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Lumbosacral Transitional Vertebrae: Association with Low Back Pain[1]

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Purpose: To assess the prevalence and degree of lumbosacral transitional vertebrae (LSTV) in the Osteoarthritis Initiative (OAI) cohort, to assess whether LSTV correlates with low back pain (LBP) and buttock pain, and to assess the reproducibility of grading LSTV.

Materials & Methods: Institutional review board approval was obtained, and informed consent documentation was approved for the study protocol. Standard standing pelvic radiographs that included the transverse processes of L5 were graded according to Castellvi classification of LSTV in 4636 participants (1992 men and 2804 women; aged 45–80 years) from the OAI cohort. These data were correlated with prevalence and severity of LBP and buttock pain.

Results: Prevalence of LSTV was 18.1% (841 of 4636), with a higher rate in men than in women (28.1% vs 11.1%, respectively; $P < .001$). Of the 841 individuals with LSTV, 41.72% were type I (dysplastic enlarged transverse process), 41.4% were type II (pseudoarticulation), 11.5% were type III (fusion), and 5.2% were type IV (one transverse process fused and one with pseudoarticulation). Of the participants without LSTV, 53.9% reported LBP, while the prevalence of LBP for types I, II, III, and IV was 46%, 73%, 40%, and 66%, respectively ($P < .05$, χ^2 test). Types II and IV had higher prevalence and severity of LBP and buttock pain ($P < .001$).

Conclusion: LSTV types II and IV positively correlate with prevalence and severity of LBP and buttock pain.

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Back pain causes a substantial loss of productivity (4), and it is one of the leading reasons for patients to seek health care in the United States (1–3). In many patients, the exact cause of their pain is unclear (5). The present study was focused on lumbosacral transitional vertebrae (LSTV), which have been previously identified as a potential cause of back pain (6–9). The prevalence of LSTV, its subtypes, and their associations with back pain are not well understood. An LSTV is an anomalous vertebra with intermediate morphologic characteristics between the sacral and the lumbar vertebrae (10,11); its transverse processes are enlarged and can articulate with the sacrum or the ilium (12). LSTV with articulation of some degree—whether partial (pseudoarthrosis) or complete fusion—is defined as either sacralization of the lowest lumbar segment or lumbarization of the most superior sacral segment of the spine (10). LSTV is a common finding in the general population, and has a reported prevalence of 5%–30% (13,14). Mario Bertolotti first described the morphologic characteristics of LTSV and its association with low back pain (LBP) in 1917, and this association has therefore been termed *Bertolotti syndrome* (12). The relationship between LSTV and LBP has been described in several studies but remains uncertain. Although Tini et al (11) suggested that LSTV was not associated with LBP (6,11), the findings of other studies indicated an association of LBP with LSTV (7,12,15,16).

The goals of this study were to describe the overall prevalence of the subtypes of LSTV in the 4796 patients of the Osteoarthritis Initiative (OAI) cohort, to determine the association of the different subtypes of LSTV with LBP and buttock pain, and to assess the reproducibility of the assessment and classification of LSTV.

Advances in Knowledge

- The prevalence of lumbosacral transitional vertebrae (LSTV) with knee osteoarthritis or risk factors for knee osteoarthritis was 18.1% in a middle-aged and elderly population, with more men affected than women.
- According to Castellvi classification, patients with LSTV that was pseudoarticulated to the sacrum (such as types II and IV) were prone to back and buttock pain ($P < .001$ and $P = .001$ for types II and IV, respectively).
- Low back pain is more severe in patients with LSTV types II and IV ($P < .001$) and is associated with lower physical activity levels ($P < .001$ and $P = .001$ for types II and IV, respectively).

Materials and Methods

The study protocol and informed consent documentation were approved by the local institutional review boards. Details on OAI enrollment and baseline datasets used for this study are available at *http://www.oai.ucsf.edu/*.

