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Correlating SPECT-CT activity in lumbar facet joints with response to lumbar medial branch and L5 dorsal ramus blocks

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ABSTRACT

Introduction: Lumbar facet arthritis is a significant source of back pain and impaired function that is amenable to treatment with medial branch radiofrequency neurotomy (RFN). Identifying appropriate patients for this treatment requires integration of information from the history, physical exam, and diagnostic imaging, but the current diagnostic standard for facet-mediated pain is positive comparative medial branch blocks (MBBs). Lumbar SPECT-CT has recently been evaluated as a potential predictor of positive MBBs with mixed results. The purpose of this retrospective analysis was to determine if the level of concordance between SPECT-CT uptake and facet joints targeted with MBB was associated with a positive block.

Methods: A retrospective review was performed to identify all patients undergoing lumbar MBB within 12 months after having a lumbar SPECT-CT. Each procedure was classified into one of four categories based on the level of concordance between facet joints demonstrating increased ^{99m}Tc uptake on SPECT-CT and those being blocked: 1) Complete Concordance (all joints demonstrating increased uptake were blocked and no additional joints blocked); 2) Partial Concordance (all joints demonstrating increased uptake were blocked, with at least one joint not demonstrating increased uptake blocked); 3) Partial Discordance (at least one but not all joints demonstrating increased uptake were blocked); 4) Complete Discordance (all blocks performed at joints not demonstrating increased uptake). Statistical analysis was performed to determine if the level of concordance between increased uptake on SPECT-CT and joints undergoing MBB was associated with a positive block using cutoffs of 50 % and 80 % pain relief.

Results: A total of 180 procedures were analyzed (23 % Complete Concordance, 22 % Partial Concordance, 31 % Partial Discordance, 24 % Complete Discordance) and all groups demonstrated improvement in pain Numeric Rating Scale (NRS) scores. There was no significant association between level of concordance and having a positive block using thresholds of 50 % pain relief, $\chi^2(3, N = 180) = 4.880$, p = .181; or 80 % pain relief, $\chi^2(3, N = 180) = 1.272$, p = .736.

Conclusion: SPECT-CT findings do not accurately predict positive lumbar MBB but may provide valuable information that can be considered with other factors when deciding which joints to treat.

1. Introduction

Chronic musculoskeletal low back pain is a common problem that results in significant impairments, activity limitations and participation restrictions within patients' daily lives. Roughly 1 in 4, or 58.8 million adults suffer from chronic low back pain making it the second-most prevalent musculoskeletal condition – surpassed only by peripheral joint arthritis [1,2]. Between the large direct costs associated with nearly 62 million health care visits annually for low back pain and the indirect costs of 149 million lost work days for back pain annually, the economic impact is profound with total costs estimated to be between $100 and $200 billion annually [3,4]. From a functional perspective, it is estimated that 8.4 million people have limitations performing activities of daily living as a result of their back pain [1]. Furthermore, while not immediately life-threatening, the associated functional impairments including reduced mobility and decreased exercise tolerance secondarily increase the risk of cardiovascular and other deadly diseases [5].

Potential anatomic sources of pain include myofascial structures, facet joints, intervertebral disks, and vertebral endplates. Given multiple overlapping potential sources of low back pain, data from the patient's history, physical examination and diagnostic testing must be integrated into the decision-making process. Typically, patients with facet-

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mediated pain report pain in the low back without radiation into the legs that is traditionally thought to worsen with activity, particularly extension, combined extension, and rotation as well as returning to neutral from a flexed position, however, dedicated studies have not corroborated this [6–8]. Radiographs demonstrating signs of degeneration including sclerosis, bone hypertrophy and osteophytes suggest underlying osteoarthritis, but conventional radiographs are insensitive in the detection of mild facet disease [9,10]. CT demonstrates similar findings, but with improved detail. Moderate to severe lumbar facet joint osteoarthritis is present on CT imaging in 36 % of adults under the age of 45 years, 67 % of adults age 45–64 years, and 89 % of those over the age of 65 years [11]. MRI demonstrates similar structural abnormalities, but with the benefit of improved soft-tissue resolution including the ability to detect active synovial inflammation and facet joint effusions. However, 8 %–14 % of asymptomatic patients have been shown to have degenerative facet changes on CT and MRI [12–14], making accurate identification of the most likely pain generator challenging based on clinical information and traditional imaging modalities challenging.

