

Available online at www.sciencerepository.org

Science Repository



# **Research Article**

# Pre and Postoperative Muscle Wastage and Sarcopenia Using CT Scans in Patients Undergoing Pelvic Exenteration Surgery

Sophie Hogan<sup>1,2#\*</sup>, James Farag<sup>1#</sup>, Claire Wilton<sup>2</sup>, Felicity Ritorni<sup>1</sup>, Virginia Chan<sup>2</sup>, Simon Lai<sup>1</sup>, Anna Rangan<sup>2</sup>, Michael Solomon<sup>1,2</sup> and Sharon Carey<sup>1,2</sup>

<sup>1</sup>Royal Prince Alfred Hospital, Camperdown, New South Wales, Australia <sup>2</sup>University of Sydney, Camperdown, New South Wales, Australia <sup>#</sup>Co-first authors

# ARTICLE INFO

Article history: Received: 9 December, 2020 Accepted: 23 December, 2020 Published: 31 December, 2020

Keywords: Sarcopenia surgical oncology pelvic exenteration nutrition

# ABSTRACT

**Background:** Sarcopenia is associated with poor postoperative outcomes in oncology patients. Computed tomography (CT) scans can be used to identify muscle wasting and sarcopenia. This study aimed to investigate if pelvic exenteration surgery leads to muscle wastage and thus, induction or exacerbation of sarcopenia.

**Methods:** This is a retrospective review involving the analysis of CT scans before and after pelvic exenteration surgery to determine skeletal muscle index and diagnose sarcopenia. Other clinical and nutritional factors were collected.

**Results:** A total of 34 patients met the inclusion criteria. Postoperative skeletal muscle index was significantly lower compared to preoperative skeletal muscle index (p=0.008). The incidence of sarcopenia was 62% preoperatively and rose to 74% postoperatively (p=0.073). Postoperative sarcopenia was not significantly associated with complications or mortality.

**Conclusion:** The skeletal muscle index significantly decreased postoperatively, indicating that pelvic exenteration surgery leads to muscle wastage. The use of CT scans to recognise sarcopenia would allow focusing of resources for those at risk.

#### © 2020 Sophie Hogan. Hosting by Science Repository.

# Introduction

Pelvic exenteration is a major surgical procedure for the treatment of advanced or recurrent cancer of the pelvis. It involves the en-bloc resection of the pelvic viscera, vessels, muscles, ligaments and part of the pelvic bone [1]. Removal of these anatomic structures may be complete or partial, depending on what is required for the tumor to be removed with a clear resection margin (R0) [1, 2]. Despite the radical nature of the surgery and its associated high morbidity of approximately 70%, this surgery is being increasingly performed as it is the only potentially curative option for locally advanced and recurrent rectal cancer [2, 3]. For those not receiving the surgery and being treated with radiotherapy alone, 5-year survival rates are as low as 3%, compared to

a 5-year survival rate of 53% in those treated with pelvic exenteration surgery in an Australian quaternary hospital [3, 4].

A common complication in oncology patients is a reduction in body stores, including muscle wasting and subcutaneous fat loss [5]. Sarcopenia is defined by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life, and death [6]. In the oncology setting, low muscle mass alone has been used to diagnose sarcopenia [7]. As other nutritional assessment tools and indicators are unable to predict changes in lean and adipose tissue, Computed Tomography (CT) scans can be used to identify sarcopenia through quantifying muscle area and density [8].

<sup>\*</sup>Correspondence to: Sophie Hogan, Deputy Manager/Clinical Educator, Nutrition and Dietetics Department, Royal Prince Alfred Hospital, Building 12, Missendon Road, Camperdown, New South Wales, 2050; University of Sydney, Camperdown, New South Wales, 2006, Australia; Tel: +61295158053; Fax: +6195155047; Email: sophie.hogan@health.nsw.gov.au

<sup>© 2020</sup> Sophie Hogan. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. Hosting by Science Repository. http://dx.doi.org/10.31487/j.JSCR.2020.04.10

2

Sarcopenia is associated with poor postoperative outcomes in oncology patients [9]. It has been identified that length of hospital stay, morbidity and mortality are all increased in oncology patients with sarcopenia, along with functional decline and a reduction of disease-free survival [10, 11]. CT scans can therefore be used to identify patients who have undergone pelvic exenteration with high postoperative risk secondary to sarcopenia. To our knowledge, there are currently no studies investigating if pelvic exenteration surgery leads to muscle wasting, and thus the induction or exacerbation of sarcopenia. An awareness of this would allow tailoring of pre and postoperative care to optimise patient outcomes. The aim of this study was to determine if muscle wastage and the proportion of sarcopenia varies before and after pelvic exenteration surgery via assessment of a protocolised and validated body composition analysis using CT.

