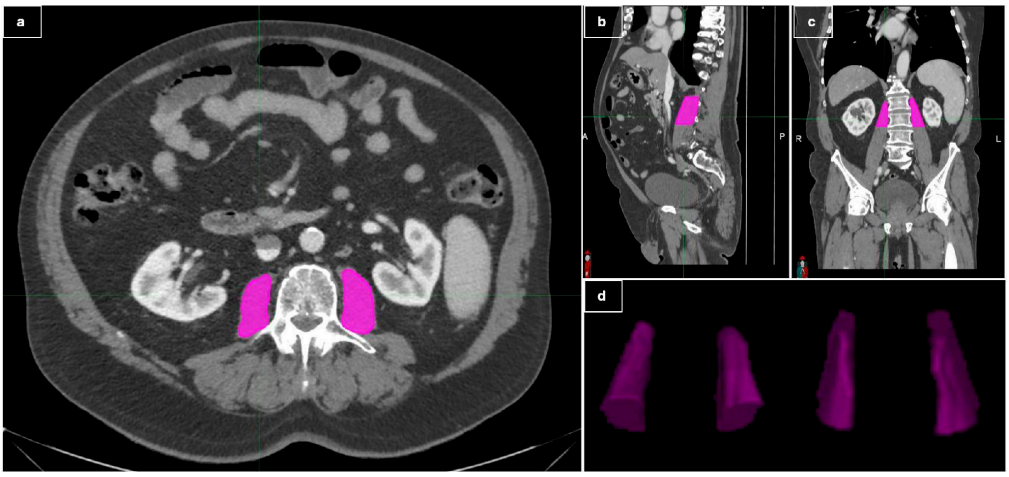



**Figure 1.** Contrast-enhanced abdominal CT acquired in the portal venous phase. Bilateral psoas muscle volumetric segmentation was performed using MIM software (MIM Software Inc., version 7.4.5, Cleveland, OH, USA) (magenta contours), providing quantitative assessment of muscle volume ($cm^3$). Psoas volume was calculated from the inferior endplate of L1 to the inferior endplate of L3. (**a**) Axial CT slice with segmented psoas muscles, (**b**) sagittal reformatted view, (**c**) coronal reformatted view with bilateral segmentation, and (**d**) 3D rendering of the segmented psoas volume.

Segmentations were performed by two radiologists on portal venous phase CT images acquired before TARE and at approximately 3 and 6 months using a machine learning-based semi-automatic workflow in MIM Maestro™ (MIM Software Inc., version 7.4.5, Cleveland, OH, USA). Both psoas muscles were segmented continuously over the predefined L1-L3 interval. Contours were reviewed on axial and multiplanar images and manually corrected when necessary to exclude adjacent non-muscular structures.

Right and left psoas volumes were summed and expressed in cubic centimeters as PMV. PMV was not normalized for height or body surface area because only a standardized portion of the muscles was measured. The same landmarks and segmentation procedure were used at all time points.

Longitudinal change was expressed as ΔPMV: ΔPMV (%) = [(PMV_follow-up − PMV_baseline)/PMV_baseline] × 100. ΔPMV was calculated separately at 3 and 6 months using pretreatment PMV as the reference. Patients with negative ΔPMV were assigned to the Muscle loss group, whereas those with stable or positive ΔPMV were assigned to the Muscle preservation group. This operational imaging-based classification reflects longitudinal muscle loss or preservation and does not include direct assessment of muscle strength or physical performance.

### 2.4. TARE Procedure and Dosimetry

All treatments were performed by two interventional radiologists with more than ten years of experience.

First, simulation angiography was carried out by injecting 99mTc-MAA in the hepatic tumor feeding arteries slowly through a 2.7-F micro-catheter (Progreat; Terumo Europe NV, Leuven, Belgium).

Single-photon emission CT with integrated CT (SPECT/CT, Symbia IntevoTM system; Siemens, Erlangen, Germany) was acquired to quantify the drug distribution into the targeted tumor volume, eventual extra-hepatic shunt and for treatment planning (voxel dosimetry).

One week after the simulation angiography, all patients underwent selective transarterial radioembolization (TARE) procedure using yttrium-90 resin microspheres (SIR-Spheres®, Sirtex Medical, St. Leonards, Australia) and SPECT/CT was performed between 1 and 20h after TARE for absorbed dose verification.

Volumes of interest (total tumor volume, perfused liver, non-tumor volume) were semi-automatically delineated using MIM Maestro™ (MIM Software Inc., Cleveland, OH, USA). The 3D-voxelized 90Y-dose distribution maps were extrapolated from the post-treatment SPECT/CT images using the local energy deposition method (LED), that considers permanent microsphere implantation and pure physical decay [19].

For each patient, the mean absorbed dose (<D>) in Gy for the normal parenchyma and tumor were compared with the expected values (<D> to tumor > 150 Gy, <D> to normal liver < 40 Gy) to assess the treatment efficacy.

### 2.5. Radiological Response Assessment

Radiological response was assessed on multiphasic contrast-enhanced CT at approximately 3 and 6 months according to modified Response Evaluation Criteria in Solid Tumors (mRECIST) for HCC [20]. Complete response and partial response were classified as objective response, whereas stable disease and progressive disease were classified as non-objective response. Finally, classification into the "Muscle loss group" and "Muscle preservation group" was based on the direction of PMV change (decreased versus stable/increased), without validated absolute or percentage cutoffs. These groups therefore describe longitudinal muscle volume changes and should not be interpreted as diagnostic or severity categories of sarcopenia according to EWGSOP2 criteria.

To assess the reproducibility of radiological treatment response evaluation, interobserver agreement between the two abdominal radiologists was assessed before consensus adjudication using Cohen's kappa coefficient. Viable tumor components were identified based on arterial-phase contrast enhancement, and the longest diameter of the viable enhancing component was measured, excluding non-enhancing necrotic areas. Discrepancies between the two readers were subsequently resolved by consensus.

### 2.6. Clinical Outcomes

The primary outcome was to evaluate the association between ΔPMV classification and radiological response at 3 and 6 months following treatment.

