대한영상의학회지

# Magnetic Resonance-Based Grading of Psoas and Paraspinal Muscle Edema: Is It Helpful in Diagnosing Lumbar Transverse Process Fractures?
## 요근과 척추주위 등 근육 부종의 자기공명영상 기반 등급화: 요추 횡돌기 골절 진단에 도움이 되는가?

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**Purpose:** To determine the reliability of edema grading of the psoas and paraspinal muscles on axial T2-weighted magnetic resonance (MR) image (T2WI) for the detection of lumbar transverse process (TP) fractures.

**Materials and Methods:** A retrospective review of lumbar spine MR images of 56 patients (mean age = 56.1 years, age range = 17–87 years, male:female = 28:28) was conducted by 2 radiologists. Based on the axial T2WI at the disc level, the paraspinal muscles were classified into 4 compartments and muscle edema (increased signal intensity on axial T2WI) grading performed for each quadrant.

**Results:** A total of 486 TPs (with fracture: 24, without fracture: 462) of 56 patients were evaluated. Muscle edema grade showed moderate correlation with the presence of TP fracture ($\rho$ = 0.466). When the total score of muscle edema was 2.50, the receiver operating characteristic curve showed a sensitivity of 72.7% and a specificity of 90.7%. A higher edema grade had a significantly higher probability of concomitant TP fracture [any sided (total): odds ratio = 1.704 (95% confidence interval = 1.410–2.060)].

**Conclusion:** Edema grading of the psoas and paraspinal muscles on axial T2WI of lumbar spine can be helpful in the detection of TP fracture.

## INTRODUCTION

In patients with blunt abdominal trauma, lumbar transverse process (TP) fractures are occasionally present along with other injuries. According to a previous study (1), among 536 patients who had blunt abdominal trauma, 39 patients (7.3%) were confirmed to have lumbar TP fractures on helical computed tomography (CT). Another study suggested that TP fractures should be regarded as an important marker for abdominal organ injuries (2).

Multi-detector CT (MDCT) is a major modality for assessing osseous injury in an acute setting. However, if the patient has any sign of myelopathy, radiculopathy, or neurologic deficit, lumbar spine magnetic resonance imaging (MRI) is indicated, rather than lumbar spine CT, because MRI is superior to CT in the assessment of spinal cord, intervertebral disc, and ligamentous injury (3). In these situations, predicting the presence or absence of TP fractures with MR is useful because it does not re-

quire additional CT imaging.

In patients with spinal trauma, transverse lumbar fractures tend to be considered as relatively minor trauma (4, 5). However, in post-trauma patients without an obvious compression fracture, TP fracture can be a source of pain and tenderness. Particularly, when avulsion fracture is accompanied, severe pain is caused by movement of muscle around the vertebrae (6). And lumbar TP fractures can also be an important marker for visceral injuries, rather than minor ones (2, 7). Untreated can also cause side effects such as scoliosis due to unopposed action of the contralateral psoas and paraspinal back muscles (8).

Nevertheless, TP fractures may be overlooked when patients undergo only a lumbar spine MRI because fractured TPs are not usually scanned axially. Plane radiography could be initial method to evaluate the presence of the TP fracture. However, radiography has a low sensitivity to diagnose fractures in subtle fractures without displacements (1).

Is there any method to predict TP fractures using routine lumbar spine MRI without an additional axial scan or CT examination? In patients with TP fractures, edema or hemorrhage occurs in the adjacent muscles (including the psoas and the paraspinal muscles) (9). Furthermore, we have observed hemorrhage or edema near the TPs on MRI through the signal intensity changes. Therefore, in patients with TP fractures, we would like to know whether a relationship between TP fractures and muscle edema at the psoas and paraspinal muscles exists or not.

Thus, the purpose of our study was to determine the reliability of grading the psoas and paraspinal muscle edema based on axial T2-weighted MR image (T2WI) for detection of lumbar TP fractures.

## MATERIALS AND METHODS

### Study Population

The Institutional Review Board of our hospital approved this retrospective study (2016-09-011), and the requirement of patient consent was waived. Data collection was performed by one independent radiologist (S.J.Y.) using picture archiving and communication system (PACS) (Piview Star; Infinitt Healthcare, Seoul, Korea) and electronic medical records.

This study included patients who visited the emergency section of our hospital for lumbar spine trauma evaluation between

January 2013 and April 2015, and subsequently underwent both lumbar spine MR and CT examinations. Out of a total of 85 patients, 23 were excluded; patients were excluded if the time interval between the lumbar spine MR and CT examinations was more than 7 days, or if the lumbar spine CT examination was not done. Additional six patients were excluded due to following reasons; inappropriate scan coverage of axial T2WI at various disc levels of the lumbar (L)-spine ($n = 2$), severe metallic artifacts in postoperative lumbar spine cases ($n = 2$), recent lumbar spine surgery ($n = 1$), and infectious spondylitis ($n = 1$). Finally, 56 patients were considered for analysis.

