Původní sdělení | Original research article

Enhancing TAVI Patient Evaluation: A User-Friendly Tool for CT-Derived Body Composition Assessment

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ARTICLE INFO

Article history:
Submitted: 16. 12. 2024
Revised: 12. 1. 2025
Accepted: 14. 1. 2025
Available online: 9. 6. 2025

Klíčová slova:
Celkové přežití
Obezita
Sarkopenie
Tělesné složení
Transkatétrová implantace aortální chlopně (TAVI)

SOUHRN

Úvod: Analýza tělesného složení pomocí CT vyšetření se v současnosti ukazuje jako významný prognostický nástroj u pacientů s indikací k transkatétrové implantaci aortální chlopně (TAVI). Její rutinní využití v klinické praxi je však limitováno složitostí dostupného softwaru a vysokými technickými nároky. Naším cílem bylo vyvinout a validovat webovou aplikaci, která by zjednodušila používání existujícího softwaru AutoMATiCA při hodnocení tělesného složení v rámci předintervenčního vyšetření před TAVI.
Metody: Vyvinuli jsme webové rozhraní integrující již validovaný software AutoMATiCA, který využívá umělou inteligenci pro automatickou segmentaci tkání. Systém analyzuje předintervenční CT snímky a automaticky vypočítává index kosterního svalstva, objem viscerálního a podkožního tuku. Aplikace zpracovává soubory DICOM a generuje přehledné reporty včetně segmentovaných snímků a kvantitativních parametrů.
Výsledky: Testování systému prokázalo průměrnou dobu analýzy 21 sekund od nahrání snímků po zobrazení výsledků. Uživatelské hodnocení pěti klinickými lékaři potvrdilo jednoduchost použití a klinickou využitelnost. Analýza ilustrativních případů odhalila významné rozdíly mezi hodnocením pomocí BMI a CT analýzou tělesného složení, například u případů sarkopenické obezity nebo zachované svalové hmoty, které by při použití samotného BMI zůstaly neodhaleny.
Závěr: Vyvinuté uživatelské rozhraní představuje praktické řešení pro hodnocení tělesného složení u pacientů před TAVI. Systém efektivně překlenuje mezeru mezi pokročilými analytickými možnostmi validovaného softwaru AutoMATiCA a klinickou praxí díky intuitivnímu uživatelskému rozhraní. Toto řešení by mělo v budoucnu umožnit přesnější stratifikaci rizika a individualizovanější přístup k pacientům s indikací k TAVI.

Keywords:
Body composition
Obesity
Overall survival
Sarcopenia
Transcatheter aortic valve implantation (TAVI)

ABSTRACT

Background: CT-derived body composition analysis has emerged as a powerful prognostic tool for TAVI patient outcomes. However, widespread clinical implementation remains limited by complex software requirements and technical expertise barriers. This study aims to develop and validate an accessible web-based interface that streamlines the implementation of existing AutoMATiCA's validated CT-based body composition assessment in the pre-TAVI evaluation workflow.
Methods: We developed a web-based interface integrating the validated AutoMATiCA's AI-driven segmentation software for automated body composition assessment. The system analyses pre-procedural CT scans to quantify Skeletal Muscle Index, Visceral Adipose Tissue, and Subcutaneous Adipose Tissue. The interface accepts DICOM files and patient data, generating comprehensive reports including segmented images and measurements.
Results: System evaluation demonstrated an average analysis time of 21 seconds from upload to results display. User experience assessment with five clinicians showed unanimous positive feedback regarding accessibility and utility. Technical validation confirmed accurate tissue segmentation and quantification capabilities. Analysis of illustrative cases demonstrated significant discrepancies between BMI-based assessment and

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DOI: 10.33678/cor.2025.008

Please cite this article as: Kantor M, Balušík J, Branny P, et al. Enhancing TAVI Patient Evaluation: A User-Friendly Tool for CT-Derived Body Composition Assessment. Cor Vasa 2025;67:323–330.

CT-derived body composition analysis, revealing conditions such as sarcopenic obesity and preserved muscle mass that would be missed by BMI evaluation alone.
Conclusion: This technical solution provides an accessible, integrated approach to body composition assessment in TAVI patients. Building upon the validated AutoMATiCA software, the system successfully bridges the gap between complex analysis capabilities and clinical practicality through an intuitive user interface. This solution should enable more precise risk stratification and a more individualized approach to patients indicated for TAVI in the future.

