KJP

Korean J Pain 2023;36(3):358-368
https://doi.org/10.3344/kjp.23092
pISSN 2005-9159, eISSN 2093-0569

Clinical Research Article

Association between fatty infiltration in the cervical multifidus and treatment response following cervical interlaminar epidural steroid injection

Hyun-Jung Kwon[1], Chan-Sik Kim[1], Sungwon Kim[1], Syn Hae Yoon[2], Jungho Koh[3], Young Ki Kim[3], Seong-Soo Choi[1], Jin-Woo Shin[1], and Doo-Hwan Kim[1]

[1]Department of Anesthesiology and Pain Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea
[2]Department of Anesthesiology and Pain Medicine, El Hospital, Namyangju, Korea
[3]Department of Anesthesiology and Pain Medicine, Gangneung Asan Hospital, University of Ulsan College of Medicine, Gangneung, Korea

ABSTRACT

Background: Recent attention has been directed towards fatty infiltration in the cervical extensor muscles for predicting clinical outcomes in several cervical disorders. This study aimed to investigate the potential association between fatty infiltration in the cervical multifidus and treatment response following cervical interlaminar epidural steroid injection (CIESI) in patients with cervical radicular pain.

Methods: The data of patients with cervical radicular pain who received CIESIs between March 2021 and June 2022 were reviewed. A responder was defined as a patient with a numerical rating scale decrease of ≥ 50% from the baseline to three months after the procedure. The presence of fatty infiltration in the cervical multifidus was assessed, along with patient characteristics, and cervical spine disease severity. To assess cervical sarcopenia, fatty infiltration in the bilateral multifidus muscles was evaluated at the C5–C6 level using the Goutallier classification.

Results: Among 275 included patients, 113 (41.1%) and 162 (58.9%) were classified as non-responders and responders, respectively. The age, severity of disc degeneration, and grade of cervical multifidus fatty degeneration were significantly lower in responders. Multivariate logistic regression analysis revealed that pre-procedural symptoms (radicular pain with neck pain, odd ratio [OR] = 0.527, P = 0.024) and high-grade cervical multifidus fatty degeneration (Goutallier grade 2.5–4, OR = 0.320, P = 0.005) were significantly associated with an unsuccessful response to CIESI.

Conclusions: These results suggest high-grade cervical multifidus fatty infiltration is an independent predictor of poor response to CIESI in patients with cervical radicular pain.

Keywords: Cervical Vertebrae; Injections, Epidural; Neck Pain; Paraspinal Muscles; Radiculopathy; Sarcopenia; Steroids; Treatment Outcome.

Received March 18, 2023; Revised May 1, 2023; Accepted May 11, 2023

Handling Editor: Woo Seog Sim

Correspondence: Doo-Hwan Kim
Department of Anesthesiology and Pain Medicine, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
Tel: +82-2-3010-1417, Fax: +82-2-3010-6790, E-mail: dh_kim@amc.seoul.kr

INTRODUCTION

Sarcopenia is a medical condition characterized by reduced muscle strength, quantity, or quality, resulting in a decline in physical performance in severe instances [1]. Sarcopenia is linked to unfavorable consequences, such as falls, functional decline, frailty, and mortality [1]. Nowadays, the diagnosis of this condition emphasizes the significance of muscle quality and function instead of solely focusing on muscle mass. Fatty infiltration in skeletal muscle plays a crucial role in reducing both muscle strength and function [2]. Recently, fatty infiltration in cervical extensor muscles was reportedly associated with clinical outcomes in several cervical disorders including cervical radiculopathy [3–6].

Cervical interlaminar epidural steroid injections (CIESIs) have been widely used for symptom relief in cases of cervical radicular pain [7]. Aside from being linked to poor outcomes following lumbar spine surgery, high-grade fatty infiltration of paraspinal muscles in the lumbar region was significantly associated with poor response to epidural steroid injections in elderly patients [8]. To the authors' knowledge, however, no studies have investigated the relationship between fatty infiltration of the paraspinal muscles and treatment outcomes after CIESI.

Therefore, this study aimed to investigate the potential association between fatty infiltration in the cervical multifidus and successful response following CIESI in patients with cervical radicular pain. This study also aimed to identify other factors associated with a successful response to CIESI.

MATERIALS AND METHODS

1. Patients

This study was approved by the institutional review board of Asan Medical Center (protocol number: 2023-0035). The requirement for informed consent was waived because of the retrospective nature of the study. A retrospective review was conducted on the medical records of patients who underwent CIESIs at a pain clinic (Asan Medical Center, Seoul, Korea) between March 2021 and June 2022. The inclusion criteria were as follows: (1) cervical radicular pain, (2) presence of cervical spinal stenosis or cervical disc degeneration on magnetic resonance imaging (MRI), (3) failure to respond to conservative treatment for > 3 months, (4) MRI performed within 1 year preceding the injection. The exclusion criteria were as follows: (1) insufficient medical records with missing numerical rating scale (NRS) scores; (2) patients lost to follow-up within three months after CIESI; (3) axial neck pain without cervical radicular pain; (4) cervical myelopathy; (5) no or insufficient radiologic tests; (6) prior cervical spinal surgery; (7) cervical epidural neuroplasty performed instead of a single injection; and (8) history of CIESI within the last 3 months.

