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Abstract:

Improved Fusion Rates with Anterior and Posterior Fusion in Habitual Tobacco Use Patients Treated for Dominant Axial-Mechanical Cervical Spine Pain

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Study Design. An extensive outcome questionnaire was used to evaluate the success of combining anterior and posterior instrumented autograft fusion of multiple cervical levels to enhance the fusion rate in the habitual tobacco use patient.

Objective. To document successful radiographic fusion and evidence of improved patient-perceived clinical outcomes leading to a favorable outcome in the habitual tobacco use patient.

Summary of Background Data. The use of tobacco products is known to increase bone resorption and may double the nonunion rates achieved in the nonsmoker. The addition of posterior lateral mass fusion to anterior cervical interbody fusion with plate instrumentation should improve the fusion rate because this construct is the most stable in all loading conditions.

Methods. 49 habitual tobacco use patients were treated with anterior and posterior combined cervical fusion. All were evaluated initially and at final follow-up with radiographs, pain analog visual scale, and a Modified Oswestry disability index. Additionally at final assessment, the North American Spine Society Satisfaction Questionnaire was administered.

Results. Healing of the surgical fusion occurred in all patients. There was no subsidence or loss of lordosis noted in the fusion. Final assessment was 35 months after the surgery. 84% reported self-perceived excellent or good results of treatment. There was a significant self-perceived 30% improvement of pain. Modified Oswestry score had significant 24% improvement. 78% reported neck pain was improved after surgery.

Conclusions. Combined anterior and posterior fusion in the tobacco use patient attained a 100% fusion rate and a high percentage of change in self-perceived improvement of pain and function. The improvement with the combined treatment is important because the habitual tobacco use patient would expect a less satisfactory outcome with anterior fusion alone, then the non-tobacco use patient. The use of anterior and posterior fusion in this difficult treatment group allows a 100% fusion rate and outcome results similar to those achieved in

previously reported series of treatment of axial neck pain. [Key words: cervical, discectomy, discogenic, fusion, neck pain, Nicotine/adverse effects, Smoking/*adverse effects, patient outcome

Key Points.

- Combined Anterior and posterior cervical fusion in the habitual tobacco use patient attained a 100% fusion rate.

Of 49 patients, 84% reported a self-perceived satisfactory outcome, and 91% reported improvement of pain.

* Mini Abstract

Habitual tobacco use complicates the healing of multi-level cervical fusions. A posterior lateral mass fusion added to the anterior cervical fusion with plate instrumentation will attain a 100% fusion rate. This report documents a high percentage of self-perceived improvement of pain and function.

Introduction

Habitual tobacco use (HTU) complicates the course of treatment of multilevel cervical arthrodesis. In general, multilevel cervical spinal arthrodesis is successful treatment of degenerative disorders of the neck. A successful outcome in the multilevel patient using tobacco products may be challenging. Tobacco use is associated with increased rates of surgical nonunion and presents with a persistent painful cervical, scapular and radicular pain syndrome [1-5]. Although not all non-unions are symptomatic, non-union in the tobacco use patient is more often symptomatic [2, 4, 6]. Experimental studies have shown nicotine to have a negative effect on bone fusion[7-13]. Some of the proposed causes are a negative effect on early graft revascularization, vascular endothelial growth factor, bone morphogenetic protein, and cytokines important to osteoblast function[8, 9, 14] Tobacco enhanced hepatic enzyme metabolism increases narcotic and sedative consumption 30% more than in the non-smoker [15]. The tobacco use patient will have an average 1/2 standard deviation greater physiologic response to pain and disability related to cervical pain[16] . The smoker will have more significant degenerative changes and more spinal levels involved than the non smoker[17].

The HTU patient most often presented with a primary indication of axial mechanical neck pain, with radicular symptoms, but no myelopathy or major loss of nerve root function. The patient had failed to respond to prolonged non-operative treatment methods. The purpose of the pre operative evaluation was to document findings that when treated surgically would give a predictable result and improve clinical patient perceived outcomes. Provocative cervical discography was used pre-operatively as an objective method to assist the surgeon in selection of operative levels to be included in the fusion.

Anterior and posterior fusion is not a new idea. Anterior and posterior combined fusion has been recommended for fusions of three or more levels, particularly with deficient posterior elements from previous laminectomy[18]. A staged posterior fusion for treatment of anterior surgical nonunion has been recommended [19]. Benefits of simultaneous anterior and posterior fusion are: a decrease in the post-operative complications

such as graft dislodgement, instrumentation failure, and surgical nonunion; and optimal decompression from front and back[20]. Biomechanical strength is better with posterior lateral-mass fusion than with anterior plating alone, and best with combined anterior and posterior fixation [21].

