

# Single-Photon Emission Computed Tomography (SPECT-CT) as a Predictor of Pain Generators in Patients Undergoing Anterior Cervical Discectomy and Fusion (ACDF) for Axial Cervical Pain

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## Abstract

**Background:** Axial neck pain is often associated with cervical instability, and surgical options are often reserved for patients with either neurological compromise or deformity of the spine. However, cervical facet arthropathy is often implicated with instability and the location of painful generators is often difficult to ascertain. Single-photon emission computed tomography (SPECT-CT) presents an adjunct to conventional imaging in the workup of patients with suspected facetogenic pain. We aimed to report our experience with patients undergoing anterior cervical discectomy and fusion (ACDF) guided by SPECT-CT for axial cervical pain.

**Methods:** We retrospectively identified all cases undergoing ACDF that presented with axial neck pain where correlating SPECT-CT high metabolism areas were identified. Patients were treated at a tertiary care institution between January 2018 and January 2021. Patients with positive radiotracer uptake pre-operatively were compared with patients undergoing ACDF without uptake on SPECT-CT. The pre- and post-operative patients who reported neck pain at one year were compared.

**Results:** Thirty-five patients were included in this retrospective cohort. The median pre- and post-intervention (at one-year follow-up) visual analog score (VAS) of patients undergoing ACDF without uptake on SPECT-CT was 7 and 3 ( $p < 0.01$ ), while the pre- and post-VAS for patients undergoing surgery with positive uptake on SPECT-CT was 8.5 and 0 ( $p < 0.01$ ). Improvement was significantly larger for patients undergoing SPECT-CT-guided ACDF ( $p = 0.02$ ). At one year after surgery, none of the assessed patients required additional surgical intervention.

**Conclusion:** This case series represents the experience of our group to date with patients undergoing SPECT-CT-guided ACDF with results suggesting potential benefit in guiding fusion.

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**Categories:** Neurosurgery, Pain Management

**Keywords:** ct, spect, acdf, spine, spinal surgery

## Introduction

Axial neck pain is common and often associated with unidentified instability (defined by Panjabi as the loss of the spine's ability to maintain its patterns of displacement under physiologic circumstances to prevent baseline or incremental deficits, deformity, or incapacitating pain) [1]. Further, it is debilitating, with painful generators being numerous and of difficult determination [2-8]. Cervical facet joint osteoarthritis is a common etiology for instability, responsible for up to 50% of patients presenting to pain clinics with a chief complaint of neck pain [5,6]. However, conventional morphological-based imaging studies, including X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), often fall short in their ability to ascertain if an osteoarthritic facet joint is truly the primary pain generator [9-14]. Further, diagnostic/treatment with intra-articular injections directed to osteoarthritic joints with local anesthetic and steroids has limited available data supporting its efficacy in predicting long-term response to surgical arthrodesis of the affected joint [15,16]. More recently, functional imaging methods have been used to locate the source(s) of pain. Such methods include bone scintigraphy with technetium 99m-methylene diphosphonate (MDP). It has been suggested to depict osteoblastic activity and synovial changes, which can be seen in patients with inflammation or hyperemia [17]. Single-photon emission computed tomography (SPECT) allows for three-dimensional (3D) image acquisition of typical two-dimensional (2D) planar data. Hybrid SPECT-CT is a SPECT scan fused with a corresponding CT scan [17-19]. However, it remains controversial whether positive uptake on a radionuclide study is a predictor of favorable response to surgical arthrodesis, with only a small case series being available in the literature and no prior work evaluating an anterior approach for surgical arthrodesis of the cervical spine [4,8]. Here, we aimed to report

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our experience using SPECT-CT before anterior cervical discectomy and fusion (ACDF) and to evaluate the potential correlation between pre-operative positive uptake and patient-reported outcomes after decompression and fusion.

## Materials And Methods

### Patient selection

We performed a single-institution, retrospective analysis of prospectively collected data evaluating patient-reported outcomes in patients undergoing ACDF for chronic axial neck pain with prior SPECT-CT between January 2018 and January 2021. Patients with positive radionuclide uptake in all fused segments were compared with patients undergoing ACDF and negative uptake on SPECT-CT. This study was reviewed and approved by the Institutional Review Board (18-003951). Patients were followed for a minimum of one year after intervention.