Initial conservative management of suspected facet-mediated pain is usually empirical and includes oral analgesics and an active therapeutic exercise program [15,16]. Thereafter, dual comparative anesthetic blockade of the medial branches of the dorsal rami (or in the case of L5, the dorsal ramus itself) that supply the sensory innervation to the facet joint (henceforth collectively termed medial branch block (MBB) for simplicity) are the accepted standard for predicting outcomes from radiofrequency neurolysis (RFN) of those nerves [17–26]. However, this technique is prone to high false-positive and false-negative rates [15, 27–32].

Recently, several publications have explored possible value in using single photon emission computed tomography combined with traditional computed tomography (SPECT-CT) to identify the source of pain in these patients. Several studies have shown increased SPECT-CT activity to be valuable in identifying painful zygapophyseal joints and predicting a positive response to intra-articular injection [33–36], while others have shown less robust results in predicting outcomes following medial branch blocks [37,38]. The value of SPECT-CT in predicting a positive response to diagnostic block of the lumbar facet joint and ultimately RFN, thus remains unknown. The purpose of this study was to determine through retrospective review if the level of concordance between SPECT-CT uptake and facet joints targeted with MBB was associated with a positive block. It was hypothesized that if all joints demonstrating increased levels of radiotracer uptake on SPECT-CT were targeted that there is a correlation with a positive response to MBB.

2. Material and methods

2.1. Patients

Institutional Review Board approval was obtained for this retrospective analysis. The institutional imaging database was searched for all records of patients who underwent SPECT-CT of the lumbar spine for pain between January 2016 and June 2020 who also underwent diagnostic lumbar medial branch block. The search excluded patients with infection, tumor, or iatrogenic complications of the spine. Injections were excluded from analysis if SPECT-CT was performed after the MBB as this would not have informed the clinical decision-making process; if MBB was done more than 365 days after the SPECT-CT as after this time the likelihood of a new or different potential chronic pain generator is increased; or if there was incomplete pre-/post-injection self-report pain data. In cases where two MBBs were performed as comparative blocks only the first block was analyzed.

2.2. ^{99m}Tc medronate SPECT-CT examination

Within our large multispecialty tertiary referral spine center providers may choose to order a SPECT-CT as part of the diagnostic evaluation, if in their clinical judgment it is expected to add diagnostic clarity and influence their decision-making with respect to the plan of care. For all scans, ^{99m}Tc medronate injection (Tc-99 m MDP), 22 mCi was administered intravenously. After approximately 3 h, planar imaging of the spine in anterior and posterior projections was performed. SPECT-CT imaging of the spine was then performed. CT images were acquired using a low-dose protocol for attenuation correction and anatomical localization purposes.

2.3. Interventional protocol

After consultation with a board-certified pain management provider, if appropriate based on the integration of all available clinical and imaging information including reports and images for SPECT-CT, orders were placed for lumbar MBBs at levels determined by each provider based on clinical judgment. Per institutional standards, all MBBs were performed under fluoroscopy. Once needles were confirmed to be in the appropriate position using AP and lateral images, nonionic iodinated high-osmolar radiopaque contrast media was injected. If no vascular flow was observed 0.5 cc of local anesthetic (0.5 % bupivacaine or 2 % lidocaine) was injected at each site. Every patient receiving diagnostic MBBs at our center is asked to self-report pre- and post-procedural pain using the Numeric Pain Rating Scale (NRS) by an independent collaborator, either a registered nurse or a pain medicine specialist one business day after completion of the block with the patient keeping a written hourly diary to prevent recall bias. This information is then documented in the chart for physician review. Age, gender, race, laterality, and level of joints blocked and pre- and minimum post-procedural NRS during the anesthetic phase were collected from the electronic medical record. Maximal percent pain relief was calculated using pre- and post-procedural NRS values.

2.4. Image analysis

Retrospective chart review of diagnostic radiology reports for all SPEC-CTs was performed. The level and laterality of any facet joints reported as demonstrating increased ^{99m}Tc uptake were recorded. Then, each injection was categorized into one of four unique groups (Complete Concordance, Partial Concordance, Partial Discordance, Complete Discordance) based on the level of concordance between facet joints demonstrating increased SPECT-CT uptake and those undergoing MBB. Complete concordance was defined as patients that had all joints demonstrating increased ^{99m}Tc uptake on SPECT-CT (level and laterality) blocked with no additional joints not demonstrating increased uptake being blocked. Partial concordance was defined as those patients who had all joints demonstrating increased uptake on SPECT-CT blocked with at least one joint not demonstrating increased uptake on SPECT-CT location also being blocked. Partial discordance was defined as patients who had at least one but not all joints demonstrating increased uptake on SPECT-CT blocked. Complete discordance was defined as patients in which all joints demonstrating increased uptake on SPECT-CT were not blocked and also included any injections that had no increased uptake on SPECT-CT.