2. Cervical interlaminar epidural steroid injections

CIESIs were performed as previously reported [9]. All procedures were performed under fluoroscopic guidance. The needle insertion level was determined at C6–C7 or C7–T1, and the paramedian approach was adopted in all procedures. After sterilization, the skin was infiltrated with 1% lidocaine, and a 22G Tuohy needle (Green Medical Supply) was inserted at the target cervical level while guided by an anteroposterior (AP) view. When the needle was advanced until the pedicle level on the vertebral body just inferior to the target interlaminar space on an AP image, fluoroscopy was rotated obliquely in the contralateral side at an angle of 50° ± 5° to visualize the ventral interlaminar line (VILL) between the laminae. Then, the needle was advanced further without loss of resistance (LOR) immediately before the VILL in the contralateral oblique (CLO) view. Subsequently, the needle was cautiously advanced using an LOR-to-air technique to reach the epidural space. When LOR was obtained, 0.5 mL of contrast medium (Omnipaque 300; GE Healthcare) was injected to confirm the epidural space using the CLO and AP views. If the epidural space was confirmed, a 3-mL mixture of 5 mg dexamethasone and 1% lidocaine was administered.

All CIESIs were performed by three attending pain physicians (≥ 4 years of procedural experience), nine fellows (0 to 8 months of experience), and 16 residents (0 to 3 months of experience) according to identical protocols. The trainees performed all the procedures under the supervision of the attending pain physicians.

3. Data collection and outcome measures

The pain intensity was evaluated at baseline and 3 months after CIESI using NRSs which ranged from 0 (no pain) to 10 (worst imaginable pain). A responder was defined as a patient with an NRS score decrease of ≥ 50% [10]. The patients were divided into non-responder and responder groups depending on the outcome.

Demographic data, including age, sex, and body mass index (BMI), were collected. Comorbidities (such as diabetes and hypertension), pain duration, last previous procedure, response to last previous procedure, and pre-procedural symptoms (radicular pain with or without neck pain, weakness) were also collected. The cervical curve type (lordosis, straight, or sigmoidal or kyphosis) was assessed using pre-procedural lateral cervical spine X-rays [11].

Based on the pre-procedural MRI, each severity of central stenosis, foraminal stenosis, and disc degeneration at the closest level in correlation with the patient's symptoms were assessed. For central stenosis, each grade was defined as follows: grade 0, normal; grade 1, obliteration of > 50% of the subarachnoid space without any signs of cord deformity; grade 2, central canal stenosis with spinal cord deformity, or cord deformation with no signal changes in the spinal cord; and grade 3, increased signal intensity of the spinal cord near the compressed level on T2-weighted images [12]. For foraminal stenosis, each grade was defined as follows: grade 0, normal or absence of neural foraminal stenosis with the narrowest neural foraminal width longer than that of the extraforaminal nerve root; grade 1, non-severe cervical neural foraminal stenosis, with the narrowest neural foraminal width the same as or less than (but > 50% of) the extraforaminal nerve root width; and grade 2, severe cervical neural foraminal stenosis, with the narrowest neural foraminal width the same as or less than 50% of the extraforaminal nerve root width [13]. For disc degeneration, each grade was defined as follows: grade 1, low-intensity or structural changes of the nucleus pulposus; grade 2, disc bulge or herniation with annulus fibrosus degeneration; and grade 3, further degeneration with a disc height decrease > 25% [14]. The severity of central stenosis, foraminal stenosis, and disc degeneration in each case was determined by consensus among the three investigators. Additionally, cervical sarcopenia was also assessed using a grading system on fatty infiltration. Fatty infiltration in the bilateral multifidus muscles were evaluated at the C5–C6 level using the Goutallier classification [15,16]. The C5–C6 level is the most commonly involved cervical spine level with degenerative changes, due to its relatively high load-bearing role and flexibility [17,18]. Thus, this level has been frequently selected as a representative for assessing fatty infiltration in the cervical paraspinal muscles. Axial cuts of T2-weighted MRI sequences were utilized by two blinded independent reviewers (**Fig. 1**). The Goutallier