### Inclusion and exclusion criteria

The inclusion criteria for this study involve patients with a clinical diagnosis of cervical axial neck pain persisting for at least six months and not showing improvement with medical management. Exclusion criteria encompass known causes of neck pain such as trauma, infection, tumor, and iatrogenic complications. Additionally, patients with isolated radiculopathy or myelopathy only are excluded, along with those having a follow-up time of less than one year.

### SPECT-CT protocol

Radionuclide imaging study in our institution is reserved for pre-operative or pre-procedural evaluation of patients with inconclusive clinical-radiographic findings and persistent pain. Our SPECT-CT protocol has further been validated in a large study evaluating SPECT-CT to guide targeted facet injections in patients with back pain [4].

### Patient outcomes

From each patient, pre-operative, surgical, and post-operative data was collected. This included the number of levels being operated on, pre-operative comorbidities, intra-operative complications, blood loss, and post-operative improvement. Baseline patient-reported outcomes including cervical pain were included at the time of surgical consultation and at one-year follow-up.

### Statistical analysis

Categorical variables were described using absolute and relative frequencies, while continuous variables were described using medians and interquartile ranges. Pre-intervention pain scores of patients undergoing ACDF were compared with post-intervention pain scores by means of a Mann-Whitney U test. Statistical significance was considered to be a p-value <0.05.

## Results

### Patient population and clinical presentation

A total of 46 patients presented with cervical spondylosis and a pre-operative SPECT-CT before ACDF was eligible for screening. Of the 46, 11 patients were excluded due to lack of appropriate follow-up, and the remaining 35 were enrolled in the study. Of these 35, 15 underwent uptake-targeted ACDF (u-ACDF) (nine male and six female). Patients undergoing u-ACDF did not differ from patients undergoing non-uptake-targeted ACDF (nu-ACDF) in age at the time of surgery ( $p=0.285$ ), average BMI ( $p=0.904$ ), number of comorbidities ( $p=0.099$ ), average blood loss ( $p=0.549$ ), number of intra-operative ( $p=0.999$ ) and post-operative ( $p=0.429$ ) complications. A complete description of the patient's demographic information is included in Table 1.

	All patients (n=35)	u-ACDF (15)	nu-ACDF (n=20)	p-value
Age at surgery (years) - median (IQR)	57 (11)	54 (10)	60.5 (12)	0.285
Gender (male) - n (%)	19 (54)	9 (60)	10 (50)	0.734
Caucasian ethnicity - n (%)	27 (77)	11 (73)	16 (80)	0.700
One level - n (%)	22 (63)	10 (67)	12 (60)	0.737
Two levels - n (%)	7 (20)	3 (20)	4 (20)	0.999
Three levels - n (%)	4 (11)	3 (20)	1 (5)	0.292
Four levels - n (%)	2 (6)	1 (7)	1 (5)	0.999
Number of comorbidities - median (IQR)	3 (2)	4 (3)	3 (1.5)	0.099
BMI (kg/m <sup>2</sup> ) - median (IQR)	30.1 (7)	30.1 (4.2)	30 (7.5)	0.904
Hypertension - n (%)	11 (31)	4 (27)	7 (35)	0.721
Diabetes - n (%)	11 (31)	5 (33)	6 (30)	0.999
Hyperlipidaemia - n (%)	15 (43)	6 (40)	9 (45)	0.999
Coagulopathy - n (%)	0	0	0	0.999
Coronary artery disease - n (%)	2 (6)	1 (7)	1 (5)	0.999
Heart failure - n (%)	0	0	0	0.999
Chronic kidney disease - n (%)	0	0	0	0.999
Stroke - n (%)	0	0	0	0.999
TIA - n (%)	1 (3)	0	1 (5)	0.999
Arrhythmia - n (%)	2 (6)	1 (7)	1 (5)	0.999
DVT - n (%)	3 (9)	1 (7)	2 (10)	0.999
PE - n (%)	1 (3)	0	1 (5)	0.999
COPD - n (%)	3 (9)	1 (7)	2 (10)	0.999
Asthma - n (%)	1 (3)	0	1 (5)	0.999
OSA - n (%)	4 (11)	2 (13)	2 (10)	0.999
Blood loss - median (IQR)	130 (150)	150 (150)	115 (125)	0.549
Intra-operative complications - n (%)	0	0	0	0.999
Post-operative complications - n (%)	1 (3)	1 <sup>a</sup> (7)	0	0.429