2.5. Statistical analysis

Categorical variables were described using absolute and relative frequencies, while continuous variables were described using means and standard deviations or medians and interquartile ranges. A Wilcoxon signed ranks test was used to compare pre-/post-procedure NRS scores in each group. A chi-square test of independence was used to determine if the level of concordance between SPECT-CT uptake and facet joints targeted with MBB was associated with a positive block using cutoffs of 50 % and 80 % pain relief. All analyses were performed using IBM SPSS Statistics (version 28.0.0.0 (190)).

3. Results

Between January 2016 and June 2020, a total of 319 patients were identified as having had both a lumbar SPECT-CT and lumbar MBBs on one or more joints on one or more occasions. Some patients underwent more than one distinct block resulting in a total of 428 procedures being reviewed. 75 were excluded for having SPECT-CT performed after the MBB, 140 for having the procedure more than 1 year after the imaging, 21 for having incomplete pre-post-injection NRS data, and 12 for being the second injection in a series of two, resulting in 180 distinct injections (defined as a single injection session in which one or more joints were blocked) among 149 unique patients being included in the analysis. Twenty-three percent of injections were categorized as completely concordant, 23 % as partially concordant, 29 % as partially discordant and 23 % as completely discordant. The demographic and baseline pain characteristics of these patients are summarized in Table 1.

A total of 535 lumbar facet joints were treated percutaneously with 250 of those demonstrating increased uptake (Table 2). The most commonly treated lumbar facet joints in order of decreasing frequency were L4/5, L5/S1, L3/4, L2/3 and L1/2 which matched the order of most frequently identified joints demonstrating increased uptake on SPECT-CT and those treated with increased activity (Fig. 1). The total number of joints targeted per procedure in order of decreasing frequency were 2, 4, 1, 3, 6, and 8 and are displayed by level of concordance in Fig. 2. Wilcoxon ranked-sum test demonstrated all groups had a significant change in NRS from pre-to post-procedure (Fig. 3).

Responder analysis was performed using thresholds of at least 50 % and 80 % improvement in pain. Using a threshold of at least 50 % relief of pain, 110 (61 %) blocks were positive and using a threshold of 80 % pain relief, 61 (34 %) blocks were positive. Proportions of patients achieving 50 % and 80 % relief by level of concordance is shown in Fig. 4. A chi-square test of independence showed that there was no significant association between level of concordance and having a positive block using thresholds of 50 % pain relief, $\chi^2(3, N = 180) = 4.880$, p = .181; or 80 % pain relief, $\chi^2(3, N = 180) = 1.272$, p = .736.

4. Discussion

The results of this study demonstrate that all four groups had a significant decrease in pain following MBB. More than half (52 %) of patients undergoing lumbar MBBs had at least one discordant level and level of concordance between SPECT-CT uptake and joints targeted with MBB was not associated with a positive response to MBB at thresholds of either >50 % or >80 % pain relief. Taken together, these results demonstrate that MBBs are successful in reducing pain in a subset of patients with axial low back pain suspected to be mediated by the zygapophyseal joint, but selection of targets using SPECT findings alone may not be an effective strategy. Other factors are and should continue to be considered when determining the most appropriate level to target with MBB.

The prevalence of lumbar facet arthritis differs by age, level of the spine, severity of morphologic changes, presence of symptoms and technique used for identification. In this population, the highest number of joints demonstrating increased uptake on SPECT-CT were found in order of decreasing frequency at L4-5, L5-S1, L3-4, L2-3, L1-2 which matches previously published data [39,40]. Interestingly at L1-2 and L2-3 there were more joints demonstrating increased uptake than were treated. This may reflect practice tendencies to target the most commonly affected joints based on prevalence data given the lack of well-defined clinical or imaging findings predictive of pain [26,41,42]. SPECT-CT may, therefore, have a role in identifying unexpected joints driving the patients' pain that may be a reasonable previously unconsidered target for intervention. Among asymptomatic individuals, there is a strong relative predominance of arthritic findings on CT imaging at L5-S1 that becomes more evenly distributed as patients reach the age of this cohort with L5-S1 being most commonly abnormal [43]. This differs from what was found in this study with L4-5 being the most commonly identified level with increased SPECT-CT uptake. The L5-S1 and L3-4 levels followed closely thereafter and were similarly affected with far fewer findings in the L1-2 and L2-3 levels. This may be due to the fact that this population was symptomatic but may also suggest that SPECT-CT provides additional valuable information beyond what standard CT provides.