The secondary outcome was PFS, defined as the time interval from yttrium-90 administration to radiological progression, as assessed according to mRECIST, or death from any cause, whichever occurred first.

Patients who were still alive and showed no disease progression at the end of the follow-up period were censored at the date of their last available clinical or diagnostic imaging assessment.

### 2.7. Statistical Analysis

Continuous variables are presented as medians and ranges. Categorical variables are summarized as numbers and frequencies with corresponding percentages (N, %).

The Mann–Whitney U test was used for comparing quantitative variables. The Chi Square or Fisher exact tests were used for categorical variables, when appropriate. The Kaplan–Meier method was used to calculate survival rates and draw survival curves. The log-rank test assessed survival differences between the two different risk class groups. The Hazard ratio (HR) and the 95% confidence intervals (95% confidence interval [CI]) were estimated for each variable of interest. An adjusted hazard ratio (aHR) was estimated to compare the risk of an event between groups while removing the distorting effect of confounding variables. $p$ value < 0.05 was considered significant. Statistical evaluation was performed by use of the SPSS 30.0 (SPSS Inc., Chicago, IL, USA) for Windows.

## 3. Results

A total of 28 consecutive patients with BCLC-B HCC undergoing yttrium-90 TARE treatment were evaluated.

Median age was 67 years (26–84 years) and most of the cohort had Eastern Cooperative Oncology Group (ECOG) performance status 0–1 (78.6%).

Patients' demographics and dosimetric features are depicted in Table 1.

**Table 1.** Baseline patients' clinical characteristics for the whole population.

| Patients' Characteristics | Number of Patients, n = 28 (%) |
|---|---|
| Age at diagnosis (years) | |
| Median (range) | 67 (26–84) |
| Gender | |
| Female | 4 (14.3) |
| Male | 24 (85.7) |
| ECOG performance status | |
| 0–1 | 22 (78.6) |
| ≥2 | 6 (21.4) |
| BMI (kg/m$^2$) | |
| Normal weight | 8 (28.6) |
| Overweight | 14 (50.0) |
| Obese class I | 6 (21.4) |
| Disease stage | |
| II | 19 (67.9) |
| III | 9 (32.1) |
| Mean Delivered Activity (GBq) | |
| Median (range) | 1.645 (0.86–3.46 GBq) |
| Mean Dose to Tumor (Gy) | |
| Median (range) | 162 (78–816) |
| Mean Dose to Normal Liver (Gy) | |
| Median (range) | 27.5 (7–54) |
| ORR (CR/PR) | |
| 3 months | 24 (85.7) |
| 6 months | 16 (57.1) |

All patients underwent TARE within approximately 1 week of simulation angiography with 99mTc-MAA. Post-treatment SPECT/CT was used to assess tracer distribution and absorbed-dose delivery (Figure 2).

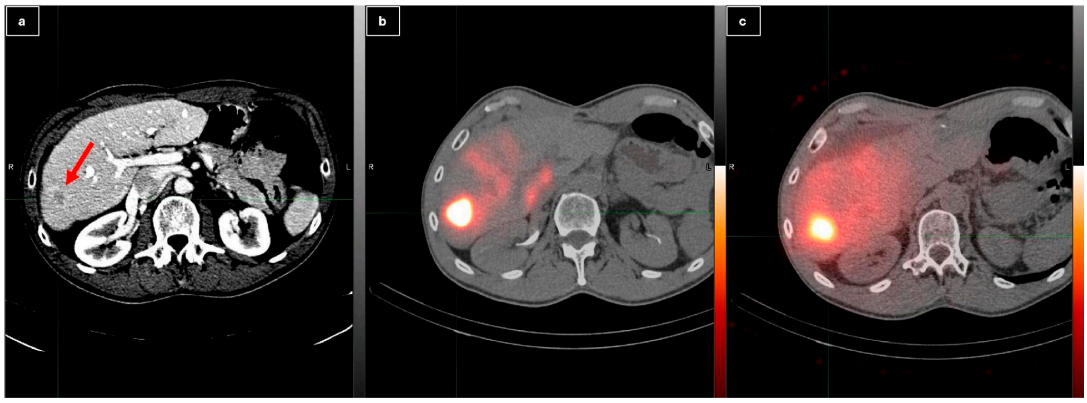



**Figure 2.** Imaging work-up in a patient with HCC undergoing yttrium-90 TARE. (**a**) Baseline portal venous phase contrast-enhanced CT showing the target HCC lesion (red arrow). (**b**) Pretreatment 99mTc-macroaggregated albumin SPECT/CT acquired after intra-arterial injection to simulate microsphere distribution and assess intrahepatic targeting. (**c**) Post-treatment yttrium-90 SPECT/CT showing radiotracer deposition within the treated hepatic territory.

All patients received a median dose to tumor of 162 Gy (78–816 Gy) and a median dose to non-tumoral liver (NTL) of 28 Gy (7–54 Gy). 24 patients (85.7%) had CR/PR at 3 months and 16 (57.1%) maintained the CR/PR at 6 months. Interobserver agreement between the two radiologists for mRECIST-based treatment response assessment was excellent, with a Cohen's kappa coefficient of 0.951 (SE = 0.049, $p < 0.001$). Concordant classifications were obtained in 27 of 28 patients (96.4%), with only one discordant case (3.6%), which was subsequently resolved by consensus.

PMV segmentations were performed on portal venous phase CT images before, 3 and 6 months after TARE in all patients. A representative longitudinal assessment is shown in Figure 3.

Baseline median PMV of our cohort was 79.2 $cm^3$ (range 34.9–147.9). At 3 months, an increase in ΔPMV was observed in 18 patients (64.3%), whereas the remaining 10 patients (35.7%) exhibited a decrease in ΔPMV. Group classification was reassessed at 6 months, confirming that all patients (100%) remained in the same group, with no transitions between the muscle loss and muscle preservation groups.

No statistical differences were observed between Muscle loss group and Muscle preservation group in terms of clinical and dosimetric variables (Table 2).

