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# Sagittal alignment to predict efficiency in pulsed radiofrequency for cervical facet joint pain

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**Neck pain due to cervical facet joint pain has a prevalence of 36–60% in chronic neck pain. Pulsed radiofrequency for such pain has been verified. After proper patient selection, pulsed radiofrequency of the cervical facet joints provide long-term pain relief in a routine clinical setting. In the patient selection, clinical and sagittal alignment parameters are rarely discussed for the outcome. In the present study, we analyzed the factors from the clinical data and sagittal alignment parameters and investigated the associated predictors of pulsed radiofrequency for cervical facet joint pain. There were 204 patients with cervical facet joint pain who received a medial branch block and pulsed radiofrequency between 2015 and 2020 after excluding patients with neurological symptoms and other confounding factors. The patients were classified into good and poor outcome groups based on the improvement of the pain score(visual analog scale). Clinical and radiological data were analyzed. Multivariable logistic model showed that the predictors were cervical lordosis including two methods (odds ratio [OR] 0.92, 95% confidence interval [CI]: 0.89–0.96 for C2–C7 Cobb angle; OR 0.91, 95% CI: 0.88–0.95 for the angle measured by the Jackson method), ossification of the nuchal ligament, number of diseased facet joints, anterior cervical discectomy with fusion, and adjacent facet joint after anterior cervical discectomy with fusion. With the results, we demonstrated that the outcome were related to cervical lordosis including two methods, formation of ossification of nuchal ligament, the number of diseased facet joints, post anterior cervical discectomy with fusion, and adjacent facet joint post anterior cervical discectomy with fusion. The corresponding optimal cutoff for discriminating a poor outcome was 7° for the C2–C7 Cobb angle and − 2° for the angle measured using the Jackson method.**

**Keywords** Cervical facet joint pain, Pulsed radiofrequency, Cervical lordosis, Sagittal alignment, C2–C7 sagittal vertical axis, Anterior cervical discectomy with fusion

**Abbreviations**

| | |
|---|---|
| ACDF | Anterior cervical discectomy with fusion |
| CT | Computed tomography |
| MRI | Magnetic resonance imaging |
| PRF | Pulsed radiofrequency |
| VAS | Visual analog scale |
| SF-36 | Short form 36 |
| SVA | Sagittal vertical axis |

Neck pain has been a leading factor for chronic disability globally[1]. Moreover, neck pain is often chronic, and the prevalence is from 30 to 50% per year[2]. Bilateral synovial facet joints connect the adjoining vertebrae at each spinal level[1]. In chronic neck pain, cervical facet joint pain has a prevalence of 36–60%[3–6]. Cervical facet joint pain can be effectively treated with pulsed radiofrequency (PRF)[7]. Thermal energy is used by PRF interrupted the nociceptive input from painful facet joints by cogulating the sensory nerves[7,8].

Patient selection and the positive diagnostic block are important for the outcomes after PRF[7,9]. In the treatment of such pain, the first step was the diagnostic cervical medial branch block[7,9]. From the point of outcome, clinical data and sagittal alignment parameters are rarely investigated for such treatment. Hence, we

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performed a retrospective study in these patients who received medial branch block and PRF treatment for cervical facet joint pain and investigated the associated predictors according to the outcome.

## Methods
### Recruitment of patients
The Institutional Review Board of E-Da hospital approved the study (EMRP-111-065). All methods were performed in accordance with the relevant guidelines and regulations. We recruited 204 patients between 2015 and 2020. All the patients understood the research and signed the informed consent. The inclusion criteria were age ≥ 18 years, predominant neck pain at least more than one month, mean neck pain score ≥ 4 (out of 10 in visual analog scale) and non-responsiveness to physical and medical therapy for neck pain at least more than one month. Cervical facet joint pain was defined as the following symptoms[10]:

axial neck pain (without involvement to the shoulders),
pain with pressure on the dorsal side of the spinal column at the level of the facet joints,
limitation of cervical spinal motion,
without neurological symptoms.

The exclusion criteria involved, neurological symptoms such as radicular and myelopathy symptoms, neck pain (e.g., cervical disc herniation, severe cervical spinal stenosis, cervical subluxation, tumor, or cervical spinal deformity according to the findings on image studies); focal neurological deficits; previous cervical facet interventions; unilateral symptom; neck pain from posterior cervical paraspinal muscles, and posterior cervical spinal operations such as laminectomy, discectomy, posterior fusion, laminoplasty, more than three levels of anterior fusion, medication with opioid drugs. Moreover, individuals with severe medical conditions (e.g., ischemic heart disease) or psychiatric diseases that may interfere with the diagnostic process and treatment response were also excluded from the study.

All patients underwent cervical radiography, MRI, and CT scans. The radiographs were obtained with the standing and neutral position.