Facet joints selected for percutaneous treatment (intra-articular facet joint injection or MBB) are often discordant with those demonstrating increased uptake on SPECT-CT, in many cases because the metabolically active facet joints do not correlate with clinical findings [44]. Our results support this finding with a nearly equal number of procedures falling into concordant and discordant groups. This may be due in part to the fact that there are no history, physical examination [26] or imaging [26,41,42] findings that have yet been found to reliably predict a positive response to MBBs. As a result of this uncertainty, clinicians may "cast a wide net" and target more than the minimum number of joints in an effort to capture all potential pain sources, obtain a positive result and proceed with RFA with the hopes of achieving clinical improvement for the benefit of the patient. This appears to be supported by the fact that a larger percentage of patients having only 1 or two joints blocked fell into the completely concordant group (i.e., when a targeted approach was taken based on SPECT-CT uptake a lower number of joints were targeted) and patients tended to have no better results when compared to discordant groups in which typically larger number of joints were blocked (non-targeted approach). Additionally, overall, an even number of joints were targeted more often than an odd number. This is likely driven by the common performance of bilateral procedures given the

Table 2
Distribution of facet joints with and without increased SPECT-CT uptake treated or not treated with MBB.

	Facet Joints Undergoing MBB (n = 535)	Facet Joints Not Undergoing MBB (n = 1265)
Increased SPECT-CT Uptake Present (n = 360)	250	110
Increased SPECT-CT Uptake Not Present (n = 1440)	285	1155

Table 1
Demographic and baseline pain characteristics by group.

	Overall	Complete Concordance	Partial Concordance	Partial Discordance	Complete Discordance
Number of unique patients (%)	149	35 (23)	35 (23)	44 (29)	35 (23)
Number of MBBs (%)	180	42 (23)	39 (22)	55 (31)	44 (24)
Average Age in years (SD)	66.9 (13.5)	61.7 (14.5)	69.1 (12.9)	72.6 (8.6)	62.7 (15.1)
% male	46.3	45.7	57.1	40.9	42.9
% Caucasian	92	81	89	97	100
% Black	4	14	2	0	0
% Other or unknown	4	5	9	3	0
Median Baseline NRS (IQR)	6 (2)	6 (2)	6 (3)	6 (2)	6 (3)
Average joints per procedure (SD)	3.01 (1.5)	2.12 (1.0)	3.97 (1.5)	2.91 (1.43)	3.14 (1.5)

