

# A Comprehensive Analysis of the Association of Psoas and Masseter Muscles with Traumatic Brain Injury Using Computed Tomography Anthropometry

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**Objective :** Psoas and masseter muscles are known markers of sarcopenia. However, the relative superiority of either muscle as a marker is unclear. Therefore, this study analyzed the two muscles in patients with a prognosis of traumatic brain injury (TBI).

**Methods :** Patients with TBI visiting a regional trauma center between January 2017 and December 2018 were selected, and their medical records were reviewed. TBI patients with an abbreviated injury score (AIS) of 4 or 5 were selected. Patients with an AIS of 4 or 5 at the chest, abdomen, and extremity were excluded. Patients with a hospital stay of 1 to 2 days were excluded. Both muscle areas were measured based on the initial computed tomography. The psoas muscle index (PMI) and the masseter muscle index (MMI) were calculated by dividing both muscle areas by height in meters squared ( $\text{cm}^2/\text{m}^2$ ). These muscle parameters along with other medical information were used to analyze mortality and the Glasgow outcome scale (GOS).

**Results :** A total of 179 patients, including 147 males (82.1%), were analyzed statistically. The mean patient age was 58.0 years. The mortality rate was 16.8% (30 patients). The mean GOS score was 3.7. Analysis was performed to identify the parameters associated with mortality, which was a qualitative study outcome. The psoas muscle area (16.9 vs. 14.4  $\text{cm}^2$ ,  $p=0.028$ ) and PMI (5.9 vs. 5.1  $\text{cm}^2/\text{m}^2$ ,  $p=0.004$ ) showed statistical differences between the groups. The PMI was also statistically significant as a risk factor for mortality in logistic regression analysis ( $p=0.023$ ; odds ratio, 0.715; 95% confidence interval, 0.535–0.954). Quantitative analyses were performed with the GOS scores. Bivariate correlation analysis showed a statistically significant correlation between PMI and GOS scores (correlation coefficient, 0.168;  $p=0.003$ ). PMI ( $p=0.004$ , variation inflation factor 1.001) was significant in multiple regression analysis. The masseter muscle area and MMI did not show significance in the study.

**Conclusion :** Larger PMI was associated with statistically significant improved survival and GOS scores, indicating its performance as a superior prognostic marker. Further analyses involving a larger number of patients, additional parameters, and more precise settings would yield a better understanding of sarcopenia and TBI.

**Key Words :** Traumatic brain injury · Psoas · Masseter muscle · Computed tomography · Prognosis.

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## INTRODUCTION

Sarcopenia (Greek ‘sarx’ or flesh + ‘penia’ or loss) is defined as a progressive and generalized skeletal muscle disorder<sup>5)</sup>. It is an important marker of nutritional and physical status and overall health<sup>6,11)</sup>. It is currently recognized as a muscle disease and considered an independent condition based on the International Classification of Diseases, 10th clinical edition<sup>1,20)</sup>. Clinically, it is associated with cardiovascular, respiratory, and malignant diseases<sup>4,8,15)</sup>. Sarcopenia is also associated with an individual’s quality of life and mortality<sup>3,9)</sup>.

Among the many methods available to assess muscle status, the measurement of psoas muscle area (PMA) using computed tomography (CT) is well known. Reports have related PMA to mortality and the quality of life in several critical patients<sup>7,10,19)</sup>. CT measurement of the masseter muscle area (MMA) is an alternative method to analyze muscle status. The masseter muscle is associated with nutritional disorders such as obesity and also with geriatric conditions<sup>14)</sup>. It is also associated with the patient’s cerebrovascular prognosis<sup>16,17)</sup>. Hu et al.<sup>13)</sup> reported that MMA was associated with early mortality in patients with severe traumatic brain injury (TBI).

Both PMA and MMA are proven prognostic markers in various diseases. However, evidence to suggest the relative superiority of each muscle as a prognostic marker is inadequate. Therefore, the present study was undertaken to compare the prognostic values of both markers including the odds ratio and correlation coefficient in inpatients with TBI. A comprehensive analysis of qualitative and quantitative parameters is presented.

## MATERIALS AND METHODS

This retrospective study was approved by the Institutional Review Board of Uijeongbu St. Mary’s Hospital (UC20RISI0093), and the requirement for informed consent was waived. Patients with TBI visiting the regional trauma center between January 2017 and December 2018 were selected. Their medical information was gathered via retrospective chart review. General parameters including age, sex, height, weight, length of hospital stay, and trauma-related factors such as intubation, operation, Glasgow coma scale (GCS) score, abbreviated injury score (AIS), and injury severity score (ISS)

were evaluated. Glasgow outcome scale (GOS) scores and mortality were analyzed together to determine the clinical outcomes. Patients with endotracheal intubation and scoring 8 or less on the GCS were regarded as having a severe TBI and compared to those with scores of 9 or higher on the GCS. Patient body mass index (BMI) was calculated and those with a BMI higher than 25 were regarded as obese.