#### Methods

# I Study Design

This is a retrospective cohort study comparing muscle mass and sarcopenia status pre- and post-pelvic exenteration surgery. The patients were selected from a single-blinded randomized controlled trial (2015-2018) comparing the impact of preoperative immunonutrition to standard polymeric supplements on those undergoing pelvic exenteration [12]. As there was no significant difference found between groups, the results of this study should not be affected by the different supplements instituted preoperatively.

# **II Study Population**

Individuals who underwent pelvic exenteration surgery between January 1st, 2015 and January 31st, 2018, at a quaternary hospital in Sydney, Australia, were assessed for eligibility. Inclusion criteria were that participants must: i) be 18 years or older; ii) have CT scans at L3 before and after surgery. Participants were excluded if: i) their CT scans were taken greater than 3 months pre- or post-surgery; ii) their CT image was of poor quality; iii) their CT image was not accessible via electronic health records. Ethics approval was granted by the Sydney Local Health District Human Ethics Review Committee.

# **III Clinical Data**

Data were obtained retrospectively from a RedCap database set up for the randomized controlled trial [13]. Baseline data were collected for each eligible participant, which included age, gender, cancer diagnosis, type of pelvic exenteration surgery, weight (kg), height (m), BMI (kg/m<sup>2</sup>), handgrip strength (HGS) (kg and % expected strength) and nutritional status using the patient-generated subjective global assessment (PG-SGA). On postoperative day 7, weight, percentage weight change, BMI, HGS and nutritional status were collected. On postoperative day 14, weight, percentage weight change, BMI and HGS were collected. On postoperative day 21- and three-months postoperation, weight, percentage weight change and BMI were collected. HGS was measured using the JAMAR hand-dynamometer according to the Southampton grip strength measurement protocol [14]. These results were calculated as a percentage of the patient's expected HGS, according to the National Isometric Muscle Strength (NIMS) Database consortium equation [15].

Nutritional status was determined using the PG-SGA which is a validated nutritional assessment tool designed for oncology patients [16]. It categorises patients as well-nourished (A), suspected or moderately malnourished (B), and severely malnourished (C) and provides a numerical number outlining the severity of symptoms. Mortality was assessed at 30 days. Postoperative complications and length of stay were also collected. Complications were reported as sepsis, wound, gastrointestinal, urological, cardiovascular, and respiratory complications in order to determine any correlation between sarcopenia and these complications.

# **IV Image Analysis**

CT scans were collected within 3 months before and after pelvic exenteration surgery. Muscle cross-sectional areas (cm<sup>2</sup>) were calculated for each lumbar 3 (L3) vertebra CT image, using the software Slice-omatic<sup>TM</sup>, version 5.0 (Tomovision, Montreal, Quebec, Canada). The L3 vertebra was used as it has been shown to be the most accurate single image cross-sectional region for correlation to whole-body skeletal muscle mass [8]. Image analysis was performed by three trained observers (CW, SH and SC), with body tissues being identified and tagged based on the use of Hounsfield Unit thresholds: -29 to 150 for skeletal muscle, -150 to -50 for visceral adipose tissue and -190 to -30 for intramuscular and subcutaneous adipose tissue [17]. Tissue crosssectional area was calculated by multiplying the tagged area by the pixel density. The skeletal muscle cross-sectional area was normalised for stature in metres squared (m<sup>2</sup>) and reported as skeletal muscle index (SMI) (cm<sup>2</sup>/m<sup>2</sup>). Observer accuracy was confirmed by testing the coefficient of variation for the SMI between observers which did not exceed 1.3% [18]. Participants were defined as sarcopenic if analysis of their CT scan indicated their SMI as less than 38.5cm<sup>2</sup>/m<sup>2</sup> for women and 52.4 cm<sup>2</sup>/m<sup>2</sup> for men as determined by Prado et al. (2008).

