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Review

OBESUS (OBESity UltraSound): A Multiorgan Bedside Ultrasound Framework for Obesity Phenotyping

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Abstract

Obesity is a heterogeneous chronic disease in which cardiometabolic and functional risks are influenced not only by total body fat but also by adipose tissue distribution, ectopic lipid accumulation in non-adipose tissues, and alterations in skeletal muscle composition. Traditional anthropometric measurements, such as body mass index and waist circumference, fail to capture these biological differences. Point-of-care ultrasound provides a portable, radiation-free, repeatable, and widely available bedside tool for assessing multiple adipose and muscular compartments, yet a broadly standardized framework integrating these measurements into a multiorgan obesity phenotype remains lacking. We propose OBESUS (OBESity UltraSound), a pragmatic multiorgan point-of-care ultrasound framework for structured obesity phenotyping. To facilitate competency-based and stepwise implementation, OBESUS comprises two complementary tiers: OBESUS-Core evaluates abdominal subcutaneous adiposity, preperitoneal fat thickness, hepatic steatosis, and rectus femoris muscle echogenicity, whereas OBESUS-Plus incorporates epicardial and perirenal adipose tissue as additional regional adipose tissue depots of cardiorenal relevance. Rather than generating a numerical score, the framework integrates these findings into four non-mutually exclusive ultrasound-derived phenotypes: metabolic, increased muscle echogenicity, epicardial adiposity, and perirenal adiposity. This narrative review describes the conceptual basis, standardized acquisition methodology, pragmatic reference thresholds, and potential clinical applications of OBESUS. The framework is intended to provide a foundation for prospective evaluation of its reproducibility, clinical validity, prognostic significance and potential utility for longitudinal monitoring.

Keywords: obesity; point-of-care ultrasound; body composition; ectopic fat; myosteatosis

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Academic Editor: Zhuhuang Zhou

Received: 3 October 2026
Revised: 8 November 2026
Accepted: 11 November 2026
Published: 16 November 2026

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1. Introduction

Obesity is a chronic, relapsing, multifactorial disease characterized by excess and dysfunctional adiposity. It represents one of the greatest healthcare challenges of the twenty-first century and is a major contributor to cardiovascular disease, chronic kidney

disease, metabolic dysfunction-associated steatotic liver disease (MASLD), sarcopenic obesity, frailty, disability, loss of functional independence and premature mortality [1]. Traditionally, obesity has been defined and classified using anthropometric parameters such as body mass index (BMI) and waist circumference. Although these measurements remain useful for population-level screening, they provide only a partial representation of the biological complexity of obesity and fail to adequately characterize the heterogeneity observed among individuals with similar body weight or BMI [2,3].

Increasing evidence indicates that obesity should no longer be understood merely as an excess of body weight, but rather as a chronic adiposity-based disease characterized by marked interindividual variability in adipose tissue distribution and function, regional adipose tissue expansion, ectopic lipid accumulation in non-adipose tissues, and alterations in skeletal muscle composition. These distinctions are consistent with contemporary methodological standards for body composition assessment, which differentiate adipose tissue as a tissue-level compartment from fat as a molecular-level component [4]. Contemporary concepts such as adiposopathy, dysfunctional adipose tissue expansion, and the personal fat threshold hypothesis have demonstrated that metabolic risk is determined not only by the amount of adipose tissue but also by its anatomical distribution and biological behaviour. Individuals with similar BMI values may therefore exhibit profoundly different cardiometabolic risk profiles depending on their capacity to safely store excess energy and the tendency to develop ectopic fat accumulation [2,3,5–8].

The growing recognition of obesity as a heterogeneous disease has led to a shift from weight-centered approaches toward phenotype-based models. Recent scientific statements and clinical practice guidelines emphasize that adipose tissue distribution is a stronger determinant of cardiometabolic risk than BMI alone [9]. In particular, visceral adiposity, the expansion of specific regional adipose tissue depots and ectopic lipid accumulation in non-adipose tissues have been implicated in insulin resistance, chronic low-grade inflammation, lipotoxicity and organ dysfunction. Conversely, subcutaneous adipose tissue, especially when functioning as an expandable metabolic reservoir, may exert relatively protective effects by limiting ectopic fat deposition. This paradigm highlights the need for tools capable of characterizing adipose tissue compartments in a simple, reproducible and clinically accessible manner [2,3,10].

Hepatic steatosis, characterized by excessive intracellular lipid accumulation in hepatocytes, represents one of the most prevalent manifestations of metabolic dysfunction and constitutes a central component of the MASLD spectrum [11]. In contrast, epicardial and perirenal adipose tissue are anatomically defined adipose tissue depots whose expansion may be associated with adverse cardiometabolic outcomes. Epicardial adipose tissue has been associated with coronary atherosclerosis, myocardial infarction, atrial fibrillation, heart failure, and cardiovascular mortality [12]. Similarly, perirenal adipose tissue has also emerged as a clinically relevant ectopic fat depot, being independently associated with chronic kidney disease, reduced glomerular filtration rate, hypertension and adverse cardiometabolic profiles [13]. In parallel, skeletal muscle alterations, particularly myosteatosis and sarcopenic obesity, have emerged as important determinants of frailty, disability, hospitalization, and poor clinical outcomes [14]. These observations support the concept that obesity should be assessed as a multiorgan disease involving interconnected adipose and muscular compartments rather than as a simple excess of total body fat.

Advanced imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and dual-energy X-ray absorptiometry (DXA) provide accurate assessment of body composition and adipose tissue distribution. However, their widespread implementation is limited by cost, exposure to ionizing radiation (for CT and DXA), the need for specialized equipment and trained personnel and limited accessibility in rou-

tine clinical practice [15]. In contrast, clinical ultrasound offers a portable, radiation-free, inexpensive and repeatable point-of-care alternative that enables bedside assessment of multiple adipose and muscular compartments during a single examination [16]. Ultrasound-based approaches have been described for the assessment of abdominal subcutaneous and preperitoneal fat, hepatic steatosis, epicardial and perirenal adipose tissue, and skeletal muscle echogenicity, although their degree of validation and clinical evidence varies across compartments [2].