We calculated the sample size based on a previous study reporting the kinematic sagittal parameters of the cervical lordosis or head posture and disc degeneration in patients with posterior neck pain[11]. Two mostly relevant parameters (i.e., C2-C7 angle and sagittal vertical axis of C2-C7) were selected to estimate the effect size. The reported mean and standard deviation of C2-C7 angle was $-21.48 \pm 5.78$ in the favorable group ($n = 26$) and $-6.53 \pm 8.29$ in the non-favorable group ($n = 87$), respectively. The reported mean and standard deviation of sagittal vertical axis of C2-C7 was $16.03 \pm 7.59$ in the favorable group and $18.88 \pm 9.85$ in the non-favorable group, respectively. The transformed effect size (standardized mean difference) was 1.92 and 0.30, respectively[12]. Given using the independent sample t-test and an assumed allocation ratio of 2 (2 favor: 1 non-favor), at least sample size was 10 (for C2-C7 angle) and 302 (for sagittal vertical axis of C2-C7) subjects to achieve an alpha level of 5% and power of 80%, respectively. The sample size calculated by PASS 2008 (NCSS, LLC. Kaysville, Utah, USA). Due to there was a large discrepancy of the calculated sample sizes between the two main parameters, we decided to enroll the patients up to at least the average of the two calculated sample sizes ($10 + 302/2 = 156$). This resulted in at least 104 patients with favorable outcome and 52 patients with non-favorable outcome to be collected.

### Medial branch blocks
The block procedures were performed according to the standard procedures[7,9,10]. With the prone position, the facet joint was identified under a C-arm system. The skin was prepared in the routine sterile fashion and local anesthesia was performed. A 22-gauge spinal needle was inserted percutaneously under C-arm guidance from lateral, and oblique directions to the midpoint of the lateral margin of the facet. Aspiration was performed without return, and the contrast medium was injected to confirm that there was no inappropriate spread and intravascular uptake. Following the confirmation, we administered the block agent 1.0 mL of a solution containing 0.5 mL of 0.5% bupivacaine mixed with 0.5 mL of Triamcinolone[9,10].

### PRF procedure
As per previously published standards and techniques, PRF was conducted after 2 weeks after the diagnostic blocks[7,9,10]. A C-arm system was used to identify the facet joint fluoroscopically. Thereafter, the needles with 10-mm active tips were inserted as the block procedures to the facet joints. The correct locations of the needles were confirmed according to the sensory and motor stimulations and then the electrodes were inserted. After electrode placement, PRF was performed at 42 °C for two minutes (NT 1100TM Radiofrequency Generator Abbott Medical, USA). After PRF, 1 ml of Triamcinolone with saline (total, 2 mL) was administered to prevent neuritis[7,8].

### Treatment course and follow-up
There were 204 patients in the study. The first assessment was performed 2 weeks after the medial branch block. Forty-seven patients only underwent a medial branch block, whereas 157 underwent a medial branch block along with PRF based on the improvement of pain. The improvement was defined as ≥ 50% pain reduction more than 12 h after the block procedure according to pain score of visual analog scale (VAS). Additionally, a good outcome was defined as a reduction in neck pain by at least 50%[8,10]. In the poor outcome group, the patients were not scheduled for further treatment. The follow-up period was 12 months, including four-time points: 2 weeks after the block, 1 month, 3 months, and 12 months after PRF for short-term and long-term follow-up in all patients. For the patients who only accepted a nerve block ($n = 47$), a good outcome was defined as a reduction of pain more than 80%. Moreover, they accepted regular follow-ups where it was determined that PRF was not needed. To evaluate pain, a visual analog scale (VAS) was used throughout the course. The general health status

was evaluated with the Short Form-36 (SF-36), and the Neck Disability Index (NDI) was for the evaluation of neck pain before and 12 months after medial branch block and PRF[13].

## Clinical factors and sagittal alignment parameters

These factors were age, gender, and cervical lordosis, including C2–C7 Cobb angle and the angle measured by the Jackson physiological stress line method ( Jackson method), C2 slope, C7 slope, C1–C7 sagittal vertical axis (C1–C7 SVA), C2–C7 SVA, C2 slope – C2–C7 Cobb angle, C7 slope – C2–C7 Cobb angle, C2 slope – the angle measured by the Jackson method, C7 slope – the angle measured by the Jackson method, C2 slope / C2–C7 Cobb angle, C7 slope / C2–C7 Cobb angle, C2 slope / the angle measured by the Jackson method, C7 slope / the angle measured by the Jackson method, number of diseased facet joints, ossification of the nuchal ligament (ONL), anterior cervical discectomy with fusion (ACDF), and adjacent facet joint post-ACDF ( rostal and caudal facet joints of fusion )[14,15]. The C2–C7 Cobb angle was measured with the Cobb method between the inferior C2 endplate and the inferior C7 endplate[14]. For the Jackson physiological stress line ( Jackson method), we drew two lines parallel to the trailing edge of the C7 and C2 vertebral bodies and measured the angle between them[16]. The C1–C7 SVA was the distance between a plumb line dropped from the anterior tubercle of C1 and the posterior superior corner of C7[16]. The C2–C7 SVA was the distance between the plumb line dropped from the centroid of C2 (or the odontoid) to the posterior-superior corner of C7[17]. The C2 slope was the angle between the C2 lower endplate and the horizontal plane[14]. The C7 slope was the angle between the C7 superior endplate and the horizontal line[17]. In cervical lordosis, the extension angles are positive, whereas kyphotic areas have negative angles during flexion[19].