**Table 2.** Baseline Demographic and Clinical Characteristics related to ΔPMV group classification.

| Variables | Muscle Loss Group N (%) | Muscle Preservation Group N (%) | *p* Value |
|---|---|---|---|
| **Gender** | | | |
| Female | 1 (25.0) | 3 (75.0) | 0.999 |
| Male | 9 (37.5) | 15 (62.5) | |
| **ECOG performance status** | | | |
| 0–1 | 8 (80.0) | 14 (77.8) | |
| ≥2 | 2 (20.0) | 4 (22.2) | 0.989 |
| **BMI ($kg/m^2$)** | | | |
| Normal weight | 1 (12.5) | 7 (87.5) | 0.208 |
| Overweight | 7 (50.0) | 7 (50.0) | |
| Obese class I | 2 (33.3) | 4 (66.7) | |
| **Disease stage** | | | |
| II | 6 (31.6) | 13 (68.4) | 0.677 |
| III | 4 (44.4) | 5 (55.6) | |

| | | | |
|---|---|---|---|
| **Mean Dose post** | | | |
| <150 Gy | 7 (50.0) | 7 (50.0) | 0.107 |
| ≥150 Gy | 3 (21.4) | 11 (78.6) | |

No post-procedural complications were reported in either group.

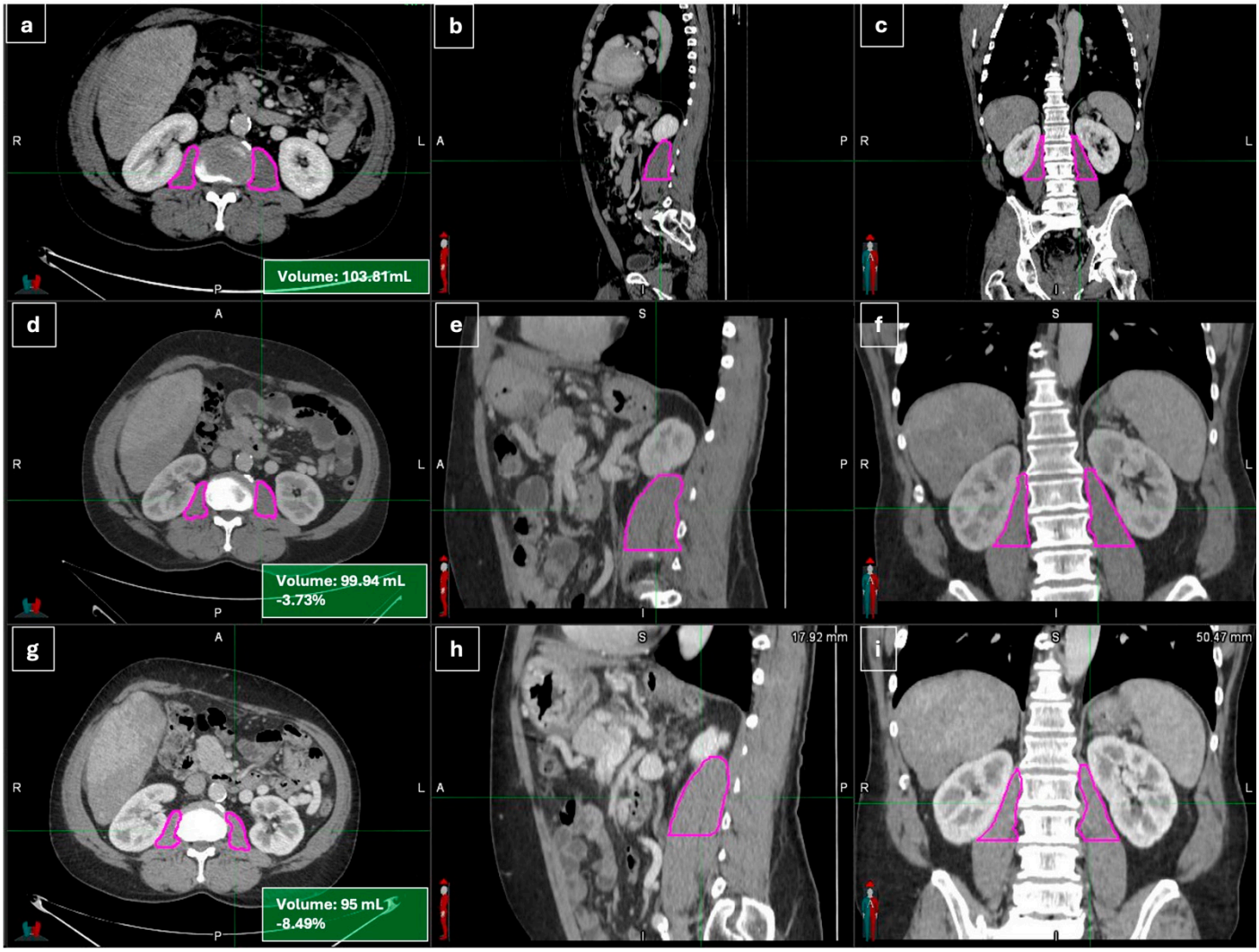



**Figure 3.** Longitudinal partial psoas muscle volume (PMV) assessment on portal venous phase contrast-enhanced CT. Baseline examination: (**a**) axial CT image showing bilateral psoas muscle segmentation; (**b**) sagittal reconstruction; (**c**) coronal reconstruction. Three-month follow-up: (**d**) axial CT image showing bilateral psoas muscle segmentation; (**e**) sagittal reconstruction; (**f**) coronal reconstruction. Six-month follow-up: (**g**) axial CT image showing bilateral psoas muscle segmentation; (**h**) sagittal reconstruction; (**i**) coronal reconstruction. Magenta contours delineate the psoas muscles segmented between the inferior endplates of L1 and L3. PMV decreased from 103.81 mL at baseline to 99.94 mL at 3 months and 95.00 mL at 6 months, corresponding to changes of −3.73% and −8.49%, respectively, relative to baseline.

Furthermore, no statistical differences were observed between the two groups in terms of biological parameters and liver function tests (Table 3).