With these cautionary findings regarding tobacco use, and the decreased surgical nonunion rate of combined anterior posterior fusion, our senior author began recommending the addition of posterior instrument fusion combined with the anterior cervical discectomy and fusion in the habitual tobacco use patient. Our purpose in presenting this anterior posterior cervical fusion group is to document a successful radiographic fusion rate and evidence of improved patient-perceived clinical outcomes and surgical results leading to a favorable outcome in the HTU patient.

Materials and Methods

83 patients were identified who underwent anterior cervical decompression and fusions combined with posterior lateral mass fusions with the indication of HTU between January 1998 and December 2000. HTU in this study is defined as smoking at least one pack per day, or use of smokeless products more than twice a day. Of the 83 patients so identified, 49 completed an extensive outcome questionnaire and had a current set of cervical radiographs. Therefore, the 49 patients are the basis of this report. The other 34 patients declined participation or could not be located to participate in the review

The chief complaint of this patient group was dominant mechanical neck pain defined as neck pain greater than arm pain. Patients with tumor, infection, or fracture-dislocation as an indication for surgery were excluded from the study. The smoking history indicated 35(72%) smoked more than one pack per day, and 14(28%) used smokeless products daily. All patients had failed outpatient treatment including physical therapy, epidural steroid injections, and pain management techniques. All patients had been counseled for smoking

cessation before surgery, and none of these patients could stop their tobacco usage. All patients had an M.R.I. (46/49) or less commonly a CT-myelogram (3/49), to document neurologic compression. The mean follow-up was 35 months \pm 13.

Preoperative provocative cervical discography was routinely used to define painful disk levels to be included in the fusion (41/49). Discography was performed by an independent neuro-radiologist. Discography demonstrated complete annular tears, the patient's response by the intensity of pain, and the pain concordance to the usual symptoms. The classification of discography by Garvey et al was applied to analyze the outcomes[22]. A classic discographic pattern of Garvey et al was defined as a significant concordant reproduction of pain at the affected level with little or no pain at adjacent levels studied. Non-classic discography of Garvey et al was defined as any other pattern, usually with a partial or full annular tear but a low level of concordant pain $< 5/10$, or non-concordant pain at adjacent segments rated greater than $5/10$ [22]. Eight patients did not have discography. The patients without discography had clear-cut levels of gross anatomic abnormalities surrounded by normal levels on the MRI. The most common diagnosis was central stenosis often with foraminal stenosis in 6 of 8 patients without discography.

The outcome instruments used were a visual pain analog scale (PAS), a modified Oswestry disability index (ODI), and the North American Spine Society instrument (NASSQ), evaluating the global effect of neck pain on patient satisfaction. In addition to the patient outcome questionnaires, hospital and office charts, discography films, C.T.-myelograms, the M.R.I. and the preoperative, post operative and final radiographs were reviewed. All patients who responded answered the questionnaire by phone conference, and those we were unable to contact by phone, answered the questionnaire by return mail. Patients when contacted were told that the authors would be blinded to the patient responses.

Statistical results were calculated for the 49 patients who completed the detailed follow-up questionnaire and evaluation. Additionally, the chart review of the 34 patients who could not be contacted at last follow-up

suggested there were no significant differences in terms of charted outcome between these patients and the 49 patients who completed the final outcome questionnaires.

At surgery, the anterior fusions were plated with PEAK plates (Depuy-AcroMed, Cleveland, OH) and posterior fusions with Summit lateral mass fixation (Depuy-AcroMed, Cleveland, OH). All patients were operated on a Jackson Table (OSI). The table allowed turning the patient without transferring to another table and back again. A Mayfield headrest was used and no additional traction was used. Longitudinal incisions were used for more than two levels, and a transverse incision was used for 2 or less levels. An anterior iliac crest structural graft of 8 mm width was obtained for each level, and additional cancellous bone is taken for the posterior fusion as well. A modified Smith-Robinson technique was used. The patient was then secured in the Jackson table and turned to the prone position. The posterior portion of the case was done through a midline vertical incision. Lateral mass screws were placed by modified technique of Magerl[23]. The patients are immobilized in an external orthosis (Philadelphia collar) for 8 weeks.

Plain lateral cervical spine radiographs, with flexion and extension views, obtained in all patients at 3-month intervals, determined radiographic union. Trabecular bony bridging across the disk space and lack of motion on flexion/extension views were the criteria used to determine fusion.