#### V Statistical Analysis

Differences between sarcopenia and muscle wastage before and after surgery were statistically analysed. Postoperative sarcopenia was assessed to determine its impact on outcomes of mortality, length of stay and complications. Nutritional markers were assessed with their relation to postoperative sarcopenia, including postoperative weight, BMI, and handgrip strength at follow-up. Additionally, preoperative characteristics were analysed to identify any predictors of postoperative sarcopenia. The analysis was performed using SPSS version 24 (IBM, Armonk, New York, USA). As the data was assumed to be nonparametric, baseline demographic data was described using median and interquartile range (IQR). Statistical analysis was performed using a Chisquare test for sarcopenia status, a Wilcoxon signed rank test for SMI and Mann Whitney U tests for outcome variables. P values <0.05 were considered significant for all tests.

# Results

A total of 79 patients who underwent pelvic exenteration were assessed for eligibility. Thirty-four patients were identified as suitable for enrolment to the study, with the primary exclusion being no postoperative scan available for assessment. Of the 34 patients, 21 patients (62%) had preoperative sarcopenia on the assessment of their preoperative CT scans. Preoperative patient demographics are outlined in (Table 1). Table 2 outlines the overall postoperative results of patients

undergoing pelvic exenteration. Of the 34 patients, 25 of them were considered sarcopenic after surgery. Eighteen were classified as malnourished (53%); and weight change progressively declined over 3 months after surgery to 9% of total body weight. Thirty-day mortality was zero.

Table 1: Preoperative patient demogr	raphics
--------------------------------------	---------

Variable	Results, n = 34	
Age (years)	62	(28-79)
Gender:		
- Male	n = 23	(67%)
- Female	n = 11	(32%)
Type of cancer:		
- Primary rectal	n = 8	(24%)
- Rectal recurrence	n = 17	(50%)
- Primary other	n = 3	(9%)
- Other recurrence	n = 6	(18%)
Surgical resection:		
- Complete	n = 26	(77%)
- Partial	n = 8	(24%)
Preoperative sarcopenia	n = 21	(62%)
Preoperative weight (kg)	77.0	IQR (67.1-89.8)
Height (cm)	171.8	IQR (158.4-177.3)
Preoperative BMI (kg/m <sup>2</sup> )	25.6	IQR (23.3-31.0)
Preoperative PG-SGA score	3.5	IQR (2.0-8.3)
Preoperative PG-SGA		
- A (well nourished)	n = 23	(67.6%)
- B/C (malnourished)	n = 11	(32.4%)
Preoperative HGS (kg)	31.5	(25.3-41.0)
Preoperative HGS (% predicted)	82.9	(76.0-106.0)
Preoperative SMI (cm <sup>2</sup> m <sup>2</sup> )	47.9	(36.1-54.9)

BMI: Body Mass Index; PG-SGA: Patient-Generated Subjective Global Assessment; HGS: Hand Grip Strength; SMI: Skeletal Muscle Index.

# Table 2: Overall postoperative outcomes.

Variable	Results, n = 34		
30 day mortality	0	(0%)	
Postoperative sarcopenia	25	(74%)	
Postoperative SMI (cm <sup>2</sup> m <sup>2</sup> )	43.4	(35.7-51.1)	
Postoperative length of stay (days)	28.5	(22.0-48.8)	
7 day postoperative PG-SGA			
• A (well-nourished)	16	(47%)	
• B/C (malnourished)	18	(53%)	
7 days postoperative HGS (% predicted)	80	(63-89)	
14 days postoperative HGS (% predicted)	82	(73-95)	
7 days postoperative weight change (%)	-1.4	(-4.9 - +3.0)	
14 days postoperative weight change (%)	-3.7	(-8.0 - +2.7)	
21 days postoperative weight change (%)	-5.6	(-11.92.0)	
3 months postoperative weight change (%)	-9.1	(-16.04.3)	

SMI: Skeletal Muscle Index; PG-SGA: Patient-Generated Subjective Global Assessment; HGS: Hand Grip Strength.

# I Muscle Wastage and Sarcopenia

Table 3 outlines sarcopenia status and SMI before and after pelvic exenteration surgery. The incidence of sarcopenia increased, but not significantly, from the pre to postoperative period (p=0.073).

Nonetheless, the median SMI was significantly lower postoperatively compared to preoperatively (p=0.008). More specifically, the SMI was significantly lower after surgery compared to before surgery, irrespective of postoperative sarcopenia status.