**Table 3.** Baseline biological and liver function tests related to ΔPMV group classification.

| Variable | Total pts Median (Range) | Muscle Preservation Group Median (Range) | Muscle Loss Group Median (Range) | *p* Value |
|---|---|---|---|---|
| PIVKA | 217.0 (18.10–8802.0) | 267.50 (18.10–8802.0) | 316.0 (70.20–4057.0) | 0.622 |
| AFP (ng/mL) | 3.51 (0–5132.0) | 3.51 (0–5132.0) | 1.81 (0–65.70) | 0.382 |
| Creatinine (mg/dL) | 0.93 (0.54–1.32) | 0.86 (0.55–1.32) | 0.98 (0.54–1.14) | 0.385 |
| Albumin (g/L) | 51.75 (35.70–60.80) | 51.0 (35.70–60.80) | 53.10 (42.70–56.20) | 0.743 |
| Blood Urea Nitrogen (BUN) (mg/dL) | 37.5 (11.0–59.0) | 37.50 (24.0–50.0) | 34.50 (11.0–59.0) | 0.437 |
| Blood glucose (mg/dL) | 98.5 (60.0–204.0) | 96.0 (60.0–144.0) | 106.0 (91.0–204.0) | 0.291 |
| AST (Aspartate transaminase) (IU/L) | 44.50 (19.0–98.0) | 36.0 (19.0–67.0) | 55.50 (37.0–98.0) | 0.067 |
| ALT (Alanine transaminase) (IU/L) | 35. (11.0–89.0) | 31.50 (11.0–68.0) | 47.0 (28.0–89.0) | 0.083 |
| GGT (Gamma-glutamyl transferase) (IU/L) | 100.50 (22.0–843.0) | 74.0 (22.0–843.0) | 165.0 (90.0–386.0) | 0.102 |
| Bilirubin (mg/dL) | 1.11 (0.24–2.77) | 1.11 (0.24–2.22) | 1.25 (0.55–2.77) | 0.616 |
| Direct bilirubin (mg/dL) | 0.38 (0.15–1.39) | 0.34 (0.15–0.79) | 0.49 (0.20–1.39) | 0.462 |
| Indirect bilirubin (mg/dL) | 0.61 (0.09–1.45) | 0.54 (0.09–1.43) | 0.77 (0.35–1.45) | 0.301 |
| Platelets count (PLT) | 129.50 (62.0–266.0) | 148.50 (68.0–266.0) | 129.50 (62.0–238.0) | 0.750 |
| Hemoglobin (Hb) (g/dL) | 13.6 (10.50–16.50) | 13.50 (10.50–16.50) | 13.80 (12.50–15.80) | 0.750 |
| INR | 1.14 (0.97–1.37) | 1.21 (0.97–1.37) | 1.113 (1.07–1.33) | 0.743 |
| White blood cell (WBC) $\times 10^9$/L | 5.46 (3.84–11.11) | 6.84 (3.84 11.11) | 5.14 (4.01–6.84) | 0.250 |
| Alpha amylase (IU/L) | 90.0 (42.0–228.0) | 83.0 (42.0–228.0) | 122.0 (57.0–149.0) | 0.221 |

Radiological response rate was then evaluated for all patients from imaging follow-up at 3 and 6 months after TARE (Figure 4) using mRECIST.




**Figure 4.** CT follow-up in the same patient with HCC treated with yttrium-90 TARE. Portal venous phase contrast-enhanced CT at baseline (**a**), 3 months after TARE (**b**), and 6 months after TARE (**c**), showing the evolution of post-treatment changes in the target lesion (red arrow).

The entire Muscle preservation group responded at 3 months (n = 18 patients, 100%) versus the 60% (n = 6 patients) in the Muscle loss group ($p = 0.01$) (Figure 5a). At 6 months, 12 patients (66.7%) of the Muscle preservation group responded versus 4 (40%) in the Muscle loss group ($p = 0.243$) (Figure 5b).

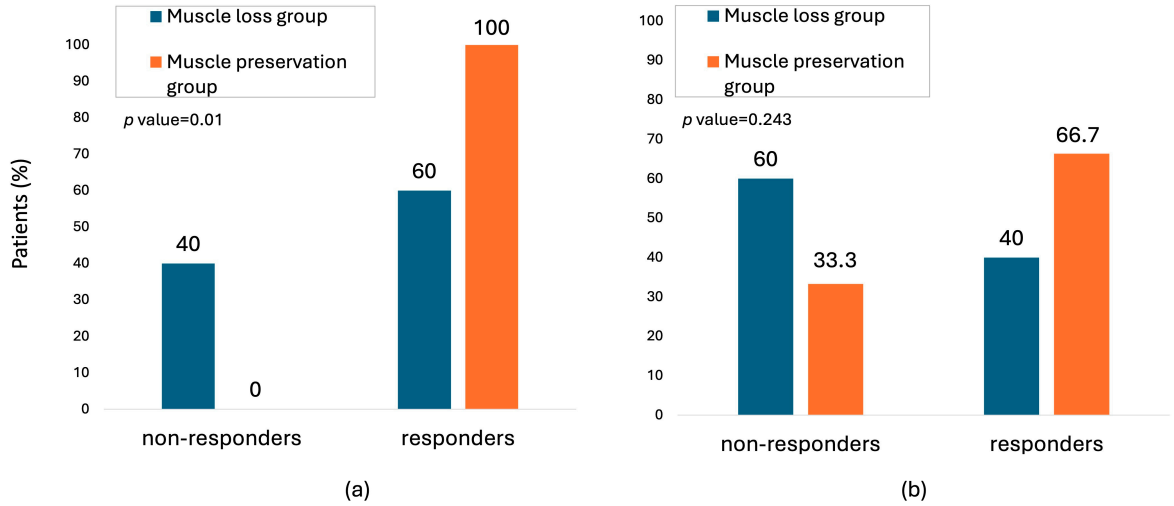



**Figure 5** Radiological response according to mRECIST in the muscle loss and muscle preservation groups at (a) 3 months and (b) 6 months after yttrium-90 radioembolization; bars indicate percentages within each group.

**Figure 5.** Radiological response according to mRECIST in the muscle loss and muscle preservation groups at (**a**) 3 months and (**b**) 6 months after yttrium-90 radioembolization; bars indicate percentages within each group.