Despite this growing body of evidence, ultrasound assessment of obesity remains largely compartment-centered, with most studies evaluating individual anatomical depots or body-composition parameters in isolation [2]. Recent multicompartmental approaches, such as the Eco-Obesity assessment, have demonstrated the feasibility of combining ultrasound measurements of several abdominal and ectopic fat depots and have highlighted their relationships with cardiometabolic parameters [17]. However, a broadly standardized point-of-care framework integrating abdominal fat distribution, hepatic ectopic lipid accumulation, regional adipose tissue depots of cardiorenal relevance and skeletal muscle echogenicity within a structured multiorgan examination remains lacking. Such integration may provide a more comprehensive representation of obesity-related tissue involvement while preserving the accessibility and repeatability of bedside ultrasound.

Building on the methodological precedent of structured multiorgan ultrasound protocols in Internal Medicine, such as those developed for vascular risk assessment [18], we propose the OBESUS (OBESity UltraSound) framework, a pragmatic and scalable point-of-care ultrasound approach designed to phenotype obesity through the assessment of anatomically distinct but pathophysiologically interconnected compartments. The framework is structured into two complementary levels. OBESUS-Core focuses on four readily accessible domains: subcutaneous adiposity, visceral adiposity using preperitoneal fat as a surrogate marker, hepatic steatosis as a manifestation of ectopic lipid accumulation, and skeletal muscle echogenicity. OBESUS-Plus expands the assessment to epicardial and perirenal adipose tissue, incorporating additional regional adipose tissue depots with potential cardiovascular and renal relevance. This Core/Plus structure is intended to facilitate competency-based, stepwise implementation rather than to define separate protocols or restrict individual measurements to specific clinical specialties.

The purpose of this narrative review is to describe the conceptual basis and standardized technical methodology of the OBESUS framework, discuss its potential clinical applications and propose a preliminary ultrasound-based phenotypic classification of obesity. These phenotypes should be regarded as conceptual constructs intended to facilitate the structured interpretation of multiorgan ultrasound findings rather than as formally validated diagnostic or prognostic entities.

2. The OBESUS Concept

2.1. Rationale and Conceptual Framework

The OBESUS framework applies a compartment-based point-of-care ultrasound approach to characterize the heterogeneous distribution of adipose and muscular tissue in obesity. Each ultrasound domain represents a distinct but interconnected component of the obesity phenotype, encompassing subcutaneous and visceral adiposity, ectopic lipid accumulation, regional adipose tissue depots and skeletal muscle echogenicity. Rather than interpreting these measurements in isolation, OBESUS integrates them within a structured multiorgan assessment. To facilitate competency-based and stepwise implementation, the framework comprises two complementary levels: OBESUS-Core and OBESUS-Plus.

2.2. OBESUS-Core

OBESUS-Core constitutes the foundational component of the OBESUS framework and is designed to provide a rapid bedside characterization of four ultrasound-accessible domains: abdominal subcutaneous adipose tissue, preperitoneal fat thickness, hepatic steatosis and skeletal muscle echogenicity.

Abdominal subcutaneous adipose tissue is included in OBESUS-Core not only as an ancillary measurement, but as an essential component for characterizing body fat distribution. While visceral adiposity is more strongly associated with cardiometabolic risk than total adiposity, individuals with similar body mass index or waist circumference may exhibit markedly different proportions of visceral and subcutaneous fat, reflecting differences in adipose tissue expandability and ectopic fat deposition [5,9]. Several ultrasound-derived indices combining visceral and subcutaneous compartments, such as the abdominal wall fat index and visceral-to-subcutaneous fat ratios, have been proposed to better characterize adipose tissue distribution and its metabolic implications. In the original study by Suzuki et al., the abdominal wall fat index showed a strong correlation with the visceral-to-subcutaneous fat ratio assessed by computed tomography and was associated with higher triglyceride and basal insulin levels and lower high-density lipoprotein (HDL) cholesterol [19]. Consequently, the assessment of abdominal subcutaneous fat in OBESUS-Core is intended to complement visceral measurements, allowing a more comprehensive evaluation of adipose tissue distribution and contributing to ultrasound-based obesity phenotyping.

Preperitoneal fat thickness was selected as the visceral adiposity domain of OBESUS-Core because it provides a practical, reproducible and clinically feasible ultrasound surrogate of visceral fat accumulation. Unlike deeper visceral compartments, preperitoneal fat is superficial, readily accessible and can be measured rapidly during routine bedside examinations. Bazzocchi et al. demonstrated excellent agreement between ultrasound and computed tomography measurements of preperitoneal fat thickness, with strong correlations between both techniques ($r \approx 0.87$), high intra- and interobserver reproducibility and acquisition times of approximately two minutes, even in patients with obesity [20]. Beyond its role as a marker of visceral fat burden, MRI-derived preperitoneal fat area has also been associated with histologically proven liver steatosis, steatohepatitis and liver fibrosis in patients with type 2 diabetes and was identified as the strongest predictor of steatohepatitis in the study by Braz Parente et al. [21]. Collectively, these findings support the inclusion of preperitoneal fat thickness as a practical ultrasound surrogate of visceral adiposity within OBESUS-Core and as a marker associated with obesity-related metabolic dysfunction.

Hepatic steatosis was selected as the ectopic lipid accumulation domain of OBESUS-Core because the liver is one of the most clinically relevant and extensively studied sites of lipid deposition in non-adipose tissues. Beyond a simple hepatic manifestation, liver fat deposition reflects systemic adipose tissue dysfunction and is closely associated with insulin resistance, type 2 diabetes, dyslipidaemia, cardiovascular disease and the spectrum of metabolic dysfunction-associated steatotic liver disease (MASLD) [11]. As such, hepatic steatosis represents a readily accessible marker of metabolic overload and ectopic lipid deposition within the broader obesity phenotype. Conventional B-mode ultrasonography remains a widely available imaging modality for assessing hepatic steatosis in routine clinical practice. Recent meta-analytic evidence supports its diagnostic utility while highlighting reduced performance for mild steatosis and improved accuracy with attenuation-based quantitative ultrasound techniques [22]. Within the OBESUS framework, liver ultrasound is not intended to replace contemporary MASLD diagnostic pathways or fibrosis risk stratification algorithms. Rather, its purpose is to identify and characterize hepatic ectopic fat as one component of a comprehensive multiorgan assessment of obesity. This distinction is particularly important given that conventional ultrasonography shows reduced sensitivity

for mild steatosis and does not allow accurate quantification of liver fat content [23]. Recent position papers have highlighted the growing role of quantitative ultrasound techniques, including attenuation-based methods and other emerging technologies, for the objective assessment of hepatic steatosis [24]. Although these techniques are not currently incorporated into the core OBESUS examination, they may complement future versions of the framework and facilitate longitudinal monitoring of obesity-related changes in ectopic fat deposition.