Initially, CT was used to perform the muscle measurements. Common sites were used for the anthropometric studies, as described previously. The cross-sectional area of the psoas muscle was measured at the level of the third lumbar vertebral body bilaterally as the PMA<sup>12)</sup>. The cross-sectional area of the masseter muscle was measured 2 cm below the zygomatic arch bilaterally as the MMA<sup>18)</sup>. The psoas muscle index (PMI) and the masseter muscle index (MMI) were calculated by dividing both muscle areas by height in meters squared ( $\text{cm}^2/\text{m}^2$ ). Patients with proper CT images were included in the study. Patients with tilted CT images or image artifacts were excluded. Patients with injured muscles or nearby bony structures were also excluded.

Patients with major TBI were selected based on an AIS of 4 or 5. Patients with an AIS of 4 or 5 at the chest, abdomen, or extremity were excluded to reduce bias associated with other conditions. Patients younger than 19 years and those with missing data were also excluded. Additionally, patients with a hospital stay of fewer than 2 days were excluded.

Comprehensive analyses were planned. Mortality was used as a qualitative outcome and GOS scores were used as a quantitative outcome. Initially, the patients were separated into two groups, survival and mortality, and their medical records were analyzed. An independent t-test was used for quantitative analysis, and chi-squared tests were used for qualitative analysis. Logistic regression analysis was performed to verify the risk factors. Bivariate correlation analysis of both muscle indices and GOS scores was conducted. Correlation coefficients were calculated after adjustment for age, BMI, AIS, and ISS. Additionally, multiple regression analysis was performed. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA).

## RESULTS

A total of 357 TBI patients had an AIS score of 4–5. Among

them, 263 patients were suspected of having major trauma and underwent both brain and torso CT (chest + abdominopelvic CT). Two hundred and forty-three patients with proper CT images and 226 patients without injury to the chest or abdomen, or extremity AIS scores of 4–5, were selected. Twenty patients were excluded due to age, and seven patients were excluded due to missing data. Additionally, 20 patients were excluded for missing data. The patient selection process is summarized in Fig. 1.

A total of 179 patients were finally included in the statistical analyses. The mean patient age was 58.0 years. The study included 147 male patients (82.1%). The patient population was as follows: 51 patients with obesity (28.5%), 64 patients with severe TBI (35.8%), and 92 patients treated with neurosurgery (51.4%). The mean PMA and MMA values were  $16.5 \text{ cm}^2$  and  $9.8 \text{ cm}^2$ , respectively. The mean PMI and MMI values were 5.8 and  $3.5 \text{ cm}^2/\text{m}^2$ , respectively. Mortality was recorded in 30 patients (16.8%). The mean GOS score was 3.7. Other basic information is summarized in Table 1.

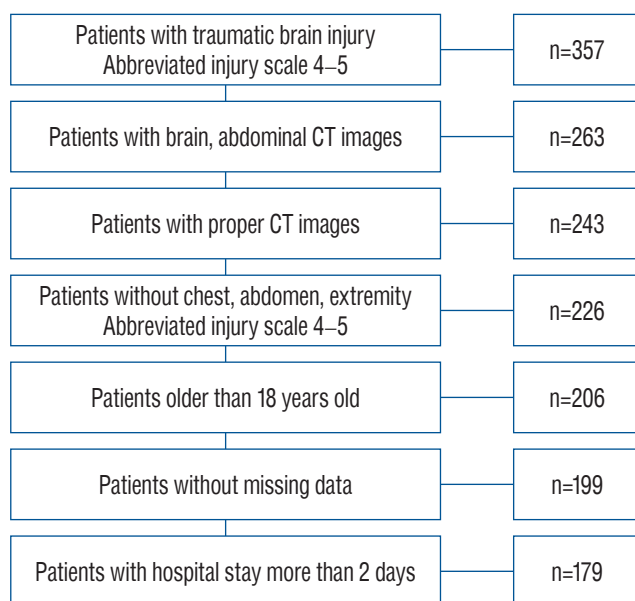
The parameters related to mortality, which was a qualitative study outcome, were analyzed. PMA ( $16.9$  vs.  $14.4 \text{ cm}^2$ ,  $p=0.028$ ) and PMI ( $5.9$  vs.  $5.1 \text{ cm}^2/\text{m}^2$ ,  $p=0.004$ ) showed statistically significant differences between the survival and mortality groups, as did patients with endotracheal intubation and scoring 8 or less on the GCS ( $p<0.001$ ). Also, the external and

facial AIS values differed statistically. The mortality analysis is summarized in Table 2. A logistic regression analysis of mor-

