

Review

Host Metabolic Status and Biomaterial–Tissue Interactions in NMIBC Surgery

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Abstract:

Body composition and metabolic health are increasingly recognised as important determinants of surgical and oncological outcomes. In uro-oncology, conditions such as sarcopenia, myosteatosis, obesity, and malnutrition have been associated with increased perioperative complications, impaired recovery, reduced treatment tolerance, and poorer prognosis. In non-muscle-invasive bladder cancer (NMIBC), however, these host-related factors remain insufficiently integrated into current clinical risk stratification models, which are predominantly focused on tumour characteristics.

The review summarises current evidence regarding the role of body composition and metabolic status in NMIBC surgery and perioperative management. Particular emphasis is placed on computed tomography (CT)-based body composition analysis, including skeletal muscle index (SMI) and skeletal muscle density (SMD), together with nutritional and metabolic assessments such as body mass index (BMI), bioimpedance analysis (BIA), Nutritional Risk Screening 2002 (NRS-2002), and serum albumin. Alterations in skeletal muscle and adipose tissue are increasingly linked to systemic inflammation, immune dysregulation, metabolic dysfunction, and impaired tissue recovery.

Evidence from surgical oncology, particularly radical cystectomy cohorts, consistently demonstrates associations between sarcopenia, myosteatosis, postoperative morbidity, prolonged hospitalisation, and reduced survival. Emerging studies further suggest that metabolic and nutritional parameters may influence recurrence and progression in NMIBC treated with transurethral resection of bladder tumour (TURBT), although available data remain limited. Overall, body composition represents a clinically relevant but underutilised component of NMIBC management. Integrating CT-derived muscle metrics and nutritional assessment into perioperative evaluation may improve risk stratification, support personalised surgical decision-making, and optimise TURBT and surveillance strategies.

Keywords: NMIBC; Body composition; Sarcopenia; Myosteatosis; TURBT; Metabolic Status; Surgical outcomes; CT imaging; SMI; Personalised surgery

1. Body Composition and Metabolic Dysfunction in Uro-Oncology

1.1. Current clinical challenges in Uro-Oncology

Non-muscle-invasive bladder cancer (NMIBC) represents approximately 75% of newly diagnosed bladder cancers and remains a major clinical and economic challenge worldwide. Although survival outcomes are generally favourable, NMIBC is associated with high recurrence rates and a risk of progression to muscle-invasive disease, requiring long-term surveillance with repeated cystoscopy, urinary cytology and imaging. This intensive follow-up places a substantial burden on patients and healthcare systems and contributes to the high lifetime cost of bladder cancer care (Lenis et al., 2020; Sung et al 2021; Chou et al., 2015). Current treatment decisions and prognostic assessment in NMIBC are primarily based on tumour-related features, including stage, grade, tumour size, multiplicity and the presence of carcinoma in situ. Established risk models, such as those developed by the European Association of Urology (EAU) and the European Organisation for Research and Treatment of Cancer (EORTC), provide valuable prognostic guidance; however, they remain largely centred on tumour biology. As a result, host-related systemic and metabolic factors that may influence recurrence, cancer progression (Figure 1), treatment tolerance and surgical outcomes are still insufficiently integrated into routine risk stratification (Mossanen & Gore, 2014; Isharwal & Konety, 2015).