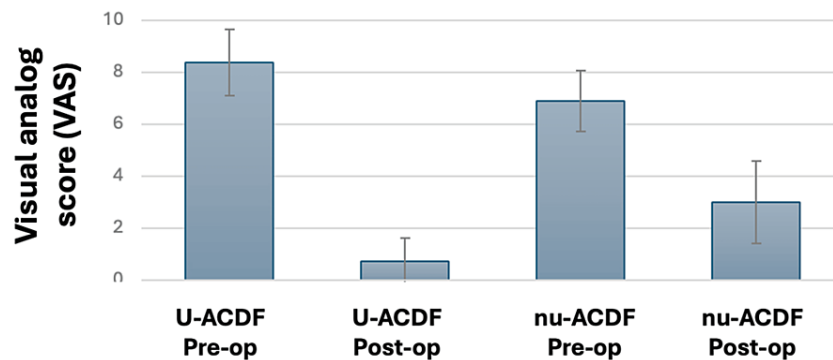
**TABLE 1: Demographic and pre-morbid characteristics of included patients**

BMI: body mass index; COPD: chronic obstructive pulmonary disease; DVT: deep venous thrombosis; IQR: interquartile range; OSA: obstructive sleep apnea; PE: pulmonary embolism; TIA: transient ischemic attack; u-ACDF: uptake-targeted ACDF; nu-ACDF: non-uptake-targeted ACDF

<sup>a</sup> Persistent dysphagia

### Management and patient-reported outcomes

Twenty-two of the assessed patients underwent a one-level ACDF (22/35), with the most common spinal level being C6-7. Another seven (7/35), four (4/35), and two (2/35) underwent a two-, three-, and four-level ACDF, respectively. In patients undergoing u-ACDF, all levels with positive uptake were targeted. The median length of stay was one night, with surgical complications being limited to one case of persistent dysphagia after surgery. A complete description of the included patients is available in Figure 1.



**FIGURE 1: Pre- and post-operative visual analog scores (VAS) for u-ACDF and nu-ACDF**

u-ACDF: uptake-targeted ACDF; nu-ACDF: non-uptake-targeted ACDF

The median pre- and post-intervention (at one-year follow-up) visual analog scores (VAS) of patients undergoing nu-ACDF were 7 and 3 ( $p < 0.01$ ), while the pre- and post-VAS for patients undergoing surgery after u-ACDF was 8.5 and 0 ( $p < 0.01$ ). Improvement was significantly larger for patients undergoing u-ACDF ( $p = 0.02$ ). At one year after surgery, none of the assessed patients required additional surgical intervention.

## Discussion

In this study, we report our experience with patients undergoing ACDF after SPECT-CT, when prior imaging findings were inconclusive. In our experience, patients undergoing ACDF for levels targeted at positive uptake were found to have good surgical outcomes after one year of follow-up. While patients undergoing ACDF for levels with negative or mixed SPECT-CT also saw improvements in their pain scores, VAS pain changes were significantly larger for patients with uptake on pre-operative SPECT-CT. This is relevant, as it corresponds to one of the first (and the largest) reports illustrating the potential benefit of incorporating SPECT-CT in the pre-operative evaluation of patients undergoing ACDF for cervical arthropathy with inconclusive findings on traditional imaging modalities.

Our results are in line with prior work, with Tender et al. suggesting the presence of abnormal radiotracer uptake on SPECT-CT as an accurate predictor for the need for potential instrumented fusion, with a significant drop in self-reported VAS six months after surgery (both from anterior and posterior approaches) in patients with pre-operative localized foci of abnormal spinal radiotracer uptake [7]. Other studies from our group [14] and others [18-20] had also previously suggested the potential benefit of incorporating SPECT-CT to guide targeted injections for facetogenic pain, with results suggesting that SPECT-CT in selected patients can help guide injections to painful generators. However, the role of SPECT-CT in guiding the placement of instrumentation remains controversial with no systematic guidelines recommending its incorporation in clinical workflows at this time. Our report represents the experience of a large tertiary academic center with good surgical outcomes where SPECT-CT was used to guide the extent of fusion in patients with chronic axial neck pain with inconclusive imaging findings on CT and MRI but with positive uptake on pre-operative SPECT-CT.