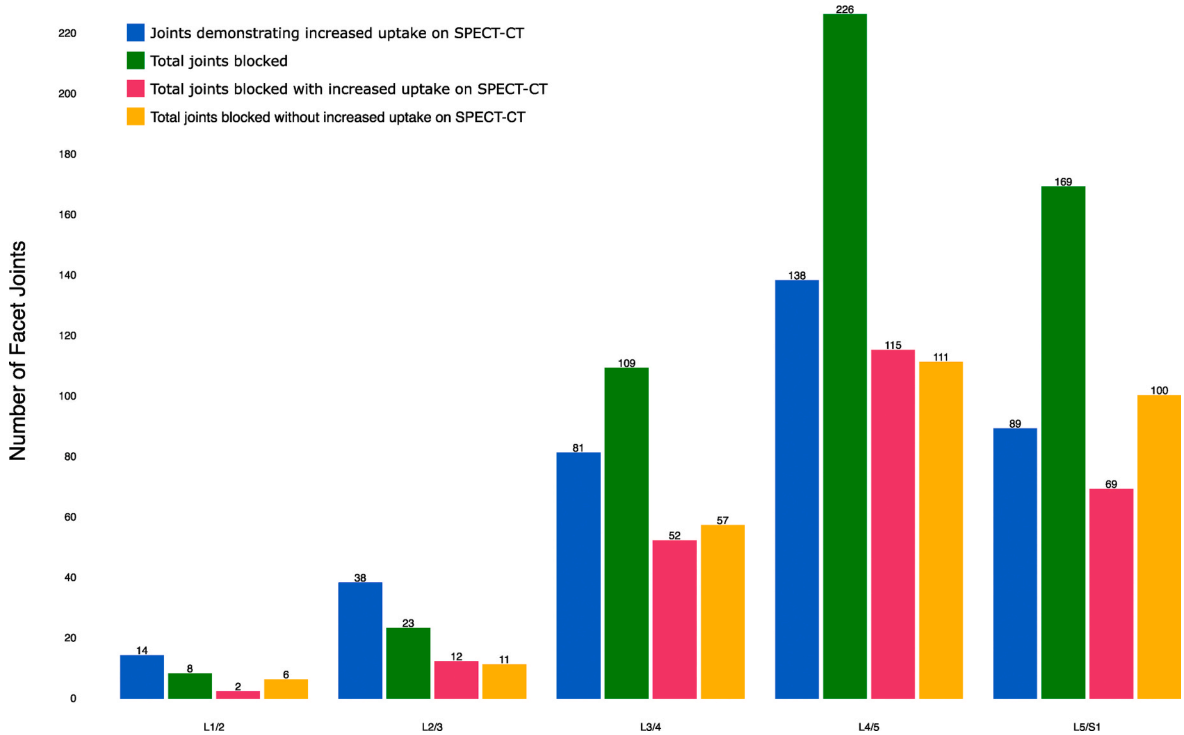

Fig. 1. Number of lumbar facet joints per level with reported increased SPECT-CT uptake, total being blocked at that level with breakdown of those being blocked with and without increased SPECT-CT uptake. The left and right facet joints are grouped at each level.

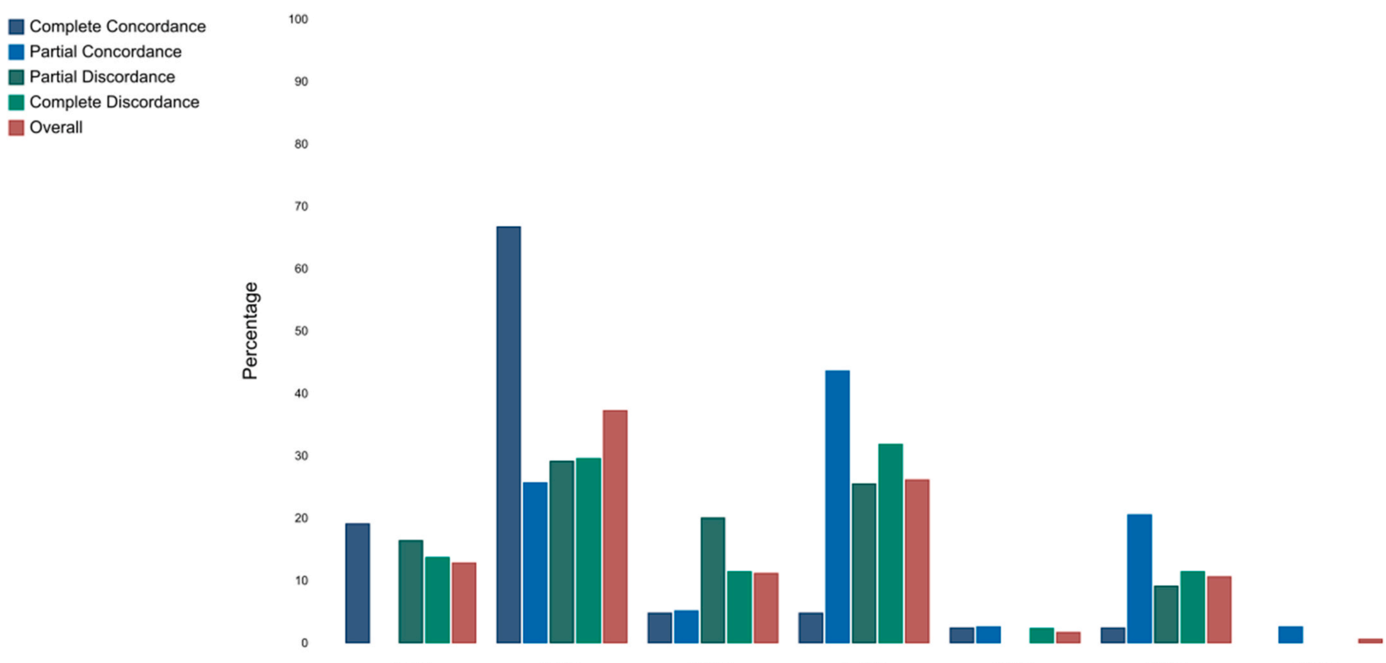

Fig. 2. Total number of facet joints blocked per procedure by level of concordance and overall.