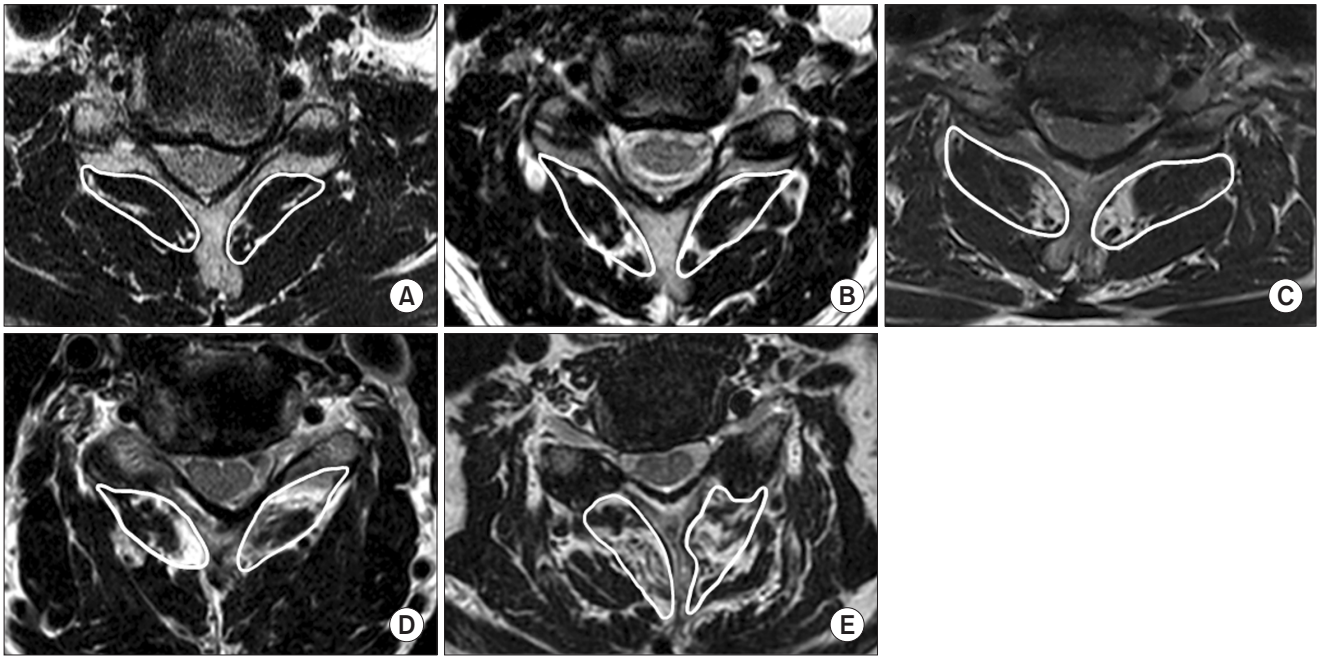

Fig. 1. Fatty infiltration in the bilateral multifidus muscles was evaluated with the Goutallier classification at the C5–C6 level. Axial cuts of T2-weighted magnetic resonance imaging sequences were utilized to assess Goutallier classification. Each grade of Goutallier classification was defined as follows: (A) Goutallier 0, no visible fat streaks; (B) Goutallier 1, minimal fatty streaks; (C) Goutallier 2, more muscle present than fat; (D) Goutallier 3, fat and muscle present in equal quantities; (E) Goutallier 4, more fat present than muscle.

classification is defined as follows: Goutallier 0, no visible fat streaks; Goutallier 1, minimal fatty streaks; Goutallier 2, more muscle present than fat; Goutallier 3, fat and muscle present in equal quantities; Goutallier 4, more fat present than muscle [19]. After the inter-rater reliability between the reviewers was tested, the grades of the two reviewers were averaged and further classified as follows: mild (Goutallier 0–1), moderate (Goutallier 1.5–2), or severe (Goutallier 2.5–4.0) sarcopenia, based on the Fuchs modification of the Goutallier grading system: no fat to minimal fat as mild, more muscles than fat as moderate, and equal/greater fat than muscle as severe [15,16]. All the reviewers were pain physicians who have more than 5 years of experience in diagnosing spine pathologies with spine MRI. Before the study, the reviewers were trained to evaluate fatty infiltration using the Goutallier classification with 30 cases each.

The pre- and post-procedural pain intensities were classified into one of three categories (mild, NRS 1-3; moderate, NRS 4-6; and severe, NRS 7-10).

4. Statistical analysis

Categorical variables were presented as absolute numbers with percentages. Continuous variables were compared between non-responders and responders using the Student's *t*-test or Mann–Whitney *U*-test, and were presented as medians with interquartile ranges. Categorical variables were compared using the chi-squared test or Fisher's exact test. To determine the factors associated with a successful response to CIESI, univariate and multivariate logistic regression analyses were performed. Variables with *P* values < 0.1 on univariate logistic regression analysis were included in the multivariate logistic regression analyses. *P* values < 0.05 were considered significant. The odds ratios (ORs) and 95% confidence intervals (CIs) for successful response in the presence of independent predictors of CIESI were calculated by logistic regression analyses. All statistical analyses were performed using IBM SPSS (version 22; IBM Corp.).

RESULTS

A total of 393 patients underwent CIESIs due to cervical radicular pain between March 2021 and June 2022. Among them, 118 were excluded for the following reasons: 21 followed up for less than 3 months, 22 had axial neck pain without cervical radicular pain, 31 had no or insufficient radiologic tests, 9 had history of prior cervical spinal surgery, and 35 underwent cervical epidural neuroplasty. Finally, 275 patients were included. The baseline demographic and clinical characteristics of the patient groups are shown in **Table 1**.

Of the patients, 162 (58.9%) exhibited a response to treatment. Most patients exhibited none to some degree of fatty infiltration, with the majority classified as Grade 1 (first *vs*. second investigator; n = 57, 20.7% *vs*. n = 62, 22.5%) or Grade 2 (n = 136, 49.5% *vs.* n = 148, 53.8%). The patients with more fatty infiltration were classified as Grade 3 (n = 54, 19.6% *vs.* n = 35, 12.7%) or Grade 4 (n = 17, 6.2% *vs.* n = 25, 9.0%). The Goutallier grading results demonstrated excellent inter-rater reliability, with an 83.7% agreement (intraclass correlation coefficient, 0.837 [95% CI, 0.791–0.873]). Cervical multifidus fatty degeneration was significantly less among responders (Goutallier 0–1, 13 [11.5] *vs.* 32 [19.8]; Goutallier 1.5–2, 56 [49.6] *vs.* 90 [55.6]; Goutallier 2.5–4, 44 [38.9] *vs.* 40 [24.7], *P* = 0.022). The age was significantly lower in responders (57.0 [49.0–66.0] years *vs.* 54.0 [45.0–64.0] years, *P* = 0.028). The disc degeneration grade was significantly lower in responders (grade 1, 1 [0.9] *vs.* 2 [1.2]; grade 2, 68 [60.7] *vs.* 121 [74.7]; grade 3, 43 [38.4] *vs.* 39 [24.1], *P* = 0.021). Although there was no significant difference in pre-procedural NRS between the groups (6.0 [5.0–7.0] *vs.* 6.0 [5.0–7.0], *P* = 0.968), NRS were significantly lower in responders at 1 month (4.0 [3.0–6.0] *vs.* 2.0 [2.0–3.0], *P* < 0.001) and 3 months (5.0 [4.0–6.0] *vs.* 2.0 [1.0–2.0], *P* < 0.001) after the procedure. The NRS difference between baseline and 3 months was significantly greater in responders (1.0 [0.0–2.0] *vs.* 4.0 [3.0–5.0], *P* < 0.001, **Table 1**).