### Imaging Acquisition

Lumbar spine MRI was performed with a 1.5 Tesla scanner (Achieva; Philips Medical Systems, Best, the Netherlands) using a dedicated lumbar spine coil and a standard protocol. Both T1-weighted spin echo images [repetition time (TR) range/echo time (TE) = 520–662/10] and T2-weighted fast spin-echo images (TR range/ TE range, 3000–3500/100–120) were obtained in the sagittal and axial planes at the lumbar spine. Typical imaging parameters for axial T2WI were as follows: field of view = $160 \times 160$ mm, matrix size = $208 \times 187$–208, section thickness = 4 mm, intersection gap = 0.4–2.0 mm, and echo-train length = 3–16. The parameters for sagittal T2WI were as follows: field of view = 300–400 mm $\times$ 300–400 mm, matrix size = 240–300 $\times$ 215–300, section thickness = 4 mm, intersection gap = 0.4–1.0 mm, and echo-train length = 4–18.

Spine CT examinations were performed using a 16- or 64-slice MDCT scanner (Brilliance 16 and 64, Philips Medical Systems, Cleveland, OH, USA) without administering oral or intravenous contrast. For the 16-slice MDCT, the CT parameters were as follows: collimation = 1.5 mm, pitch = 1.188, rotation time = 0.75 seconds. For the 64-slice MDCT scanner, the parameters were as follows: collimation = 0.625 mm, pitch = 1.014, and rotation time = 0.5 seconds. The tube voltage was 120 kVp, and the tube current was 150 mA to 300 mA in both scanners. Axial section data were reconstructed at a thickness of 5 mm with 5-mm increments. Second data sets were coronally and sagittally reformatted at a thickness of 3 mm with 3-mm increments.

### Imaging Analysis

The MR images were evaluated by 2 radiologists (W.J. and

H.S.J., with 17 years and 1 year of experience, respectively, in musculoskeletal radiology) in consensus. All MR images were analyzed using PACS (Piview Star; Infinitt Healthcare), and the reviewers were blinded to the patient information and final diagnosis (especially, about presence or absence of TP fracture).

For assessing the muscle edema grade on axial T2WI at the disc level, the muscles around the spine were classified into 4 compartments: right psoas (RA), left psoas (LA), right paraspinal (RP), and left paraspinal (LP) muscles (Fig. 1). Paraspinal muscles consist of the multifidus and erector spinae muscles.

The presence of muscle edema was evaluated by comparing the axial T2WI and T1-weighted image (T1WI) of each compartment. We defined muscle edema to be present when each muscle compartment around the lumbar spine had an area of low signal intensity on axial T1WI, and increased signal intensity on axial T2WI (Fig. 2).

Muscle edema grading was performed for each compartment as follows: grade 0 = no signal change, grade 1 = < 25% of signal change in each compartment, grade 2 = 25–50% of signal change in each compartment, grade 3 = ≥ 50% of signal change in each compartment (Fig. 3).

For the evaluation of a one-leveled TP on one side, two-leveled (at 2 disc levels, just cranial and caudal to the targeted TP) muscle edema grades were summed (Fig. 4). Finally, the grades for RA, RP, LA, LP, LAP (LA + LP), RAP (RA + RP), RLA (RA + LA), and RLP (RP + LP) for each TP, and the total score (RA + RP + LA + LP) for each lumbar spine level were obtained (Fig. 5). At every level, the TP of each side was evaluated independently. Therefore, the range of summed edema grades for each TP was from zero to a maximum of 12 points. A total score (RA + RP +
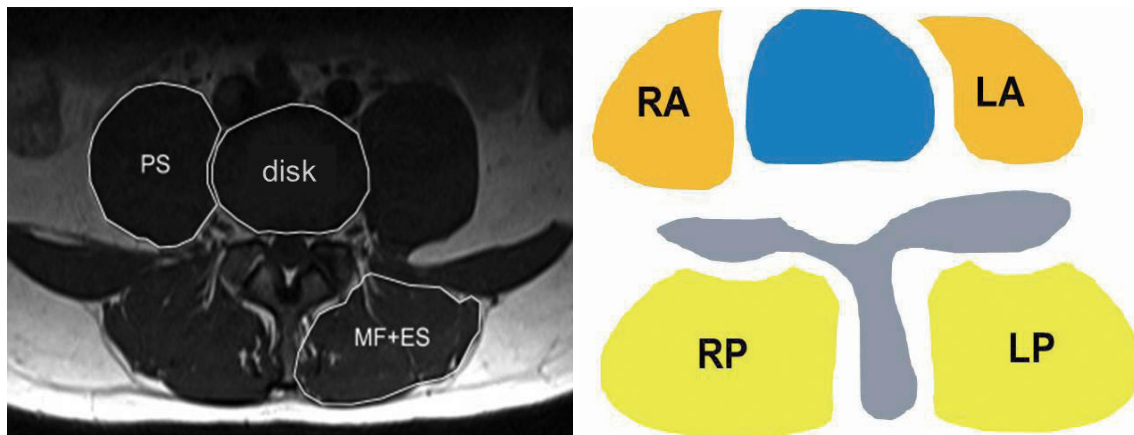


