Research Square

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Radiologic evaluation of segmental translational movement in lumbar spinal stenosis patients without spondylolisthesis using flexion-extension radiographs: a descriptive study

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Abstract

Purpose:

Using flexion-extension radiographs to examine the prevalence of segmental translational movement among patients with degenerative lumbar spinal stenosis (LSS) without spondylolisthesis.

Methods:

The NORwegian Degenerative Spondylolisthesis and spinal STENosis-spinal stenosis trial (NORDSTEN-SST) includes 437 patients with symptomatic LSS without degenerative spondylolisthesis. In this descriptive study, pre-operative flexion-extension radiographs of 296 patients were evaluated for segmental translational movement of ≥3 mm or more at L2-L5.

Results:

Segmental translational movement ≥3 mm was observed in 78 of 296 patients (26.4%) at one or more levels between L2/L3 and L4/L5. Of these, 62.8% (49/78) showed movement at one level, 29.5% (23/78) at two levels, and 7.7% (6/78) at three levels. Across the 78 patients, 113 spinal levels with movement ≥3 mm were identified. Mean movement overall was 3.7 mm. No significant baseline differences were identified between groups with or without segmental translational movement.

Of the 78 patients with movement, 50.0% were operated in a level with movement. Overall, 38.1% of the spinal levels with movement were scheduled for decompressive surgery. Among patients with segmental translational movement in L2/L3, 4 of 45 patients (8.9%) were operated at this level. The numbers for L3/L4 and L4/L5 were 16 of 39 (41.0%) and 23 of 29 (79.3%), respectively.

Conclusion:

A considerable proportion of LSS patients without spondylolisthesis on neutral radiographs had segmental translational movement of ≥3 mm between L2 and L5 on pre-operative flexion-extension radiographs. Half underwent surgery at a spinal level demonstrating movement. Levels showing segmental translational movement were not operated significantly more often than levels without movement.

Introduction

Lumbar spinal stenosis (LSS) is characterized by pathological narrowing of the spinal canal and/or intervertebral foramen, leading to mechanical compression of the cauda equina and/or nerve roots. Clinically, this condition can become symptomatic with lower back pain often radiating to the lower extremities. LSS is a widespread and debilitating condition, affecting many elderly individuals worldwide and being the most common cause for spinal surgery in the elderly population [1]. Diagnosis typically involves a comprehensive medical history, physical examination, and radiologic imaging. Magnetic

resonance imaging (MRI) is the primary imaging modality, often supplemented by standing lateral radiographs to assess scoliosis and spondylolisthesis [1].

As a part of the radiological evaluations in LSS patients who are candidates for surgical treatment, assessing spinal segmental instability is one of many factors that can influence the surgical planning [1–2]. When considered stable, the surgical treatment of LSS is usually a posterior decompression without fusion. However, there is an ongoing debate whether patients with instability require an additional fusion [1].

Lumbar spinal instability is broadly defined as abnormal motion within a spinal segment [3]. However, due to the lack of a universally accepted definition, how to define, examine and further deal with suspected instability, this remains a contentious issue in spinal research [4]. Flexion-extension radiographs are commonly utilized in the assessment of instability, which implies comparison of lateral radiographs taken while the patients stand in a static flexed as well as in an extended spinal position [5]. While commonly used when a neutral radiograph indicates degenerative spondylolisthesis, the added value of these functional radiographs in preoperative assessments for LSS remains a subject of debate. This is particularly relevant as these radiographs contribute to additional radiation exposure, physical strain for patients experiencing pain, and increased workload for radiology departments [6]. Further, the value of flexion and extension radiographs in absence of spondylolisthesis on neutral radiographs is unknown.

The main aim of this descriptive study was to investigate the prevalence of segmental translational movement on flexion-extension radiographs in LSS patients without apparent spondylolisthesis on neutral standing lateral radiographs.

Materials and methods

Patient recruitment

Data were collected from the NORwegian Degenerative Spondylolisthesis and spinal STENosis - Spinal Stenosis Trial (NORDSTEN-SST). The NORDSTEN-SST is a national, multicenter study on surgical treatment of symptomatic LSS patients without degenerative spondylolisthesis, conducted across orthopedic and neurosurgical departments at 16 public hospitals in Norway. The study protocol and main results have been described extensively in previous publications [7–9]. This is a secondary analysis of the NORDSTEN-SST.