Population

OAI included 4796 participants who were recruited on the basis of their risk factors for knee osteoarthritis (OA) or mild to moderate knee OA. Of these participants, 4636 (97%) patients with diagnostic baseline pelvic radiographs were studied. The study population consisted of 1919 men (41%) between the ages of 45 and 79 years (mean age, 61 years ± 9 [standard deviation]) and 2717 women (58.5%) between the ages of 45 and 79 years (mean age, 61 years ± 9). Patient characteristics, including age, sex, race, and body mass index are shown in Table 1. The study's participants represented a sample selected by OAI for the study of knee OA and were not recruited on the basis of whether they experienced back pain. Sixty-two percent (860 of 1390) of the participants who had knee OA and were in the progression subcohort of OAI had back pain, and 58% (1900 of 3289) of the participants in the incidence subcohort (patients who did not have knee OA but who were at risk for developing it) had back pain. However, this difference was not statistically significant ($P = .08$).

Imaging Technique

Standardized standing pelvic radiographs were performed by using a dedicated foot-positioning mat with the toes internally rotated at a 5° angle, and the x-ray beam was positioned approximately 7 cm above the pubic symphysis. The images were obtained at five institutions: Ohio State University (Columbus, Ohio), University of Maryland School of Medicine (Baltimore, Md), Johns Hopkins University School of Medicine (Baltimore, Md), University of Pittsburgh School of Medicine (Pittsburgh, Pa), and Memorial Hospital of Rhode Island (Pawtucket, RI). Representative radiographs are shown in the Figure.

Image Analysis

All images were reviewed on picture archiving and communication system workstations (Agfa, Ridgefield Park, NJ). All of the 4796 pelvic anteroposterior radiographs were independently

Implication for Patient Care

- LSTV types II and IV are associated with back pain, which may affect patient care.

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Abbreviations:
CI = confidence interval
LBP = low back pain
LSTV = lumbosacral transitional vertebrae
OA = osteoarthritis
OAI = Osteoarthritis Initiative
OR = odds ratio
PASE = Physical Activity Scale for the Elderly

Author contributions:
Guarantors of integrity of entire study, L.N., H.A., N.E.L., T.M.L.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, L.N., H.A., W.V., N.E.L., T.M.L.; clinical studies, L.N., H.A., W.V., T.M.L.; statistical analysis, W.V., A.H., J.A.L., C.E.M.; and manuscript editing, all authors

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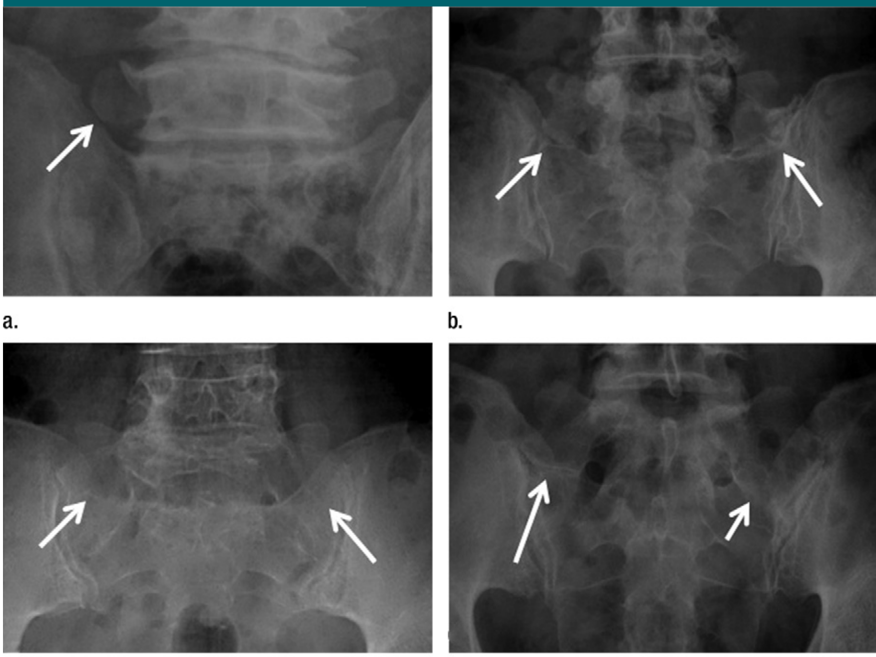
Conflicts of interest are listed at the end of this article.



a. b. c. d.