Table 3: Sarcopenia status and SMI in th	pre and postoperative	periods of pelvic	exenteration surgery.
--	-----------------------	-------------------	-----------------------

	Preopera n (%)	ntive	Postoper n (%)	ative	p-value
Sarcopenic patients	21	(62)	25	(74)	0.073
SMI (cm <sup>2</sup> m <sup>2</sup> )	47.9	(36.1-54.9)	43.4	(35.7-51.1)	0.008
SMI (cm <sup>2</sup> m <sup>2</sup> ) of patients classified as non-sarcopenic after surgery SMI	57.4	(46.8-61.7)	54.2	(46.2-61.2)	0.002
SMI (cm <sup>2</sup> m <sup>2</sup> ) of patients classified as sarcopenic after surgery	43.6	(35.2-50.9)	39.2	(34.1-47.9)	< 0.001

SMI: Skeletal Muscle Index

# **II Predictors of Postoperative Sarcopenia**

Table 4 outlines preoperative and intraoperative differences between postoperative sarcopenic and non-sarcopenic patients. Neither gender nor age was predictive of postoperative sarcopenia. Unsurprisingly,

Table 4: Preoperative and intraoperative characteristics.

preoperative sarcopenia was significantly associated with postoperative sarcopenia (p < 0.001). Lower BMI, weight and SMI were also predictive of postoperative sarcopenia. There was no correlation between the type of cancer or extent of surgical resection (partial vs complete) and postoperative sarcopenia.

	<u>^</u>	Postoper	ostoperative sarcopenic patients (n = 25)		5) Postoperative non-sarcopenic patients (n = 9)	
Gender						0.969
•	Male	17	(68%)	6	(67%)	
•	Female	8	(32%)	3	(33%)	
Age (year	s)	61	(52-67)	67	(61-75)	0.06
Height (cr	m)	175	(161-180)	163	(158-169)	0.05
Preoperat	ive weight (kg)	75.2	(61.5-83.4)	88.5	(80.4-95.4)	0.015
Preoperat	ive BMI (kg/m <sup>2</sup> )	24.3	(22.7-27.3)	31.7	(30.0-36.1)	< 0.001
Preoperat	ive PG-SGA score	4.0	(1.5-10.5)	3.0	(2.0-4.0)	0.298
Preoperat	ive PG-SGA					0.216
•	A (well nourished)	15	(60%)	8	(88.9%)	
•	B/C (malnourished)	10	(40%)	1	(11.1%)	
Preoperat	ive HGS (% predicted)	82.8	(76.2-106.4)	84.8	(74.5-107.1)	0.759
Preoperat	ive SMI (cm <sup>2</sup> m <sup>2</sup> )	43.6	(35.2-50.9)	57.4	(46.8-61.7)	0.001
Preoperat	ive sarcopenia	21	(84%)	4	(16%)	< 0.001
Surgical r	esection					0.163
•	Complete	17	(68%)	9	(100%)	
•	Partial	8	(32%)	0	(0%)	
Type of c	ancer					0.397
•	Primary rectal	7	(28%)	1	(11%)	
•	Rectal recurrence	12	(48%)	5	(56%)	
•	Primary other	2	(8%)	1	(11%)	
•	Recurrent other	4	(16%)	2	(22%)	
Rectal or other cancer						0.701
•	Rectal	19	(76%)	6	(67%)	
•	Other	6	(24%)	3	(33%)	

BMI: Body Mass Index; PG-SGA: Patient-Generated Subjective Global Assessment; HGS: Handgrip Strength; SMI: Skeletal Muscle Index.

# **III Postoperative Mortality and Complications**

There was no difference in mortality between patients that were sarcopenic and non-sarcopenic after surgery, as overall mortality was

#### Table 5: Postoperative survival and complications.

0%. As outlined in (Table 5), there was no difference in postoperative length of stay (PO-S 29, IQR 29-46 vs PO-NS 28, 24-59; p=0.489). Additionally, there was no difference in any postoperative complications.

	Postoperative sarcopenic patients (n=25)		Postopera	p-value	
30 day mortality	0	(0%)	0	(0%)	1.000
Postoperative length of stay (days)	29	(29-46)	28	(24-59)	0.489
Total complications	3	(1.0-4.0)	6	(1.5-6.5)	0.072
Postoperative sepsis	11	(44%)	7	(78%)	0.14
Wound complications	12	(48%)	6	(67%)	0.163
Respiratory complications	7	(28%)	6	(67%)	0.120
Gastrointestinal complications	18	(72%)	6	(67%)	0.489
Urological complications	1	(4%)	1	(11%)	0.759
Cardiovascular complications	5	(20%)	3	(33%)	0.645

# **IV Postoperative Nutrition Related Outcomes**

Postoperative BMI and weight were unsurprisingly lower in the sarcopenic population, however as demonstrated in Table 6, there was a greater percent loss of weight in the postoperative non-sarcopenic group.