Radiologic measurements

Given the variability in how lumbar spinal instability is defined and interpreted, we have chosen to use the term “segmental translational movement” in this study to minimize ambiguity [4]. Herein, segmental

translational movement is defined as a net sagittal translation of 3 mm or more between flexion and extension radiographs.

The present study analyzed preoperative flexion-extension radiographs. Radiographic measurements were performed by the first author, trained and supervised by an experienced consultant musculoskeletal radiologist using integral tools within a Picture Archiving and Communication System (PACS Sectra IDS7, Sweden). Inter-rater reliability for radiographic measurements of spinal parameters, including lumbar lordosis, segmental lumbar lordosis, sacral slope, and the anteroposterior diameter and height of the L3 vertebral body, has previously been evaluated in our group, demonstrating intraclass correlation coefficients ranging from 0.74 to 0.99 [10].

Sagittal dynamic translations were measured at the levels of L2/L3, L3/L4, and L4/L5 following a method described by Dupuis et al. [11]. This method involves drawing a line in the caudal direction from a bony prominence on the superior vertebra that is located on the very posterior part of the inferior endplate. This line should be parallel to the inferior vertebra and end below the inferior vertebra. Another parallel line is drawn from a bony prominence on the posterior end of the superior endplate of the inferior vertebra. The distance between these two lines is the sagittal dynamic translation (Fig. 1). Previous studies have demonstrated high inter-rater and intra-rater reliability of this measurement method [12–14]. Luk et al. found the inter- and intra-observer error to be insignificant [12]. Cabraja et al. found the interobserver error when measuring segmental translation to be 1.4 mm, which did not affect the stastical analysis [13]. Pieper et al. found the intra- and interobserver reliability for flexion-extension comparison to be good to excellent, with kappa-coefficients of 0.82 and 0.70, respectively [14].

Both anterior and posterior translation was measured. Posterior translation was denoted with a negative sign in the records. The net difference in sagittal translation between extension and flexion radiographs was calculated for each patient. Segmental motion was defined as a net sagittal translation of 3 mm or more.

Statistical analysis

Standard descriptive statistics were presented using mean and standard deviation (SD) for continuous variables and absolute numbers and percentages for categorical variables. Differences in means between groups were assessed using independent samples t-tests. Differences in distributions of categorical outcomes were tested using chi-square tests. Significance level was set to 5%. All analyses were done using Stata (StataCorp 2021. Release 17.1, College Station, TX, USA).

Results

Of 437 patients originally included in the NORDSTEN-SST, 296 patients had the necessary pre-operative flexion-extension radiographs and were included for the analysis in the present study (Fig. 2).

NORDSTEN-SST: NORwegian Degenerative spondylolisthesis and spinal STENosis-Spinal Stenosis Trial. N: number of patients.

Assessed with flexion-extension radiographs, 78 of 296 patients (26.4%) with LSS without visible spondylolisthesis on neutral, lateral radiographs demonstrated segmental translational movement of 3 mm or more in one or more lumbar segment between L2 and L5 (Table 1). Among these patients, 49 (62.8%) had movement at one level, 23 (29.5%) at two levels, and 6 (7.7%) at three levels. In total, 113 levels in 78 patients demonstrated movement. No significant baseline differences were identified between groups with or without segmental translational movement ≥ 3 mm at baseline (Table 2).

Table 1
Assessment of flexion-extension radiographs in 296 LSS patients without visible spondylolisthesis on neutral radiographs.

No. of patients with segmental translational movement (≥ 3 mm)		
	No segmental movement	**Segmental movement**
L2/L3 – L4/L5	218 (73.6%)	78 (26.4%)
L2/L3	251 (84.8%)	45 (15.2%)
L3/L4	257 (86.8%)	39 (13.2%)
L4/L5	267 (90.2%)	29 (9.8%)

The mean segmental translational movement for all moving levels was 3.7 mm (SD = 1.2). For L2/L3, L3/L4 and L4/L5 the mean segmental translational movement was 3.9 mm (SD = 1.4), 3.7 mm (SD = 1.0) and 3.3 mm (SD = 0.9), respectively. Maximum segmental translational movement recorded was 7.4 mm for L2/L3, 7.0 mm for L3/L4, and 5.8 mm for L4/L5. Among patients with segmental translational movement a net anterior shift dominated with 44 of 45 (97.8%) at L2/L3 and 36 of 39 (92.3%) and 28 of 29 (96.6%) patients at L3/L4 and L4/L5, respectively.