Radiographs demonstrate the Castellvi classification of LSTV: **(a)** Type I: dysplastic enlarged transverse process (arrow); **(b)** Type II: pseudoarticulation of the transverse process with the sacrum with increased sclerosis (arrows); **(c)** Type III: fusion with the sacrum (arrows); **(d)** Type IV: unilateral LSTV type II (long arrow) with type III on the contralateral side (short arrow).

Table 1

Characteristics of 4636 Patients with and without LSTV

	LSTV (*n* = 841)	No LSTV (*n* = 3795)	*P* Value*
Male	539 (64.1)	1380 (36.4)	< .001
Female	302 (35.9)	2415 (63.6)	
Mean age (y)	61 ± 9.0	61 ± 9.2	.96
Race			.10
White	687 (81.7)	2967 (78.2)	
Black	131 (15.6)	721 (19.0)	
Asian	10 (1.2)	35 (0.9)	
Other	13 (1.5)	68 (1.8)	
Presence of Hip OA	266 (31.6)	1069 (28.2)	.045
Mean BMI (kg/m²)	28.7 ± 4.3	28.6 ± 5.0	.25

Note.—Unless otherwise stated, data are numbers of patients, with percentages in parentheses.

* χ^2 for categorical variables and analysis of variance for continuous variables.

† BMI = body mass index

Table 2

LSTV according to Castellvi Classification

Castellvi Type	Definition
LSTV type I: forme fruste	Dysplastic transverse process with height > 19 mm
LSVT type II: incomplete lumbarization/sacralization	Enlarged transverse process with pseudoarthrosis with the adjacent sacral ala
LSTV type III: complete lumbarization/sacralization	Enlarged transverse process, which has a complete fusion with the adjacent sacral ala
LSTV type IV: mixed	Type II on one side and type III on the other side

read by two radiologists (L.N., 5 years of experience; W.V., 8 years of experience). Initially, the pelvic radiographs were independently screened by these radiologists for image quality (ie, the ability to assess the relationship between the sacral ala and the lumbar transverse process), postsurgical changes obscuring transitional anatomy, and presence of LSTV. Out of 4796 radiographs, 160 were considered to be of poor quality and were excluded from the study.

Radiographs with adequate image quality were classified according to the presence of LSTV. The presence of an LSTV was determined manually by evaluating the craniocaudal width of the transverse process, with a threshold of greater than 19 mm as measured by using the digital caliper on a picture archiving and communication system, or by the presence of articulation or complete fusion of the transverse process with the sacrum. All discrepancies were settled by a third radiologist (T.M.L., 25 years of experience). LSTV cases were graded according to a radiographic classification system modified from that of Castellvi et al (9), hereafter, the Castellvi classification (Figure). Table 2 outlines the main characteristics of the Castellvi classification. To minimize the number of categories, we classified the cases independently from the bilateral or unilateral findings into four basic types (11,14). The hip joints were also assessed for OA according to the Osteoarthritis Research Society International classification (18). All of the hip images had been independently read 1 year earlier by both a radiologist (L.N.) and a rheumatologist (N.E.L., 30 years of experience). In cases where there was disagreement among the readers, a radiologist (T.M.L.) was also consulted.

Clinical Data

The OAI back pain and function questionnaire provided information about frequency, severity, and location of pain. Patients were asked about the frequency of their back pain during the past 30 days and graded it as never, rarely, some of the time, most of the time, or all of the time. Patients were also asked to evaluate the average severity of their back pain during the past 30 days and to classify it as none, mild, moderate, or severe. The location of the pain was assessed with four questions that varied according to the presence of upper back pain, middle back pain, LBP, or buttock pain within the past 30 days. A five-part variable was created for location of back pain. The categories were mutually exclusive and included LBP, buttock pain (without LBP), pain located in the middle or upper back (without LBP or buttock pain), and no back pain at any location.

Information was also provided regarding limitation of physical activity due to back pain and physical activity level by using the Physical Activity Scale for the Elderly (PASE) (19–22).