Figure 6 shows the estimation of 24-month progression-free survival (PFS) for the two groups of patients. At the median follow-up of 24 months, PFS was statistically significantly higher in the Muscle preservation group than in the Muscle loss group (53.9% versus 20%, respectively; $p = 0.04$).

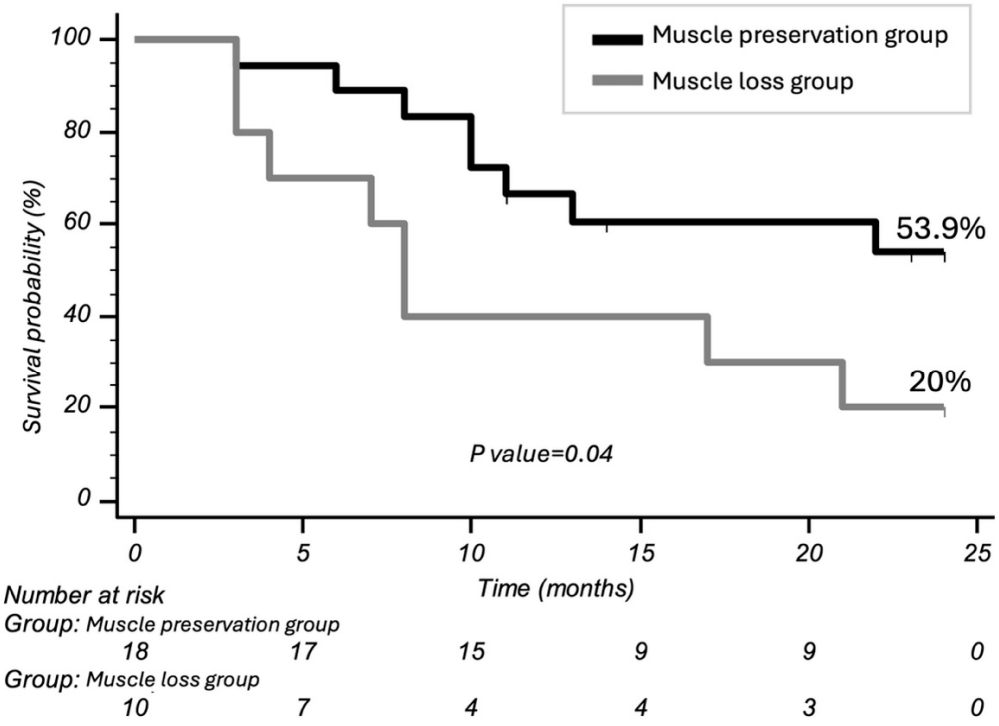



**Figure 6.** Kaplan–Meier curves for progression-free survival according to ΔPMV group.

Patients in the Muscle loss group showed a higher risk of disease progression (HR 2.261; 95% CI 0.975–5.794; $p = 0.056$). Adjusting HR for stage, the risk remained

substantially unchanged (aHR 2.431; 95% CI 0.897–6.584; $p$ = 0.081), although these findings did not reach statistical significance.

Radiological response was assessed on multiphasic contrast-enhanced CT at approximately 3 and 6 months according to mRECIST for HCC.

## 4. Discussion

In this pilot cohort of patients with BCLC-B HCC treated with yttrium-90 TARE, longitudinal reductions in CT-derived PMV were associated with a lower objective response rate at 3 months and a shorter PFS. These findings support the hypothesis that changes in body composition during follow-up may provide clinically relevant information beyond that obtained from a single pretreatment assessment. We therefore investigated whether standardized three-dimensional measurement of the psoas muscle volume, obtained from CT examinations routinely performed for oncologic surveillance, could help elucidate the relationship between post-treatment muscle loss and outcomes following TARE.

Most of the existing literature on sarcopenia in HCC has focused on baseline muscle status as a static prognostic marker, typically assessed through single-slice measurements at the L3 level (skeletal muscle index or psoas muscle index). While these approaches are convenient and widely validated, they carry intrinsic limitations: cross-sectional area at a single anatomical level is vulnerable to slice-selection variability and does not necessarily reflect whole-muscle volume, and the psoas muscle, in particular, correlates poorly with total skeletal muscle area, so that psoas measurements alone have not been confirmed as a reliable surrogate of low skeletal muscle mass [10,11]. Volumetric assessment has been proposed as a more robust alternative, since it captures the three-dimensional heterogeneity of muscle bulk [13]. Our PMV, calculated from the inferior margin of L1 to the inferior margin of L3, represents a pragmatic adaptation of this volumetric approach to a real-world interventional oncology setting, where follow-up CT protocols after TARE are frequently restricted to the upper abdomen to limit cumulative radiation exposure. This partial-volume strategy allowed opportunistic, no-additional-cost quantification of muscle burden on imaging that was already being acquired for oncologic surveillance, without requiring dedicated scans or added radiation.

Our findings are consistent with, and extend, a growing body of literature addressing dynamic—as opposed to baseline—muscle change after locoregional liver-directed therapy for HCC. In a retrospective cohort of 86 patients with HCC treated with TARE, worsening of the psoas muscle index 1 month after treatment, rather than its baseline value, predicted subsequent disease progression, with progressive disease occurring in 38.6% of patients with a declining index versus 11.9% of those with a stable or increasing one [21]. A subsequent pilot study using a similar partial psoas index-based approach in patients treated with Holmium-166 TARE found that a decline in ΔPMV at 3 months, rather than baseline sarcopenia status, discriminated radiological responders from non-responders [18]. Outside of the TARE setting specifically, MRI-derived fat-free muscle area measured opportunistically on pre-treatment imaging has independently predicted overall survival in patients undergoing Y-90 TARE for HCC, reinforcing that body-composition assessment on imaging was already acquired for treatment planning and follow-up carries prognostic value in this population [22]. The present study builds on these findings by extending follow-up to 6 months and using a volumetric rather than a linear or cross-sectional measurement. Our results suggest an association between longitudinal changes in PMV, radiological response, and PFS. However, given the retrospective design, limited sample size, and potential methodological biases, these findings should be considered exploratory and require validation in larger prospective cohorts.