Among patients with segmental translational movement in one or more levels, 39 of 78 (50.0%) were operated at a level with pre-operative movement. In sum, 43 out of 113 spinal levels with movement (38.1%) were scheduled for surgery. For patients with segmental translational movement in L2/L3, 4 of 45 (8.9%) were operated on this level (Table 3). For patients with segmental translational movement at L3/L4, 16 of 39 (41.0%) were operated on this level. For those with segmental translational movement at L4/L5, 23 of 29 patients (79.3%) were operated on this level (Table 3). There was no statistically significant difference in the frequency of surgery between levels with and without segmental translational movement (Table 3).

Table 2
Baseline characteristics.

Segmental translational movement (≥ 3 mm)				
		No segmental movement (n = 218)	**Segmental movement (n = 78)**	**P-value**
Age	Mean	66.7	66.3	0.73
	SD	8.7	8.2	
	N	218	78	
BMI	Mean	27.7	27.6	0.93
	SD	4.1	4.2	
	N	210	76	
ODI	Mean	38.6	36.2	0.21
	SD	14.2	14.7	
	N	215	78	
Sex	Men	119 (54.6%)	39 (50.0%)	0.49
	Women	99 (45.4%)	39 (50.0%)	
Smoking	Yes	46 (21.5%)	18 (23.1%)	0.77
	No	168 (78.5%)	60 (76.9%)	

SD: Standard Deviation. N: number of patients. BMI: Body Mass Index. ODI: Oswestry Disability Index.

Table 3
Relationship between lumbar segmental translation movement and surgical decompression in indicated level

No. of patients with segmental translational movement (≥ 3 mm) who were operated in the indicated level				
		Operated in indicated level	**Not operated on indicated level**	**P-value**
Segm. movement L2/L3	Yes (N = 45)	4 (1.4%)	41 (13.9%)	0.30
	No (N = 251)	37 (12.5%)	214 (72.3%)	
Segm. movement L3/L4	Yes (N = 39)	16 (5.4%)	23 (7.8%)	0.29
	No (N = 257)	129 (43.6%)	128 (43.2%)	
Segm. movement L4/L5	Yes (N = 29)	23 (7.8%)	6 (2.0%)	0.42
	No (N = 267)	193 (65.2%)	74 (25.0%)	

Discussion

This secondary analysis of the NORDSTEN-SST cohort shows that a considerable proportion of patients with symptomatic LSS show significant segmental translational movement (≥ 3mm) in one or more lumbar segment between L2 and L5 when assessed with flexion-extension radiographs, despite no visible spondylolisthesis on neutral, lateral radiographs. Unadjusted analyses of baseline parameters revealed no association between the presence of segmental translational movement and pain-related disability (ODI). Notably, only 38.1% of lumbar levels demonstrating segmental translational movement corresponded to the level scheduled for decompressive surgery.

We were unable to find any studies describing the prevalence of segmental translational movement and/or instability in patients with spinal stenosis without any spondylolisthesis. However, the findings in the present study align with current reports from studies looking at patients diagnosed with spondylolisthesis. Austevoll et al. demonstrated that 22% of patients (26 of 121) with degenerative spondylolisthesis had segmental instability defined as ≥ 3 mm forward translation on flexion-extension radiographs [15]. Moradi et al. have shown that among patients operated for degenerative LSS and a Meyerding grade of 1 or 2, 27.6% of patients (132 of 478) had instability on pre-operative flexion-extension radiographs defined as > 3 mm dynamic translation [16]. Kashigar et al. (2021) found that among patients with grade 1 spondylolisthesis, 34% (66 of 191) had motion on flexion-extension radiographs using the same definition [6]. Chan et al. (2019) found that for patients with any grade of spondylolisthesis, 21.4% (12 of 56) had dynamic instability in the affected level [17].

Liu et al. (2015) demonstrated that among 68 patients with single level spondylolisthesis of any grade, 17.6% (12 of 68) had instability defined as dynamic translation of > 8% the width of the adjacent, superior vertebrae [5]. These findings are hard to compare to our results because the authors excluded those with multilevel spondylolisthesis and their definition of instability differs from ours. Nevertheless, we found that 26.4% of patients with LSS without radiographic spondylolisthesis demonstrated segmental translational movement of ≥ 3 mm, suggesting that dynamic translational movement may be present even in the absence of static spondylolisthesis.