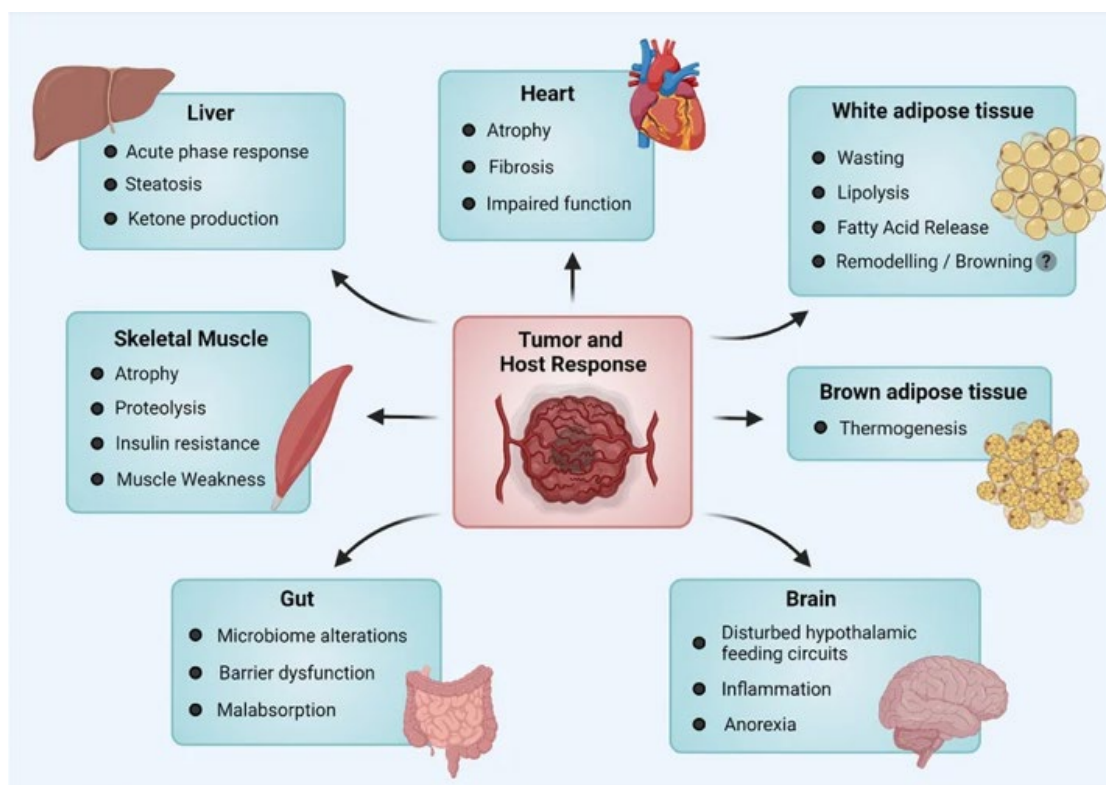


Figure 1. Tumour-Host Metabolic Crosstalk Driving Cancer Progression

2. Assessment of Skeletal Muscle and Adipose Tissue

2.1 The objective evaluation of muscle mass, muscle quality, and fat distribution

Although body composition is increasingly recognised as an important factor in oncology, its prognostic role in non-muscle-invasive bladder cancer (NMIBC) remains insufficiently defined. Most evidence linking sarcopenia and myosteatosis with poorer survival, increased postoperative complications, and adverse oncological outcomes originates from muscle-invasive bladder cancer and radical cystectomy cohorts rather than NMIBC populations. Nevertheless, computed tomography, CT- based body composition analysis has emerged as a valuable and objective approach for evaluating skeletal muscle quantity and quality using routinely acquired imaging, supporting its growing potential in uro-oncological risk stratification (Babjuk et al., 2022; Alameddine et al., 2018).

2.2 Translational Research Challenges and Future Directions

In NMIBC, accumulating evidence suggests that nutritional and metabolic status may provide clinically relevant prognostic information beyond conventional tumour characteristics. Nutritional and inflammation-related indices, including the Controlling Nutritional Status score (CONUT) score, Geriatric Nutritional Risk Index (GNRI), and Prognostic Nutritional Index (PNI), have been associated with recurrence and progression risk, indicating that systemic metabolic and nutritional factors may influence tumour behaviour and treatment response. However, currently used prognostic systems, including the European Organisation for Research and Treatment of Cancer, and European Association of Urology risk models, remain predominantly based on clinicopathological tumour variables and demonstrate only moderate predictive performance, particularly in contemporary Bacillus Calmette–Guérin (BCG)-treated cohorts. These limitations underscore the need for additional biomarkers capable of better capturing biological heterogeneity, systemic metabolic status, and tumour–host interactions in NMIBC progression. In this context, CT-derived body composition biomarkers, including skeletal muscle index, skeletal muscle density, visceral adiposity, and myosteatosi s, may represent promising complementary tools for more personalised prognostic assessment and future precision surgical management strategies (Sun et al., 2025; Claps et al., 2023).

3. Surgical Outcomes in Bladder Cancer

3.1. Sarcopenia and Cancer

Sarcopenia, characterised by progressive loss of skeletal muscle mass and function, has been consistently associated with increased postoperative complications, poorer treatment response, prolonged recovery, and adverse oncological outcomes across multiple malignancies. In cancer patients, sarcopenia reflects reduced physiological reserve together with systemic inflammation, metabolic dysregulation, and cancer-related catabolism (Mayr et al., 2018; Fukushima & Koga, 2022).