When demographics and clinical characteristics were stratified by the severity of fatty degeneration in the cervical multifidus (Goutallier grade 0–1 *vs.* 1.5–2 *vs.* 2.5–4), the 1-month (2.0 [1.0–3.0] *vs.* 3.0 [2.0–4.0], *vs.* 4.0 [2.0–5.0], *P* = 0.001) and 3-month (2.0 [1.0–3.0] *vs.* 3.0 [2.0–4.0] *vs.* 3.0 [2.0–5.0], *P* = 0.009) post-procedural NRS scores were lower in low Goutallier grades. The NRS difference between baseline and 3 months after CIESI was also greater in low Goutallier grades (3.0 [2.0–5.0] *vs.* 3.0 [2.0–4.0] *vs.* 2.0 [1.0–3.0], *P* = 0.001). Similarly, the proportion of responders was also greater in low Goutallier grades (**Table 2**).

The results of the univariate logistic regression analysis are shown in **Table 3**. Age (OR, 0.976; 95% CI, 0.956–0.997; *P* = 0.022) and fatty degeneration in the cervical multifidus (Goutallier grade 1.5–2, 0.653 [0.316–1.349], *P* = 0.250; Goutallier grade 2.5–4, 0.369 [0.170–0.801], *P* = 0.012) were associated with successful response to CIESIs. Multivariate logistic regression analysis revealed that pre-pro-

Table 1. Baseline demographics and clinical characteristics

Variables	Non-responders (n = 113)	Responders (n = 162)	Total (n = 275)	*P* value
Age (yr)	57.0 (49.0–66.0)	54.0 (45.0–64.0)	56.0 (47.0–65.0)	0.028
Sex, male	64 (56.6)	87 (53.7)	151 (54.9)	0.720
BMI (kg/m^2)	24.3 (22.0–25.8)	24.7 (22.3–27.0)	24.5 (22.3–26.5)	0.096
Diabetes	10 (8.8)	13 (8.0)	23 (8.4)	0.873
Hypertension	28 (24.8)	28 (17.3)	56 (20.4)	0.172
Pain duration (mo)	5.0 (2.0–12.0)	3.5 (2.0–8.0)	4.0 (2.0–9.5)	0.129
Last previous procedure				0.968
CIESI	21 (18.6)	30 (18.5)		
Cervical MBB	7 (6.2)	7 (4.3)		
SGB	23 (20.4)	33 (20.4)		
TPI	13 (11.5)	21 (13.0)		
None	49 (43.4)	71 (43.8)		
Response to last previous procedure				0.962
Yes	35 (54.7)	52 (57.1)		
No	29 (45.3)	39 (42.9)		
Type of pre-procedural pain				0.100
Radicular pain only	29 (25.7)	58 (35.8)	46 (16.7)	
Radicular pain with neck pain	84 (74.3)	104 (64.2)	188 (68.4)	
Weakness	27 (24.1)	43 (26.5)	70 (25.5)	0.754
Cervical curve				
Lordosis	32 (28.3)	37 (22.8)	69 (25.1)	0.324
Straight	62 (54.9)	103 (63.6)	165 (60.0)	0.185
Sigmoidal or kyphosis	19 (16.8)	22 (13.6)	41 (14.9)	0.460
Central stenosis				0.538
Grade 1	4 (9.1)	14 (9.7)	9 (10.7)	
Grade 2	40 (90.9)	130 (89.7)	72 (85.7)	
Grade 3	0 (0)	1 (0.7)	3 (3.6)	
Foraminal stenosis				0.747
Grade 1	5 (4.5)	10 (6.2)	15 (5.5)	
Grade 2	27 (24.3)	42 (26.2)	69 (25.5)	
Grade 3	79 (71.2)	108 (67.5)	187 (69.0)	
Disc degeneration				0.021
Grade 1	1 (0.9)	2 (1.2)	3 (1.1)	
Grade 2	68 (60.7)	121 (74.7)	189 (69.0)	
Grade 3	43 (38.4)	39 (24.1)	82 (29.9)	
Diagnosis				0.322
Herniated disc	64 (57.1)	81 (50.3)	145 (53.1)	
Spinal stenosis	48 (42.9)	80 (49.7)	128 (46.9)	
Cervical sarcopenia, grade				0.022
Goutallier 0–1	13 (11.5)	32 (19.8)	45 (16.4)	
Goutallier 1.5–2	56 (49.6)	90 (55.6)	146 (53.1)	
Goutallier 2.5–4	44 (38.9)	40 (24.7)	84 (30.5)	
Pre-procedural NRS	6.0 (5.0–7.0)	6.0 (5.0–7.0)	6.0 (5.0–7.0)	0.968

 https://doi.org/10.3344/kjp.23092

Table 1. Continued

Variables	Non-responders (n = 113)	Responders (n = 162)	Total (n = 275)	*P* value
Pre-procedural pain intensity				0.378
Mild	10 (8.8)	8 (4.9)	18 (6.5)	
Moderate	69 (61.1)	108 (66.7)	177 (64.4)	
Severe	34 (30.1)	46 (28.4)	80 (29.1)	
Post-procedural NRS, 1 mo	4.0 (3.0–6.0)	2.0 (2.0–3.0)	3.0 (2.0–4.0)	< 0.001
Post-procedural NRS, 3 mo	5.0 (4.0–6.0)	2.0 (1.0–2.0)	3.0 (2.0–4.0)	< 0.001
NRS difference, 3 mo	1.0 (0.0–2.0)	4.0 (3.0–5.0)	3.0 (1.0–4.0)	< 0.001

Values are expressed as medians (interquartile ranges) or number (%).
BMI: body mass index, CIESI: cervical interlaminar epidural steroid injection, MBB: medial branch block, SGB: stellate ganglion block, TPI: trigger point injection, NRS: numerical rating scale.

cedural symptoms (radicular pain with neck pain, 0.527 [0.302–0.920], $P = 0.024$) and cervical multifidus fatty degeneration (Goutallier grade 2.5–4; 0.320 [0.144–0.713], $P = 0.005$) were independent factors significantly associated with an unsuccessful response to CIESIs (**Table 3**).