Skeletal muscle assessment is also included in OBESUS-Core because obesity-related risk is influenced not only by adipose tissue distribution but also by obesity-associated alterations in skeletal muscle composition. In recent years, myosteatosis, defined as pathological fat infiltration within skeletal muscle, has emerged as an important component of obesity-related muscle dysfunction and has been associated with frailty, impaired physical performance, metabolic dysfunction and adverse clinical outcomes [14]. Ultrasound provides a practical bedside method for assessing skeletal muscle echogenicity, which may reflect alterations in muscle composition, including fat infiltration and fibrosis [25]. Within the OBESUS framework, the rectus femoris was selected because it is easily accessible and commonly used for ultrasound assessment of lower-limb muscle status. The Modified Heckmatt Scale offers a simple semiquantitative assessment of muscle echogenicity and has demonstrated good inter- and intra-rater reliability and strong correlation with quantitative grayscale analysis [26], although its validation was performed primarily in patients with spasticity. Unlike traditional assessments focused on muscle mass, OBESUS incorporates rectus femoris echogenicity as an indirect marker of altered skeletal muscle composition. Importantly, increased echogenicity is not specific for intramuscular fat accumulation and should not be interpreted as definitive evidence of myosteatosis. Accordingly, rectus femoris echogenicity is incorporated as the muscular domain of the protocol, providing a feasible bedside marker of altered skeletal muscle composition potentially related to myosteatosis within a multiorgan ultrasound evaluation of obesity.

2.3. OBESUS-Plus

2.3.1. Cardiovascular Ectopic Adiposity: Epicardial Adipose Tissue

Epicardial adipose tissue (EAT) is included in OBESUS-Plus as a regional adipose tissue depot of cardiovascular relevance because its assessment may provide information that extends beyond conventional measures of adiposity and reflects the interaction between obesity, inflammation and cardiovascular disease [27]. Anatomically, EAT is located between the myocardium and the visceral layer of the pericardium, surrounding the coronary arteries without an intervening fascial barrier. This unique anatomical relationship enables direct paracrine and vasocrine communication between adipose tissue and the adjacent vascular wall, distinguishing EAT from other regional adipose tissue depots [28].

Under physiological conditions, EAT contributes to myocardial energy homeostasis and provides mechanical and thermogenic support. However, obesity and metabolic dysfunction induce profound changes in its biological behaviour, including adipocyte hypertrophy, inflammatory cell infiltration and increased secretion of pro-inflammatory cytokines such as interleukin-1 beta (IL-1β), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF-α) and monocyte chemoattractant protein-1 (MCP-1) [29]. These alterations have been implicated in local vascular inflammation and may contribute to the development and progression of coronary atherosclerosis through the so-called “outside-in” hypothesis, whereby inflammatory signalling originating in perivascular adipose tissue influences the underlying arterial wall [30].

A growing body of evidence supports the association between EAT and adverse cardiovascular outcomes. In a systematic review and meta-analysis including 3772 patients,

Nerlekar et al. demonstrated that increasing EAT was significantly associated with the presence of high-risk coronary plaque characteristics (*odds ratio* (OR) 1.26, 95% confidence interval (CI) 1.11–1.43; $p < 0.001$). Notably, this association was primarily supported by volumetric EAT assessment, whereas evidence for linear EAT thickness was more limited. Patients with vulnerable plaques also exhibited greater epicardial fat volumes than those without such features [31].

Beyond coronary atherosclerosis, EAT has been linked to atrial fibrillation, heart failure, metabolic syndrome, type 2 diabetes mellitus and cardiovascular mortality. As summarized by Tarsitano et al., epicardial fat appears to represent a biologically active adipose depot whose quantity and inflammatory profile may provide incremental prognostic information beyond traditional cardiovascular risk factors [32].

Although volumetric quantification by computed tomography or cardiac magnetic resonance imaging remains the reference standard for EAT assessment, echocardiographic measurement of epicardial fat thickness offers a pragmatic, radiation-free and widely accessible alternative suitable for routine clinical ultrasound evaluation [29]. While linear thickness measurements do not fully capture total EAT volume, echocardiography allows rapid bedside assessment and has demonstrated clinically relevant associations with both metabolic and cardiovascular outcomes [12].

Recent evidence further supports the integration of epicardial adipose tissue into multiorgan ultrasound protocols for obesity assessment. In a standardized ultrasound body composition study, epicardial fat thickness correlated with DXA-derived visceral adiposity as well as abdominal ectopic fat depots, including omental and perirenal fat, reinforcing the concept that epicardial adiposity should not be interpreted as an isolated cardiac finding but rather as one component of a broader ectopic fat network [17]. These observations provide additional support for incorporating epicardial adipose tissue into multiorgan ultrasound frameworks such as OBESUS, where individual fat depots are interpreted collectively to improve obesity phenotyping.

2.3.2. Perirenal Adipose Tissue: Pathophysiological and Clinical Rationale

Perirenal fat is included in OBESUS-Plus as an exploratory marker of obesity-related renal and metabolic involvement. Perirenal adipose tissue is an anatomically defined adipose tissue depot confined within the renal fascia and surrounds the kidneys in close proximity to the renal vasculature and parenchyma. This unique anatomical location has generated increasing interest in recent years, as several studies have demonstrated that perirenal fat thickness correlates with traditional measures of obesity, visceral adiposity and metabolic dysfunction. However, its clinical relevance appears to extend beyond its association with overall adiposity. In hypertensive patients, Geraci et al. showed that para-perirenal ultrasonographic fat thickness was independently associated with reduced estimated glomerular filtration rate (eGFR), even after adjustment for body mass index, waist circumference and other anthropometric indices. Moreover, para-perirenal fat thickness demonstrated greater discriminatory capacity for impaired renal function than conventional obesity markers, suggesting that regional fat distribution may provide clinically relevant information not captured by anthropometry alone [13].

Additional evidence comes from patients with type 2 diabetes. In a longitudinal cohort study using CT-derived perirenal fat thickness, Chen et al. demonstrated that greater perirenal fat thickness independently predicted the development of chronic kidney disease (CKD), whereas total body fat, subcutaneous adipose tissue and visceral adipose tissue did not retain predictive value after multivariable adjustment. Notably, each standard deviation increase in baseline perirenal fat thickness was associated with a significantly higher risk of incident CKD, supporting the concept that perirenal fat may represent a specific ectopic

fat depot involved in obesity-related renal injury [33]. More recently, Shen et al. described the sonographic appearance of hypoechoic perinephric fat and reported that its presence was strongly associated with prediabetes and diabetes, reporting very high specificity and positive predictive value, although with low sensitivity, for identifying prediabetes or diabetes [34].