**Table 1.** Patients' baseline demographics

	Value
Age (years)	57.95±16.24
Sex	
Female	32 (17.9)
Male	147 (82.1)
Height (cm)	167.59±8.22
Weight (kg)	65.65±11.32
Body mass index ( $\text{kg}/\text{cm}^2$ )	23.27±3.03
Obesity	
No	128 (71.5)
Yes	51 (28.5)
Traumatic brain injury	
Non-severe	115 (64.2)
Severe	64 (35.8)
Operation	
No	87 (48.6)
Yes	92 (51.4)
Psoas muscle area ( $\text{cm}^2$ )	16.47±5.60
Masseter muscle area ( $\text{cm}^2$ )	9.76±2.50
Psoas muscle index ( $\text{cm}^2/\text{m}^2$ )	5.80±1.75
Masseter muscle index ( $\text{cm}^2/\text{m}^2$ )	3.47±1.75
Abbreviated injury score	
Head and neck	4.54±5.0
Face	0.36±0.76
Chest	1.03±1.35
Abdomen	0.25±0.75
Extremity	0.75±1.08
External	0.36±0.54
Injury severity score	26.59±6.43
Glasgow outcome score	3.65±1.50
1	30 (16.8)
2	9 (5.0)
3	35 (19.6)
4	24 (13.4)
5	81 (45.3)
Mortality	
No	149 (83.2)
Yes	30 (16.8)

Values are presented as mean±standard deviation or number (%)



**Fig. 1.** Flowchart showing the enrollment of patients with traumatic brain injury. CT: computed tomography.

tality parameters is presented in Table 3. Patients with endotracheal intubation and scoring 8 or less on the GCS was statistically associated with mortality. PMI was also a statistically significant risk factor for mortality ( $B=-0.336$ ;  $p=0.023$ ; odds

ratio, 0.715; 95% confidence interval, 0.535–0.954). The mean MMA and MMI decreased in the mortality group, but the difference was not significant.

Analysis of the GOS scores was performed and the results

**Table 2.** Mortality analysis of patients with traumatic brain injury

Parameter	Survival (n=149, 83.2%)	Mortality (n=30, 16.8%)	p-value
Age (years)	57.23±16.59	61.53±14.08	0.186
Sex			
Female	24 (75.0)	8 (25.0)	0.168
Male	125 (85.0)	22 (15.0)	
Height (cm <sup>3</sup> )	167.76±8.07	166.73±9.04	0.535
Weight (kg)	65.76±11.23	65.08±11.96	0.767
Body mass index (kg/m <sup>2</sup> )	23.27±3.08	23.27±2.85	0.999
Obesity			
No	106 (82.8)	22 (17.2)	0.808
Yes	43 (84.3)	8 (15.7)	
Severity			
GCS ≥9	108 (93.9)	7 (6.1)	<0.001
GCS ≤8 or intubated	41 (64.1)	23 (35.9)	
Operation			
No	77 (88.5)	10 (11.5)	0.067
Yes	72 (78.3)	20 (21.7)	
Psoas muscle area (cm <sup>2</sup> )	16.88±5.70	14.43±4.65	0.028
Masseter muscle area (cm <sup>2</sup> )	9.79±2.54	9.59±2.32	0.694
Psoas muscle index (cm <sup>2</sup> /m <sup>2</sup> )	5.94±1.80	5.10±1.27	0.004
Masseter muscle index (cm <sup>2</sup> /m <sup>2</sup> )	3.48±0.87	3.45±0.80	0.883
Abbreviated injury score			
Head and neck	4.53±0.50	4.60±0.50	0.487
Face	0.40±0.80	0.17±0.46	0.030
Chest	1.03±1.34	1.03±1.40	0.981
Abdomen	0.23±0.72	0.33±0.88	0.513
Extremity	0.77±1.08	0.70±1.12	0.765
External	0.40±0.54	0.17±0.46	0.020
Injury severity score	26.52±6.33	26.90±7.00	0.771

Values are presented as mean±standard deviation or number (%). An independent t-test was used for quantitative analysis, and chi-squared tests were used for qualitative analysis. GCS : Glasgow coma score