Introduction

Transcatheter aortic valve implantation (TAVI) has revolutionized the treatment of severe aortic stenosis, particularly in elderly or high-risk patients who are not candidates for traditional surgical approaches.[1] Recent evidence suggests that body composition parameters, derived from routine pre-procedural computed tomography (CT) scans, can significantly impact patient outcomes and aid in risk stratification.[2] Specifically, the analysis of skeletal muscle index (SMI) and visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) characteristics at the third lumbar vertebra (L3) level has shown prognostic value for post-TAVI mortality.[3]

Currently, the assessment of body composition requires specialized software tools, such as AutoMATiCA developed by Paris et al., which utilizes artificial intelligence for automated segmentation of CT images.[4] While highly accurate and efficient, these tools often present a significant barrier for clinicians without extensive IT expertise, potentially limiting the widespread adoption of body composition analysis in clinical practice.

The importance of accessible body composition analysis in TAVI patients cannot be overstated. Our previous research has demonstrated that SMI is a significant predictor of mortality in male patients undergoing TAVI. Additionally, VAT density shows predictive value for both male and female patients, while SAT density provides additional prognostic information in male patients.[2]

To address the technical barriers and facilitate wider adoption of body composition analysis, we have developed a user-friendly web interface that simplifies the CT segmentation process. This interface integrates with the existing AutoMATiCA software, maintaining its analytical power while providing an intuitive user experience suitable for clinicians of all technical backgrounds.

The existing workflow for CT segmentation and analysis presents several obstacles: complex software interfaces requiring specialized training, time-consuming data input and analysis processes, limited accessibility across different clinical settings, and difficulty in integrating analysis results into clinical decision-making. Our web-based solution aims to overcome these challenges by providing a streamlined, intuitive user interface; automated data processing and analysis; clear and clinically relevant output presentation; and seamless integration with existing clinical workflows.

Material and methods

System architecture and implementation

Our system presents a web-based interface designed to simplify CT segmentation analysis for body composition assessment. The technical infrastructure operates on a Windows Server 2022 Standard (IP 10.2.111.20, port 5001), accessible to medical staff through the hospital's local network. The system integrates the existing AutoMATiCA's AI-driven segmentation capabilities with our user-friendly interface, making advanced analysis accessible to clinicians of all technical backgrounds. AutoMATiCA, the core segmentation engine, employs U-Net architecture and was validated in the study of Paris et al. on 893 patient scans (80% training, 10% validation, 10% testing). The system demonstrated excellent agreement between human and AI segmentations with processing speeds of ~350 ms per scan on modern hardware.[4]

Our implementation architecture consists of two primary components. The front-end component, developed using HTML, CSS, and JavaScript, provides comprehensive functionality for patient data management and result visualization. It enables clinicians to input patient parameters, calculate body composition metrics including SMI, VAT, SAT, and Whole Body Fat Mass (WBFM) measurements, and interact with analysis outcomes through interactive visualizations powered by Chart.js. The interface allows detailed inspection of processed CT scans with segmentation overlays while maintaining access to raw CT data for verification.

The back-end system, built with Python's Flask framework, implements a sophisticated processing pipeline. It manages HTTP request routing, integrates with AutoMATiCA's Convolutional Neural Networks based on U-Net architecture, and handles comprehensive data security protocols. All data is stored securely on the hospital's local server and retained only during computation, with access restricted to authorized personnel within the hospital's local network.

Processing pipeline

The system employs a sophisticated multi-stage processing workflow. Initially, the system securely uploads and preprocesses DICOM files, followed by loading pretrained TensorFlow models utilizing U-Net architecture for rapid processing. The pipeline continues with image standardization through resizing and normalization protocols, preparing data for consistent analysis across different input sources.

The segmentation process generates detailed probability maps for each tissue type using CNNs, followed by refined post-processing through thresholding and filtering techniques. Hounsfield Unit analysis provides precise tissue characterization. The system then processes this data into JSON format for front-end presentation while maintaining strict anonymization protocols and efficient temporary file management. Additional computational processes generate comprehensive body composition parameters, including SMI calculations and both percentage and absolute WBFM measurements.