difficulty in differentiating between right and left sources of pain based on clinical information. The rapid decline in the number of joints blocked above four is most likely secondary to a lack of reimbursement when more than 4 joints (2 levels bilaterally) are blocked.

There were also a relatively high number of injections classified as Completely Discordant (23 %). There are several possible explanations for this. In our multidisciplinary clinic, patients are often evaluated by several specialties including PM&R, pain medicine and neurosurgery. Any one of these providers may have ordered a SPECT-CT to help their own clinical decision-making, but ultimately the team-based approach may result in a different specialist deciding about the need and location of injections. Ultimately, if most injection decision-making is done by a team member who de-emphasizes the importance of SPECT-CT findings there is likely to be more discordant injections. Additionally, the Completely Discordant group contained any subjects not having any increased uptake on SPECT-CT. SPECT-CTs are ordered for patients

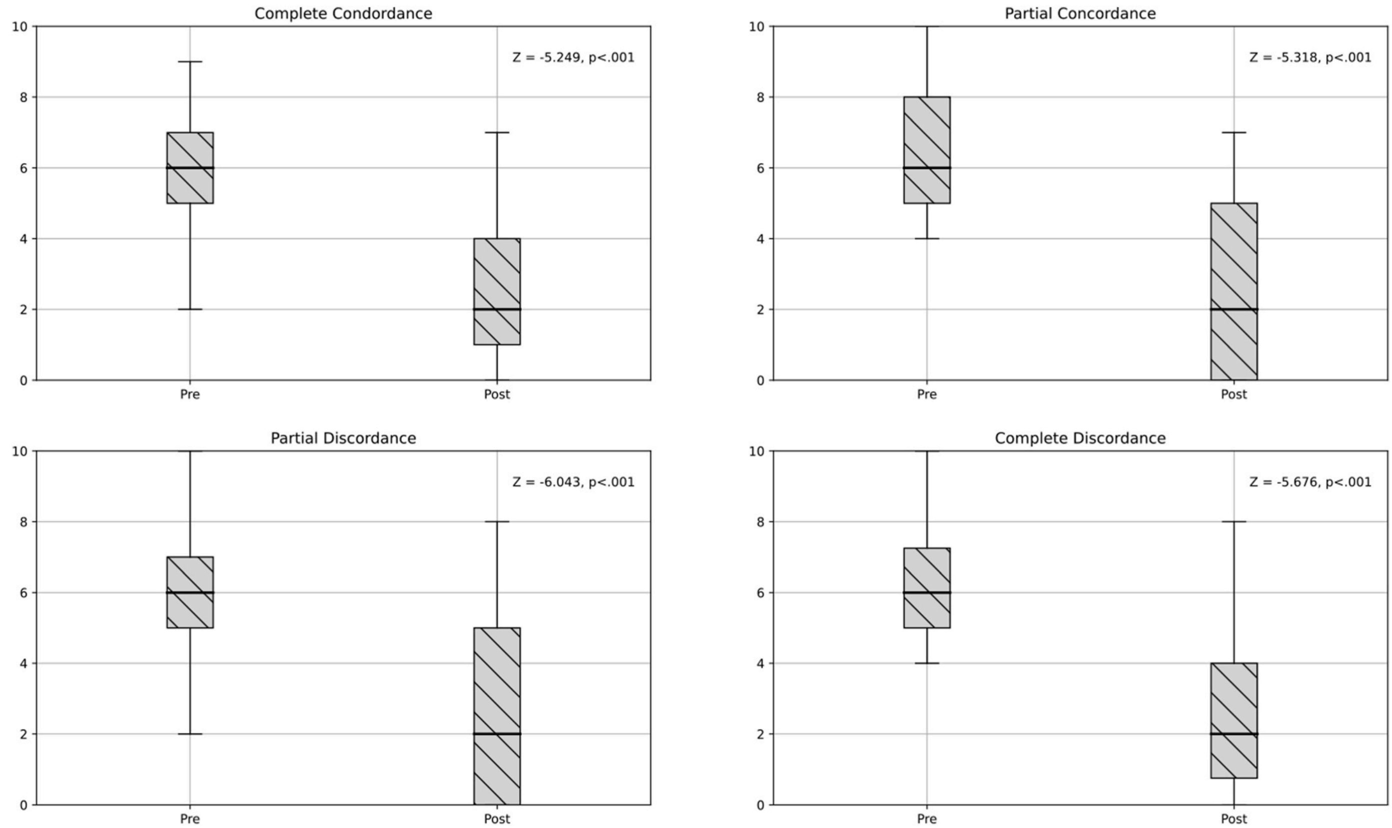

Fig. 3. Pre-/post-MBB comparison of NRS by group. Z statistic and p-value for Wilcoxon rank sum test reported.

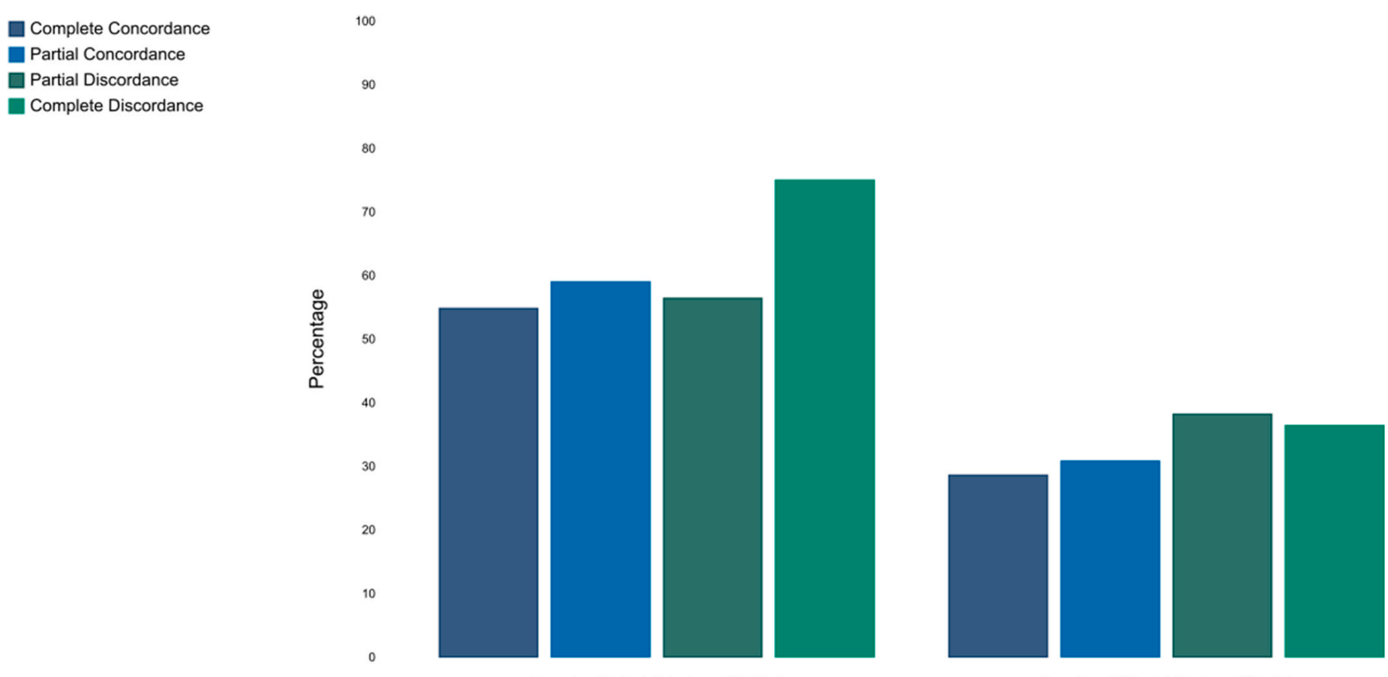

Fig. 4. Proportion of patients with positive MBB using thresholds of >50 % and >80 % improvement in NRS by level of concordance.

suspected of having facet-mediated pain based on other clinical criteria, so it is not surprising that a large proportion of patients having negative SPECT-CT would still undergo MBB, thus disproportionately increasing the number of patients categorized as Completely Discordant.