Table 6: Postoperative nutrition related outcomes.

The difference was initially not significant at 7 then 14 days but diverged over time and was significantly different at 21 days (PO-S 3% vs PO-NS 7%, p=0.016) and 3 months (PO-S 7% vs PO-NS 17%, p=0.016) [1-19]. Both PG-SGA and HGS did not correlate with sarcopenia in the postoperative period.

	Postop Sa	arcopenic Patients (n = 25)	Postoper	ative Non-Sarcopenic Patients (n = 9)	p-value
Postoperative SMI	39.2	(34.1-47.9)	54.2	(46.2-61.2)	< 0.001
7 day postoperative weight change (%)	-1.34	(-4.6 - +3.8)	-1.4	(-60.1)	0.471
7 day postoperative BMI (kg/m <sup>2</sup> )	24.1	(21.3-27.5)	31.1	(29.9-35.1)	0.001
7 day postoperative PG-SGA					0.618
• A (well-nourished)	11	(44%)	5	(55.6%)	
• B, C (malnourished)	14	(56%)	4	(44.4%)	
7 day postoperative HGS (% predicted)	80.2	(64.2-95)	62.1	(46.1-84.2)	0.102
14 day postoperative weight change (%)	-3	(-6.1 - +4.5)	-5.9	(-8.43.5)	0.097
14 day postoperative BMI (kg/m <sup>2</sup> )	23.4	(20-27.9)	30.4	(28.5-30.4)	0.001
14 day postoperative HGS (% predicted)	81.5	(70.9-92.5)	88.3	(75.1-101.1)	0.324
21 day postoperative weight change (%)	-3	(-7.20.8)	-7	(-14.65.6)	0.016
21 day postoperative BMI (kg/m <sup>2</sup> )	23.6	(19.9-26)	28.2	(27.5-32.9)	0.001
3 month postoperative weight change (%)	-7.3	(-12.73.5)	-16.5	(-18.911.4)	0.016

SMI: Skeletal Muscle Index; BMI: Body Mass Index; PG-SGA: Patient-Generated Subjective Global Assessment; HGS: Handgrip Strength.

#### Discussion

Although the sample size was not large enough to demonstrate a significant rise in sarcopenia from the pre to postoperative period for pelvic exenteration, the results showed that median SMI significantly decreased from 47.9cm<sup>2</sup>m<sup>2</sup> (IQR 36.1-54.9) to 43.4cm<sup>2</sup>m<sup>2</sup> (IQR 35.7-51.1) (p=0.008). It was demonstrated that the most significant preoperative risk factors for postoperative sarcopenia were preoperative sarcopenia, low BMI, weight, and SMI. There was no difference in postoperative complications between those that were sarcopenic and not

in the postoperative period. There was no difference in mortality whether patients were sarcopenic or not, as all patients survived to discharge and at 3 months on follow-up. The increase in the incidence of sarcopenia from the pre to postoperative period reflects the muscle wastage that pelvic exenteration undoubtedly induces. This is reinforced by the significant reduction in SMI across the whole cohort. Furthermore, SMI was significantly reduced even in patients who were non-sarcopenic postoperatively, suggesting that the surgical insult leads to a reduction in muscle mass in all patients.

The high incidence of sarcopenia post-surgery is a multifaceted issue, and poor nutrition intake alone is unlikely the sole determinant. Protein requirements are higher post pelvic exenteration surgery due to the pathophysiologic demands of wound healing, combating potential infections, and an overall systemic inflammatory response [19]. Pelvic exenteration surgery is a major surgical insult and the magnitude of the surgery is reflected in rates of prolonged postoperative recovery and complications [20]. Furthermore, with the majority of patients indicated for surgery due to recurrence, preoperative irradiation and/or chemotherapy would have likely impacted their recovery [21]. Protein losses are also increased due to catabolism and its associated metabolic changes, resulting in lean tissue loss [19, 22]. These catabolic changes may be minimised but are not entirely preventable [23]. It is likely a combination of decreased nutritional intake, increased protein needs and altered protein metabolism that results in the increase of sarcopenia after pelvic exenteration surgery, as was observed in this study.