This study has important limitations. This is a retrospective single-institution study at a large tertiary care academic institution, which might limit its external validity to other healthcare settings. However, it represents a real clinical experience with long-term follow-up of patients commonly seen in community settings. The sample size is relatively small, which might have affected the precision of our estimates and observations. However, the aim of our study was to report the experience of our center with pre-operative SPECT-CT in patients with inconclusive findings, which we expect to lay the foundation for future randomized studies with control groups. However, it also has important strengths. The data collection, including patient-reported neck pain pre- and post-procedure, was independently collected by personnel not involved in this study. A potential limitation arises from the fact that patient-reported neck pain before surgery was collected through phone calls. However, this is a commonly used method in observational studies on this topic [7,20]. To minimize potential information bias, professionals collecting patient-reported outcome data are trained to do so and are blinded to whether patients were submitted to an SPECT-CT before the procedure. In fact, this study provides results from a real clinical scenario in which the real benefit of employing SPECT-CT in a tertiary academic center was evaluated. Further, the short follow-up time could have also limited our observations.

## Conclusions

In conclusion, we present the experience of our center using SPECT-CT to guide the extent of fusion in patients with axial neck pain and inconclusive findings on CT and MRI, with good surgical outcomes. Future studies are needed to be aimed at establishing clear guidelines before the generalized incorporation of SPECT-CT in clinical workflows.

## Additional Information

### Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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**Supervision:** Eric Nottmeier

### Disclosures

**Human subjects:** Consent was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

## References

1. Panjabi MM: Clinical spinal instability and low back pain. *J Electromyogr Kinesiol.* 2003, 13:371-9. [10.1016/s1050-6411\(03\)00044-0](https://doi.org/10.1016/s1050-6411(03)00044-0)
2. Garcia D, Akinduro OO, De Biase G, et al.: Robotic-assisted vs nonrobotic-assisted minimally invasive transforaminal lumbar interbody fusion: a cost-utility analysis. *Neurosurgery.* 2022, 90:192-8. [10.1227/NEU.0000000000001779](https://doi.org/10.1227/NEU.0000000000001779)
3. Garcia D, Sousa-Pinto B, De Biase G, et al.: Minimally invasive transforaminal lumbar interbody fusion: cost of a surgeon's learning curve. *World Neurosurg.* 2022, 162:e1-7. [10.1016/j.wneu.2021.11.039](https://doi.org/10.1016/j.wneu.2021.11.039)
4. Brusko GD, Perez-Roman RJ, Tapamo H, Burks SS, Serafini AN, Wang MY: Preoperative SPECT imaging as a tool for surgical planning in patients with axial neck and back pain. *Neurosurg Focus.* 2019, 47:E19. [10.3171/2019.9.FOCUS19648](https://doi.org/10.3171/2019.9.FOCUS19648)
5. Kirpalani D, Mitra R: Cervical facet joint dysfunction: a review. *Arch Phys Med Rehabil.* 2008, 89:770-4. [10.1016/j.apmr.2007.11.028](https://doi.org/10.1016/j.apmr.2007.11.028)
6. Lee MJ, Riew KD: The prevalence cervical facet arthrosis: an osseous study in a cadveric population. *Spine J.* 2009, 9:711-14. [10.1016/j.spinee.2009.04.016](https://doi.org/10.1016/j.spinee.2009.04.016)
7. Tender GC, Davidson C, Shields J, Robichaux J, Park J, Crutcher CL, DiGiorgio AM: Primary pain generator identification by CT-SPECT in patients with degenerative spinal disease. *Neurosurg Focus.* 2019, 47:E18. [10.3171/2019.9.FOCUS19608](https://doi.org/10.3171/2019.9.FOCUS19608)
8. Witiw CD, Tsapenko N, Traynelis VC: The utility of radionuclide imaging in the surgical management of axial neck pain from cervical facet joint arthropathy. *J Neurosurg Spine.* 2019, 32:168-75. [10.3171/2019.8.SPINE19806](https://doi.org/10.3171/2019.8.SPINE19806)
9. Eubanks JD, Lee MJ, Cassinelli E, Ahn NU: Prevalence of lumbar facet arthrosis and its relationship to age, sex, and race: an anatomic study of cadaveric specimens. *Spine (Phila Pa 1976).* 2007, 32:2058-62. [10.1097/BRS.0b013e318145a5a9](https://doi.org/10.1097/BRS.0b013e318145a5a9)
10. Savage RA, Whitehouse GH, Roberts N: The relationship between the magnetic resonance imaging appearance of the lumbar spine and low back pain, age and occupation in males. *Eur Spine J.* 1997, 6:106-14. [10.1007/BF01358742](https://doi.org/10.1007/BF01358742)
11. De Biase G, Gassie K, Garcia D, Abode-Iyamah K, Deen G, Nottmeier E, Chen S: Perioperative comparison of robotic-assisted versus fluoroscopically guided minimally invasive transforaminal lumbar interbody fusion. *World Neurosurg.* 2021, 149:e570-5. [10.1016/j.wneu.2021.01.133](https://doi.org/10.1016/j.wneu.2021.01.133)
12. Moniz-Garcia D, Stolf D, Akinduro O, et al.: Two- versus multi-rod constructs for adult spinal deformity: a systematic review and Random-effects and Bayesian meta-analysis. *J Clin Neurosci.* 2023, 107:9-15. [10.1016/j.jocn.2022.11.011](https://doi.org/10.1016/j.jocn.2022.11.011)