The biological plausibility of these findings is supported by several proposed mechanisms. Perirenal adipose tissue is metabolically active and secretes adipokines, inflammatory mediators and free fatty acids that may directly influence renal microcirculation and promote local inflammation [35,36]. In addition, the anatomical confinement imposed by the renal fascia may facilitate local compression of renal vessels and parenchyma, potentially contributing to increased interstitial pressure, altered renal hemodynamics and progressive renal dysfunction [37].

Collectively, these observations support further investigation of perirenal adipose tissue as an ultrasound-accessible marker of obesity-related metabolic and renal involvement.

3. Technical Implementation of the OBESUS Framework

OBESUS is designed as a standardized multiorgan ultrasound examination performed during a single bedside assessment. Moving beyond traditional anthropometrics, the framework allows direct visualization of interconnected adipose and muscular compartments to characterize individual patterns of tissue involvement rather than generating a rigid diagnostic score. While it does not replace reference imaging techniques such as computed tomography or magnetic resonance imaging when precise body-composition quantification is required, OBESUS provides a practical and radiation-free bedside framework for multidimensional obesity characterization.

Although the conceptual structure of OBESUS distinguishes between Core and Plus components, this distinction is intended to facilitate stepwise implementation according to the operator's ultrasound competencies and the clinical objectives of the examination, rather than to establish separate protocols or restrict their use to specific medical specialties. OBESUS-Core relies primarily on conventional B-mode ultrasound techniques and commonly available transducers, whereas OBESUS-Plus incorporates additional assessments that may require more advanced training, particularly for echocardiographic measurement of epicardial adipose tissue. Accordingly, operators may progressively incorporate additional ultrasound domains as they acquire experience with multiorgan ultrasound assessment, following a competency-based approach consistent with contemporary recommendations for *point-of-care ultrasound* POCUS education and implementation [38].

The technical implementation of the OBESUS framework follows a standardized approach. The four domains comprising OBESUS-Core, along with their anatomical landmarks and ultrasound acquisition patterns, are illustrated in Figure 1. To evaluate organ-specific cardiorenal ectopic fat, OBESUS-Plus incorporates epicardial and perirenal adipose tissue assessment (Figure 2). Table 1 provides a ready-to-use reference summarizing the recommended acquisition techniques and suggested reference thresholds for each OBESUS domain.

Table 1. Technical reference guide for OBESUS ultrasound acquisition and reference thresholds.

Compartment	Technique	Suggested Reference Threshold *
Preperitoneal fat	Linear 7–12 MHz, along the *linea alba* (midpoint between xiphoid and umbilicus)	≥12 mm
Abdominal subcutaneous fat	Linear 7–12 MHz, 1–2 cm below umbilicus	No isolated cut-off; AFI > 1 suggests visceral predominance †

Table 1. *Cont.*

Compartment	Technique	Suggested Reference Threshold *
Perirenal fat	Convex 2–5 MHz, coronal flank view	≥22.5 mm in men and ≥12.5 mm in women
Epicardial fat	Phased array 2–4 MHz, parasternal long-axis (end-systole)	≥7 mm
Hepatic steatosis	Convex 2–5 MHz, longitudinal/intercostal view	Grade ≥ 2 (moderate)
Rectus femoris muscle echogenicity	Linear 7–12 MHz, transverse view at the junction of the proximal two-thirds and distal one-third of the thigh	Modified Heckmatt ≥ 3

* Suggested reference thresholds are based on the best available observational evidence and are intended to facilitate standardized ultrasound phenotyping within the OBESUS framework. They should not be interpreted as universally validated diagnostic cut-offs and may vary according to population characteristics, clinical outcomes and imaging methodology. † The Abdominal Fat Index (AFI) is calculated as the ratio between maximum preperitoneal fat thickness and minimum subcutaneous fat thickness. AFI values > 1 may suggest a relative predominance of preperitoneal over subcutaneous adiposity, although this value has not been validated as a diagnostic cut-off. Higher thresholds (approximately 1.18) have been proposed for specific clinical outcomes such as metabolic dysfunction-associated steatotic liver disease (MASLD) but require external validation before routine clinical application.