Additional evidence from radioembolization cohorts provides context for these results. Wu et al. reported that the prognostic utility of CT-defined sarcopenia varied with the muscle compartment used for assessment [23], while Guichet et al. associated MRI-derived sarcopenia with increased mortality after yttrium-90 radioembolization [24]. Recent investigations have also explored automated CT-derived body composition metrics in TARE-treated HCC [25] and the prognostic significance of muscle loss during intra-arterial therapies [26]. However, none directly validates the specific partial L1–L3 PMV metric used in our study.

Evidence from TACE cohorts also suggests that muscle-related parameters may contribute to prognostic stratification. Loosen et al. reported an association between sarcopenia and adverse outcomes following TACE for hepatic malignancies [27], whereas Bannangkoon et al. investigated the combined prognostic relevance of myosteatosis and albumin–bilirubin grade in HCC treated with TACE [28]. Because the procedures and patient populations differ, these observations cannot be directly extrapolated to yttrium-90 TARE.

From a biological standpoint, the observed association between a decline in psoas volume and reduced treatment response and PFS is consistent with the broader concept of cancer-associated sarcopenia as a dynamic marker of tumor–host interaction rather than a fixed, pre-treatment trait. The difference in objective response rates was smaller at 6 months (66.7% versus 40.0%, $p = 0.243$) than at 3 months (100% versus 60.0%, $p = 0.01$) and did not reach statistical significance. All 28 patients had evaluable imaging at both time points; therefore, this finding was not attributable to loss to follow-up within the analyzed cohort. The persistence of a significant difference in PFS at 24 months (53.9% in the Muscle preservation group versus 20% in the Muscle loss group $p = 0.04$), despite this attenuation in radiological response concordance at 6 months, suggests that the prognostic signal captured by early ΔPMV changes extends beyond the immediate post-treatment response window.

The hazard ratio for disease progression associated with a lack of ΔPMV increase (HR 2.261, 95% CI 0.975–5.794, $p = 0.056$), which remained essentially unchanged after adjusting for disease stage (HR 2.431, 95% CI 0.897–6.584, $p = 0.081$), did not reach conventional statistical significance, most likely reflecting the limited sample size of this cohort (28 patients, with only 10 in the Muscle loss group). Nevertheless, the magnitude and direction of the observed effect estimate is consistent with a clinically meaningful association, supporting the need_for validation in larger cohorts. Importantly, the two groups did not differ significantly in baseline demographic, dosimetric, or biochemical parameters. These findings suggest that baseline disease severity or treatment intensity may not fully explain the observed differences in outcomes, on the other hand, the trajectory of muscle volume after treatment may provide additional prognostic information. However, residual confounding cannot be excluded, and independence from conventional baseline variables remains to be established.

This study has several limitations. First, the retrospective, single-center design and the relatively small sample size (n = 28, with 10 patients in the muscle loss group) limit statistical power.

Second, the use of a partial, rather than complete, psoas volume (L1–L3)—dictated by the constraints of a liver-focused post-TARE imaging protocol—has not been formally validated against whole-muscle or full L3 skeletal muscle index measurements in this population, and comparative validation studies would strengthen the generalizability of the PMV metric. In addition, differences in CT contrast phase and reconstructed slice thickness may affect body-composition measurements and should be standardized in future validation studies [29].

Third, because ΔPMV groups were defined using follow-up imaging while PFS was measured from the TARE date, a potential guarantee-time bias cannot be excluded [30]. Landmark or time-dependent analyses are needed to address this limitation in future studies.

Fourth, the analysis was restricted to patients with follow-up CT examinations available at both 3 and 6 months. Most exclusions occurred because follow-up imaging had been performed at other institutions, rather than because of a worse clinical course. Nevertheless, this requirement may have introduced a selection bias which, together with the potential guarantee-time bias, limits the generalizability of the PFS findings.

Finally, classification into the "Muscle loss group" and "Muscle preservation group" was based on the direction of PMV change (decreased versus stable/increased), without validated absolute or percentage cutoffs. These groups therefore describe longitudinal muscle volume changes and should not be interpreted as diagnostic or severity categories of sarcopenia according to EWGSOP2 criteria.

## 5. Conclusions

In this exploratory cohort of patients with BCLC-B HCC treated with yttrium-90 TARE, longitudinal loss of partial psoas muscle volume was associated with a lower objective response rate at 3 months and shorter PFS. These findings suggest that serial PMV assessment may provide complementary information on muscle changes during post-treatment follow-up. Because PMV can be derived from routinely acquired CT examinations without additional imaging or radiation exposure, it represents a practical approach with potential clinical relevance. Larger prospective studies are needed to validate these associations, establish measurement reproducibility and clinically significant thresholds, and determine whether ΔPMV provides prognostic information beyond established clinical factors.

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**Informed Consent Statement:** Written informed consent obtained at the time of the TARE procedure also covered the use of anonymized clinical and imaging data for research purposes. The present retrospective analysis relied on this previously obtained consent, and no additional consent was obtained specifically for this study.

**Data Availability Statement:** All relevant data supporting the findings of this study are included in the article. Additional details are available from the corresponding author upon request.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| AFP | alpha-fetoprotein |
| ALT | alanine aminotransferase |
| AST | aspartate aminotransferase |
| BCLC | Barcelona Clinic Liver Cancer |
| BMI | body mass index |
| BUN | blood urea nitrogen |
| CI | confidence interval |
| CR | complete response |
| CT | computed tomography |
| ECOG | Eastern Cooperative Oncology Group |
| EWGSOP2 | European Working Group on Sarcopenia in Older People 2 |
| GGT | gamma-glutamyl transferase |
| HCC | hepatocellular carcinoma |
| HR | hazard ratio; |
| INR | international normalized ratio |
| mRECIST | modified Response Evaluation Criteria in Solid Tumors |
| NTL | non-tumoral liver |
| ORR | objective response rate |
| PD | progressive disease |
| PFS | progression-free survival |
| PIVKA-II | protein induced by vitamin K absence or antagonist-II |
| PLT | platelet count |
| PMI | psoas muscle index |
| PMV | partial psoas muscle volume |
| PR | partial response |
| SD | stable disease |
| SMI | skeletal muscle index |
| SPECT/CT | single-photon emission computed tomography/computed tomography |
| TARE | transarterial radioembolization |
| WBC | white blood cell count |
| 99mTc-MAA | technetium-99m macroaggregated albumin |