Table 3

ORs of Buttock Pain, LBP, and Middle/Upper Back Pain Compared within LSTV Patients and Subtypes Compared with Non-LSTV Patients

Variable	OR*	95% CI	*P* Value
Non-LSTV	(reference)		
LBP			
All LSTV	1.42	1.21, 1.68	<.001
LSTV type I	0.78	0.62, 0.99	.038
LSTV type II	3.48	2.62, 4.64	<.001
LSTV type III	0.69	0.45, 1.07	.095
LSTV type IV	3.94	1.63, 9.54	.002
Buttock pain			
All LSTV	1.68	1.09, 2.59	.019
LSTV type I	0.4	0.15, 1.12	.082
LSTV type II	4.12	2.31, 7.33	<.001
LSTV type III	1.52	0.59, 3.92	.38
LSTV type IV	9.47	2.62, 34.24	<.001
Middle/upper back pain			
All LSTV	0.99	0.67, 1.47	.96
LSTV type I	0.44	0.22, 0.88	.02
LSTV type II	1.9	1.04, 3.48	.037
LSTV type III	0.97	0.41, 2.31	.95
LSTV type IV	6.48	1.95, 21.55	.002

Note.—Results from a multinomial model.

* OR, 95% CI, and *P* value from multinomial model. LBP, buttock pain, or middle/upper back pain compared to no back pain.

Reproducibility Analysis

Interobserver reproducibility was calculated from all studies by using the initial readings by the two radiologists. Intraobserver reproducibility was obtained by using 500 randomly selected studies that were independently analyzed by two radiologists on two separate occasions. Cohen κ values were calculated to assess intraobserver and interobserver agreement of the radiographic classification according to Castellvi classification.

Statistical Analysis

Statistical analysis was performed by using SAS 9.2 (SAS Institute, Cary, NC). Descriptive statistics for baseline demographic data were calculated for LSTV and non-LSTV groups, as well as for each LSTV subtype compared with non-LSTV. Continuous variables are presented as mean ± standard deviation and categorical variables as frequency (percentages). For bivariate comparisons, continuous variables were compared by using analysis of variance or ranked analysis of variance as required, and categorical variables were compared by using a χ^2 test.

Multivariable models were used to assess the relationship between back pain and LSTV, adjusted for age, sex, race, body mass index, and radiographic hip OA. Age, race, hip OA, and body mass index were included in the models because these are known risk factors for back pain. Back pain variables, measured as presence or absence of upper back pain, middle back pain, LBP, or buttock pain, were modeled by using a multinomial model. Odds ratios (ORs), 95% confidence intervals (CIs), and *P* values were reported for comparison of LSTV to non-LSTV, with each back pain location category (lower back, buttocks, and middle or upper back) versus no back pain. The LSTV subtypes were treated as a categorical variable, and separate ORs were obtained for each value. Back pain variables measured with ordinal scales used proportional odds models, reported as the OR, and were in a higher category on the ordered scale compared with the next lower category. The statistical significance of all calculations was defined as $P < .05$.

Results

Patient Characteristics

LSTV was found in 18.1% (841 of 4636) of participants (Table 1)—28.1% (539 of 1919) of men and 11.1% (302 of 2717) of women ($P < .001$). No significant difference in the prevalence of LSTV was observed by race. The 841 patients with LSTV were placed into four modified Castellvi classification (9) subgroups; of these, 351 patients (41.7%) had LSTV type I, 349 (41.4%) had LSTV type II, 97 (11.5%) had LSTV type III, and 44 (5.2%) had LSTV type IV (Table 2).

LSTV and LBP

Overall, patients with LSTV were more likely to have reported LBP in the past 30 days than were participants without LSTV (OR: 1.42 [95% CI: 1.21, 1.68], $P < .001$) (Table 3). Four hundred eighty-four patients (10.4%) were

Table 4

Severity of Pain, Pain Frequency, and Limitation of Activity in LSTV Patients

Parameter and Subtype	OR	95% CI	*P* Value
Severity*†			
All LSTV	1.40	1.16, 1.69	< .001
LSTV type I	0.78	0.63, 0.96	.021
LSTV type II	2.18	1.80, 2.65	< .001
LSTV type III	0.77	0.52, 1.13	.18
LSTV type IV	2.98	1.74, 5.08	< .001
Frequency*‡			
All LSTV	1.22	1.01, 1.48	.042
LSTV type I	0.76	0.61, 0.96	.022
LSTV type II	1.67	1.37, 2.05	< .001
LSTV type III	0.73	0.48, 1.11	.15
LSTV type IV	2.39	1.40, 4.06	.001
Limitation of activity§			
All LSTV	1.05	0.80, 1.38	.73
LSTV type I	0.76	0.61, 0.96	.022
LSTV type II	1.67	1.37, 2.05	< .001
LSTV type III	0.73	0.48, 1.11	.15
LSTV type IV	2.39	1.40, 4.06	.001

Note.—Reference standard was patients without LSTV.