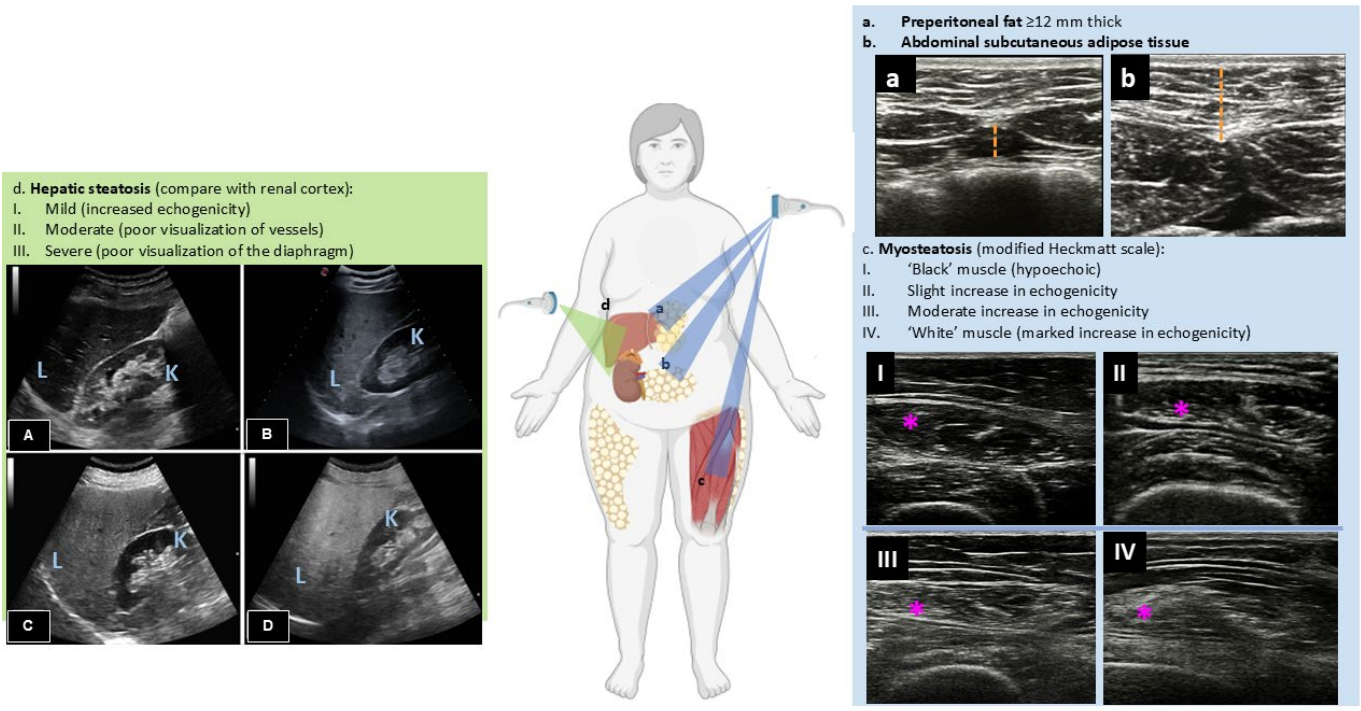


Figure 1. Schematic representation and representative bedside ultrasound images of the four OBESUS-Core domains. (**a**) Abdominal subcutaneous adipose tissue thickness measured with a linear transducer (7–12 MHz) placed 1–2 cm below the umbilicus. (**b**) Preperitoneal fat thickness evaluated along the linea alba (midpoint between the xiphoid process and the umbilicus) during end-expiration. (**c**) Rectus femoris muscle (*) echogenicity assessed at the junction between the proximal two-thirds and distal one-third of the thigh using the Modified Heckmatt Scale, ranging from normal hypoechoic "black" muscle (Grade I) to markedly increased muscle echogenicity with shadow formation ("white" muscle, Grade IV). (**d**) Hepatic steatosis evaluated in the right mid-axillary line with a convex transducer (2–5 MHz) by comparing liver parenchymal echogenicity with the adjacent renal cortex, categorized into Grade 1 (mild), Grade 2 (moderate), and Grade 3 (severe). In the ultrasound images, L indicates the liver, K indicates the kidney, and the asterisk (*) identifies the rectus femoris muscle.

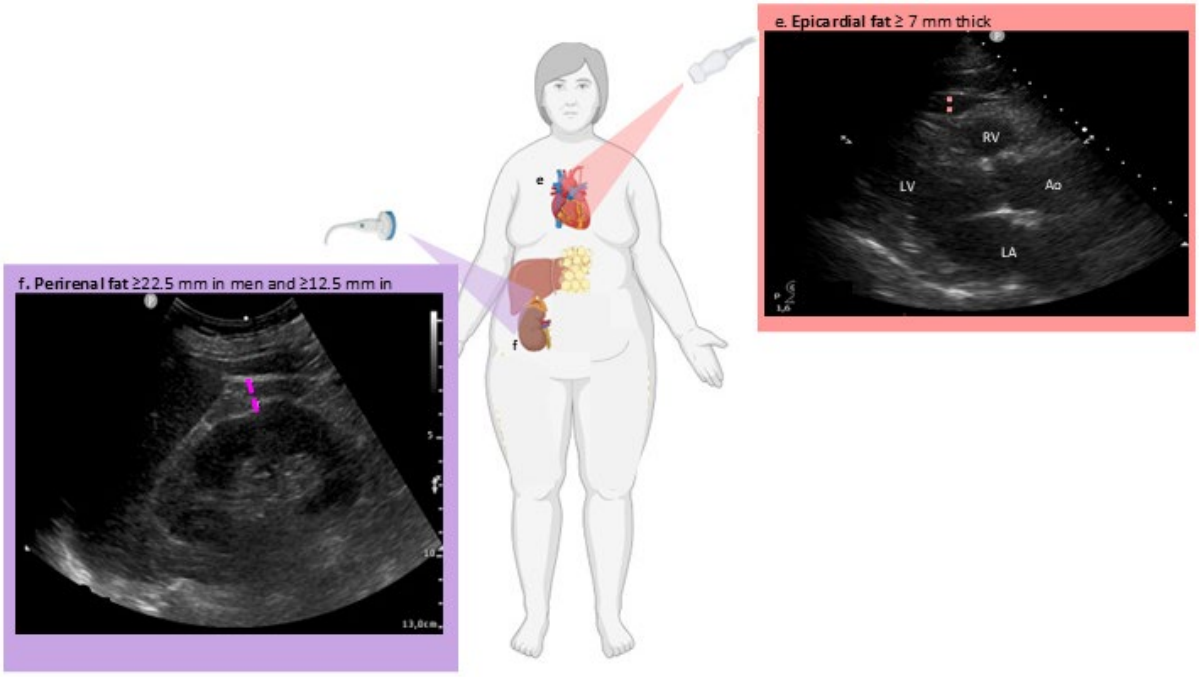


Figure 2. Schematic representation and representative ultrasound views of the OBESUS-Plus regional adipose tissue compartments. (**e**) Epicardial adipose tissue (EAT) measured with a phased-array transducer (2–4 MHz) in the parasternal long-axis view. EAT thickness is quantified perpendicular to the right ventricular free wall at end-systole over three cardiac cycles (reference threshold: ≥7 mm). LV: left ventricle; LA: left atrium; RV: right ventricle; Ao: aorta. (**f**) Perirenal fat thickness evaluated with a convex transducer (2–5 MHz) in a coronal flank view, measured as the distance between the renal capsule and the surrounding retroperitoneal fascia (suggested thresholds: ≥22.5 mm in men and ≥12.5 mm in women).

3.1. The OBESUS Profile

Rather than generating a single numerical score, the OBESUS framework is intended to describe the overall ultrasound profile of obesity by integrating findings across multiple adipose and muscular compartments. Four main ultrasound-derived phenotypes are proposed, each defined by the presence of abnormalities in specific ultrasound domains, using the provisional reference thresholds summarized in Table 1. The metabolic phenotype is characterized by increased preperitoneal adiposity and/or hepatic steatosis; the increased muscle echogenicity phenotype, by increased rectus femoris echogenicity; the epicardial adiposity phenotype, by increased epicardial adipose tissue thickness; and the perirenal adiposity phenotype, by increased perirenal adipose tissue thickness. Phenotype assignment is domain-based rather than hierarchical: an individual may exhibit one or several phenotypes simultaneously and no single phenotype is required to predominate. Subcutaneous adiposity is assessed as an additional descriptive component of the overall ultrasound profile but does not independently define any of the four proposed phenotypes. Because the biological and prognostic significance of these patterns has not yet been prospectively established, no weighting system or composite score is currently proposed. Accordingly, OBESUS phenotypes should be regarded as structured descriptive patterns for obesity phenotyping rather than as validated measures of disease severity or cardiometabolic risk. Future prospective studies should determine whether individual phenotypes or their combinations identify clinically meaningful patterns with distinct prognostic trajectories or therapeutic implications. The conceptual relationship between these ultrasound-derived

phenotypes and obesity-related cardiometabolic and mechanical comorbidities is illustrated in Figure 3.