We found no significant differences in age, sex, BMI, smoking status, or baseline disability (ODI) between patients with and without segmental translational movement. Few previous studies have specifically compared these characteristics. Consistent with our results, Chan et al. found that age, sex, BMI, and smoking status were not associated with dynamic instability in patients with degenerative spondylolisthesis [17].

The presence of segmental translational movement was not significantly associated with a higher likelihood of surgery at that level. These results suggest that segmental translational movement at a specific level does not predict the level of the most stenotic level(s) on MRI. We were unable to find other studies that have directly examined the correlation between the lumbar level with manifest segmental translational movement and the level where surgery was ultimately performed. However, other studies have investigated the overall utility of flexion-extension radiographs in surgical planning. Kashigar et al. found that pre-operative planning for 90% of patients with spondylolisthesis could be performed by comparing standing, neutral radiographs and supine MRI [6]. Lee at al. found that flexion-extension radiographs underestimated instability in patients with degenerative spondylolisthesis. They conclude that this method had lower sensitivity in evaluating dynamic lumbar instability than comparing standing neutral and flexion radiographs to MRI in the supine position [18].

The different radiologic definitions of lumbar segmental instability and their respective frequencies have been discussed in a systematic review by Elmose et al. from 2023. This review examined 118 studies and found that the most frequently used defining parameters were ≥ 3 mm dynamic translation and > 10° dynamic angulation as seen when comparing flexion and extension radiographs [4]. Other definitions covered by the review include static translation, slip percentage difference, facet effusion, narrative definitions and spondylolisthesis. The authors recommend using ≥ 3 mm dynamic translation because of the large variation in definition, threshold and method of measurement of dynamic angulation [4]. Based on this recommendation we elected to measure dynamic translation in this study instead of dynamic angulation.

The wide range of definitions and implications of “instability” reported by Elmose et al. was the reason we decided to use the term “segmental translational movement” for this study [4]. According to a 2016 qualitative review by Simmonds et al. the presence of lumbar instability seems to be considered synonymous with the need for surgical fixation. Based on 5 biomechanical and 40 clinical/radiographic articles, the authors propose a qualitative guide for assessing stability in patients with degenerative

lumbar spondylolisthesis pre-operatively. Here they recommend decompression and posterior fusion for patients with 3–5 mm dynamic translation with the addition of interbody fusion for patients with > 5 mm dynamic translation [19]. The present study does not provide guidance on whether some patients with LSS do better with a fusion or not. Rather, it highlights that translational segmental movement in one or more spinal segments is relatively common in this patient population. The clinical relevance of segmental translational movement for decision-making and treatment selection remains to be further elucidated.

Several limitations should be considered when interpreting our findings. This study represents a secondary analysis of data from the NORDSTEN-LSS trial. Although flexion–extension radiographs were prospectively collected as part of the preoperative assessment, the analyses presented here were not prespecified in the original study protocol [7–9]. Although the reliability of our measurement method has been shown to be high, measurement precision may be affected by image quality, spinal rotation, and the inherent uncertainty of radiographic magnification [12–14, 20]. Finally, it is worth considering that the flexion-extension radiographs employed in this study were captured at 16 different hospitals across Norway. Local variations in imaging technique might influence the interpretation of our results.

Conclusion

This descriptive study finds that even when spondylolisthesis is not visible on neutral radiographs, 26.4% of patients with symptomatic LSS have a lumbar segmental translational movement ≥ 3 mm between L2/L3 and L4/L5 when assessed with pre-operative flexion-extension radiographs. Among these patients, 50.0% demonstrated movement in a spinal level scheduled for surgery. In total, 38.1% of the spinal levels with segmental translational movement corresponded to the level scheduled for decompressive surgery. Levels demonstrating segmental translational movement were not operated significantly more frequently than levels without such movement.

Declarations

Author Contribution

Funding was secured by K.I, I.M.A, H.Br, E.H, and H.B. The study was conceived and designed by K.I, E.H, H.B, and E.B. Data were collected by E.B, following training from H.B. Data curation and statistical analyses were carried out by T.Å.M. The first draft of the manuscript was written by E.B with contribution from T.Å.M, under the supervision of K.I, E.H, and H.B. All authors contributed to the interpretation of the results, critically revised the manuscript for important intellectual content, and approved the final version.