Output generation

Results are presented through a comprehensive single-page report integrating multiple data visualization elements. The interface generates interactive graphs and visualizations using Chart.js, alongside segmented CT images with customizable overlay options. Key metrics include SMI, VAT, and SAT areas and densities, and WBFM measurements in both absolute values and percentages. The system additionally provides survival probability estimations based on established study data.

Results

Our system performance evaluation revealed an average analysis time of 21 seconds from image upload to results display. The system consistently identified the L3 vertebra level in uploaded scans.

We conducted a technical expertise validation study with five experienced clinicians representing different specialties with varying technical expertise levels. Participants included two cardiologists, one cardiac surgeon, and two general surgeons. In terms of ease of use, all users successfully uploaded and analysed a CT scan on their first attempt without assistance, with an average time to run the interface and upload an image of 53 seconds. Previously, only one technically skilled clinician could use the AutoMATiCA software. Now, all clinicians in the study can easily utilize the new web interface, regardless of their technical background. The technical validation showed maximum interface satisfaction rating of 5/5, with all expert users rating the results display as "clear and informative". The most appreciated features were the one-page comprehensive report layout, visual representation of obesity and sarcopenia metrics, and immediate access to survival rate predictions. Regarding clinical utility, all clinicians reported that the tool would "significantly improve" their ability to assess TAVI patient risks. Key benefits cited included rapid risk stratification, objective quantification of body composition, and easy comparison to established clinical thresholds. Expert validation feedback included detailed assessments from a general surgeon and a cardiac surgeon, confirming the tool's efficiency and illustrative capabilities.

Areas for future enhancement based on user feedback include integration with hospital PACS systems for streamlined image access, addition of trend analysis for repeat scans, and customizable reporting options for different clinical contexts.

Case reports

To illustrate the enhanced diagnostic capabilities of CT-derived body composition analysis compared to traditional BMI assessment, we analyzed four distinct patient cases that demonstrate the limitations of relying solely on BMI measurements. The patient cases presented serve as illustrative examples of the interface's clinical application rather than a validation cohort. Sarcopenic status is calculated from skeletal mass index (SMI, cut off for sarcopenia: under 55 and 39 cm²/m² for men and women respectively) and obesity is calculated from estimated fat mass (WBFM, cut off for obesity: over 27 and 38 % for men and women respectively). Our imaging protocol utilized two Siemens Somatom CT scanners: the Definition model for studies conducted before 2016, followed by the Somatom Drive for subsequent examinations. All scans were performed using a tri-iodinated non-ionic monomeric contrast medium (Iomeron), with ECG gating implemented for the thoracic region. To optimize image quality while minimizing radiation exposure, we employed differential slice thickness parameters, with 3 mm slices above the diaphragm and 5 mm slices below. The scanning voltage was maintained at 100 kV throughout, while the current was adjusted according to anatomical region: 284 mAs for thoracic imaging and 84 mAs for sub-diaphragmatic sections.

Case 1: Sarcopenic obesity

An 85-year-old male patient (height 170 cm, weight 90 kg, BMI 31.14 kg/m²) who would be classified as obese by BMI standards. However, CT segmentation revealed an SMI of 31.44 cm²/m², indicating significant muscle mass depletion. WBFM was 38,26%. This case represents classic sarcopenic obesity – high BMI masking underlying muscle loss (**Fig. 1**).

Case 2: Moderate sarcopenia with high BMI

An 83-year-old female patient (height 157 cm, weight 79 kg, BMI 32.05 kg/m²) with a BMI in the obese range. The CT analysis showed an SMI of 21.78 cm²/m² indicating moderate sarcopenia, that would not be apparent from BMI alone (**Fig. 2**).

Case 3: Severe sarcopenia despite high BMI

An 87-year-old male patient (height 168 cm, weight 91 kg, BMI 32.24 kg/m²) demonstrates another critical pattern. Despite being classified as obese by BMI, CT analysis showed an SMI of 22.94 cm²/m², indicating significant sarcopenia. This case highlights how BMI alone can mask serious muscle depletion in elderly patients (**Fig. 3**).