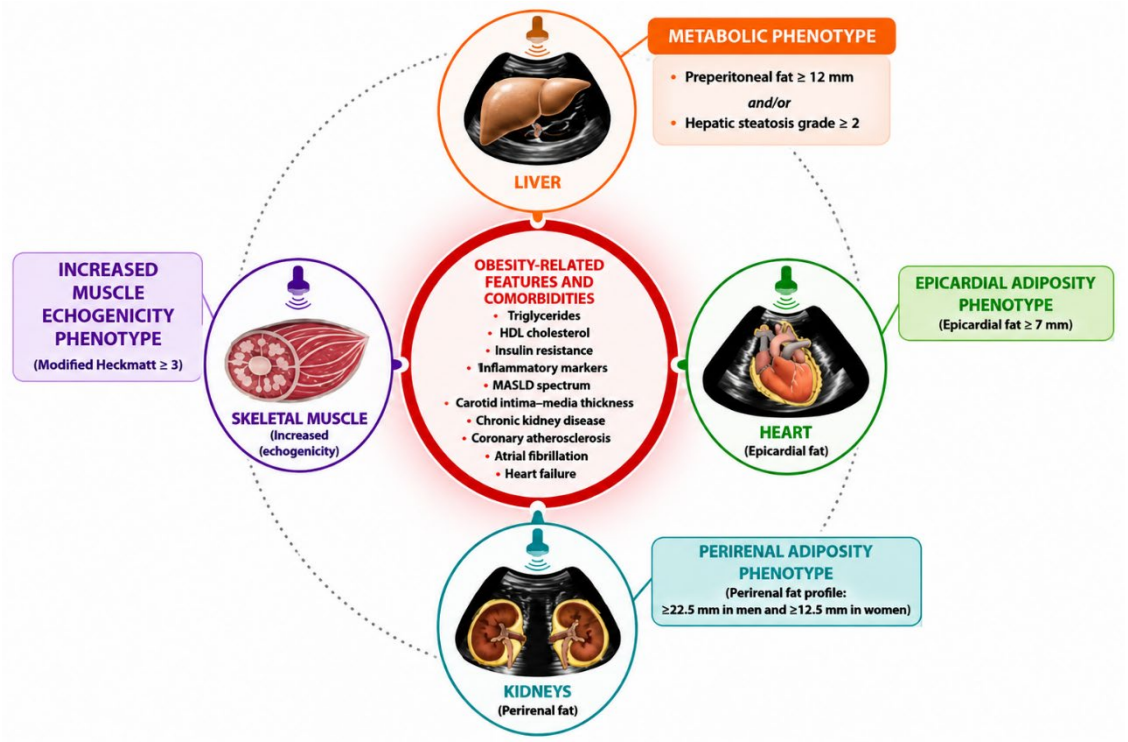


Figure 3. Conceptual integration of ultrasound-derived OBESUS phenotypes and obesity-related comorbidities. The framework identifies four main patterns of tissue involvement: metabolic, increased muscle echogenicity, epicardial adiposity, and perirenal adiposity phenotypes. These patterns are not mutually exclusive and may coexist within the same individual. The diagram illustrates their potential associations with systemic and organ-specific obesity-related complications rather than implying established causal or prognostic relationships. MASLD: metabolic dysfunction-associated steatotic liver disease.

3.2. Abdominal Subcutaneous Adipose Tissue

Abdominal subcutaneous adipose tissue is assessed using a linear transducer (7–12 MHz). In the supine position, the thickness of the subcutaneous compartment is measured as the distance between the dermis and the anterior fascia of the rectus abdominis muscle, typically 1–2 cm below the umbilicus. Particular care should be taken to avoid compression of the subcutaneous tissue during image acquisition [39].

The main limitations include variability related to probe pressure, difficulties standardizing the exact measurement site and alterations in tissue echogenicity caused by oedema, inflammation or other subcutaneous abnormalities [40].

The Abdominal Fat Index (AFI), originally proposed by Suzuki et al. as the ratio between maximum preperitoneal fat thickness and minimum subcutaneous fat thickness, provides an ultrasound estimate of the relative distribution of visceral and subcutaneous adiposity. In the original study, AFI correlated strongly with the visceral-to-subcutaneous fat ratio assessed by computed tomography [19]. More recently, Sezer et al. reported an AFI threshold of approximately 1.18 for identifying MASLD in a specific clinical population [41]. Given the limited evidence and population-specific variability, AFI should currently be interpreted as a complementary index of abdominal fat distribution rather than according to a universally validated diagnostic cut-off.

3.3. Preperitoneal Fat Thickness

Preperitoneal fat thickness is evaluated using a high-frequency linear transducer (7–12 MHz). With the patient in the supine position, the transducer is placed along the linea alba at the midpoint between the xiphoid process and the umbilicus. During end-expiration and without compressing the abdominal wall, the distance between the posterior surface of the rectus abdominis muscle and the anterior peritoneal line is measured [42].

Potential sources of error include compression of adipose tissue by excessive probe pressure, difficulties identifying the peritoneal interface in individuals with marked obesity, inaccurate alignment of the midline plane and reduced image quality due to bowel gas artefacts [43].

No universally accepted ultrasound threshold for preperitoneal fat thickness currently exists. Published cut-offs vary substantially according to ethnicity, study population, and the clinical outcome under investigation. For example, Bi et al. identified a threshold of approximately 12 mm to predict insulin resistance and low HDL cholesterol in Asian men [44], whereas Sezer et al. recently reported an optimal cut-off of >15.9 mm for identifying MASLD in a hepatology cohort [41]. These differences highlight that available thresholds are disease- and population-specific rather than universally applicable. Therefore, the OBESUS framework adopts ≥12 mm as a pragmatic reference threshold for standardized phenotyping, recognizing that future prospective studies in European populations are needed to establish clinically validated cut-offs.