DISCUSSION

In this study, successful response at 3 months after CIESI was obtained in about 60% of patients with cervical radicular pain. Additionally, radicular pain combined with neck pain and high-grade multifidus fatty degeneration (Goutallier grade 2.5–4) were independently associated with unsuccessful response after CIESI. To the best of the authors' knowledge, this is the first study to elicit the association between fatty degeneration in the cervical multifidus and the effect of CIESI.

Patients with accompanying neck pain showed poorer responses after CIESI in this study. CIESI is reportedly the most effective method in reducing radicular pain caused by a herniated disc [20–22]. Overall, the effect of CIESI has been more evident in radicular pain than axial neck pain; it can be explained by the substantial inflammation reduction from CIESI on cervical nerve roots, and complex pathologies of neck pain [21,23,24]. The results of this study were in agreement with this context.

As paraspinal muscle degeneration has been extensively investigated in low back pain and lumbar radiculopathy, it has been also recently explored in neck pain and cervical radiculopathy [6,25,26]. Fatty infiltration is considered a late stage of muscle degeneration, and it is clinically the most important sign of muscle degeneration correlated with clinical outcomes, rather than cross sectional area or volume [27]. In addition, fatty infiltration in the cervical extensor muscles is reportedly associated with clinical symptoms, such as neck pain, cervical functional disability, and postural instability, in several cervical disorders (*e.g.*, whiplash associated disorder, cervical myelopathy) as well as cervical radiculopathy [3–6,28,29]. In patients with cervical radiculopathy, paraspinal muscle degeneration and various spinal pathologies, such as disc degeneration, severe facet joint degeneration, and ossification of the posterior longitudinal ligament, may interact with each other [30–32].

Furthermore, the multifidus muscle seemed to be the most susceptible cervical extensor muscle to fatty changes, due to abundant type I collagen [3], thereby making it the most closely related to clinical outcomes [29,33]. Therefore, multifidus sarcopenia was evaluated using the grading system for muscle fatty infiltration [15,16]. As patients with cervical radiculopathy have significantly larger amounts of fatty infiltration in their muscles compared with healthy controls [3], this study revealed that high-grade fatty infiltration in the multifidus muscle might have adverse impacts on the response to CIESI in patients with cervical radicular pain. Similarly, a recent study found that high fatty infiltration of the paraspinal muscles in the lumbar area was independently associated with poor response to lumbar epidural steroid injections in patients with lumbar spondylosis [8]. The underlying mechanisms of multifidus fatty infiltration in spinal disorders are not well-understood. Although severe and extensive atrophy in the multifidus muscle was also associated with radiculopathy [34], it is uncertain whether fatty infiltration is a cause or consequence of cervical radiculopathy. Muscle denervation or disuse from persistent pain and disability can lead to deconditioning and subsequent histologic changes [35,36]. A chronic or recurrent proinflammatory state due to a spinal pathology is also

Table 2. Baseline demographics and clinical characteristics stratified by Goutallier grade

Variables	Goutallier 0–1 (n = 45)	Goutallier 1.5–2 (n = 146)	Goutallier 2.5–4 (n = 84)	*P* value
Age (yr)	50.0 (43.0–61.0)	53.0 (46.0–64.0)	63.0 (54.0–68.0)	< 0.001
Sex, male	22 (48.9)	86 (58.9)	43 (51.2)	0.355
BMI (kg/m^2)	24.7 (22.9–26.2)	24.6 (22.4–26.9)	24.3 (22.0–26.0)	0.318
Diabetes	3 (6.7)	9 (6.2)	11 (13.1)	0.206
Hypertension	8 (17.8)	32 (21.9)	16 (19.0)	0.782
Type of pre-procedural pain				0.087
Radicular pain only	8 (17.8)	49 (33.6)	30 (35.7)	
Radicular pain with neck pain	37 (82.2)	97 (66.4)	54 (64.3)	
Weakness	12 (26.7)	40 (27.6)	18 (21.4)	0.578
Pain duration (mo)	4.0 (2.0–7.0)	4.0 (2.0–11.0)	4.0 (2.0–10.5)	0.517
Cervical curve				
Lordosis	12 (26.7)	35 (23.9)	22 (26.2)	0.911
Straight	24 (53.3)	88 (60.3)	53 (63.1)	0.556
Sigmoidal or kyphosis	9 (20.0)	23 (15.8)	9 (10.7)	0.338
Central stenosis				0.538
Grade 1	4 (9.1)	14 (9.7)	9 (10.7)	
Grade 2	40 (90.9)	130 (89.7)	72 (85.7)	
Grade 3	0 (0.0)	1 (0.7)	3 (3.6)	
Foraminal stenosis				0.828
Grade 1	3 (6.8)	9 (6.2)	3 (3.7)	
Grade 2	13 (29.5)	35 (24.1)	21 (25.6)	
Grade 3	28 (63.6)	101 (69.7)	58 (70.7)	
Disc degeneration				0.287
Grade 1	1 (2.2)	2 (1.4)	0 (0)	
Grade 2	29 (64.4)	106 (73.1)	54 (64.3)	
Grade 3	15 (33.3)	37 (25.5)	30 (35.7)	
Diagnosis				0.321
Herniated disc	27 (60.0)	71 (49.0)	47 (56.6)	
Spinal stenosis	18 (40.0)	74 (51.0)	36 (43.4)	
Pre-procedural NRS	6.0 (4.0–7.0)	6.0 (5.0–7.0)	6.0 (4.0–6.5)	0.678
Pre-procedural pain intensity				0.331
Mild	5 (11.1)	7 (4.8)	6 (7.1)	
Moderate	24 (53.3)	96 (65.8)	57 (67.9)	
Severe	16 (35.6)	43 (29.5)	21 (25.0)	
Post-procedural NRS, 1 mo	2.0 (1.0–3.0)	3.0 (2.0–4.0)	4.0 (2.0–5.0)	0.001
Post-procedural NRS, 3 mo	2.0 (1.0–3.0)	3.0 (2.0–4.0)	3.0 (2.0–5.0)	0.009
NRS difference, 3 mo	3.0 (2.0–5.0)	3.0 (2.0–4.0)	2.0 (1.0–3.0)	0.001
Successful responders	32 (71.1)	90 (61.6)	40 (47.6)	0.022