* Proportional odds regression model adjusted for age, sex, race, body mass index, and hip OA was used.

† Severity scale: 0 = no pain, 1 = mild pain, 2 = moderate pain, 3 = severe pain.

‡ Frequency scale: 0 = rarely bothered by pain, 1 = bothered by pain some of the time, 2 = bothered by pain most of the time, 3 = bothered by pain all of the time.

§ Past 30 days activity limited by back pain (yes or no). Logistic regression model adjusted for age, sex, race, body mass index, and hip OA was used.

diagnosed with Bertolotti syndrome (ie, LSTV with LBP). The subgroup analysis (Table 4) demonstrated that types II and IV were strongly associated with LBP. Compared to the non-LSTV group, types II and IV had respective ORs of 3.48 (95% CI: 2.62, 4.64) and 3.94 (95% CI: 1.63, 9.54). Types I and III had respective ORs of 0.78 (95% CI: 0.62, 0.99) and 0.69 (95% CI: 0.45, 1.07).

LSTV and Buttock Pain

Individuals with LSTV were more likely to report buttock pain than were participants without LSTV (OR: 1.68 [95% CI: 1.09, 2.59], P = .019) (Table 3). Compared to the non-LSTV group, Types II and IV were associated with buttock pain, with respective ORs of 4.12 (95% CI: 2.31, 7.33) and 9.47 (95% CI: 2.62, 34.24) (Table 3). Types I and III were not associated with buttock pain.

LSTV and Middle and Upper Back Pain

Pain in the middle or upper back was not associated with the presence or absence of LSTV (P = .96) (Table 4). The relationships of LSTV subtypes with middle or upper back pain, however, were similar to those of LBP and buttock pain, with pain in type II (OR: 1.9 [95% CI: 1.04, 3.48], P = .037) and type IV (OR: 6.48 [95% CI: 1.95, 21.55], P = .002), and less pain in type I (OR: 0.44 [95% CI: 0.22, 0.88], P < .001).

Comparison between Back Pain and Other Variables

As presented in Table 4, back pain frequency (OR: 1.22 [95% CI: 1.01, 1.48], P = .042) and severity (OR: 1.40 [95% CI: 1.16, 1.69], P < .001) at any location were higher in the LSTV group; types I, II, and IV had a significant association with frequency and severity of back pain, but type III did not. Types II and IV were more likely to report higher severity or frequency, while type I was less likely to report higher severity or frequency of back pain. No significant differences in physical activity were observed between the LSTV and non-LSTV groups. However, the subgroup analysis demonstrated via PASE that types II and IV were associated with lower physical activity levels. Compared to the non-LSTV group, type II and IV had respective ORs of 1.67 (95% CI: 1.37, 2.05) and 2.39 (95% CI: 1.40, 4.06). Type I and III had no statistically significant associations with PASE.

No significant differences were found between LSTV and non-LSTV hip OA cohorts. No differences in presence, absence, or severity of hip OA were found among LSTV subgroups.

Reproducibility Analysis

The Cohen κ value for interobserver agreement on the presence or absence of LSTV in the entire cohort was 0.75, and intraobserver agreements for the two radiologists in a set of 500 randomly selected radiographs were 0.78 and 0.79. The Cohen κ value for interobserver agreement using the categorical Castellvi classification was 0.65, and the values for intraobserver agreement were 0.72 and 0.68. These values were classified as good reader agreement (23).

Discussion

Our study demonstrated that LSTV was associated with LBP and buttock pain; types II and IV had the strongest correlation, probably due to the pseudoarticulation of the transverse process of L5 with the sacrum. Increased severity and frequency of LBP were also associated with types II and IV. Within the OAI population, LSTV was nearly three times as prevalent for men as it was for women. The findings of our study demonstrate the importance of correctly diagnosing LSTV due to the association of LSTV with back pain.