13. Akinduro OO, Garcia DP, Domingo RA, et al.: Cervical chordomas: multicenter case series and meta-analysis. *J Neurooncol.* 2021, 153:65-77. [10.1007/s11060-021-03742-6](https://doi.org/10.1007/s11060-021-03742-6)
14. Garcia D, Sousa-Pinto B, Akinduro OO, et al.: SPECT-CT as a predictor of pain generators in patients undergoing intra-articular injections for chronic neck and back pain. *World Neurosurg.* 2022, 164:e1243-50. [10.1016/j.wneu.2022.06.013](https://doi.org/10.1016/j.wneu.2022.06.013)
15. Scholten P, Sheikh M, Atchison J, et al.: Correlating SPECT-CT activity in lumbar facet joints with response to lumbar medial branch and L5 dorsal ramus blocks. *Interventional Pain Medicine.* 2024, 3:100387. [10.1016/j.inpm.2024.100387](https://doi.org/10.1016/j.inpm.2024.100387)
16. Scholten P, Sheikh M, Atchison J, et al.: Correlating SPECT-CT activity in cervical facet joints with positive response to cervical medial branch blocks. *Interventional Pain Medicine.* 2024, 3:100393. [10.1016/j.inpm.2024.100393](https://doi.org/10.1016/j.inpm.2024.100393)
17. Pneumaticos SG, Chatziioannou SN, Hipp JA, Moore WH, Esses SI: Low back pain: prediction of short-term outcome of facet joint injection with bone scintigraphy. *Radiology.* 2006, 238:693-8. [10.1148/radiol.2382041930](https://doi.org/10.1148/radiol.2382041930)
18. Dolan AL, Ryan PJ, Arden NK, et al.: The value of SPECT scans in identifying back pain likely to benefit from facet joint injection. *Br J Rheumatol.* 1996, 35:1269-73. [10.1093/rheumatology/35.12.1269](https://doi.org/10.1093/rheumatology/35.12.1269)
19. Holder LE, Machin JL, Asdourian PL, Links JM, Sexton CC: Planar and high-resolution SPECT bone imaging in the diagnosis of facet syndrome. *J Nucl Med.* 1995, 36:37-44.
20. Freiermuth D, Kretzschmar M, Bilecen D, Schaeren S, Jacob AL, Aeschbach A, Ruppen W: Correlation of (99m) Tc-DPD SPECT/CT scan findings and diagnostic blockades of lumbar medial branches in patients with unspecific low back pain in a randomized-controlled trial. *Pain Med.* 2015, 16:1916-22. [10.1111/pme.12841](https://doi.org/10.1111/pme.12841)