**Fig. 1.** Four muscular compartments around the spine. Muscles around the spine consist of 4 compartments: right psoas muscle (RA), left psoas muscle (LA), right paraspinal back muscle (RP), and left paraspinal back muscle (LP). And Paraspinal back muscle (RP or LP) consists of mulitifidus muscle (MF) and erector spinae muscle (ES). PS means the psoas muscle.
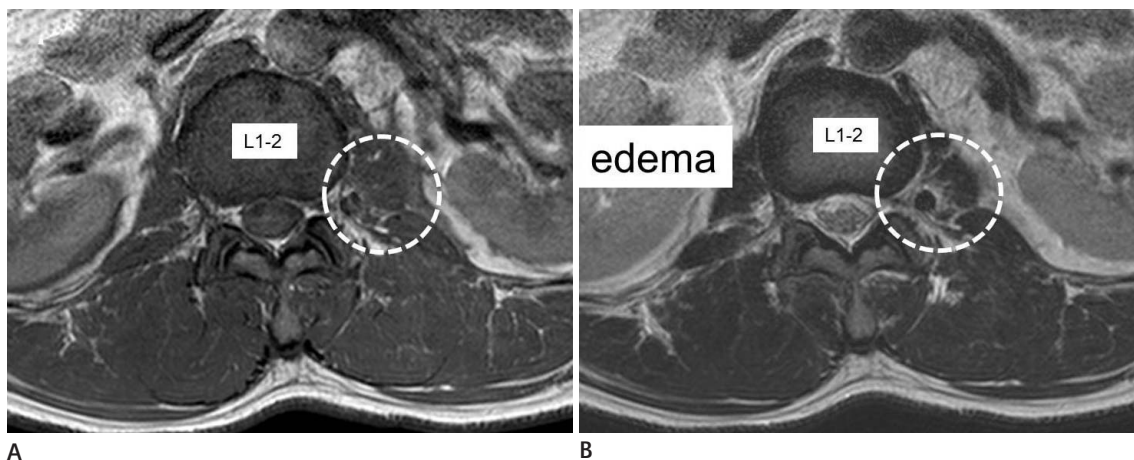