Values are expressed as medians (interquartile ranges) or number (%).
BMI: body mass index, NRS: numerical rating scale.

attributable to muscle degeneration with fatty infiltration [30,37–39]. Muscular fatty change, in turn, can lead to a vicious cycle of chronic systemic inflammation and progressive mechanical and metabolic skeletal muscle dysfunction [2,40]. Low levels of chronic inflammation can contribute to the widespread symptoms observed in chronic pain disorders [41]. Further research on plausible mechanisms is required to make better treatment plans

Table 3. Univariate and multivariate logistic regression analyses for predictive factors associated with successful response after cervical interlaminar epidural steroid injection

Variables	Univariate		Multivariate	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Age	0.976 (0.956–0.997)	0.022	0.985 (0.961–1.010)	0.230
BMI	1.075 (0.997–1.160)	0.060	1.076 (0.992–1.167)	0.076
Hypertension	0.634 (0.352–1.144)	0.131		
Type of pre-procedural pain				
Radicular pain only	1		1	
Radicular pain with neck pain	0.619 (0.364–1.052)	0.076	0.527 (0.302–0.920)	0.024
Pain duration (mo)	0.995 (0.983–1.006)	0.363		
Cervical curve, straight	1.436 (0.880–2.343)	0.147		
Disc degeneration				
Grade 1	1		1	
Grade 2	0.890 (0.079–9.993)	0.925	1.136 (0.093–13.801)	0.921
Grade 3	0.453 (0.040–5.199)	0.525	0.574 (0.046–7.141)	0.666
Cervical sarcopenia, grade				
Goutallier 0–1	1		1	
Goutallier 1.5–2	0.653 (0.316–1.349)	0.250	0.562 (0.266–1.187)	0.131
Goutallier 2.5–4	0.369 (0.170–0.801)	0.012	0.320 (0.144–0.713)	0.005

OR: odds ratio, CI: confidence interval, BMI: body mass index.

and predict clinical outcomes of CIESI.

In the additional analysis stratified by fatty infiltration severity, only age was significantly associated with the severity of multifidus fatty infiltration, which corresponds with the prior study [16]. Although intramuscular adipose tissues compositionally varied in different body locations depending on sex and BMI [42,43], they did not have a significant association with fatty infiltration severity in this study, which was consistent with the results of a prior lumbar-related study [8].

Although disc degeneration was significantly different between the groups, it was not associated with an unsuccessful post-injection response. Other radiologic findings, such as cervical curve, central stenosis, and foraminal stenosis, were not significantly different between the groups, as they were in other studies [44,45].

This study has several limitations. First, the grade of sarcopenia was evaluated only with fatty degeneration of the multifidus muscle at a single C5-C6 level. Thus, a single axial-cut evaluation could not reflect the entire muscle composition. Furthermore, it is impossible to draw conclusions regarding degeneration of other cervical muscles. Second, only the pre-procedural MRI was evaluated. Therefore, imaging studies may not exactly reflect the condition of the patient at the time of the procedure. Third, successful response was defined using only the NRS difference, which did not reflect any changes in other symptoms, such as sensory disturbance and motor weakness. Finally, the outcomes were only assessed within the 3 months after the procedure; long-term effects were not evaluated due to a lack of data.

In conclusion, high-grade cervical multifidus fatty infiltration may independently predict a poor response to CIESI in patients with cervical radicular pain. Further prospective studies are needed to investigate the relationship between long-term outcomes following CIESI and associated factors.

DATA AVAILABILITY

The datasets supporting the findings of this study are available from the corresponding author upon reasonable request.

ACKNOWLEDGMENTS

The authors thank the residents and clinical fellows of the Pain Clinic of Asan Medical Center for their kind support in conducting this research.

CONFLICT OF INTEREST

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

FUNDING

No funding to declare.

AUTHOR CONTRIBUTIONS

Hyun-Jung Kwon: Writing/manuscript preparation; Chan-Sik Kim: Investigation; Sungwon Kim: Investigation; Syn Hae Yoon: Investigation; Jungho Koh: Investigation; Young Ki Kim: Investigation; Seong-Soo Choi: Writing/manuscript preparation; Jin-Woo Shin: Writing/manuscript preparation; Doo-Hwan Kim: Supervision.