## Statistical analyses

The clinical data in the favorable outcome analysis was compared using the independent sample t-test for continuous variables (e.g., cervical lordosis) or Fisher's exact test for categorical variables (e.g., spine level). Variables with a significance of $<0.15$ were entered into the multivariable logistic regression analysis with the backward deletion approach. Some of input variables had multicollinearity (e.g., cervical lordosis vs. C7 slope, cervical lordosis vs. C7 slope / (C2–C7 slope); C1–C7 SVA vs. C1–C7 SVA – C2–C7 SVA; etc.) and were each introduced into the multivariable logistic regression model separately. The aforementioned analyses were conducted separately for patients who underwent block only and those who underwent block and PRF. There were two types of measurements for cervical lordosis in the study, and the analysis involving cervical lordosis was conducted separately for the two measurements. Furthermore, the generalized estimating equation (GEE) of patients with and without favorable prognoses was used to compare pain improvement (VAS), general health status (SF-36), and NDI from baseline to 12 months. The identity link function and normal distribution were specified in the GEE analysis. Finally, the potential optimal cutoff of the input parameters (e.g., cervical lordosis) was determined using the Youden index from receiver operating characteristic (ROC) curve analysis. All tests were two-tailed, and statistical significance was set at $P<0.05$. Data were analyzed using SPSS version 26 (IBM SPSS Inc., Chicago, Illinois, USA).

## Results

We recruited 204 patients between 2015 and 2020. All the patients understood the research and signed the informed consent. 47 patients underwent block whereas, 157 patients underwent block along with PRF. In the study, 40% of the included patients were men with a mean age of 49.6 years (standard deviation: 13.3 years). Moreover, the patients were classified into two groups according to the improvement of the pain score. The patients with a poor outcome had older age(52 vs. 48.5 years, $P=0.08$), had a smaller cervical lordosis (2.5 ° vs. 10.4 ° for C2–C7 Cobb angle and 0.9 ° vs. 11.8 ° for the angle measured by the Jackson physiological stress line method; both $P<0.001$), had greater C2 slope – cervical lordosis including two measurements ($P<0.05$), had a smaller C2 slope / cervical lordosis including two measurements ($P<0.05$), had a greater C7 slope – cervical lordosis including two measurements ($P<0.05$), had a smaller C7 slope / cervical lordosis including two measurements ($P<0.05$), had more facet joint levels, were more likely to have ONL, ACDF, and adjacent facet joint post-ACDF. Notably, in the patients who just accept nerve block most had poor outcomes (31% vs. 19%, $P=0.078$) (Table 1).

The multivariate logistic analysis demonstrated that more facet joint levels and the presence of ACDF or adjacent facet joints post-ACDF were associated with a higher risk of poor outcomes. Importantly, a lower value of cervical lordosis was associated with a higher risk of poor outcome (odds ratio [OR] 0.92, 95% confidence interval [CI]: 0.89–0.96 for C2–C7 Cobb angle; OR 0.91, 95% CI: 0.88–0.95 for the angle measured by the Jackson method) as opposed to its higher value (Table 2). The area under the ROC curve (AUC) was 70.5% and 76.5% for the C2–C7 Cobb angle and the angle measured using the Jackson method, respectively. The corresponding optimal cutoff for discriminating a poor outcome was 7 ° for the C2–C7 Cobb angle and − 2 ° for the angle measured using the Jackson method (Table 3).

Among the patients who underwent block surgery alone, 43% (20/47) had poor outcomes. Patients with a poor outcome had a smaller angle measured by the Jackson method, a larger degree of C7 slope, a smaller ratio of C7 slope to the angle measured by the Jackson method, more facet joint levels and were more likely to have ONL (Table 4). The multivariable logistic analysis revealed that a smaller degree in the angle measured by the Jackson method (OR 0.92, 95% CI: 0.83–0.99) was associated with poor outcome (Table 5). However, the C2–C7 Cobb angle trended towards an association with poor outcome (OR 0.93, 95% CI: 0.86–1.001, $P=0.058$).

Among the patients who underwent subsequent PRF, 29% (45/157) had poor outcomes. The patients with a poor outcome had a smaller C2–C7 Cobb angle (1.7 vs. 10.7 cm, $P<0.001$), a smaller angle measured by the Jackson method (0.8 vs. 12.1 cm, $P<0.001$), larger C7 slope – cervical lordosis for both measurements, smaller C7 slope / cervical lordosis for both measurements, more diseased facet joint levels, and more ACDF and