A               B

**Fig. 2.** Definition of muscle edema, 40-year-old man with right transverse process fracture of L3 and L4, and L3 burst fracture.
**A, B.** Increased signal intensity is noted at left psoas muscle (L1-2 level) on T2-weighted image **(B)** compared with T1-weighted image **(A)**.
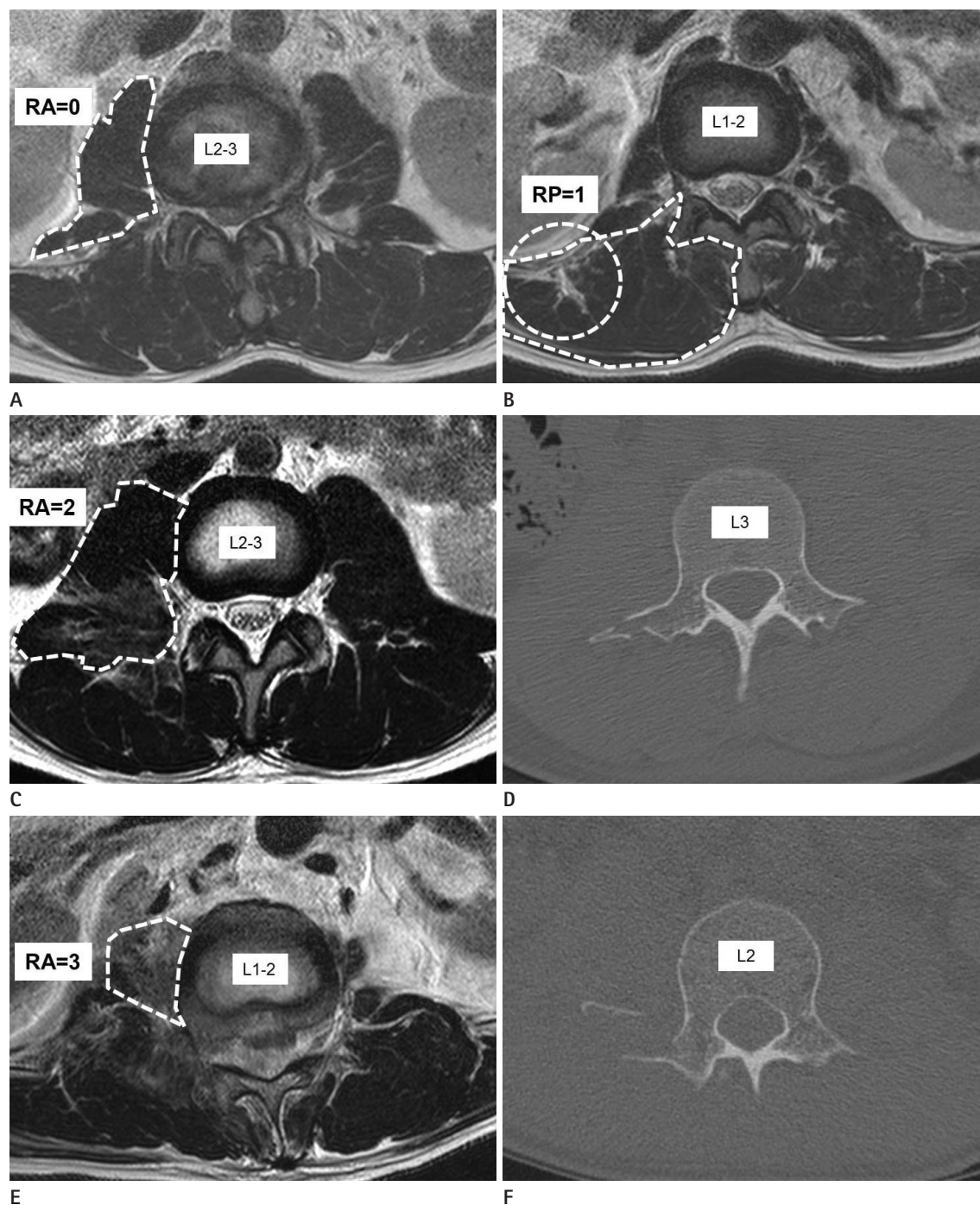
**Fig. 3.** Muscle edema grading.
**A, B.** Grade 0 and grade 1, 40-year-old man with transverse process fractures of right L3 and L4, and L3 burst fracture. **(A)** Grade 0, RA muscle (L2-3 level) shows no increased T2 signal intensity. **(B)** Grade 1, RP muscle (L1–2 level) shows increased T2 signal intensity involving less than 25 percent of the compartment.
**C, D.** Grade 2, 23-year-old man with transverse process fractures of right L1, L2, L3, and L4. RA muscle (L2-3 level) shows increased T2 signal intensity involving more than 25 percent and less than 50 percent of the compartment **(C)**, transverse process fracture of right L3 in the same patient **(D)**.
**E, F.** Grade 3, 33-year-old man with both L1 and right L2 transverse process fractures. RA muscle (L1-2 level) shows increased T2 signal intensity involving more than 50 percent of the compartment **(E)**, transverse process fracture of right L2 in the same patient **(F)**.
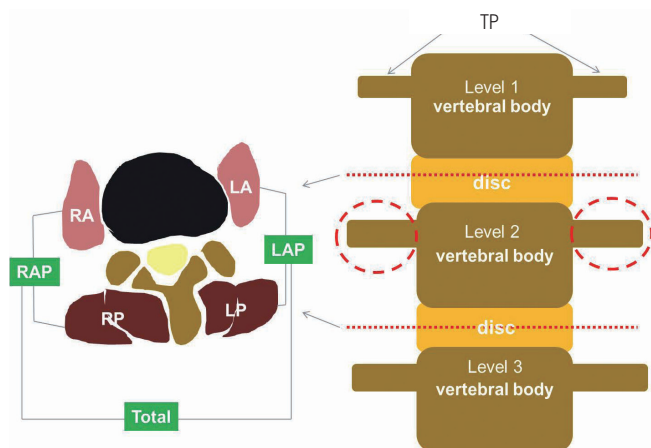RA = right psoas, RP = right paraspinal

**Fig. 4.** Evaluation of each transverse process. For evaluation of one leveled TP in one side, two leveled (two disc levels, just cranial and caudal to a targeted TP) muscle edema grades were summed.
LA = left psoas, LAP = left psoas + left paraspinal, LP = left paraspinal, RA = right psoas, RAP = right psoas + right paraspinal, RP = right paraspinal, TP = transverse process

LA + LP) for each lumbar spine level was also obtained. Correlation between TP fracture and the muscle edema grading regardless of side (right or left) was also evaluated. The total score ranged from zero to a maximum of 24 points.

Because CT is the most sensitive modality for diagnosing the TP fracture (5, 10), the final diagnosis regarding presence or absence of TP fracture was confirmed on lumbar spine CT images by two musculoskeletal radiologists (J.S.P. with 14 years of experience, and S.Y.P. with 7 years of experience) with consensus.