ORCID

Hyun-Jung Kwon, https://orcid.org/0000-0001-5688-4181
Chan-Sik Kim, https://orcid.org/0000-0002-5038-0203
Sungwon Kim, https://orcid.org/0009-0004-8432-5626
Syn Hae Yoon, https://orcid.org/0000-0001-5395-0606
Jungho Koh, https://orcid.org/0000-0002-2792-6837
Young Ki Kim, https://orcid.org/0000-0002-7205-6746
Seong-Soo Choi, https://orcid.org/0000-0002-2333-0235
Jin-Woo Shin, https://orcid.org/0000-0003-4773-2738
Doo-Hwan Kim, https://orcid.org/0000-0002-3875-0857

REFERENCES

1. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al; Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019; 48: 16-31. Erratum in: Age Ageing 2019; 48: 601.
2. Li CW, Yu K, Shyh-Chang N, Jiang Z, Liu T, Ma S, et al. Pathogenesis of sarcopenia and the relationship with fat mass: descriptive review. J Cachexia Sarcopenia Muscle 2022; 13: 781-94.
3. Mitsutake T, Sakamoto M, Chyuda Y, Oka S, Hirata H, Matsuo T, et al. Greater cervical muscle fat infiltration evaluated by magnetic resonance imaging is associated with poor postural stability in patients with cervical spondylotic radiculopathy. Spine (Phila Pa 1976) 2016; 41: E8-14.
4. Paliwal M, Weber KA 2nd, Smith AC, Elliott JM, Muhammad F, Dahdaleh NS, et al. Fatty infiltration in cervical flexors and extensors in patients with degenerative cervical myelopathy using a multi-muscle segmentation model. PLoS One 2021; 16: e0253863.
5. Fortin M, Dobrescu O, Courtemanche M, Sparrey CJ, Santaguida C, Fehlings MG, et al. Association between paraspinal muscle morphology, clinical symptoms, and functional status in patients with degenerative cervical myelopathy. Spine (Phila Pa 1976) 2017; 42: 232-9.
6. Kim CY, Lee SM, Lim SA, Choi YS. Impact of fat infiltration in cervical extensor muscles on cervical lordosis and neck pain: a cross-sectional study. Clin Orthop Surg 2018; 10: 197-203.
7. Manchikanti L, Knezevic NN, Navani A, Christo PJ, Limerick G, Calodney AK, et al. Epidural interventions in the management of chronic spinal pain: American Society of Interventional Pain Physicians (ASIPP) comprehensive evidence-based guidelines. Pain Physician 2021; 24(S1): S27-208.
8. Kim HJ, Rho M, Yoon KB, Jo M, Lee DW, Kim SH. Influence of cross-sectional area and fat infiltration of paraspinal muscles on analgesic efficacy of epidural steroid injection in elderly patients. Pain Pract 2022; 22: 621-30.
9. Sim JH, Kwon HJ, Kim CS, Kim EH, Kim DH, Choi SS, et al. Comparison of contralateral oblique view with the lateral view for fluoroscopic-guided cervical epidural steroid injection: a randomized clinical trial. Reg Anesth Pain Med 2022; 47: 171-6.
10. Dworkin RH, Turk DC, Wyrwich KW, Beaton D, Cleeland CS, Farrar JT, et al. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. J Pain 2008; 9: 105-21.
11. Grob D, Frauenfelder H, Mannion AF. The association between cervical spine curvature and neck pain. Eur Spine J 2007; 16: 669-78.
12. Kang Y, Lee JW, Koh YH, Hur S, Kim SJ, Chai JW, et al. New MRI grading system for the cervical canal stenosis. AJR Am J Roentgenol 2011; 197: W134-40.
13. Kim S, Lee JW, Chai JW, Yoo HJ, Kang Y, Seo J, et al. A new MRI grading system for cervical foraminal stenosis based on axial T2-weighted images. Korean J Radiol 2015; 16: 1294-302.