| Variable | Total ($n$ = 204) | Good outcome ($n$ = 139) | Poor outcome ($n$ = 65) | *P* |
|---|---|---|---|---|
| Male sex | 81 (39.7) | 53 (38.1) | 28 (43.1) | 0.541 |
| Age, year | 49.6 ± 13.3 | 48.5 ± 13.4 | 52.0 ± 13.0 | 0.080 |
| Cervical lordosis[1] | 7.9 ± 11.1 | 10.4 ± 10.0 | 2.5 ± 11.3 | < 0.001 |
| Cervical lordosis[2] | 8.3 ± 11.8 | 11.8 ± 9.8 | 0.9 ± 12.5 | < 0.001 |
| C2 slope | 10.5 ± 7.8 | 10.2 ± 7.4 | 11.1 ± 8.7 | 0.486 |
| C7 slope | 17.1 ± 8.5 | 17.5 ± 8.9 | 16.3 ± 7.4 | 0.345 |
| C2 slope –Cervical lordosis[1] | 2.6 ± 14.9 | -0.2 ± 13.1 | 8.5 ± 16.8 | < 0.001 |
| C2 slope –Cervical lordosis[2] | 2.2 ± 15.8 | -1.5 ± 13.3 | 10.1 ± 17.8 | < 0.001 |
| C2 slope / Cervical lordosis[1] | 0.3 ± 1.9 | 0.4 ± 1.7 | -0.1 ± 2.4 | 0.055 |
| C2 slope / Cervical lordosis[2] | 0.1 ± 2.0 | 0.6 ± 1.9 | -0.9 ± 1.9 | < 0.001 |
| C7 slope –Cervical lordosis[1] | 9.2 ± 10.1 | 7.1 ± 9.3 | 13.8 ± 10.3 | < 0.001 |
| C7 slope –Cervical lordosis[2] | 8.8 ± 11.1 | 5.7 ± 9.6 | 15.4 ± 11.2 | < 0.001 |
| C7 slope / Cervical lordosis[1] | 0.8 ± 2.1 | 1.1 ± 1.7 | 0.3 ± 2.8 | 0.012 |
| C7 slope / Cervical lordosis[2] | 0.5 ± 2.2 | 1.1 ± 1.9 | -0.8 ± 2.4 | < 0.001 |
| C1-C7 SVA | 1.5 ± 0.8 | 1.5 ± 0.8 | 1.6 ± 0.9 | 0.163 |
| C2-C7 SVA | 1.1 ± 0.6 | 1.0 ± 0.6 | 1.1 ± 0.7 | 0.220 |
| C1-C7 SVA - C2-C7 SVA | 0.5 ± 0.4 | 0.4 ± 0.3 | 0.5 ± 0.5 | 0.256 |
| Level | | | | < 0.001 |
| 2 | 50 (24.5) | 46 (33.1) | 4 (6.2) | |
| 4 | 137 (67.2) | 83 (59.7) | 54 (83.1) | |
| 6 | 17 (8.3) | 10 (7.2) | 7 (10.8) | |
| ossification of nuchal ligament | 48 (23.5) | 20 (14.4) | 28 (43.1) | < 0.001 |
| Fusion | 44 (21.6) | 17 (12.2) | 27 (41.5) | < 0.001 |
| Adjacent facet joint pain due to fusion | 43 (21.1) | 17 (12.2) | 26 (40.0) | < 0.001 |
| Group | | | | 0.078 |
| Block only | 47 (23.0) | 27 (19.4) | 20 (30.8) | |
| Block and PRF | 157 (77.0) | 112 (80.6) | 45 (69.2) | |

**Table 1**. The clinical characteristic of patient with good outcome versus with poor outcome. Abbreviation: PRF, pulse radiofrequency; Cervical lordosis[1]: C2-C7 cobb angle; Cervical lordosis[2]: the angle measured by the Jackson physiological stress line method, SVA: sagittal vertical axis ( cm ).

adjacent facet joint post-ACDF (Table 4). The multivariable logistic analysis revealed that a smaller C2–C7 Cobb angle (OR 0.92, 95% CI: 0.88–0.96) and the angle measured by the Jackson method (OR 0.91, 95% CI: 0.87–0.95) were significantly associated with poor outcome (Table 6).

We collected pain improvement data using the VAS during the 1-, 3-, 6-, and 12-month follow-ups. The results exhibited that pain did not improve across the follow-up visits in patients in either of the two groups (the nerve block or block and PRF group) (Supplemental Fig. 1A–1B). We examined the general health status (SF-36) and NDI scores before and 12 months after treatment. The result revealed that patients with poor outcomes did not improve after treatment in either group (Supplemental Figs. 2–3).

## Discussion

The first step of the treatment is the medial branch block, which provide predictive value for PRF in the further treatment[18]. Its efficacy was established in the late 1990s[1,2,20–22].

Our study demonstrated that the outcome after treatment was associated with cervical lordosis including two measurements, a degree in C2 slope – (C2–C7 Cobb angle) and C2 slope – the angle measured by the Jackson method, the ratio of C2 slope / C2–C7 Cobb angle and C2 slope/ the angle measured by the Jackson method, a degree in C7 slope – (C2–C7 Cobb angle) and C7 slope – the angle measured by the Jackson method, the ratio of C7 slope / C2–C7 Cobb angle and C7 slope/ the angle measured by the Jackson method, ONL, number of diseased facet joints, and the presence of ACDF or adjacent facet joint post-ACDF. In the analysis about the parameters of cervical spinal alignment, the most predictive factor was cervical lordosis including two measurements. Cervical lordosis is the first physiological curvature of the human spine and is the predominant site of disc herniation owing to its load-bearing function. It maintains spinal stability and is an important part of normal spinal biomechanics[23,24]. The natural sagittal curve of the cervical spine is known to have lordosis[17,25,26]. Abnormal cervical curvature, including excessive or meager cervical lordosis, loss of cervical curvature, kyphosis, and complex cervical curvature, is an early manifestation of degenerative changes in the spine that can cause neck pain[22]. In general, normal values of the C2–C7 Cobb angle has been reported to range from 20 ° to 35°[27–30]. The mean value of the angle measured by the Jackson method was 18.92 °± 10.98 °[30]. Our results established that the angles of C2–C7 Cobb angle were 10.4 °± 10.0 ° in the good outcome group and 2.5 °± 11.3 ° in the