Regardless of the fracture, all 56 subjects included in the study underwent plain radiography within 3 days of MRI examination. And diagnostic value of MRI and plain radiography were compared using CT as a reference standard. In plain radiography, the TP fracture was defined when there was a clear radiolucent line or when the cortex showed discontinuity or dis-
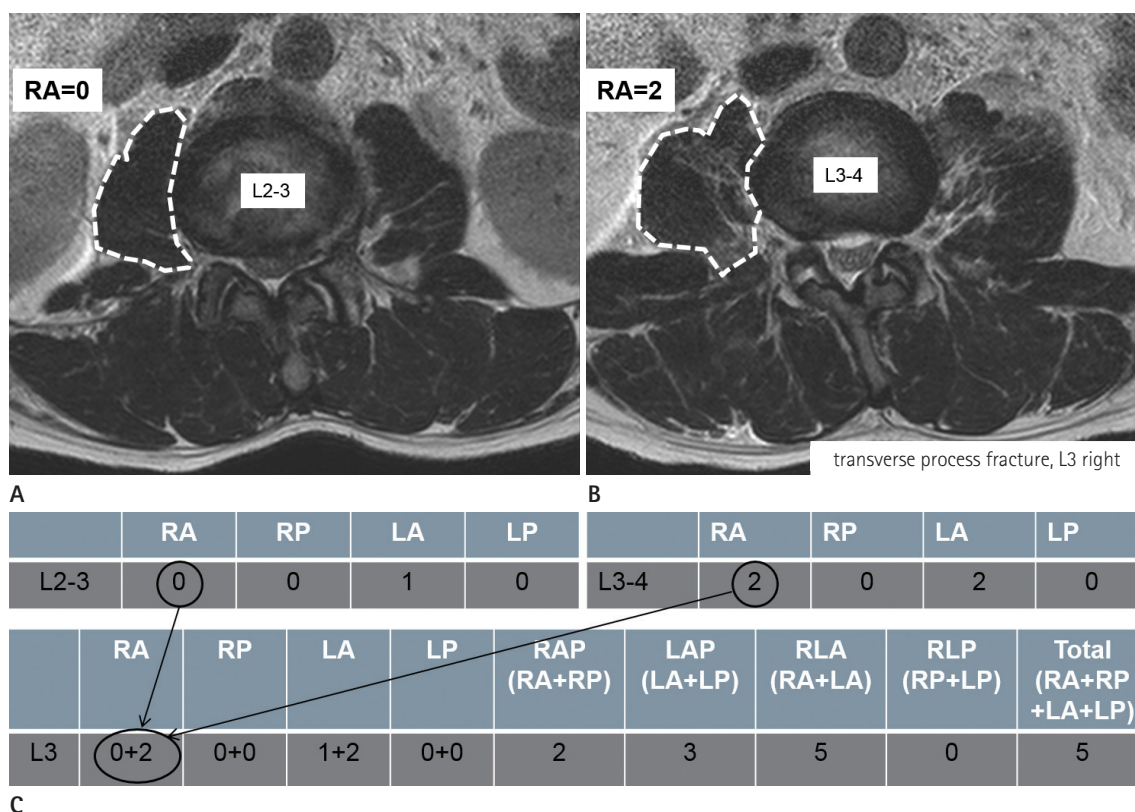


**Fig. 5.** Method to calculate muscle edema grading. A 40-year-old man with right transverse process fractures of L3 and L4, and L3 burst fracture.
**A.** Muscle edema grading for each compartment at L2–3 level is RA (0), RP (0), LA (1), and LP (0).
**B.** Muscle edema grading for each compartment at L3–4 level is RA (2), RP (0), LA (2), and LP (0).
**C.** In the next step, the two-leveled scores for each compartment are summed. For example, L3 RA score (0 + 2) is derived from L2-3 RA score (0) plus L3-4 RA score (2). L3 RAP score (2) means RA score (2) plus RP score (0) and L3 LAP score (3) means LA score (3) plus LP score (0). L3 RLA score (5) means RA score (2) plus LA score (3) and L3 RLP score (0) means RP score (0) plus LP score (0). Finally, we can obtain total score of L3 (5) by adding RA score (2), RP score (0), LA score (3), and LP score (0) together.
LA = left psoas, LAP = left psoas + left paraspinal, LP = left paraspinal, RA = right psoas, RAP = right psoas + right paraspinal, RLA = right psoas + left psoas, RLP = right paraspinal + left paraspinal, RP = right paraspinal

placement. The presence or absence of TP fracture on plain radiography was determined by two musculoskeletal radiologists (J.S.P. with 14 years of experience, and S.Y.P. with 7 years of experience) with consensus and they were blinded to the information about the presence or absence of TP fracture on CT.

### Statistical Analysis

Spearman's correlation was used to assess the relationship between the muscle edema grade and the presence of TP fracture (0–0.19: very weak, 0.20–0.39: weak, 0.40–0.59: moderate, 0.60–0.79: strong, 0.80–1.00: very strong) (11).

Receiver operating characteristic (ROC) curve analysis was done to assess the diagnostic performance of the muscle edema grade for TP fractures. It also provides information on the trade-offs between sensitivity and specificity. A logistic regression model was then used to determine the association (odds ratio) between the muscle edema grade and the presence of TP fracture.

$p$-value < 0.05 (95% confidence interval) was considered to indicate a statistically significant difference. All statistical analyses were performed using SPSS (SPSS version 18.0 for Windows; SPSS Inc., Chicago, IL, USA).