Case 4: Normal body composition with preserved muscle mass despite high BMI

An 82-year-old female patient (height 155 cm, weight 78 kg, BMI 42.47 kg/m²). This case depicts the normal body composition despite BMI in obesity range. CT analysis shows normal muscle mass (SMI 46.92 cm²/m²) and normal estimated fat mass (31.86%) despite obesity classification by BMI (**Fig. 4**).

These cases highlight the significant discrepancies between BMI-based assessment and CT-derived body composition analysis. While BMI provides a rough estimate of

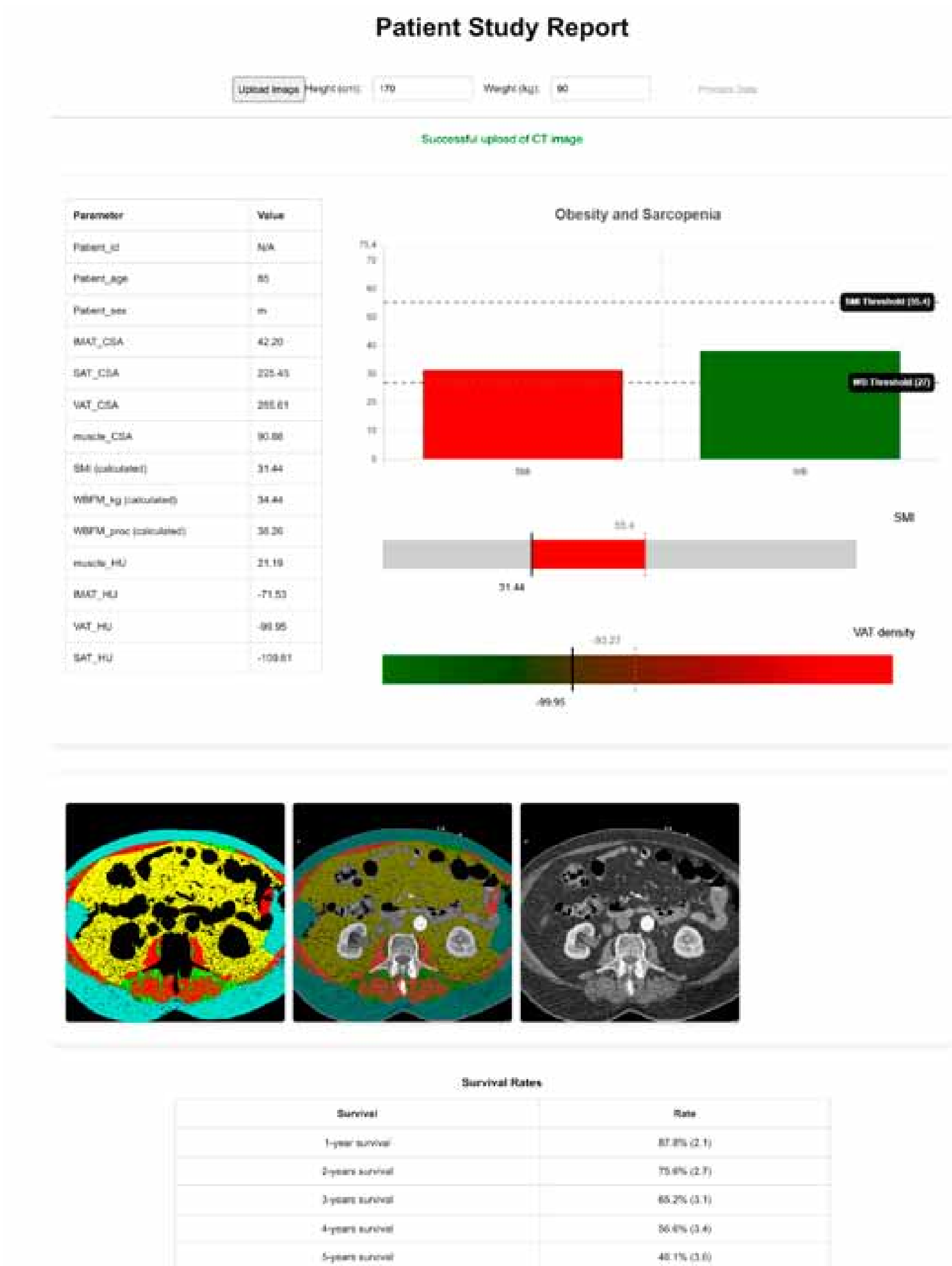

Fig. 1 – CT-based body composition analysis revealing sarcopenic obesity. Analysis of an 85-year-old male (BMI 31.14 kg/m²). The segmented CT image demonstrates low muscle mass (SMI 31.44 cm²/m²) despite high BMI, a classic pattern of sarcopenic obesity.