| Variable | Univariate analysis OR (95% CI) | *P* value | Multivariable analysis OR (95% CI) | *P* value | Multivariable analysis OR (95% CI) | *P* value |
|---|---|---|---|---|---|---|
| Male sex | 0.81 (0.45–1.48) | 0.501 | | | | |
| Age, year | 1.02 (1.00-1.04) | 0.082 | | | | |
| Cervical lordosis[1] | 0.93 (0.90–0.96) | < 0.001 | 0.92 (0.89–0.96) | < 0.001 | | |
| Cervical lordosis[2] | 0.91 (0.88–0.94) | < 0.001 | | | 0.91 (0.88–0.95) | < 0.001 |
| C2 slope | 1.01 (0.98–1.05) | 0.485 | | | | |
| C7 slope | 0.98 (0.95–1.02) | 0.344 | | | | |
| C2 slope – Cervical lordosis[1] | 1.04 (1.02–1.07) | < 0.001 | | | | |
| C2 slope – Cervical lordosis[2] | 1.05 (1.03–1.08) | < 0.001 | | | | |
| C2 slope / Cervical lordosis[1] | 0.86 (0.73–1.01) | 0.060 | | | | |
| C2 slope / Cervical lordosis[2] | 0.62 (0.51–0.77) | < 0.001 | | | | |
| C7 slope – Cervical lordosis[1] | 1.08 (1.04–1.11) | < 0.001 | | | | |
| C7 slope – Cervical lordosis[2] | 1.10 (1.06–1.13) | < 0.001 | | | | |
| C7 slope / Cervical lordosis[1] | 0.83 (0.71–0.96) | 0.014 | | | | |
| C7 slope / Cervical lordosis[2] | 0.64 (0.54–0.76) | < 0.001 | | | | |
| C1-C7 SVA | 1.29 (0.90–1.83) | 0.166 | | | | |
| C2-C7 SVA | 1.35 (0.83–2.20) | 0.221 | | | | |
| C1-C7 SVA - C2-C7 SVA | 1.62 (0.71–3.70) | 0.257 | | | | |
| Level | | | | | | |
| 2 | Reference | | Reference | | Reference | |
| 4 | 7.48 (2.55–21.98) | < 0.001 | 9.65 (2.80–33.24) | < 0.001 | 9.82 (2.73–35.35) | < 0.001 |
| 6 | 8.05 (1.97–32.84) | 0.004 | 8.88 (1.72–45.90) | 0.009 | 11.93 (2.14–66.40) | 0.005 |
| ossification of nuchal ligament | 4.50 (2.28–8.91) | < 0.001 | 4.20 (1.81–9.72) | 0.001 | 3.72 (1.55–8.94) | 0.003 |
| Fusion or adjacent facet joint pain | 5.10 (2.51–10.35) | < 0.001 | 6.04 (2.40–15.19) | < 0.001 | 6.15 (2.36–16.07) | < 0.001 |
| Group | | | | | | |
| Block only | Reference | | | | | |
| Block and PRF | 0.54 (0.28–1.06) | 0.075 | | | | |

**Table 2**. Logistic regression analysis for factor associated with the risk of poor outcome. Abbreviation: OR, odds ratio; CI, confidence interval; PRF: pulse radiofrequency. Cervical lordosis[1]: C2-C7 cobb angle; Cervical lordosis[2]: the angle measured by the Jackson physiological stress line method, SVA: sagittal vertical axis (cm).

| Population / Variable | AUC, % (95% CI) | *P* | Cutoff* | Sensitivity, % (95% CI) | Specificity, % (95% CI) |
|---|---|---|---|---|---|
| Total population | | | | | |
| Cervical lordosis[1] | 70.5 (63.8 to 76.7) | < 0.001 | ≤7 | 67.7 (54.9 to 78.8) | 65.5 (56.9 to 73.3) |
| Cervical lordosis[2] | 76.5 (70.1 to 82.1 | < 0.001 | ≤-2 | 56.9 (44.0 to 69.2) | 89.9 (83.7 to 94.4) |
| Block only | | | | | |
| Cervical lordosis[1] | 62.4 (47.1 to 76.1) | 0.132 | NA | NA | NA |
| Cervical lordosis[2] | 73.4 (58.5 to 85.2) | 0.003 | ≤ -4 | 55.0 (31.5 to 76.9) | 92.6 (75.7 to 99.1) |
| Block and PRF | | | | | |
| Cervical lordosis[1] | 73.6 (66.0 to 80.3) | < 0.001 | ≤7 | 77.8 (62.9 to 88.8) | 65.2 (55.6 to 73.9) |
| Cervical lordosis[2] | 77.3 (70.0 to 83.6) | < 0.001 | ≤0 | 66.7 (51.0 to 80.0) | 84.8 (76.8 to 90.9) |

**Table 3**. The diagnostic property of the degrees to discriminate poor outcome. Abbreviation: AUC, area under curve; CI, confidence interval; NA, not applicable; Cervical lordosis1: C2-C7 cobb angle; Cervical lordosis2: the angle measured by the Jackson physiological stress line method SVA: sagittal vertical axis (cm). * According to the Youden index.

poor outcome group. More kyphotic changes were noted in our patients, especially in the poor outcome group. Excessive flexion of the cervical spine results in increased disc load and, since the facet joints of the cervical spine tilt from the front to the back when disc degenerates and the supporting force id decreased, the joint will have a certain degree of pressure and injury[31]. The cutoff point of the C2–C7 Cobb angle was 7 ° and the angle measured by the Jackson method was − 2 °.