## RESULTS

A total of 476 TPs of 56 patients was evaluated. Out of these, 10 patients (mean age = 45.2 years, age range = 23–71 years, male:female = 8:2, single fracture:multiple fracture = 3:7) had 24 TP fractures (right:left = 16:8; L1 = 7, L2 = 7, L3 = 5, L4 = 3, and L5 = 2).

Out of the 10 patients with TP fractures, 2 patients had TP fractures alone, and 8 patients had other accompanying injuries (burst fracture: 4 patients, compression fracture: 2 patients, fracture-dislocation injury: 1 patient, fractures of both sacral ala: 1 patient). The causes of injury for the 10 patients were accidental falls in 5 (50%), motor vehicle collision in 3 (30%), pedestrian accident in 1 (10%), and slip down in 1 (10%). Forty-six patients (mean age = 58.5 years, age range = 17–87 years, male:female = 20:26) did not have TP fractures (Table 1). Results of the chi-square tests for homogeneity were statistically significant (age: $p = 0.042$, gender: $p = 0.081$, side of fracture: $p = 0.155$).

Mean score of muscle edema grade at each compartment (RA, RP, LA, LP, RAP, LAP, RLA, RLP, and total) with or without TP fracture was obtained. Muscle edema grade was significantly higher in cases with TP fractures (mean score = 4.54, range of total score = 0–10) than in cases without TP fracture (mean score = 0.75, range of total score = 0–11) ($p < 0.001$) (Table 2). Muscle edema grade had a moderate positive correlation with the presence of TP fracture ($\rho = 0.466$). When the relationship between the TP fracture and the grade of muscle edema was analyzed separately for each compartment, some compartments showed a weak positive correlation [RA ($\rho = 0.344$), LA ($\rho = 0.312$), LP ($\rho = 0.352$), RAP ($\rho = 0.349$), LAP ($\rho = 0.271$)] and some compartments showed a moderate positive correlation [RP ($\rho = 0.458$), RLA ($\rho = 0.472$), RLP ($\rho = 0.486$)] (Table 3).

When the total (T = RA + RP + LA + LP) score of muscle edema was 2.50, the ROC curve showed a sensitivity of 72.7% and a specificity of 90.7%, a false positive rate of 27.3% and a false negative rate of 9.3%.

**Table 1. Number of Patients with and without Transverse Process Fractures, Their Mean Age and Age Range**

| | Fracture (+) | Fracture (−) | *p* |
|---|---|---|---|
| Age* | 45.2 (23–71) | 58.5 (17–87) | 0.042 |
| Gender† | | | 0.081 |
| Male | 8 (80) | 20 (43.5) | |
| Female | 2 (20) | 26 (56.5) | |

*Mean ± standard deviation.
†Frequency (%).

**Table 2. Number and Mean Score (RA, RP, LA, LP, RAP, LAP, RLA, RLP, and total) of TP with and without Fracture**

| | Fracture (+) | Fracture (−) | *p* |
|---|---|---|---|
| TP* | | | 0.155 |
| Right | 16 (66.7) | 222 (49.1) | |
| Left | 8 (33.3) | 230 (50.9) | |
| RA† | 2.06 (2.07) | 0.36 (1.14) | < 0.001 |
| RP† | 1.38 (1.45) | 0.09 (0.45) | < 0.001 |
| LA† | 1.38 (1.58) | 0.19 (0.66) | < 0.001 |
| LP† | 0.88 (0.93) | 0.07 (0.35) | < 0.001 |
| RAP† | 3.44 (3.04) | 0.46 (1.33) | < 0.001 |
| LAP† | 2.25 (2.49) | 0.20 (0.77) | < 0.001 |
| RLA† | 2.91 (2.33) | 0.43 (1.31) | < 0.001 |
| RLP† | 1.50 (1.47) | 0.15 (0.69) | < 0.001 |
| Total | 4.54 (2.91) | 0.75 (1.88) | < 0.001 |

*Frequency (%).
†Mean ± standard deviation.
LA = left psoas, LAP = left psoas + left paraspinal, LP = left paraspinal, RA = right psoas, RAP = right psoas + right paraspinal, RLA = right psoas + left psoas, RLP = right paraspinal + left paraspinal, RP = right paraspinal, TP: transverse process

**Table 3. Spearman Correlation Coefficients between Edema Grade of Each Muscle Compartment and Transverse Process Fracture**

|  | $\rho$ | $p$ |
| --- | --- | --- |
| RA fracture | 0.344 | < 0.001 |
| RP fracture | 0.458 | < 0.001 |
| LA fracture | 0.312 | < 0.001 |
| LP fracture | 0.352 | < 0.001 |
| RAP fracture | 0.349 | < 0.001 |
| LAP fracture | 0.271 | < 0.001 |
| RLA fracture | 0.472 | < 0.001 |
| RLP fracture | 0.486 | < 0.001 |
| Total fracture | 0.466 | < 0.001 |

LA = left psoas, LAP = left psoas + left paraspinal, LP = left paraspinal, RA = right psoas, RAP = right psoas + right paraspinal, RLA = right psoas + left psoas, RLP = right paraspinal + left paraspinal, RP = right paraspinal, TP: transverse process

Based on the odds ratio, a higher muscle edema grade had a significantly higher probability of the presence of TP fracture. The odds ratios of right-sided TP fracture, left-sided TP fracture, and any sided (total) TP fracture were 1.696 (1.360–2.115), 2.491 (1.576–3.938), and 1.704 (1.410–2.060), respectively.