Oncology patients of higher weights and BMI have been shown in the literature to have lower rates of sarcopenia [24, 25]. Kalantar-Zadeh reported on what they described as the "risk-factor paradox", where high body weight and obesity are found to be protective in wasting diseases such as cancer and its associated cachexia [26]. It has been suggested that this survival advantage is due to the greater energy stores available, able to be drawn on throughout the negative energy balance experienced during the disease state [18]. The cohort in this study demonstrated the same result, with median (preoperative) weight and BMI of postoperatively sarcopenic patients significantly lower than non-sarcopenic patients.

In this study, patients that were non-sarcopenic postoperatively had a significantly higher percentage of weight loss at 3 weeks and 3 months post-surgery than the postoperative sarcopenic patients. This may seem counter-intuitive but likely reflects the great need for energy stores to be utilised in times of high metabolic demand. In cases of sarcopenia, these stores are overall already diminished or unavailable. These energy stores being drawn on during the times of increased nutritional need postsurgery may explain the greater weight loss at 3 months post operation seen in our postoperative non-sarcopenic patients. Although not significant at the 1-week postoperative period, the loss of weight gradually increased over time to become significant at 3 weeks and 3 months thereafter, reflecting the gradual temporal catabolic nature that pelvic exenteration can induce. This suggests longer follow-up to monitor the progress of weight loss and identify at-risk patients is needed. As outlined in Bauer position paper on sarcopenia, patients may benefit from a resistance exercise programme and protein-rich diet postoperatively [27]. Furthermore, prehabilitation is an emerging field showing promise to improving postoperative recovery. In the cardiac

surgery population, it has been shown to reduce the length of stay and improve reported quality of life compared with the control populations [28]. Similarly, functional capacity was shown to have improved in the colorectal surgical population [29].

Of note, the PG-SGA was not predictive of sarcopenia in the postoperative period. There are several reasons that may be attributed in part or collectively to this phenomenon. The definition of sarcopenia is highly debated and inconsistently agreed-upon, likely contributing to differences in outcomes across studies utilising HGS as a marker of sarcopenia [30]. Souza reported on a significant correlation between PG-SGA and sarcopenia; however, it is important to note the differences between the two cohorts to explain this aberrancy and why this study did not come to the same conclusion [31]. Although most of the patients in this study suffered from colorectal cancer, Souza's study was reporting on primarily non-surgical patients with more advanced disease. Furthermore, the changes in PG-SGA that would have been reported by this study's postoperative cohort were likely to be similar whether sarcopenic or not. Looking at the four components of the PG-SGA it is clear to see why this method of assessment is likely to be highly confounded by surgical interventions. With regards to change in diet, that would have likely been driven primarily by postoperative surgeons' orders and the anatomical area resected, rather than any sarcopeniarelated factors.

Similarly, the physical symptoms would likely have been induced by a surgical intervention such as pelvic exenteration and postoperative pain management. In fact, all three components of the diet, physical symptoms, and activities and function would have deteriorated across the board for both postoperative sarcopenic and non-sarcopenic patients independent of their nutritional status. Furthermore, the weight loss component is confounded by the fact that non-sarcopenic patients lost more weight than sarcopenic patients, as discussed earlier. Hence, it is indicative that the PG-SGA may not be a superior assessment to identify at-risk patients in the postoperative period, being less sensitive and specific than other body-composition measures.

Sarcopenia can have a large effect on the quality of life, functional status and clinical outcomes, even being an independent predictor of diseasefree survival in cancer patients [11, 23]. CT scan technology allows sensitive body composition analysis that is more accurate than current methods at identifying sarcopenia in an increasingly obese population [8, 32]. This study has shown an increase in sarcopenia prevalence after patients undergo pelvic exenteration surgery. This muscle wastage needs to be minimised in order to reduce adverse outcomes associated with sarcopenia. Thus, an accurate body composition tool using CT scans could allow for targeted dietetic interventions to those most at risk, resulting in improved patient outcomes. As CT scans are performed routinely in this patient group, their use for accurate body composition analysis is not unreasonable. However, analysis of the scans is a timeconsuming process, and therefore more practical strategies are required. A potential method is to identify patients at the highest risk of postoperative sarcopenia, i.e. those at the lower end of normal BMI and/or weight (with their appropriate age, height and gender bracket).