overall body mass relative to height, it fails to detect critical variations in muscle mass and adipose tissue distribution. The CT segmentation approach enables identification of specific body composition patterns that would be missed by BMI assessment alone: sarcopenic obesity, moderate sarcopenia, severe sarcopenia and normal body composition (despite high BMI in all four cases). Each pattern carries different clinical implications and risk factors, demonstrating the importance of tissue-specific analysis. This detailed characterization of body composition offers more precise risk stratification and could potentially guide more personalized treatment approaches for TAVI patients.

Discussion

The development of our web-based interface for CT segmentation analysis represents a significant step forward in the risk assessment of patients undergoing TAVI. To fully appreciate the value and potential limitations of this new tool, it is crucial to consider it within the broader context of existing scoring systems used in TAVI patient evaluation.

Several established scoring systems are currently used in TAVI patient evaluation, each with its own strengths and limitations. The EuroSCORE II is widely used for estimating

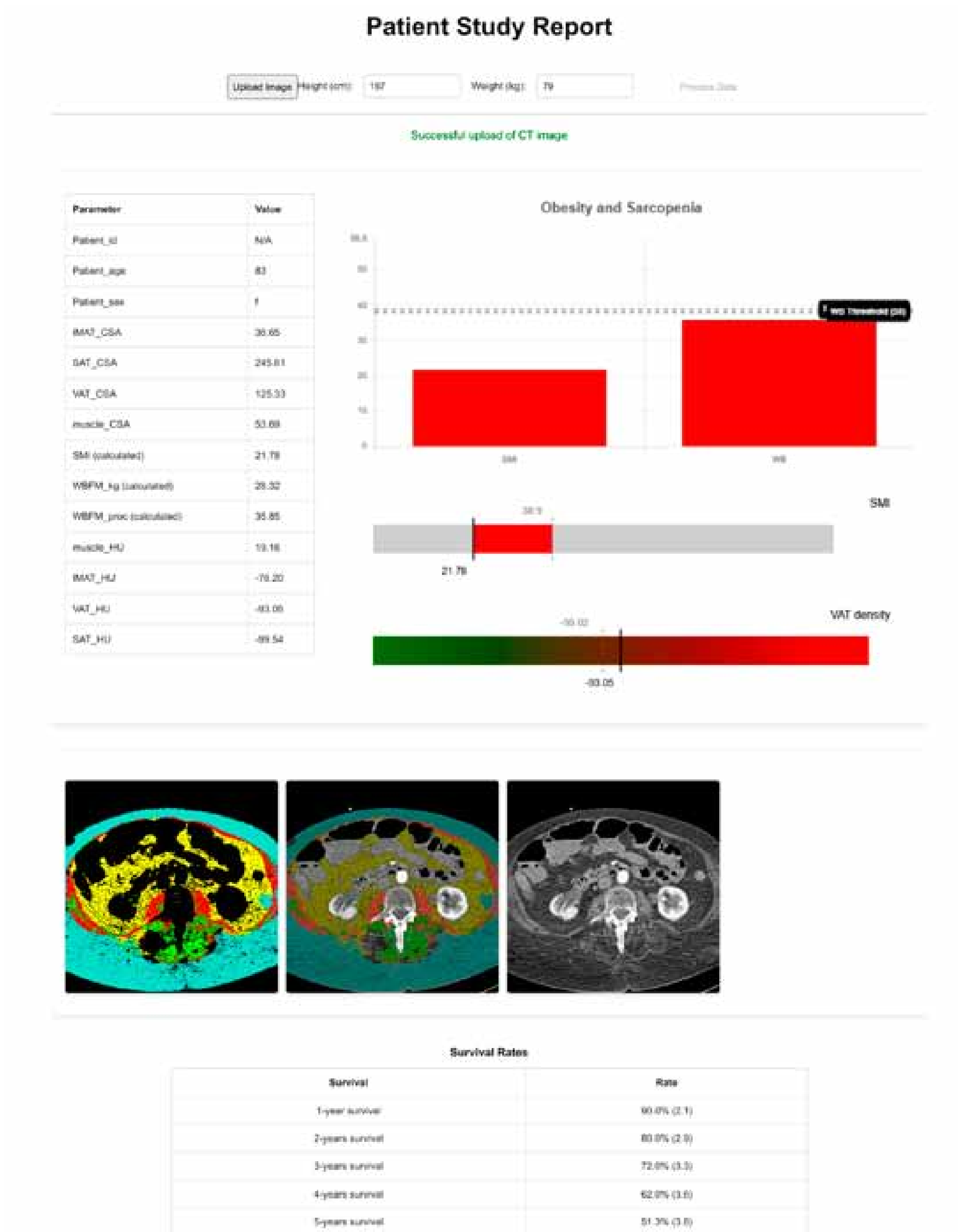

Fig. 2 – Moderate sarcopenia with high BMI. Analysis of an 83-year-old female (BMI 32.05 kg/m²). CT segmentation reveals moderate sarcopenic changes (SMI 21.78 cm²/m²) that would be missed by BMI assessment alone.

surgical mortality risk.[5] However, it does not assess long-term survival and is not specifically designed for minimally invasive or catheter-based procedures. The Clinical Frailty Scale offers a simple 9-point scale that evaluates overall health status, activity level, and dependency.[6] It is easily applicable in clinical practice and internationally validated, but it may be biased when assessed during inpatient care due to patients' typically deteriorated condition. The 6-Minute Walk Test provides data for predicting long-term mortality but is time- and space-intensive to perform.[7] The Comprehensive Geriatric Assessment is the most comprehensive test, including physical, cognitive, psychosocial, and nutritional assessments, with robust data for predicting long-term mortality. However, it is highly time- and personnel-intensive.[8] The Charlson Comorbidity Index generally provides excellent results in risk assessment and long-term mortality prediction[9] but is not primarily designed for patients undergoing minimally invasive or catheter-based procedures, potentially overestimating risk.

Our CTL3 parameters offer several advantages over these existing systems. They provide a comprehensive body composition analysis, unlike BMI, offering detailed insights into muscle mass, visceral fat, and subcutaneous fat distribution. This allows for the detection of hidden