**Table 3.** Results of logistic regression analysis of mortality parameters

Parameter	B	p-value	OR (95% CI)
Psoas muscle index	-0.336	0.023	0.715 (0.535–0.954)
Glasgow coma score ≤8 or intubated	-2.185	<0.001	0.112 (0.044–0.287)

OR : odds ratio, CI : confidence interval

**Table 4.** Results of bivariate and partial correlation analyses with Glasgow outcome scale

Type of analysis	Psoas muscle index	Masseter muscle index
Bivariate correlation analysis		
Kendall's tau b		
Correlation coefficient	0.168	0.061
<i>p</i> -value	0.003	0.281
Partial correlation analysis		
Adjustment with age, BMI, AIS, ISS		
Correlation coefficient	0.176	0.067
<i>p</i> -value	0.023	0.390
Adjustment with BMI, AIS, ISS		
Correlation coefficient	0.211	0.106
<i>p</i> -value	0.006	0.170
Adjustment with AIS, ISS		
Correlation coefficient	0.211	0.060
<i>p</i> -value	0.005	0.434

BMI : body mass index, AIS : abbreviated injury score, ISS : injury severity score

**Table 5.** Result of multiple regression analysis with Glasgow outcome scale

Parameter	B	<i>p</i> -value	Variation inflation factor
Psoas muscle index	0.184	0.004	1.001
AIS - external	0.476	0.020	1.001

AIS : abbreviated injury score

were defined as a quantitative outcome. Bivariate correlation analysis showed a statistical correlation between PMI and GOS (correlation coefficient, 0.168;  $p=0.003$ ). Partial correlation analyses were performed after adjustment for age, BMI, AIS, and ISS. PMI was correlated with GOS scores after multiple adjustments, but the MMI was not significantly correlated (Table 4). The results of the multiple regression analysis are presented in Table 5 ( $R^2=0.048$ ). PMI showed a statistically significant association with GOS ( $B=0.184$ ,  $p=0.004$ , variation inflation factor 1.001).

## DISCUSSION

The present study is unique for several reasons. First, the study goal was uncommon in that it was planned to compare the relative superiority of the psoas muscle (PM) and masseter muscle (MM), which are well-known prognostic markers.

Second, the study selected patients with severe TBI (AIS 4

or 5). Patients with other severe injuries were excluded. To reduce the impact of other injuries, patients with AIS scores of 4 or 5 at the chest, abdomen, or extremity were excluded. Additionally, patients with hospital stays of longer than 2 days were selected. Dead trauma patients during this period usually had severe, incurable injuries and their mortality might be inevitable. In addition, the guardians of some patients wanted patients transferred to another hospital. These patients were regarded as improper candidates for the analysis and excluded from the study. Consequently, the study included patients with serious TBI and reduced the possibility of bias, although the number of analyzed patients was decreased.

Third, comprehensive analyses of qualitative and quantitative parameters were planned. A similar study of PM and MM analysis was reported previously<sup>21)</sup>. Both parameters were analyzed based on mortality alone, which was a qualitative parameter. However, this study analyzed mortality and GOS scores comprehensively.

The AIS face and external scores showed a statistical differ-

ence. However, the mean AIS score was less than 1 point, indicating a very minor injury. Those injuries were too minor and might have had an insignificant effect on mortality or GOS scores.

However, the authors could not define or analyze sarcopenia in the present study. The initial target for analysis was not sarcopenia but involved both the PM and MM. Muscle strength and physical performance were not assessed because patient cooperation was hindered by their TBI. Further, it has been reported that sarcopenia cannot be represented by a single muscle<sup>2)</sup>. Nevertheless, the relationship between both muscles and the prognosis of patients with TBI was determined statistically. Further study is needed to diagnose sarcopenia in a larger population of patients.

## CONCLUSION

A larger PMA was associated with statistically significant survival outcomes and better GOS scores and showed superiority as a prognostic marker. Although TBI severity was the most significant mortality parameter, PMI was statistically significant in various analyses, suggesting that the PMI can be used to predict the prognosis of patients with TBI, whereas the MM showed no statistically significant results and was not comparable to the PM. Consequently, the PM showed its superiority over MM as a prognostic marker for TBI. Further analyses with a larger number of patients might show different results because this study had a relatively low number of participants. Additional parameters and more precise settings can yield better outcomes and increase our understanding of the relationship between sarcopenia and TBI.

## CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

## INFORMED CONSENT

This type of study does not require informed consent.

## AUTHOR CONTRIBUTIONS

**Conceptualization :** HJC

**Data curation :** YH, SY, MK

**Formal analysis :** MK

**Funding acquisition :** MK

**Methodology :** HJC, MK

**Visualization :** YH, SY, HJC

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