In the cases of ACDF and the adjacent facet joint post-ACDF, the spinal biomechanics were altered. The fusion increased load and it is transferred to the adjacent facet joints ( rostal and caudal facet joints), which can accelerate the degeneration of the surrounding joints[32]. Most patients with pain in the adjacent facet joint

| Variable | Block only | | | Block and RF | | |
|---|---|---|---|---|---|---|
| | Good outcome (*n* = 27) | Poor outcome (*n* = 20) | *P* | Good outcome (*n* = 112) | Poor outcome (*n* = 45) | *P* |
| Male sex | 8 (29.6) | 6 (30.0) | 1.000 | 45 (40.2) | 22 (48.9) | 0.373 |
| Age, year | 47.8 ± 10.8 | 53.3 ± 13.0 | 0.121 | 48.6 ± 14.0 | 51.4 ± 13.1 | 0.255 |
| Cervical lordosis$^1$ | 9.5 ± 11.2 | 4.4 ± 9.9 | 0.115 | 10.7 ± 9.8 | 1.7 ± 11.9 | < 0.001 |
| Cervical lordosis$^2$ | 10.4 ± 9.5 | 1.4 ± 10.9 | 0.004 | 12.1 ± 9.9 | 0.8 ± 13.3 | < 0.001 |
| C2 slope | 10.9 ± 6.4 | 9.1 ± 5.3 | 0.306 | 10.1 ± 7.6 | 11.9 ± 9.7 | 0.205 |
| C7 slope | 17.1 ± 9.8 | 16.5 ± 6.4 | 0.798 | 17.6 ± 8.7 | 16.2 ± 7.9 | 0.360 |
| C2 slope – Cervical lordosis$^1$ | 1.4 ± 14.5 | 4.7 ± 12.2 | 0.421 | -0.6 ± 12.8 | 10.2 ± 18.3 | < 0.001 |
| C2 slope – Cervical lordosis$^2$ | 0.5 ± 13.3 | 7.8 ± 13.6 | 0.073 | -2.0 ± 13.4 | 11.2 ± 19.4 | < 0.001 |
| C2 slope / Cervical lordosis$^1$ | 0.1 ± 2.1 | 0.1 ± 2.7 | 0.965 | 0.5 ± 1.6 | -0.3 ± 2.2 | 0.020 |
| C2 slope / Cervical lordosis$^2$ | 0.8 ± 2.1 | -0.4 ± 1.5 | 0.042 | 0.6 ± 1.9 | -1.1 ± 2.0 | < 0.001 |
| C7 slope – Cervical lordosis$^1$ | 7.7 ± 9.7 | 12.1 ± 7.4 | 0.094 | 6.9 ± 9.2 | 14.5 ± 11.3 | < 0.001 |
| C7 slope – Cervical lordosis$^2$ | 6.7 ± 9.5 | 15.2 ± 8.2 | 0.003 | 5.5 ± 9.6 | 15.5 ± 12.4 | < 0.001 |
| C7 slope / Cervical lordosis$^1$ | 0.9 ± 1.4 | 0.5 ± 3.1 | 0.577 | 1.2 ± 1.7 | 0.2 ± 2.7 | 0.009 |
| C7 slope / Cervical lordosis$^2$ | 1.1 ± 1.3 | -0.1 ± 2.6 | 0.045 | 1.1 ± 2.0 | -1.1 ± 2.3 | < 0.001 |
| C1-C7 SVA | 1.4 ± 0.5 | 1.5 ± 0.6 | 0.375 | 1.5 ± 0.8 | 1.7 ± 1..0 | 0.193 |
| C2-C7 SVA | 1.0 ± 0.3 | 1.1 ± 0.5 | 0.229 | 1.0 ± 0.6 | 1.1 ± 0.7 | 0.355 |
| C1-C7 SVA - C2-C7 SVA | 0.4 ± 0.3 | 0.4 ± 0.4 | 0.961 | 0.5 ± 0.3 | 0.6 ± 0.5 | 0.130 |
| Level | | | 0.018 | | | < 0.001 |
| 2 | 11 (40.7) | 2 (10.0) | | 35 (31.3) | 2 (4.4) | |
| 4 | 16 (59.3) | 16 (80.0) | | 67 (59.8) | 38 (84.4) | |
| 6 | 0 (0.0) | 2 (10.0) | | 10 (8.9) | 5 (11.1) | |
| Ossification of nuchal ligament | 5 (18.5) | 13 (65.0) | 0.002 | 15 (13.4) | 15 (33.3) | 0.007 |
| Fusion | 6 (22.2) | 9 (45.0) | 0.122 | 11 (9.8) | 18 (40.0) | < 0.001 |
| Adjacent facet joint pain due to fusion | 6 (22.2) | 9 (45.0) | 0.122 | 11 (9.8) | 17 (37.8) | < 0.001 |