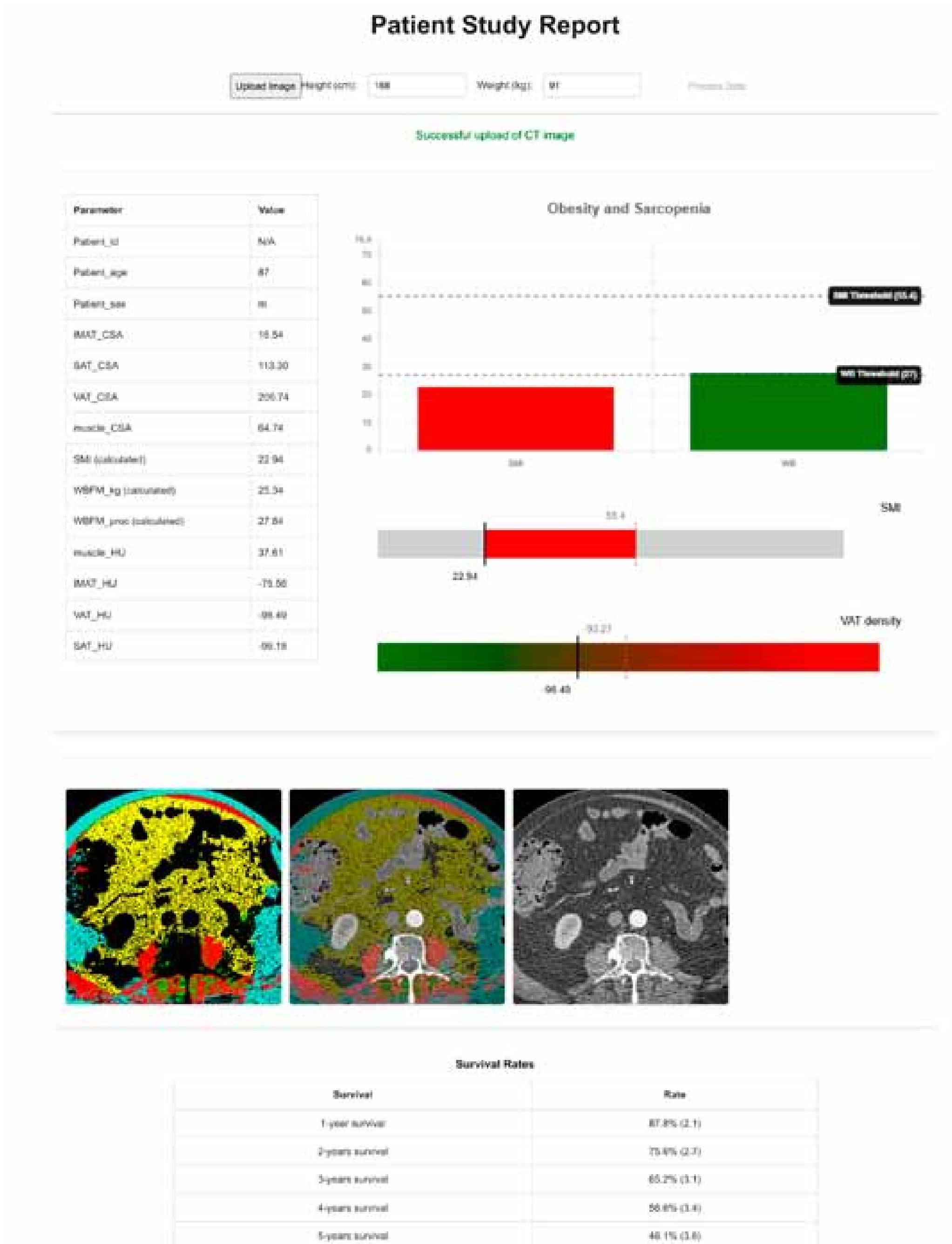

Fig. 3 – Severe sarcopenia masked by high BMI. CT analysis of an 87-year-old male (BMI 32.24 kg/m²) revealing significant muscle depletion (SMI 22.94 cm²/m²) despite obesity by BMI standards, emphasizing the importance of tissue-specific analysis.

conditions such as sarcopenia, obesity, or sarcopenic obesity that may not be apparent from external examination or traditional metrics like BMI. The CTL3 parameters offer objective quantification, providing precise measurements of tissue areas and densities, allowing for more accurate risk stratification. They also enable longitudinal comparison, allowing tracking of body composition changes over time, which could be valuable for assessing treatment efficacy or disease progression. Importantly, this analysis integrates with routine imaging, utilizing CT scans already performed as part of the TAVI workup, requiring no additional patient procedures.

However, it's important to acknowledge potential limitations of relying solely on CTL3 parameters. While providing detailed body composition data, CTL3 analysis does not capture other important factors such as cardiovascular function, frailty, or cognitive status. The predictive value of CTL3 parameters for TAVI outcomes, while promising, requires further large-scale, multicenter validation. The analysis relies on the availability of high-quality CT scans and specialized software, which may not be universally accessible. Additionally, it does not provide information about the patient's physical capabilities or daily living activities, which are crucial for comprehensive risk assessment.

Fig. 4 – Normal body composition with preserved muscle mass despite high BMI. Results from an 82-year-old female with high BMI (42.47 kg/m²). CT analysis shows normal muscle mass (SMI 46.92 cm²/m²) and normal estimated fat mass (31.86%) despite obesity classification by BMI.