## References

1. Sung, H.; Ferlay, J.; Siegel, R.L.; Laversanne, M.; Soerjomataram, I.; Jemal, A.; Bray, F. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA A Cancer J. Clin.* **2021**, *71*, 209–249. https://doi.org/10.3322/caac.21660.
2. Cruz-Jentoft, A.J.; Bahat, G.; Bauer, J.; Boirie, Y.; Bruyère, O.; Cederholm, T.; Cooper, C.; Landi, F.; Rolland, Y.; Sayer, A.A.; et al. Sarcopenia: Revised European consensus on definition and diagnosis. *Age Ageing* **2019**, *48*, 16–31. https://doi.org/10.1093/ageing/afy169.
3. Baracos, V.; Arribas, L. Sarcopenic obesity: Hidden muscle wasting and its impact for survival and complications of cancer therapy. *Ann. Oncol.* **2018**, *29*, ii1–ii9. https://doi.org/10.1093/annonc/mdx810.
4. Shachar, S.S.; Williams, G.R.; Muss, H.B.; Nishijima, T.F. Prognostic value of sarcopenia in adults with solid tumours: A meta-analysis and systematic review. *Eur. J. Cancer* **2016**, *57*, 58–67. https://doi.org/10.1016/j.ejca.2015.12.030.
5. Caan, B.J.; Cespedes Feliciano, E.M.; Prado, C.M.; Alexeeff, S.; Kroenke, C.H.; Bradshaw, P.; Quesenberry, C.P.; Weltzien, E.K.; Castillo, A.L.; Olobatuyi, T.A.; et al. Association of Muscle and Adiposity Measured by Computed Tomography with Survival in Patients with Nonmetastatic Breast Cancer. *JAMA Oncol.* **2018**, *4*, 798–804. https://doi.org/10.1001/jamaoncol.2018.0137.

6. Jiang, C.; Wang, Y.; Fu, W.; Zhang, G.; Feng, X.; Wang, X.; Wang, F.; Zhang, L.; Deng, Y. Association between sarcopenia and prognosis of hepatocellular carcinoma: A systematic review and meta-analysis. *Front. Nutr.* **2022**, *9*, 978110. https://doi.org/10.3389/fnut.2022.978110.
7. Guo, Y.; Ren, Y.; Zhu, L.; Yang, L.; Zheng, C. Association between sarcopenia and clinical outcomes in patients with hepatocellular carcinoma: An updated meta-analysis. *Sci. Rep.* **2023**, *13*, 1–10. https://doi.org/10.1038/s41598-022-27238-z.
8. Cespiati, A.; Smith, D.; Lombardi, R.; Fracanzani, A.L. The Negative Impact of Sarcopenia on Hepatocellular Carcinoma Treatment Outcomes. *Cancers* **2024**, *16*, 2315. https://doi.org/10.3390/cancers16132315.
9. Chen, Y.-C.; Kuo, M.-H.; Hsu, C.-S.; Kao, I.-T.; Wu, C.-Y.; Tseng, C.-W.; Shao, S.-C. Impact of Low Muscle Mass on Hepatocellular Carcinoma Patients Undergoing Transcatheter Liver-Directed Therapies: Systematic Review & Meta-Analysis. *Cancers* **2024**, *16*, 319. https://doi.org/10.3390/cancers16020319.
10. Rollins, K.E.; Gopinath, A.; Awwad, A.; Macdonald, I.A.; Lobo, D.N. Computed tomography-based psoas skeletal muscle area and radiodensity are poor sentinels for whole L3 skeletal muscle values. *Clin. Nutr.* **2020**, *39*, 2227–2232. https://doi.org/10.1016/j.clnu.2019.10.003.
11. Pigneur, F.; Di Palma, M.; Raynard, B.; Guibal, A.; Cohen, F.; Daidj, N.; Aziza, R.; El Hajjam, M.; Louis, G.; Goldwasser, F.; et al. Psoas muscle index is not representative of skeletal muscle index for evaluating cancer sarcopenia. *J. Cachexia Sarcopenia Muscle* **2023**, *14*, 1613–1620. https://doi.org/10.1002/jcsm.13230.
12. Mourtzakis, M.; Prado, C.M.M.; Lieffers, J.R.; Reiman, T.; McCargar, L.J.; Baracos, V.E. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. *Appl. Physiol. Nutr. Metab.* **2008**, *33*, 997–1006. https://doi.org/10.1139/H08-075.
13. Takahashi, M.; Sakamoto, K.; Kogure, Y.; Nojiri, S.; Tsuchiya, Y.; Honjo, K.; Kawai, M.; Ishiyama, S.; Sugimoto, K.; Nagakari, K.; et al. Use of 3D-CT-derived psoas major muscle volume in defining sarcopenia in colorectal cancer. *BMC Cancer* **2024**, *24*, 1–10. https://doi.org/10.1186/s12885-024-12524-y.
14. Singal, A.G.; Llovet, J.M.; Yarchoan, M.; Mehta, N.; Heimbach, J.K.; Dawson, L.A.; Jou, J.H.; Kulik, L.M.; Agopian, V.G.; Marrero, J.A.; et al. AASLD Practice Guidance on prevention, diagnosis, and treatment of hepatocellular carcinoma. *Hepatology* **2023**, *78*, 1922–1965. https://doi.org/10.1097/hep.0000000000000466.
15. Reig, M.; Sanduzzi-Zamparelli, M.; Forner, A.; Rimola, J.; Ferrer-Fàbrega, J.; Burrel, M.; Garcia-Criado, Á.; Díaz, A.; Llarch, N.; Iserte, G.; et al. BCLC strategy for prognosis prediction and treatment recommendations: The 2026 update. *J. Hepatol.* **2026**, *84*, 631–654. https://doi.org/10.1016/j.jhep.2025.10.020.
16. Nam, H.; Yang, H.; Chun, H.S.; Lee, H.A.; Nam, J.Y.; Jang, J.W.; Seo, Y.S.; Kim, D.Y.; Kim, Y.J.; Bae, S.H. Impact of Low Skeletal Muscle Mass on Long-Term Outcomes in Hepatocellular Carcinoma Treated with Trans-Arterial Radioembolization: A Retrospective Multi-Center Study. *Cancers* **2023**, *15*, 5195. https://doi.org/10.3390/cancers15215195.
17. Vangelov, B.; Bauer, J.; Kotevski, D.; Smee, R.I. The use of alternate vertebral levels to L3 in computed tomography scans for skeletal muscle mass evaluation and sarcopenia assessment in patients with cancer: A systematic review. *Br. J. Nutr.* **2021**, *127*, 722–735. https://doi.org/10.1017/s0007114521001446.
18. Trobiani, C.; Ubaldi, N.; Teodoli, L.; Tipaldi, M.A.; Cappelli, F.; Ungania, S.; Vallati, G. The Deterioration of Sarcopenia Post-Transarterial Radioembolization with Holmium-166 Serves as a Predictor for Disease Progression at 3 Months in Patients with Advanced Hepatocellular Carcinoma: A Pilot Study. *J. Pers. Med.* **2024**, *14*, 511. https://doi.org/10.3390/jpm14050511.
19. Pasciak, A.S.; Bourgeois, A.C.; Bradley, Y.C. A Comparison of Techniques for 90Y PET/CT Image-Based Dosimetry Following Radioembolization with Resin Microspheres. *Front. Oncol.* **2014**, *4*, 121. https://doi.org/10.3389/fonc.2014.00121.
20. Lencioni, R.; Llovet, J.M. Modified RECIST (mRECIST) Assessment for Hepatocellular Carcinoma. *Semin. Liver Dis.* **2010**, *30*, 052–060. https://doi.org/10.1055/s-0030-1247132.
21. Vallati, G.E.; Trobiani, C.; Teodoli, L.; Lai, Q.; Cappelli, F.; Ungania, S.; Catalano, C.; Lucatelli, P. Sarcopenia Worsening One Month after Transarterial Radioembolization Predicts Progressive Disease in Patients with Advanced Hepatocellular Carcinoma. *Biology* **2021**, *10*, 728. https://doi.org/10.3390/biology10080728.
22. Faron, A.; Sprinkart, A.M.; Pieper, C.C.; Kuetting, D.L.; Fimmers, R.; Block, W.; Meyer, C.; Thomas, D.; Attenberger, U.; Luetkens, J.A. Yttrium-90 radioembolization for hepatocellular carcinoma: Outcome prediction with MRI derived fat-free muscle area. *Eur. J. Radiol.* **2020**, *125*, 108889. https://doi.org/10.1016/j.ejrad.2020.108889.
23. Wu, C.-H.; Ho, M.-C.; Chen, C.-H.; Liang, J.-D.; Huang, K.-W.; Cheng, M.-F.; Chang, C.-K.; Chang, C.-H.; Liang, P.-C. Computed Tomography-Defined Sarcopenia in Outcomes of Patients with Unresectable Hepatocellular Carcinoma Undergoing Radioembolization: Assessment with Total Abdominal, Psoas, and Paraspinal Muscles. *Liver Cancer* **2023**, *12*, 550–564. https://doi.org/10.1159/000529676.