In comparison of the diagnostic ability of TP fracture between MRI and plain radiography, the fracture on MRI was defined as total edema score was higher than 2.50, which showed the best diagnostic ability on ROC curve analysis. When CT was the reference standard, the sensitivity and specificity of fracture in MRI were 75.0% and 88.5%, and in plain radiography were 25% and 99.6%, respectively.

## DISCUSSION

Spine trauma is a destructive injury with accompanying high morbidity and mortality. According to the National Spinal Cord Injury Association Resource Center in the USA, approximately 3% of blunt trauma patients registered in a large trauma registry had a spinal column injury (12). According to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification, thoracolumbar spine injuries consist of 3 categories based on the type of mechanical force involved. Type A results from compressive forces, type B results from distraction forces, and type C results from axial torque forces causing translation or rotation injuries. TP fractures are related to type A0 and type C injuries (13, 14). Type A0 injuries refer to vertebral injuries without a fracture, or vertebral injuries with fractures of the transverse or spinous processes that are clinically insignificant. Type C injuries are the most severe among the 3 types, and are associated with displacement and/or translational injuries. Therefore, TP fractures are seen in injuries ranging from clinically insignificant ones to the most severe form of vertebral injuries.

In our study, single fractures were seen in 3 patients (30%), and fractures involving more than 1 TP were seen in 7 patients (70%). This study showed a similar ratio of single and multiple fractures as that in the study by Patten et al. (1). In our study, the most commonly fractured vertebrae were L1 and L2 ($n$ = 7, each), the second most was L3 vertebra ($n$ = 5), the third most was L4 ($n$ = 3) vertebra, and the least common was L5 ($n$ = 2) vertebra. Compared to the L3 predominance in the study by Patten et al. (1), our study showed an upper vertebral predominance, with a decreasing order of predominance from the upper to lower vertebrae. In this context, a previous study had demonstrated that 60% to 70% of all thoracolumbar spine fractures occurred between T12 and L2 (15). Still, it does not mean that TP fractures occur predominantly in the upper lumbar vertebrae. However, we observed that the tendency for the upper vertebral predominance in spinal fractures was in accordance with our study.

When interpreting the lumbar spine MRI of patients with TP fractures, often muscle edema or hemorrhage is noted around the fractured TPs. TP fractures of the lumbar vertebrae may result from a direct blunt trauma, violent lateral flexion-extension forces, or avulsion of the psoas or paraspinal muscles (1). Muscle edema or hemorrhage around the fractured TPs may result from the resultant paraspinal muscle injuries attached to the involved TP, or avulsion of the paraspinal muscles causing TP fractures. A previous study reported that soft tissue edema on the MRI could improve the diagnostic performance of an MRI for fractures in the TP (16).

Our study showed several statistically meaningful positive correlations between the muscle edema grade and the presence of TP fracture. However, 2 results from our study were contrary to our expectations. First, although the correlation between any TP fractures and RLA (RA + LA), RLP (RP + LP), the total score (RA + RP + LA + LP) of muscle edema grade was moderately positive ($\rho$ = 0.472, 0.486, and 0.466, respectively), the correlation between one-sided TP fractures and one-sided muscle edema grade was weak [RAP ($\rho$ = 0.349), LAP ($\rho$ = 0.271)]. This

may be related to transverse fractures as well as other associated injuries. Of the patients with more than one TP fracture (total 88 TPs included in the study), there were 25 cases of edema in the psoas or paraspinal muscle without TP fracture, of which 22 were at the appropriate or adjacent level associated injuries (burst fracture, compression fracture, fracture-dislocation, and sacral alae fracture) and the remaining three had a TP fracture on the contralateral side of the same level. Therefore, most TPs with high muscle edema grade without fracture are thought to be due to associated injury.

Second, the maximum total score was higher in patients without TP fracture than in patients with TP fracture (11 and 10, respectively). Among 452 TPs without fracture, 31 TPs (6.85%) had a higher score (> 4.45) than the mean total score of patients with TP fracture. However, most of these non-fractured TPs (25 out of 31) with high scores were associated with TP fractures at another level or on the contralateral side in the same patients.