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Data Availability

The datasets generated during the current study are available from the corresponding author upon a reasonable request. Medical researchers' request must be in accordance with local registration and ethical approval, and datasets will be provided following review and approval of a research proposal and Statistical Analysis Plan (SAP). Data requests can be submitted at any time and the data will be accessible for 12 months, with possible extensions considered. All proposals requesting data access will need approval of the scientific board of the NORDSTEN study before any data can be released.

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Figures

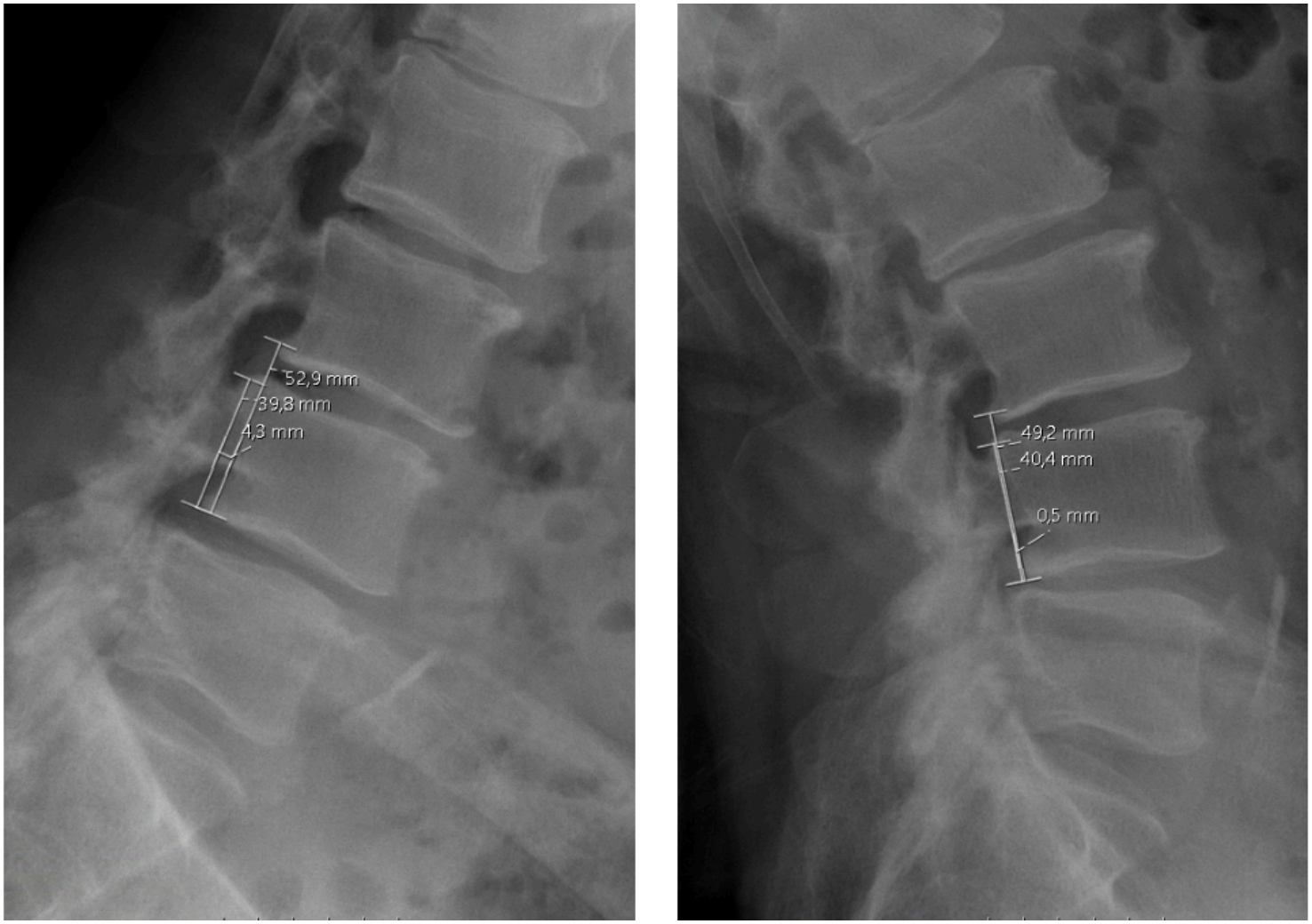


Figure 1

Example images displaying the method of measuring dynamic sagittal translation in flexion-extension radiographs at the level of L3/L4 using the integral tools in Sectra IDS7.