3.4. Hepatic Steatosis

Hepatic steatosis is evaluated using a convex transducer (2–5 MHz). In longitudinal or transverse hepatic views, liver echogenicity is compared with that of the renal cortex. Increased hepatic echogenicity, posterior beam attenuation and impaired visualization of intrahepatic vessels are considered suggestive of steatosis. Steatosis is graded semi-quantitatively as grade 1 (mild), characterized by a slight increase in hepatic echogenicity with preserved visualization of intrahepatic vessels and the diaphragm; grade 2 (moderate), with a more evident increase in echogenicity and reduced definition of vascular structures; and grade 3 (severe), characterized by marked hyperechogenicity, pronounced posterior beam attenuation and poor or absent visualization of intrahepatic vessels and the diaphragm [2,45].

Several technical limitations should be considered. Qualitative assessment remains partly operator-dependent and may be influenced by coexisting fibrosis or cirrhosis. Sensitivity decreases in mild steatosis, particularly at low levels of hepatic fat infiltration. In addition, posterior attenuation may be less apparent in lean individuals. Although quantitative ultrasound techniques based on attenuation measurements are emerging, conventional B-mode assessment remains the most widely available approach in routine clinical practice [46].

3.5. Rectus Femoris Muscle Echogenicity

Muscle assessment is performed using a linear transducer (7–12 MHz). With the patient in the supine position and the lower limb relaxed, the distance between the anterior superior iliac spine and the superior border of the patella is measured and divided into thirds. The transducer is positioned at the junction between the proximal two-thirds and distal one-third of the thigh to obtain a transverse image of the rectus femoris including both anterior and posterior fascial borders [47].

Muscle echogenicity may be evaluated using the Modified Heckmatt Scale [26]. Within OBESUS, a Modified Heckmatt grade ≥3 is proposed pragmatically to identify markedly increased muscle echogenicity. This threshold should be regarded as an operational reference for phenotyping rather than as a validated diagnostic cut-off for myosteatosis. Further-

more, increased rectus femoris echogenicity should be interpreted as a nonspecific marker of altered skeletal muscle composition rather than definitive evidence of myosteatosis. Potential limitations include anisotropy resulting from inadequate probe orientation, variations related to hydration status or muscle tone, and difficulties distinguishing advanced myosteatosis from fibrotic changes [48].

3.6. Epicardial Adipose Tissue

Epicardial adipose tissue is assessed using a phased-array transducer (2–4 MHz). The measurement is obtained from the parasternal long-axis view, where EAT appears as the echo-free or hypoechoic space located between the outer wall of the myocardium and the visceral layer of the pericardium. Following the original methodology described by Iacobellis et al., epicardial fat thickness should be measured over the free wall of the right ventricle, perpendicular to the aortic annulus, at end-systole, preferably averaging three consecutive cardiac cycles to improve reproducibility [28]. Although both end-systolic and end-diastolic measurements have been widely used in the literature and both appear capable of identifying increased cardiovascular risk, they should not be considered interchangeable because cyclic changes in ventricular geometry influence the apparent thickness of epicardial fat. Accordingly, the OBESUS framework adopts end-systolic assessment to ensure methodological consistency and facilitate comparison across studies and during longitudinal follow-up [49].

Potential limitations include suboptimal acoustic windows in patients with severe obesity, interference from respiratory and cardiac motion and difficulties distinguishing epicardial from pericardial fat when anatomical landmarks are not clearly identified. Furthermore, echocardiography provides a linear thickness measurement rather than a true volumetric assessment, which remains the domain of CT and cardiac MRI [29]. Additional methodological variability may arise from differences in the cardiac phase selected for measurement, highlighting the importance of using a standardized acquisition protocol when interpreting serial examinations or comparing results across studies [49].

A threshold of 7 mm was selected pragmatically based on available observational and prospective echocardiographic studies [50,51]. Epicardial fat thickness around or above this value has been associated with adverse cardiovascular phenotypes and an increased risk of major adverse cardiovascular events. However, because reported cut-offs vary across populations, clinical settings, cardiac-cycle timing, and imaging methodologies, 7 mm should not be interpreted as a universally validated diagnostic cut-off but rather as a pragmatic reference threshold for standardized ultrasound phenotyping within the OBESUS framework [17,50,52].

3.7. Perirenal Fat

Perirenal fat is assessed using a convex transducer (2–5 MHz). With the patient in the supine position, a coronal view of each kidney is obtained through the corresponding flank. Fat thickness is measured as the distance between the renal capsule and the surrounding fascial boundary, preferably during end-expiratory breath-hold and without exerting pressure on the abdominal wall [13].

Technical challenges include difficulties identifying fascial planes, interference from bowel gas and central adiposity and variability introduced by probe angulation. Accurate identification of perirenal adipose tissue requires familiarity with renal anatomy and adjacent retroperitoneal structures [53].

Although no universally accepted ultrasound threshold for perirenal fat currently exists, Cuatrecasas et al. proposed sex-specific reference values of ≥22.5 mm in men and ≥12.5 mm in women for identifying individuals with metabolic syndrome using *receiver*

operatin characteristic (ROC) analysis. These thresholds were derived from a Spanish cohort and represent one of the few ultrasound-based studies providing outcome-oriented reference values [54]. Within the OBESUS framework, they are adopted as pragmatic reference thresholds for standardized phenotyping rather than as universally validated diagnostic cut-offs.

4. Potential Clinical Applications

The primary objective of OBESUS is to provide a standardized multiorgan ultrasound framework for obesity phenotyping that complements conventional anthropometric and clinical assessment. By integrating information from different adipose and muscular compartments, OBESUS may facilitate a more comprehensive characterization of obesity-related tissue involvement at the individual level.

In routine clinical practice, OBESUS could be applied during the initial evaluation of patients with obesity by identifying the predominant pattern of adipose tissue distribution and ectopic lipid accumulation. Such information may complement traditional anthropometric indices and contribute to a more biologically informed assessment of obesity beyond body mass index and waist circumference.

A further potential application is longitudinal assessment. Because ultrasound is non-invasive, radiation-free, and readily repeatable, serial OBESUS examinations could potentially be used to evaluate changes in adipose and muscular compartments during lifestyle interventions, pharmacological treatment, or after bariatric surgery. This application is particularly attractive because tissue redistribution and changes in ectopic lipid accumulation, regional adipose tissue depots, or skeletal muscle echogenicity may not be fully reflected by changes in body weight alone. However, the responsiveness, measurement variability, and clinically meaningful longitudinal change in individual OBESUS domains require prospective evaluation before the framework can be recommended for treatment monitoring.