Therefore, if we divide our cases into 2 groups, one with fractured TPs, regardless of lumbar spine level or side (right or left) in the same patient, and the other with non-fractured TPs at any side or level, only 6 TPs (1.32%) out of 452 without fracture gained a higher score than the mean total score of TP fracture. These 6 cases were caused by definite spine column fracture injuries, namely, burst fractures (4 cases) and compression fractures (2 cases). The highest score among TPs without fracture was associated with a compression fracture of the spinal column (total score = 11), and the second highest had an associated burst fracture and fracture-dislocation injury (total score = 9 each). In clinical practice, if some patients, especially those without definite lumbar spine fracture such as burst fracture or compression fracture or high-energy trauma like fracture-dislocation injury, get a high score on muscle edema grading, one can strongly suspect the presence of TP fracture.

Out of the 10 patients with TP fractures, 3 patients had TP fractures alone, and 7 patients had other accompanying injuries (burst fracture: 3 patients, compression fracture: 2 patients, fracture-dislocation injury: 1 patient, fractures of both sacral ala: 1 patient).

For the diagnosis of TP fracture using muscle edema grading, the best total score (RA + RP + LA + LP) cut-off value, based on the ROC curve, was found to be more than 2.50. On the basis of this value, the sensitivity and specificity of the total score were 72.7% and 90.7%, respectively.

A logistic regression model for determining the association (odds ratio) between the muscle edema grade and the presence of TP fracture showed that if muscle edema is present, one can expect a higher probability of the presence of TP fracture. Left-sided fracture showed a higher value than right-sided fracture. Although we were not able to determine the exact cause for this tendency, we are of the opinion that muscle edema grade on the left side is more reliable than that on the right side, in assessing the probability of the presence of TP fracture.

In comparing the diagnostic ability of MRI and plain radiography, when the cutoff of the total score of muscle edema was 2.50, MRI showed much higher sensitivity than plain radiography (75% and 25%). The reason for the low sensitivity of fracture diagnosis in plain radiography is that fracture without displacement is not visible, fracture cannot be seen by fecal material or bowel gas, low quality of the radiography in the acute setting in emergency room, and remained contrast media after CT examination, etc.

This study had several limitations. First, we included a relatively small number of patients in this study. Especially, there were only a small number of patients with TP fractures. In this study, right side TP fractures showed a slightly higher positive correlation with muscle edema grade than left side TP fractures [RAP ($\rho$ = 0.349), LAP ($\rho$ = 0.271)]. This difference may be due to the difference in the sample size (right side TP fractures: 16, left side TP fractures: 8). Better results may be expected if there are more number of patients and TP fractures. Second, it is not possible to exclude the possibility of muscle edema due to other associated injuries not due to transverse process fractures in trauma patients. Third, our method to evaluate the muscle edema grade lacked objectivity. Interobserver agreement was not evaluated because the images were evaluated by 2 radiologists in consensus. A more objective method to evaluate muscle edema grade should be adopted in further studies. Lastly, we could not use fat-suppressed T2WI as a sequence for muscle edema grading, because the routine lumbar spine MR protocol in our hospital did not include a fat-suppressed T2WI but only sagittal fat-suppressed T2WI in the case of fat suppression imaging. If axial fat-suppressed T2WI is used, a higher muscle edema grade may be obtained.

In conclusion, muscle edema grade showed moderate corre-

lation with TP fracture. Therefore, edema grading of the psoas and paraspinal muscles on axial T2WI of lumbar spine MRI can be helpful not to overlook TP fracture, and to predict the presence of TP fracture especially in the case with a patient, who does not show definite lumbar spine fracture such as burst fracture or compression fracture, with a high score on muscle edema grading system.

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# 요근과 척추주위 등 근육 부종의 자기공명영상 기반 등급화: 요추 횡돌기 골절 진단에 도움이 되는가?

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**목적:** 요추 횡돌기 골절의 진단에서 축 방향 T2 강조 자기공명영상에서 요근과 척추 주위 등 근육 부종 등급화의 신뢰성을 알아보고자 하였다.

**대상과 방법:** 2명의 영상의학과 의사가 56명 환자(평균연령: 56.1세, 연령범위: 17-87세, 남자:여자 = 28명:28명)의 요추 자기공명영상을 후향적으로 분석하였다. 디스크 레벨에서 축 방향 T2 강조영상를 기반으로 척추 주위의 근육은 4구역으로 분류하고 근육 부종(축 방향 T2 강조영상에의 신호 강도 증가) 등급을 매겼다.

**결과:** 56명의 환자, 총 486개의 횡돌기(골절: 24건, 정상: 462건)가 평가되었다. 근육 부종 등급은 횡돌기 골절과 중등도의 상관관계를 보여주었다($\rho$ = 0.466). Receiver operating characteristic curve 분석에서 근육 부종 등급 총점의 cut-off 값을 2.50으로 정했을 때 횡돌기 골절 진단의 민감도는 72.7%, 특이도는 90.7%였다. 근육 부종 등급이 높을수록 횡돌기 골절의 가능성이 유의하게 높았다[양면(전체): 교차비 1.704 (95% 신뢰 구간 1.410-2.060)].

**결론:** 요추 자기공명영상 축 방향 T2 강조영상에서 요근과 등 주위 근육 부종의 등급화는 횡돌기 골절을 놓치지 않는데 도움이 된다.

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