This study is in agreement with others that have shown SPECT-CT is not alone able to predict a positive response to MBBs [37,38]. Positive response to MBBs was chosen as the criteria against which SPECT-CT findings were compared in this study because it is the recommended diagnostic test to identify painful facet joints before proceeding to RFN [26], and given the interval on the order of hours between block and determination of success is less prone to recall bias than assessing responses to intra-articular injections with which relief is observed on the order of days or weeks. Intra-articular facet joint corticosteroid injections, however, do appear to produce favorable results when performed at areas of increased uptake on SPECT-CT [33,34,38]. This may be a result of the specific pathophysiology being detected by this imaging modality. SPECT-CT uses radionuclide bone scintigraphy to identify areas of increased osteogenic activity and skeletal blood flow, representing local inflammation or hyperemia [34,45]. Such inflammation typically occurs early in the degenerative facet cascade and is predictive of progressive radiologic anatomic abnormalities [46] such as joint hypertrophy, peri-articular osteophytes and cartilage degeneration typically seen later in the course of disease on MRI [9,47]. However, these later findings do not necessarily correlate with areas of increased uptake on SPECT-CT [44]. Thus, the positive response to intra-articular injection of steroids at areas of increased uptake on SPECT-CT that was not observed with MBBs likely represents the delivery to the optimal location of an appropriately matched injectate (anti-inflammatory steroids) for the pathophysiology present (inflammation) at that point in the disease process. Similar relief of pain may not have been observed with diagnostic MBBs in this study even if levels of increased uptake on SPECT-CT are targeted if inflammation exists beyond the region of anesthesia created by the MBB. Therefore, SPECT-CT may help identify patients during an early inflammatory period of facet disease who will benefit from intra-articular steroid injections, whereas MBBs and RFN may still offer a viable treatment option for a more chronic phase of the disease process not associated with inflammation for which SPECT-CT may not be as valuable a diagnostic tool.

Previous studies looking at MRI have also failed to prove a relationship between anatomic abnormalities and pain [14,48,49]. However, these modalities offer information about the underlying anatomy and metabolic changes that may be contributing to patients' pain and are valuable to the clinician making decisions when considered with other clinical factors. Similarly, SPECT-CT findings may not independently predict a positive response to MBB, but still provide valuable information to the clinician making decisions about the most appropriate target for intervention.

There are several limitations to the methodology of this study. Given the retrospective nature there was incomplete data in 9 % of injections which had to subsequently be eliminated from the study which has potential to introduce information bias. Although medial branch blocks were selected as the diagnostic test of choice to minimize the time between intervention and patient self-report of pain, the potential for recall bias still exists given any delay in query or report of this information. The NRS value chosen to calculate the maximal pain improvement could have been from a single timepoint and may not necessarily reflect a sustained positive response. Furthermore, this study relied on review of previously generated radiology reports to identify levels of increased uptake on SPECT-CT. Given multiple raters and a lack of a standardized grading scale that is used across the institution, there is inherent subjectivity and interrater variability in identifying facet joints with increased uptake. Additionally, due to practice variability many patients, particularly early in the period of review, had only one MBB available for review. To remain consistent across all patients only the first medial branch block response was reviewed. Ideally, dual comparative blocks would have been used to determine if individuals had a positive response.

In conclusion, this study suggests that SPECT-CT cannot alone predict a positive response to lumbar MBBs, despite it being effective in reducing pain in a subset of this population. Additional investigations are needed to determine what additional clinical and imaging factors taken in combination may best predict which subset of patients with axial back pain will have a positive response to MBB. One potential confounder of particular interest is the presence of increased uptake in intervertebral endplates (an indicator of potential vertebral endplate pain that may respond to basivertebral nerve ablation) at levels where MBB was performed. Furthermore, future prospective studies using SPECT-CT in patients with and without pain undergoing intra-articular corticosteroid and MBBs at various stages of the facet degenerative process are needed to fully characterize the potential benefit of this modality in identifying specific sources of pain in the lumbar spine. Until more definitive conclusions can be reached, choosing the most appropriate level at which to perform facet-targeting procedures will continue to depend upon integration of all available clinical data including SPECT-CT when available.

5. Conclusions

These results do not support a significant isolated relationship between SPECT-CT findings and positive MBB. Other factors are and should continue to be considered when deciding which lumbar facet joints are injected until additional future research is able to help identify which combinations of clinical and imaging findings best predict positive MBBs.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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