A limitation of our study was the small sample size. Our study was a retrospective cohort study and thus, a limitation was the uniformity of

time to a postoperative CT. A larger prospective study with dedicated CT protocols and timing postoperatively would provide more consistency and accuracy (in particular at 3 weeks and 3 months postoperatively), although they should only be performed where clinically indicated in view of the radiation risk. Furthermore, this cohort of pelvic exenteration patients represents a population undergoing major surgical insult with significant tumor burden, and thus these results cannot be generalised to other postoperative groups.

#### Conclusion

This study has demonstrated that pelvic exenteration surgery leads to muscle wastage, which will likely lead to an increase in the incidence of sarcopenia in larger studies. This is established by a reduction in SMI from the pre to postoperative period. Multiple factors may be attributed to this change, including preoperative clinical condition, extensive surgery, poor nutritional intake post-surgery, increased protein needs and altered protein metabolism. The practical use of CT scans to sensitively and accurately recognise sarcopenia can allow for the identification of patients requiring further follow-up and monitoring of long-term outcomes. Optimisation of nutritional intake and prehabilitation may demonstrate a long-term improvement in outcomes studied in the future.

#### Data Availability

Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

# **Conflicts of Interest**

None.

# Funding

None.

# Acknowledgement

None.

# REFERENCES

- Austin KK, Young JM, Solomon MJ (2010) Quality of life of survivors after pelvic exenteration for rectal cancer. *Dis Colon Rectum* 53: 1121-1126. [Crossref]
- Brown KGM, Solomon MJ, Koh CE (2017) Pelvic Exenteration Surgery: The Evolution of Radical Surgical Techniques for Advanced and Recurrent Pelvic Malignancy. *Dis Colon Rectum* 60: 745-754. [Crossref]
- Austin KK, Herd AJ, Solomon MJ, Ly K, Lee PJ (2016) Outcomes of Pelvic Exenteration with en Bloc Partial or Complete Pubic Bone Excision for Locally Advanced Primary or Recurrent Pelvic Cancer. *Dis Colon Rectum* 59: 831-835. [Crossref]

- Dobrowsky W, Schmid AP (1985) Radiotherapy of presacral recurrence following radical surgery for rectal carcinoma. *Dis Colon Rectum* 28: 917-919. [Crossref]
- Rossi F, Valdora F, Barabino E, Calabrese M, Tagliafico AS (2019) Muscle mass estimation on breast magnetic resonance imaging in breast cancer patients: comparison between psoas muscle area on computer tomography and pectoralis muscle area on MRI. *Eur Radiol* 29: 494-500. [Crossref]
- Huang DD, Wang SL, Zhuang CL, Zheng BS, Lu JX et al. (2015) Sarcopenia, as defined by low muscle mass, strength and physical performance, predicts complications after surgery for colorectal cancer. *Colorectal Dis* 17: O256-O264. [Crossref]
- Prado CM, Lieffers JR, McCargar LJ, Reiman T, Sawyer MB et al. (2008) Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. *Lancet Oncol* 9: 629-635. [Crossref]
- Prado CMM, Heymsfield SB (2014) Lean Tissue Imaging. JPEN J Parenter Enteral Nutr 38: 940-953. [Crossref]
- Reisinger KW, Derikx JP, van Vugt JL, Von Meyenfeldt MF, Hulsewé KW et al. (2016) Sarcopenia is associated with an increased inflammatory response to surgery in colorectal cancer. *Clin Nutr* 35: 924-927. [Crossref]
- Levolger S, van Vugt JL, de Bruin RW, JN IJ (2015) Systematic review of sarcopenia in patients operated on for gastrointestinal and hepatopancreatobiliary malignancies. *Br J Surg* 102: 1448-1458. [Crossref]
- Hopkins JJ, Skubleny D, Bigam DL, Baracos VE, Eurich DT et al. (2018) Barriers to the interpretation of body composition in colorectal cancer: a review of the methodological inconsistency and complexity of the CT-defined body habitus. *Ann Surg Oncol* 25: 1381-1394. [Crossref]
- Hogan S, Solomon M, Rangan A, Ferrie S, Carey S (2019) The Impact of Preoperative Immunonutrition and Standard Polymeric Supplements on Patient Outcomes After Pelvic Exenteration Surgery, Taking Compliance Into Consideration: A Randomized Controlled Trial. JPEN J Parenter Enteral Nutr 44: 806-814. [Crossref]
- Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N et al. (2009) Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 42: 377-381. [Crossref]
- Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H et al. (2011) A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing* 40: 423-429. [Crossref]
- (1996) Muscular weakness assessment: use of normal isometric strength data. The National Isometric Muscle Strength (NIMS) Database Consortium. Arch Phys Med Rehabili 77: 1251-1255. [Crossref]
- Bauer J, Capra S, Ferguson M (2002) Use of the scored Patient-Generated Subjective Global Assessment (PG-SGA) as a nutrition assessment tool in patients with cancer. *Eur J Clin Nutr* 56: 779-785. [Crossref]
- Mourtzakis M, Prado CM, Lieffers JR, Reiman T, McCargar LJ et al. (2008) 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* 33: 997-1006. [Crossref]