The multiorgan nature of the framework may also make it applicable across different clinical settings, including cardiovascular and metabolic risk clinics, obesity medicine programmes, and the evaluation of patients with suspected sarcopenic obesity. In these settings, OBESUS could provide a common structured approach for describing the predominant pattern of adipose and muscular tissue involvement. Whether these ultrasound-derived patterns can inform treatment selection or predict differential therapeutic response remains to be established prospectively.

Although these potential applications are supported by current knowledge regarding obesity pathophysiology and ultrasound imaging [2], prospective studies are required to determine whether OBESUS phenotyping improves clinical decision-making, risk stratification or patient outcomes compared with conventional assessment alone.

5. Limitations

Several limitations should be considered when interpreting the proposed OBESUS framework. First, OBESUS is a conceptual multiorgan ultrasound framework for obesity phenotyping rather than a validated diagnostic or prognostic tool. The proposed phenotypes should therefore be regarded as hypothesis-generating constructs requiring prospective validation before being incorporated into routine clinical decision-making. In addition, the strength of the supporting evidence varies across ultrasound domains. Hepatic steatosis assessment and abdominal adiposity measurements are supported by a relatively established body of evidence, although their diagnostic performance and clinical interpretation depend on the technique and population studied. Epicardial adipose tissue thickness has also been extensively investigated in relation to cardiovascular outcomes, but its incremental clinical

value and optimal ultrasound thresholds remain uncertain. In contrast, evidence supporting perirenal adipose tissue thickness and semiquantitative skeletal muscle echogenicity as obesity-related phenotyping markers is more limited. Furthermore, the proposed OBESUS thresholds have not been validated collectively and the clinical significance of the resulting phenotypes remains to be established.

Second, OBESUS remains inherently operator-dependent, and measurements may be influenced by acquisition technique, patient habitus, acoustic window quality, and equipment characteristics. Although several individual ultrasound measurements included in the framework have demonstrated acceptable reproducibility, the reproducibility of the complete multiorgan OBESUS examination has not yet been formally established. Furthermore, the proposed thresholds were derived from heterogeneous studies involving different populations, imaging protocols and clinical outcomes. Consequently, they should be interpreted as provisional operational references for standardized phenotyping rather than validated diagnostic or prognostic cut-offs. Their applicability to the proposed OBESUS phenotypes requires prospective assessment. Although the required ultrasound equipment is widely available in many clinical settings, access to appropriate transducers and adequately trained operators may vary across healthcare systems. Consequently, the feasibility of implementing the complete OBESUS examination in routine practice, including its training requirements and examination time, remains to be established.

Finally, clinical ultrasound does not replace reference imaging techniques such as computed tomography or magnetic resonance imaging when precise quantification of adipose tissue distribution or body composition is required. OBESUS should instead be regarded as a pragmatic bedside framework intended to complement conventional anthropometric assessment and, when clinically indicated, advanced imaging. Multicentre prospective studies are required to establish its reproducibility, external validity, prognostic significance, responsiveness to longitudinal change, and clinical utility.

6. Future Perspectives

Future research should prioritize the stepwise methodological and clinical validation of the OBESUS framework. Initial studies should assess feasibility, acquisition time, intra- and interobserver reproducibility and the influence of operator experience and ultrasound equipment on individual measurements. Subsequently, multicentre studies should evaluate the external validity of the proposed reference thresholds and the reproducibility and stability of the ultrasound-derived phenotypes across different populations and clinical settings. Longitudinal studies should also determine the responsiveness of individual ultrasound domains to changes in adiposity and muscle echogenicity over time.

Once methodological validity has been established, prospective studies should determine whether OBESUS phenotypes, or their combinations, provide incremental diagnostic or prognostic information beyond conventional anthropometric, clinical and metabolic assessment. Relevant outcomes may include cardiovascular events and subclinical atherosclerosis, incident or progressive chronic kidney disease, MASLD and liver fibrosis, and functional outcomes such as frailty, disability, and impaired physical performance. Studies evaluating lifestyle, pharmacological, or surgical interventions should also investigate whether changes in individual ultrasound compartments reflect treatment response independently of changes in body weight. Ultimately, studies should establish whether incorporating OBESUS into clinical practice improves risk stratification, informs therapeutic decisions or leads to better patient outcomes.

Future iterations of OBESUS may additionally incorporate complementary ultrasound biomarkers of obesity-related organ damage. Vascular ultrasound markers such as carotid plaque burden could potentially link adiposity phenotyping with direct assessment of sub-

clinical vascular disease. However, such extensions should be evaluated only after validation of the current framework and remain beyond the scope of the present position paper.

Author Contributions: Conceptualization, J.A.P.-R., L.C.-G., M.V.B.-H., L.M.B.-R., M.F.-T. and N.M.-R.; methodology, J.A.P.-R., L.C.-G., M.V.B.-H., L.M.B.-R., M.F.-T. and N.M.-R.; investigation, J.A.P.-R., L.C.-G., M.V.B.-H., L.M.B.-R., M.F.-T. and N.M.-R.; writing—original draft preparation, J.A.P.-R.; writing—review and editing, J.A.P.-R., L.C.-G., M.V.B.-H., L.M.B.-R., M.F.-T. and N.M.-R.; visualization, J.A.P.-R.; supervision, J.A.P.-R., L.C.-G., M.V.B.-H., L.M.B.-R., M.F.-T. and N.M.-R. All authors have read and agreed to the published version of the manuscript.

Funding: The article processing charge for this publication was supported by Novo Nordisk. The funder had no role in the conception or design of the manuscript; in the selection, analysis, or interpretation of the literature; in the writing of the manuscript; or in the decision to submit the manuscript for publication.

Institutional Review Board Statement: Not applicable. This manuscript is a narrative review and conceptual framework and does not involve original research involving human participants or animals.

Informed Consent Statement: Not applicable. No identifiable patient information is presented in this manuscript.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: During the preparation of this manuscript, the authors used ChatGPT (GPT-6; OpenAI) to assist with text drafting, language editing, translation and condensation. The authors subsequently reviewed, edited and verified the generated content for scientific accuracy and take full responsibility for the content of the publication.

Conflicts of Interest: The authors declare no conflicts of interest. Novo Nordisk provided financial support for the article processing charge but had no role in the conception or design of the manuscript; the selection, analysis or interpretation of the literature; the writing of the manuscript or the decision to submit the manuscript for publication.

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