24. Guichet, P.L.; Taslakian, B.; Zhan, C.; Aaltonen, E.; Farquharson, S.; Hickey, R.; Horn, C.J.; Gross, J.S. MRI-Derived Sarcopenia Associated with Increased Mortality Following Yttrium-90 Radioembolization of Hepatocellular Carcinoma. *Cardiovasc. Interv. Radiol.* **2021**, *44*, 1561–1569. https://doi.org/10.1007/s00270-021-02874-6.
25. Steinberg-Vorhoff, H.L.; Ketelsen, A.; Schuch, T.; Theysohn, J.M.; Schaarschmidt, B.M.; Haubold, J.; Vahidi Noghani, F.; Jeschke, M.; Jochheim, L.; Ludwig, J.M. Muscle and fat matter: Automated CT-based body composition analysis predicts survival in hepatocellular carcinoma patients undergoing radioembolization. *Eur. J. Radiol. Open* **2026**, *16*, 100721. https://doi.org/10.1016/j.ejro.2025.100721.
26. Ozbay, Y.; Eldem, F.G.; Cay, F.; Bozkurt, M.F.; Salancı, B.V.; Ormancı, A.; Aydingoz, U.; Dizdar, O.; Peynircioglu, B. Sarcopenia, myosteatosis, and skeletal muscle loss as predictors of poor prognosis in hepatocellular carcinoma patients undergoing intra-arterial therapies. *Clin. Radiol.* **2026**, *95*, 107259. https://doi.org/10.1016/j.crad.2026.107259.
27. Loosen, S.H.; Schulze-Hagen, M.; Bruners, P.; Tacke, F.; Trautwein, C.; Kuhl, C.; Luedde, T.; Roderburg, C. Sarcopenia Is a Negative Prognostic Factor in Patients Undergoing Transarterial Chemoembolization (TACE) for Hepatic Malignancies. *Cancers* **2019**, *11*, 1503. https://doi.org/10.3390/cancers11101503.
28. Bannangkoon, K.; Hongsakul, K.; Tubtawee, T.; Ina, N. Prognostic Value of Myosteatosis and Albumin–Bilirubin Grade for Survival in Hepatocellular Carcinoma Post Chemoembolization. *Cancers* **2024**, *16*, 3503. https://doi.org/10.3390/cancers16203503.
29. Morsbach, F.; Zhang, Y.-H.; Martin, L.; Lindqvist, C.; Brismar, T.B. Body composition evaluation with computed tomography: Contrast media and slice thickness cause methodological errors. *Nutrition* **2019**, *59*, 50–55. https://doi.org/10.1016/j.nut.2018.08.001.
30. Giobbie-Hurder, A.; Gelber, R.D.; Regan, M.M. Challenges of guarantee-time bias. *J. Clin. Oncol.* **2013**, *31*, 2963–2969. https://doi.org/10.1200/JCO.2013.49.5283.


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