- Martin L, Birdsell L, MacDonald N, Reiman T, Clandinin MT et al. (2013) Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index. *J Clin Oncol* 31: 1539-1547. [Crossref]
- Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M et al. (2017) ESPEN guideline: clinical nutrition in surgery. *Clin Nutr* 36: 623-650. [Crossref]
- Schiltz B, Buchs NC, Penna M, Scarpa CR, Liot E et al. (2017) Biological mesh reconstruction of the pelvic floor following abdominoperineal excision for cancer: A review. *World J Clin Oncol* 8: 249. [Crossref]
- Jimenez RE, Shoup M, Cohen AM, Paty PB, Guillem J et al. (2003) Contemporary outcomes of total pelvic exenteration in the treatment of colorectal cancer. *Dis Colon Rectum* 46: 1619-1625. [Crossref]
- 22. Sandrucci S, Beets G, Braga M, Dejong K, Demartines N (2018) Perioperative nutrition and enhanced recovery after surgery in gastrointestinal cancer patients. A position paper by the ESSO task force in collaboration with the ERAS society (ERAS coalition). *Eur J Surg Oncol* 44: 509-514. [Crossref]
- Beaton J, Carey S, Solomon M, Young J (2013) Preoperative and postoperative nutritional status of patients following pelvic exenteration surgery for rectal cancer. *e-SPEN J* 8: e164-e168.
- Nipp RD, Fuchs G, El Jawahri A, Mario J, Troschel FM et al. (2018) Sarcopenia is associated with quality of life and depression in patients with advanced cancer. *Oncologist* 23: 97-104. [Crossref]

- Aoyama T, Sato T, Segami K, Maezawa Y, Kano K et al. (2016) Risk factors for the loss of lean body mass after gastrectomy for gastric cancer. *Ann Surg Oncol* 23: 1963-1970. [Crossref]
- Kalantar Zadeh K, Horwich TB, Oreopoulos A, Kovesdy CP, Younessi H et al. (2007) Risk factor paradox in wasting diseases. *Current Opin Clin Nutr Metabol Care* 10: 433-442. [Crossref]
- Bauer J, Morley JE, Schols AMWJ, Ferrucci L, Cruz Jentoft AJ et al. (2019) Sarcopenia: A Time for Action. An SCWD Position Paper. J Cachexia Sarcopenia Muscle 10: 956-961. [Crossref]
- Hulzebos EH, Smit Y, Helders PP, van Meeteren NL (2012) Preoperative physical therapy for elective cardiac surgery patients. *Cochrane Database Syst Rev* 11: CD010118. [Crossref]
- Mayo NE, Feldman L, Scott S, Zavorsky G, Kim DJ et al. (2011) Impact of preoperative change in physical function on postoperative recovery: argument supporting prehabilitation for colorectal surgery. *Surgery* 150: 505-514. [Crossref]
- Reginster JY, Cooper C, Rizzoli R, Kanis JA, Appelboom G et al. (2016) Recommendations for the conduct of clinical trials for drugs to treat or prevent sarcopenia. *Aging Clin Exp Res* 28: 47-58. [Crossref]
- Souza BUd, Souza NCS, Martucci RB, Rodrigues VD, Pinho NBd et al. (2018) Factors Associated with Sarcopenia in Patients with Colorectal Cancer. *Nutr Cancer* 70: 176-183. [Crossref]
- 32. Collaboration NCDRF (2017) Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet* 390: 2627-2642. [Crossref]