The reported prevalence of LSTV ranges from 4% to 37% (14,24–27). This variability may be caused by a difference in diagnostic criteria for the definition of LSTV. The prevalence of

LSTV was higher in studies that selected patients for LBP, while lower prevalence was seen in community-based studies (4%–24%) (14). We did not use back pain as an inclusion criterion, and the prevalence of LSTV in our study was similar to that of community-based studies. However, our study population had a higher incidence of knee OA than that found in the general population. Our study also confirms the results presented in the literature (13,28) regarding higher prevalence of LSTV in men.

LSTV's relationship to back pain has been debated since it was first described in 1917 (6,7,29,30). In terms of the number of patients and the clinical parameters analyzed (such as low back pain), a study by Tini et al (11) included 4000 patients and did not demonstrate any difference regarding LBP in patients with LSTV or patients without LSTV (11). Other studies, however, support our results: Oyinloye et al (30) described the association of LBP and LSTV in a cohort of 561 patients (2009); Quinlan et al (12) also concluded that LSTV should be considered a possible cause of LBP.

Interestingly, the association between LBP and LSTV subgroups demonstrates that LSTV types II and IV are affiliated with presence of pain, as well as pain severity and frequency. Our results differ from those of Tini et al (11), which did not demonstrate any evidence of an association of LSTV with LBP when using a subtype-specific analysis. However, most of the studies (8–10,14,31,32) that support the association of LSTV with LBP implicate types II and IV.

Although literature connecting pain severity to physical activity with LSTV is limited, Taskaynatan et al (7) studied 881 young men and demonstrated an association between LSTV and severity of pain. This association is clinically relevant because patients with severe pain are more likely to seek health care, including physician visits, medication, and surgical treatment.

Pain was less frequent in type I, which suggested that type I may be a protective factor for both LBP and buttock pain. This may result from an alteration of the spine movement where a large transverse process may prevent bending. Castellvi et al (9) stated that type I was not clinically relevant and was just a forme fruste of LSTV.

The pathophysiologic mechanism of pain associated with LSVT (6,9,16,31) remains unclear. Some of the proposed mechanisms include the association of extraforaminal stenosis (8), disk prolapses, and spinal stenosis (10) with LSTV. Connolly et al (33) used skeletal scintigraphy in young patients with LSTV to demonstrate that mechanical stress at the transverse process–sacral articulation with repeated flexion and extension of the spine may contribute to pain.

Buttock pain that is associated with LSTV in types II and IV may result from nerve compression (34,35). A mechanical irritation of the nerve root may result in pain with radicular characteristics. Some studies have demonstrated an association of LSTV with extraforaminal stenosis secondary to the dysplastic transverse process (16,36), and Taskaynatan et al (7) reported an increased prevalence of nerve root symptoms in patients with LSTV. Studies concerning the correlation of buttock pain to LSTV subtypes are limited.

Our study had a number of limitations. A major limitation was that cross-sectional imaging for assessment of disk-related causes of back pain was unavailable. Another limitation was that identification of LSTV was occasionally difficult, even with objective criteria, due to poor image quality or overprojection of bowel structures; most of these poor-quality images were excluded after the initial screening. We did not make a distinction between unilateral and bilateral pseudoarthrosis and fusion in terms of back pain. Using this additional information would make the model complicated, increasing the four-level outcome to an eight-level outcome and resulting in very small numbers of individuals in some of these groups. Analysis of the raw data did not reveal a difference between unilateral and bilateral pseudoarthrosis and fusion in terms of back pain. Finally, the patient population was selected by OAI for a study of knee OA; the main differences between the OAI cohort and the general population are that the OAI cohort had higher levels of obesity, lower levels of physical activity, and presence of knee OA, and was at risk for knee OA. Of these differences, only obesity (and perhaps low levels of physical activity) is likely associated with back pain; there is no established association between knee OA and back pain (17).

In conclusion, our study highlights the association of LSTV and types II and IV with lumbar back and buttock pain; therefore, LSTV should be considered part of the differential diagnosis of back pain, especially in cases of pain refractory to conventional management.

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