14. Suzuki A, Daubs MD, Hayashi T, Ruangchainikom M, Xiong C, Phan K, et al. Patterns of cervical disc degeneration: analysis of magnetic resonance imaging of over 1000 symptomatic subjects. Global Spine J 2018; 8: 254-9.
15. Pinter ZW, Salmons HI 4th, Townsley S, Omar A, Freedman BA, Currier BL, et al. Multifidus sarcopenia is associated with worse patient-reported outcomes following posterior cervical decompression and fusion. Spine (Phila Pa 1976) 2022; 47: 1426-34.
16. Wang XJ, Huang KK, He JB, Wu TK, Rong X, Liu H. Fatty infiltration in cervical extensor muscle: is there a relationship with cervical sagittal alignment after anterior cervical discectomy and fusion? BMC Musculoskelet Disord 2022; 23: 641.
17. Binder AI. Cervical spondylosis and neck pain. BMJ 2007; 334: 527-31.
18. Haghnegahdar A, Sedighi M. An outcome study of anterior cervical discectomy and fusion among Iranian population. Neurosci J 2016; 2016: 4654109.
19. Pinter ZW, Wagner S, Fredericks D Jr, Xiong A, Helgeson M, Currier B, et al. Cervical paraspinal muscle fatty degeneration is not associated with muscle cross-sectional area: qualitative assessment is preferable for cervical sarcopenia. Clin Orthop Relat Res 2021; 479: 726-32.
20. Kwon JW, Lee JW, Kim SH, Choi JY, Yeom JS, Kim HJ, et al. Cervical interlaminar epidural steroid injection for neck pain and cervical radiculopathy: effect and prognostic factors. Skeletal Radiol 2007; 36: 431-6.
21. Cohen SP, Bicket MC, Jamison D, Wilkinson I, Rathmell JP. Epidural steroids: a comprehensive, evidence-based review. Reg Anesth Pain Med 2013; 38: 175-200.
22. Diwan S, Manchikanti L, Benyamin RM, Bryce DA, Geffert S, Hameed H, et al. Effectiveness of cervical epidural injections in the management of chronic neck and upper extremity pain. Pain Physician 2012; 15: E405-34.
23. Ferrante FM, Wilson SP, Iacobo C, Orav EJ, Rocco AG, Lipson S. Clinical classification as a predictor of therapeutic outcome after cervical epidural steroid injection. Spine (Phila Pa 1976) 1993; 18: 730-6.
24. Choi JW, Lim HW, Lee JY, Lee WI, Lee EK, Chang CH, et al. Effect of cervical interlaminar epidural steroid injection: analysis according to the neck pain patterns and MRI findings. Korean J Pain 2016; 29: 96-102. Erratum in: Korean J Pain 2017; 30: 73.
25. De Pauw R, Coppieters I, Kregel J, De Meulemeester K, Danneels L, Cagnie B. Does muscle morphology change in chronic neck pain patients? - A systematic review. Man Ther 2016; 22: 42-9.
26. Fortin M, Macedo LG. Multifidus and paraspinal muscle group cross-sectional areas of patients with low back pain and control patients: a systematic review with a focus on blinding. Phys Ther 2013; 93: 873-88.
27. Shahidi B, Hubbard JC, Gibbons MC, Ruoss S, Zlomislic V, Allen RT, et al. Lumbar multifidus muscle degenerates in individuals with chronic degenerative lumbar spine pathology. J Orthop Res 2017; 35: 2700-6.
28. Elliott JM, Courtney DM, Rademaker A, Pinto D, Sterling MM, Parrish TB. The rapid and progressive degeneration of the cervical multifidus in whiplash: an MRI study of fatty infiltration. Spine (Phila Pa 1976) 2015; 40: E694-700.
29. Cloney M, Smith AC, Coffey T, Paliwal M, Dhaher Y, Parrish T, et al. Fatty infiltration of the cervical multifidus musculature and their clinical correlates in spondylotic myelopathy. J Clin Neurosci 2018; 57: 208-13.
30. Shi L, Yan B, Jiao Y, Chen Z, Zheng Y, Lin Y, et al. Correlation between the fatty infiltration of paraspinal muscles and disc degeneration and the underlying mechanism. BMC Musculoskelet Disord 2022; 23: 509.
31. Kalichman L, Klindukhov A, Li L, Linov L. Indices of paraspinal muscles degeneration: reliability and association with facet joint osteoarthritis: feasibility study. Clin Spine Surg 2016; 29: 465-70.
32. Doi T, Ohtomo N, Oguchi F, Tozawa K, Nakarai H, Nakajima K, et al. Association between deep posterior cervical paraspinal muscle morphology and clinical features in patients with cervical ossification of the posterior longitudinal ligament. Global Spine J 2023; 13: 8-16.
33. Snodgrass SJ, Stanwell P, Weber KA, Shepherd S, Kennedy O, Thompson HJ, et al. Greater muscle volume and muscle fat infiltrate in the deep cervical spine extensor muscles (multifidus with semispinalis cervicis) in individuals with chronic idiopathic neck pain compared to age and sex-matched asymptomatic controls: a cross-sectional study. BMC Musculoskelet Disord 2022; 23: 973.
34. Min JH, Choi HS, Ihl Rhee W, Lee JI. Association between radiculopathy and lumbar multifidus atrophy in magnetic resonance imaging. J Back Musculoskelet Rehabil 2013; 26: 175-81.
35. Hodges P, Holm AK, Hansson T, Holm S. Rapid atro-

phy of the lumbar multifidus follows experimental disc or nerve root injury. Spine (Phila Pa 1976) 2006; 31: 2926-33.
36. Pagano AF, Brioche T, Arc-Chagnaud C, Demangel R, Chopard A, Py G. Short-term disuse promotes fatty acid infiltration into skeletal muscle. J Cachexia Sarcopenia Muscle 2018; 9: 335-47.
37. James G, Sluka KA, Blomster L, Hall L, Schmid AB, Shu CC, et al. Macrophage polarization contributes to local inflammation and structural change in the multifidus muscle after intervertebral disc injury. Eur Spine J 2018; 27: 1744-56.
38. Thoma A, Lightfoot AP. NF-kB and inflammatory cytokine signalling: role in skeletal muscle atrophy. Adv Exp Med Biol 2018; 1088: 267-79.
39. Hodges PW, James G, Blomster L, Hall L, Schmid AB, Shu C, et al. Can proinflammatory cytokine gene expression explain multifidus muscle fiber changes after an intervertebral disc lesion? Spine (Phila Pa 1976) 2014; 39: 1010-7.
40. Ahn H, Kim DW, Ko Y, Ha J, Shin YB, Lee J, et al. Updated systematic review and meta-analysis on diagnostic issues and the prognostic impact of myosteatosis: a new paradigm beyond sarcopenia. Ageing Res Rev 2021; 70: 101398.
41. Hysing EB, Smith L, Thulin M, Karlsten R, Bothelius K, Gordh T. Detection of systemic inflammation in severely impaired chronic pain patients and effects of a multimodal pain rehabilitation program. Scand J Pain 2019; 19: 235-44.
42. Burian E, Franz D, Greve T, Dieckmeyer M, Holzapfel C, Drabsch T, et al. Age- and gender-related variations of cervical muscle composition using chemical shift encoding-based water-fat MRI. Eur J Radiol 2020; 125: 108904.
43. Hicks GE, Simonsick EM, Harris TB, Newman AB, Weiner DK, Nevitt MA, et al. Cross-sectional associations between trunk muscle composition, back pain, and physical function in the health, aging and body composition study. J Gerontol A Biol Sci Med Sci 2005; 60: 882-7.
44. Borghouts JAJ, Koes BW, Bouter LM. The clinical course and prognostic factors of non-specific neck pain: a systematic review. Pain 1998; 77: 1-13.
45. Kim MS, Lee DG, Chang MC. Outcome of transforaminal epidural steroid injection according to severity of cervical foraminal stenosis. World Neurosurg 2018; 110: e398-403.