In bladder cancer, most evidence originates from muscle-invasive disease and radical cystectomy cohorts, where reduced skeletal muscle mass has been linked to higher perioperative morbidity and poorer survival outcomes. CT-based body composition analysis enables objective assessment of skeletal muscle quantity and quality, including skeletal muscle index (SMI) and skeletal muscle density (SMD), and has emerged as a promising tool for personalised risk stratification in uro-oncology (Elhakim et al., 2023).

Although evidence in non-muscle-invasive bladder cancer (NMIBC) remains limited, growing data suggest that sarcopenia and related metabolic alterations may also influence recurrence, progression, treatment tolerance, and long-term clinical outcomes.

3.2. Myosteatosi s and Cancer

Myosteatosi s, characterised by fatty infiltration of skeletal muscle and impaired muscle quality, has emerged as an important prognostic factor in oncology. Computed tomography (CT) enables objective assessment of skeletal muscle index (SMI) and skeletal muscle density (SMD) from routine imaging, allowing evaluation of both muscle quantity and quality.

Nutritional and metabolic status may additionally influence tumour biology, immune response, treatment tolerance, and clinical outcomes. Commonly used assessments include body mass index (BMI), waist circumference, bioelectrical impedance analysis (BIA), Nutritional Risk Screening 2002 (NRS-2002), and serum albumin levels (Mayr et al., 2018).

4. Metabolic and Nutritional Biomarkers in NMIBC Risk Stratification

4.1. Systemic Metabolic Alterations in Oncology

Increasing attention has recently been directed toward the role of body composition and metabolic status in cancer progression and clinical outcomes. Host-related factors such as sarcopenia, myosteatosi s, obesity, and malnutrition are increasingly recognised as important systemic determinants that may influence tumour biology, immune response, treatment tolerance, postoperative recovery, and long-term survival. These alterations reflect complex interactions between metabolism, inflammation, nutritional status, and cancer-related physiological stress.

4.2. Integrating Metabolic Biomarkers into NMIBC Care

In non-muscle-invasive bladder cancer (NMIBC), emerging evidence suggests that metabolic and nutritional biomarkers may provide additional prognostic information beyond conventional tumour-based risk factors. Integration of CT-derived body composition parameters and nutritional assessments may therefore improve personalised risk stratification and support more individualised therapeutic and surveillance strategies.

5. Future Uro- Surgery Perspectives

5.1. Towards Personalised NMIBC Management

The advances in non-muscle-invasive bladder cancer (NMIBC) management are expected to increasingly incorporate host-related biological and metabolic factors alongside conventional tumour characteristics. Growing evidence suggests that body composition, nutritional status, systemic inflammation, and metabolic dysfunction may influence perioperative recovery, treatment response, recurrence, and disease progression. Integrating these parameters into existing prognostic frameworks may therefore improve risk stratification and support more personalised clinical decision-making. CT-based body composition analysis represents a particularly promising approach because it enables objective and reproducible assessment of skeletal muscle quantity and quality using routinely acquired imaging. Combined with nutritional, functional, and laboratory biomarkers, these assessments may help identify vulnerable patients at increased risk for postoperative complications or adverse oncological outcomes. Such strategies could support personalised perioperative optimisation, including nutritional intervention, prehabilitation, physical rehabilitation, and tailored surveillance protocols.

5.2. Clinical Translational Perspectives in NMIBC Risk Stratification

Further prospective multicentre studies are needed to validate body composition biomarkers in NMIBC populations and determine their integration into contemporary prognostic models including the risk classifications. A better understanding of tumour–host interactions, metabolic dysfunction, and nutritional status may ultimately support the transition from predominantly tumour-centred management toward a more personalised and biologically integrated approach to NMIBC surgery and surveillance.

6. Conclusions

The advances in regenerative medicine and biomaterials may further contribute to personalised uro-oncological care. The development of biologically active biomaterials, tissue-engineered biomaterials, and regenerative strategies capable of improving tissue healing, reducing inflammation, and supporting functional recovery may represent an important complementary direction in bladder cancer surgery and reconstruction. Together, integration of metabolic, imaging, and biomaterial-based approaches may contribute to the development of next-generation personalised surgical management in NMIBC.

Conflicts of Interest: The authors declare no conflict of interest.

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