**Table 4.** The clinical characteristic of patient with good outcome versus with poor outcome stratified by receiving block only or both block and RF surgery. Abbreviation: PRF, pulse radiofrequency. Cervical lordosis$^1$: C2-C7 cobb angle; Cervical lordosis$^2$: the angle measured by the Jackson physiological stress line method, SVA: sagittal vertical axis (cm).

undergo ACDF. Another cause was a kyphotic change after the fusion procedure, and it may be due to the changes of sagittal alignment after cage fusion. All patients in this study underwent cervical spinal fusion with 0° rectangular cages, and it would cause loss of cervical lordosis. 41.5% of patients with poor outcomes underwent ACDF.

In our study, ONL was associated with unfavorable outcomes, and 43.1% of patients in the unfavorable outcome group had lesions. ONL is a radiopaque ossification of the soft tissues behind the spinous processes that may be related to neck pain, headache, and upper back pain in some patients[33,34]. ONL is observed more often in male patient and the incidence was associated with the patent's age. The formation of ONL may be due to the nuchal ligament injury or, from chronic overload in the nuchal ligament[35–37]. Tsai et al. reported correlation between ONL and clinical cervical disorders such cervical spondylosis and disc degeneration[38]. Based on our findings and those of previous studies, ONL can be considered a predictor for the cervical degenerative diseases[15]. Limitations of the study include the lack of placebo controlled diagnostic block, relatively smaller sample size, and a retrospective study. Placebo-controlled block could provide an irrefutable diagnosis but the experimental and clinical findings from the points of the electrophysiological effects of 0.9% sodium chloride has added new knowledge and controversy to multiple aspects of neurostimulation used in regional anesthesia. Flushing with normal saline would result in current density away from the stimulation tip of the needle, and subsequently, more current is required to stimulate the nevre. Thus, the potential inaccuracy by 0.9% sodium chloride has been described[39]. In the diagnosis and treatment of lumbar facet joint pain it needed controlled, comparative diagnostic blocks to decrease the false - positive rate[40]. In the systemic review of the cervical facet joint pain and treatment, the strength of evidence for diagnostic blocks is good with utilization of controlled diagnostic blocks but the clinical trials evaluating cervical facet joint block and radiofrequency are characterized by widely disparate outcomes, and there is enormous variation in selecting patients and performing procedures[41]. The factors affecting the diagnosis were age, psychological factors, and the use of opoid drugs[42]. In our research we performed single facet block combining with many exclusion criterias for patient selection to decrease false-positive rate.

## Conclusion

The research provides a scientific result in the performance of medical branch block and subsequent PRF for cervical facet joint pain. The research demonstrated that the predictors were the C2–C7 Cobb angle (< 7 °), the

| | Univariate analysis | | Multivariable analysis | | Multivariable analysis | |
|---|---|---|---|---|---|---|
| Variable | OR (95% CI) | *P* value | OR (95% CI) | *P* value | OR (95% CI) | *P* value |
| Male sex | 0.98 (0.28–3.48) | 0.978 | | | | |
| Age, year | 1.04 (0.99–1.10) | 0.131 | 1.07 (0.99–1.16) | 0.109 | 1.07 (0.99–1.16) | 0.104 |
| Cervical lordosis[1] | 0.96 (0.90–1.01) | 0.117 | 0.93 (0.86–1.001) | 0.058 | | |
| Cervical lordosis[2] | 0.92 (0.86–0.98) | 0.008 | | | 0.90 (0.83–0.99) | 0.023 |
| C2 slope | 0.95 (0.85–1.05) | 0.305 | | | | |
| C7 slope | 0.99 (0.92–1.06) | 0.793 | | | | |
| C2 slope – Cervical lordosis[1] | 1.02 (0.97–1.06) | 0.413 | | | | |
| C2 slope – Cervical lordosis[2] | 1.04 (1.00–1.09) | 0.079 | | | | |
| C2 slope / Cervical lordosis[1] | 0.99 (0.77–1.28) | 0.964 | | | | |
| C2 slope / Cervical lordosis[2] | 0.64 (0.41–1.01) | 0.054 | | | | |
| C7 slope – Cervical lordosis[1] | 1.06 (0.99–1.14) | 0.102 | | | | |
| C7 slope – Cervical lordosis[2] | 1.11 (1.03–1.20) | 0.008 | | | | |
| C7 slope / Cervical lordosis[1] | 0.93 (0.71–1.21) | 0.570 | | | | |
| C7 slope / Cervical lordosis[2] | 0.72 (0.51–1.01) | 0.054 | | | | |
| C1-C7 SVA | 1.64 (0.56–4.81) | 0.370 | | | | |
| C2-C7 SVA | 2.38 (0.58–9.77) | 0.228 | | | | |
| C1-C7 SVA minus C2-C7 SVA | 0.96 (0.17–5.54) | 0.960 | | | | |
| Level | | | | | | |
| 2 | Reference | | Reference | | Reference | |
| 4 or 6* | 6.19 (1.19–32.23) | 0.030 | 8.87 (1.20–65.66) | 0.033 | 7.79 (1.07–56.70) | 0.043 |
| Ossification of nuchal ligament | 8.17 (2.15–31.11) | 0.002 | 5.99 (1.30–27.52) | 0.021 | 4.48 (0.93–21.50) | 0.061 |
| Fusion or adjacent facet joint pain | 2.86 (0.81–10.14) | 0.103 | | | | |