Given the strengths and limitations of each scoring system, including our CTL3-based analysis, we propose a synergistic approach to TAVI patient evaluation. This approach would combine CTL3 analysis with established scoring systems like EuroSCORE II and Clinical Frailty Scale for a more comprehensive risk profile. The CTL3 parameters provide unique insights into body composition that complement, rather than replace, existing functional assessments. For instance, while the 6-minute walk test evaluates cardiorespiratory fitness and functional capacity through dynamic exercise testing, CTL3 analysis offers objective quantification of muscle mass and adipose tissue distribution that may influence exercise capacity and post-procedural outcomes. This complementary relationship is particularly valuable in cases where traditional metrics may be misleading or where functional tests may be difficult to perform. By integrating these different assessment modalities, clinicians can develop a more nuanced understanding of each patient's risk profile: CTL3 providing detailed body composition data, functional tests like the 6-minute walk test assessing physical capacity, and established risk scores evaluating broader clinical parameters. This multi-modal approach promises to enhance risk stratification accuracy and support more individualized treatment decisions in TAVI candidates.

Study limitations

Several limitations of our study should be acknowledged. First, while our interface successfully streamlines the implementation of AutoMATiCA's validated AI model, its effectiveness depends on the availability of high-quality CT scans and specific technical infrastructure requirements, which may not be universally available across all healthcare settings. Second, our current implementation requires manual file handling, as direct integration with hospital PACS systems has not yet been achieved. This may impact workflow efficiency in high-volume clinical settings. Third, while body composition analysis provides valuable prognostic information, it captures only one aspect of patient health status; it does not directly assess functional capacity, cardiovascular status, or cognitive function, which are also crucial for comprehensive TAVI risk assessment. Fourth, although our interface demonstrates excellent usability among the tested clinician group, broader validation across multiple centers and diverse healthcare settings would be beneficial to ensure generalizability. Fifth, the system's reliance on specific CT scan parameters (including slice thickness and radiation dosage) may require protocol standardization across institutions for optimal results. Finally, while our tool effectively identifies body composition patterns, longitudinal studies are needed to validate its predictive value for specific TAVI outcomes across diverse patient populations. Future development should focus on addressing these limitations through PACS integration, protocol standardization, and multi-center validation studies.

Conclusion

The development and implementation of our web-based interface for CT segmentation analysis represents a significant advancement in the risk assessment and management of patients undergoing TAVI. This study has demonstrated that our user-friendly interface has successfully bridged the gap between complex body composition analysis and clinical practicality, making advanced risk stratification tools more accessible to a broader range of clinicians. The integration of sarcopenia and obesity assessment according to CT-derived body composition and risk stratification according to adipose tissue density provides a more nuanced understanding of patient health status compared to traditional metrics such as BMI alone. While CTL3 parameter analysis offers valuable insights into body composition and potential risks for TAVI patients, it should be used as part of a comprehensive evaluation strategy. By combining the strengths of various scoring systems and assessment tools, including our new CT segmentation interface, clinicians can develop a more nuanced understanding of each patient's risk profile and tailor treatment approaches accordingly. This synergistic and individualized approach holds the promise of improving outcomes and patient care in the evolving field of TAVI.

Authors contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work. MP, MK, JB, and PB contributed to concept and design; MP, MK, and JH were responsible for acquisition, analysis, and interpretation of data; MP, MK, JB, and PB drafted the manuscript; MP, MK, LB, and JH provided critical review of the manuscript for important intellectual content; MP supervised the project.

Conflicts of interest

The authors declare no conflicts of interest.

Funding

This article has been produced with the financial support of the European Union under the LERCO project number CZ.10.03.01/00/22_003/0000003 via the Operational Programme Just Transition. The work and the contributions were supported by the project SP2024/071 "Biomedical Engineering systems XX" and Internal grant of Agel INT2023001.

Ethical statement

The four cases presented in this technical report were selected from the comprehensive TAVI Registry at Hospital AGEL Třinec-Podlesí, the Czech Republic, which contains demographic information, pre-TAVI CT scans, and clinical follow-up data collected since 2010. All data processing complied with GDPR requirements. Registry participants provided written informed consent for both the TAVI procedure and future research use of their anonymized data. The Hospital AGEL Třinec-Podlesí ethics committee approved the analysis of registry data (EK 301/22) according to the Declaration of Helsinki principles, and the primary study was registered under NCT05672160 at Clinical Trials.

Data availability statement

The data supporting this study are available from the authors upon reasonable request.

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