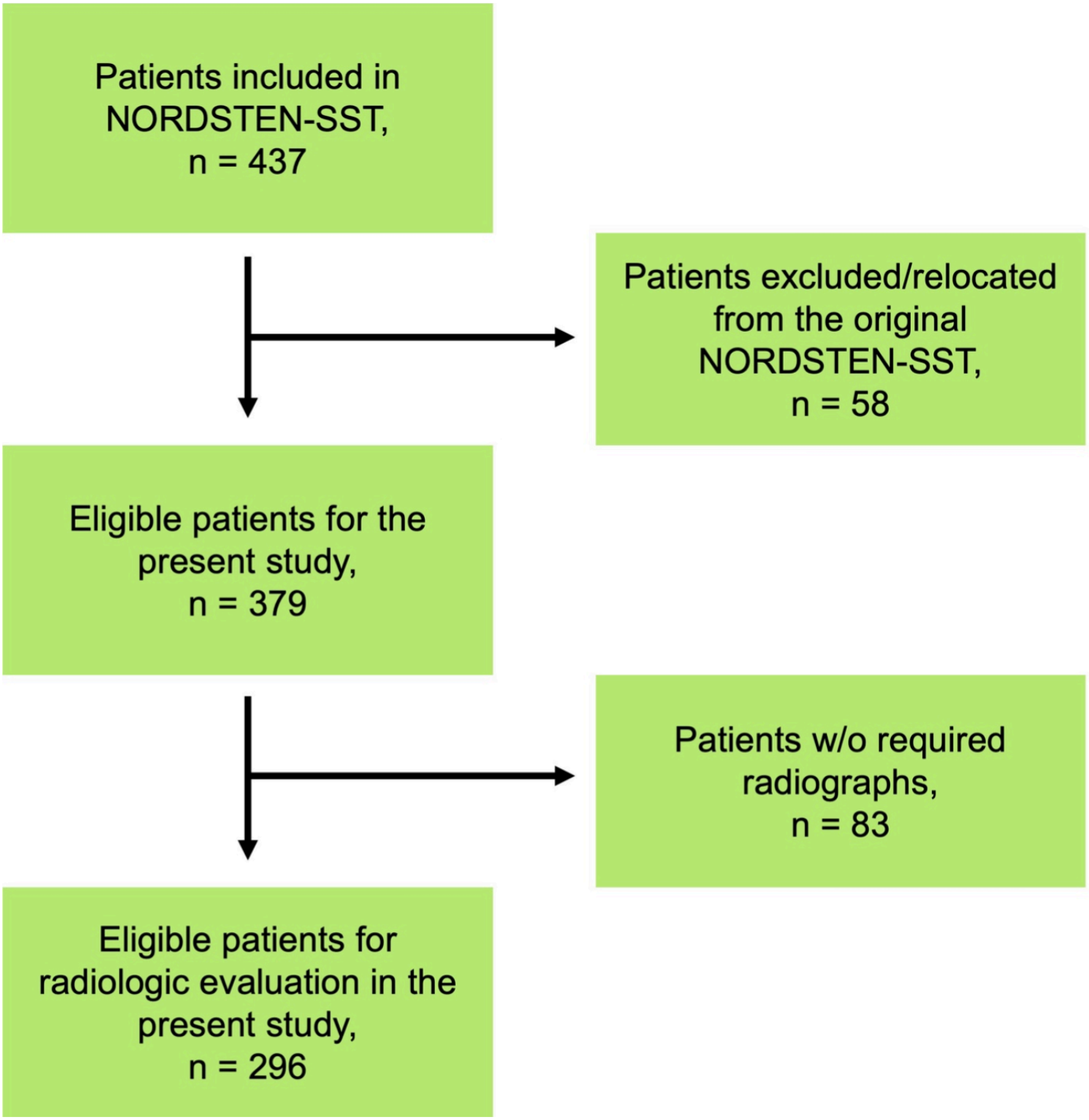


Figure 2

Flowchart illustrating the patients included in this study from the original NORwegian Degenerative spondylolisthesis and spinal STENosis-Spinal Stenosis Trial (NORDSTEN-SST).

NORDSTEN-SST: NORwegian Degenerative spondylolisthesis and spinal STENosis-Spinal Stenosis Trial. N: number of patients.