**Table 5**. Logistic regression analysis for factor associated with the risk of poor outcome in patients who received block only. Abbreviation: OR, odds ratio; CI, confidence interval; Cervical lordosis[1]: C2-C7 cobb angle; Cervical lordosis[2]: the angle measured by the Jackson physiological stress line method, SVA: sagittal vertical axis ( cm ). * The number of patients with spine level of 6 was only 3, therefore the level 4 and level 6 were combined in the logistic regression analysis.

angle measured by the Jackson method (< -2 °), ONL, the number of diseased facet joints, presence of ACDF and adjacent facet joint post-ACDF.

| Variable | Univariate analysis | | Multivariable analysis | | Multivariable analysis | |
|---|---|---|---|---|---|---|
| | OR (95% CI) | *P* value | OR (95% CI) | *P* value | OR (95% CI) | *P* value |
| Male sex | 0.70 (0.35–1.41) | 0.319 | | | | |
| Age, year | 1.02 (0.99–1.04) | 0.255 | | | | |
| Cervical lordosis[1] | 0.92 (0.89–0.96) | < 0.001 | 0.92 (0.88–0.96) | < 0.001 | | |
| Cervical lordosis[2] | 0.91 (0.87–0.95) | < 0.001 | | | 0.91 (0.87–0.95) | < 0.001 |
| C2 slope | 1.03 (0.99–1.07) | 0.208 | | | | |
| C7 slope | 0.98 (0.94–1.02) | 0.358 | | | | |
| C2 slope – Cervical lordosis[1] | 1.05 (1.02–1.08) | < 0.001 | | | | |
| C2 slope – Cervical lordosis[2] | 1.06 (1.03–1.08) | < 0.001 | | | | |
| C2 slope / Cervical lordosis[1] | 0.79 (0.64–0.97) | 0.024 | | | | |
| C2 slope / Cervical lordosis[2] | 0.61 (0.48–0.77) | < 0.001 | | | | |
| C7 slope – Cervical lordosis[1] | 1.08 (1.04–1.12) | < 0.001 | | | | |
| C7 slope – Cervical lordosis[2] | 1.09 (1.05–1.13) | < 0.001 | | | | |
| C7 slope / Cervical lordosis[1] | 0.80 (0.66–0.95) | 0.013 | | | | |
| C7 slope / Cervical lordosis[2] | 0.61 (0.49–0.74) | < 0.001 | | | | |
| C1-C7 SVA | 1.29 (0.88–1.89) | 0.195 | | | | |
| C2-C7 SVA | 1.28 (0.76–2.18) | 0.354 | | | | |
| C1-C7 SVA minus C2-C7 SVA | 2.05 (0.80–5.25) | 0.135 | | | | |
| Level | | | | | | |
| 2 | Reference | | Reference | | Reference | |
| 4 | 9.93 (2.26–43.58) | 0.002 | 11.98 (2.19–65.48) | 0.004 | 14.12 (2.32–85.91) | 0.004 |
| 6 | 8.75 (1.47–52.10) | 0.017 | 8.78 (1.12–68.78) | 0.039 | 15.46 (1.75–136.27) | 0.014 |
| Ossification of nuchal ligament | 3.23 (1.42–7.38) | 0.005 | 3.62 (1.30–10.14) | 0.014 | 3.25 (1.09–9.66) | 0.034 |
| Fusion or adjacent facet joint pain | 6.12 (2.59–14.49) | < 0.001 | 7.53 (2.46–23.01) | < 0.001 | 8.73 (2.72–28.02) | < 0.001 |

**Table 6**. Logistic regression analysis for factor associated with the risk of poor outcome in patients who received both block and RF. Abbreviation: OR, odds ratio; CI, confidence interval; PRF, pulse radiofrequency. Cervical lordosis[1]: C2-C7 cobb angle; Cervical lordosis[2]: the angle measured by the Jackson physiological stress line method, SVA: sagittal vertical axis (cm).

## Data availability
Data is provided within the manuscript.

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## Author contributions

Cheng-Yo Yen: He is a expert of facet joint disease and organize the research. Sheng-Min Lin: She is a medical student and she help to check the alignment of cervical spine. Hong Yu Chen: He is a medical student and she help to check the alignment of cervical spine. Shih-Wei Wang: Dr Wang is an expert of joint arthritis and he help to exclude the patients with inflammatory origin. Yu-Duan Tsai: Dr Tsai help to the field of methods and statistical analyses. Cien-Leong Chye: Dr Chye worked in the field of methods and statistical analyses. Te-Yuan Chen: worked in the field of methods and statistical analyses and check the angree of the cervical spinal alignment. Hao-Kuangn Wang: Dr Wang help in the data analysis. Kuo-Wei Wang: Dr Wang finished the paper and designed the research.

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## Declarations

## Ethics approval

The study was approved by the Institutional Review Board of E-Da hospital (EMRP-111-065).

## Competing interests
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No.

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