Results

Of the 49 patients there were 30 men (62%), and 19(38%) women. The average age was 45 with a range from 25-66 years. The education level was less than High School graduation in 20(40%), Graduated High School 23(47%), Some College 5(10%), College or technical degree 1(3%). The type of injury was an identifiable injury in 37(76%) and poorly defined injury in 12(24%). There were 20(40%) workplace injuries and 17(35%) motor vehicle injuries. 46(94%) were involved with Workers' compensation or litigation. The length of onset from injury to date of surgery was 24 months \pm 13. The number of levels fused was an average of 3 levels \pm 1 (Table 1).

The PAS for all patients improved significantly from a mean $9/10 \pm 1$ pre-operatively to 5 ± 2 ($P < 0.001$) (table 2). The average ODI improved significantly from a mean of 61 ± 10 to 40 ± 14 ($P < 0.001$) (Table 2). In response to the NASSQ query “If you had to spend the rest of your life with your neck condition as it was before your surgery, how would you feel about it?” 92% would be dissatisfied if the neck condition was as before the surgery (Table 3). The average answer was very “dissatisfied” ± 1 . In answer to the question, “How has your pain been affected by the surgery?” 78% reported neck pain was improved after surgery ($P = 0.01$). The average answer was “somewhat improved” ± 1 (Table 4). In answer to the question, “Would you have the same treatment again if you had the same condition?” significantly, 66% would have the same treatment ($P < 0.0001$) (Table 5). In answer to the question, “How would you rate the overall results of your treatment for your neck or arm pain?” 84% were excellent to good, 8% fair, and 8% were poor ($P = 0.003$) (Table 6).

When the surgery is based on a classic pattern of discography, provocative pain at involved levels with little or no pain at surrounding levels is predictive of a better outcome. To compare the patients who had pre-operative discography (classical vs. non-classical), the NASSQ were compared by discography results. 85% of patients with classical concordant discography, regardless of number of levels operated had an excellent or good result (Table 7). 63% of the patients who did not have discography had an excellent or good result. Patients who did not undergo discography showed abnormal levels on the MRI with normal levels above and below on radiographs and MRI.

The final radiographic assessment was a mean of 20 ± 11 months All 49 had solid radiographic fusion of every level. There were no lucent lines seen, no subsidence, and no instability or motion detected on flexion-extension views. Additionally 2 patients had adjacent segment deterioration below the fusion, which required subsequent fusion. Hardware removal with exploration of the fusion allowed the best evaluation of the fusion, and the subsequent radiographs give the best radiographic confirmation of the fusion. Surgical nonunion was not reported in any of the exploration cases.

Ten patients had previous surgery. There were 4 patients with previous laminectomy and 6 patients with previous anterior cervical discectomy and fusion. 21 of the 49 patients had additional operations. There were 4 posterior cervical infections 3 were within a month of the index surgery, and one occurred one year later secondary to hematogenous seeding from an infectious bronchitis. All infections resolved with wound debridement and intravenous antibiotics. One patient had continued lateral femoral cutaneous nerve dyesthesias (meralgia paresthetica) at the anterior iliac crest donor site. This patient was treated with multiple cortisone injections, and when outpatient treatment failed, debridement of the iliac crest to resect the lateral femoral cutaneous nerve and its branches. One patient had a subsequent posterior laminotomy for continued right radiculopathy with identified residual foraminal narrowing on CT scan. Two patients had extension of their fusion to an adjacent level. Thirteen patients had removal of anterior and posterior hardware for indications of symptomatic hardware, and evaluation for surgical nonunion. No operated patient was found to have a surgical nonunion. Seven of the hardware removal patients had the additional indication of significant dysphagia of solid and liquids. All seven patients improved in their dysphagia after removal of the hardware. Not counting the post-operative debridements for infection, 15 patients underwent a secondary cervical surgery after the index anterior-posterior fusion. At the time of the secondary procedure, each level of fusion was healed. No level of surgical nonunion could be found.

Discussion

All human body tissues are affected adversely by tobacco use. Habitual tobacco users are at increased risk of cardiovascular disease, depression, cancer, pulmonary disease, osteoporosis with related fractures, and disk degeneration[16]. Tobacco products experimentally have been shown interfere with bone metabolism and revascularization of bone and also a suppression of bone formation [7, 9-13, 24-28]. Clinically, the tobacco use patient is more likely to be depressed than the non-smoker and more likely to report chronic depressive symptoms [16, 29, 30]. The smoker reports his symptoms are more severe and long lasting than the non-

smoker[16, 31]. Studies of identical twins have shown smoking is associated with an increased rate of degenerative change of the disc on MRI[17, 32]. Self-reported functional outcome studies in patients with spinal disorders are usually 2 standard deviations below the U.S. norms and smokers may report half a standard deviation below the non-smoker[16]. Patients report the need to smoke increases with pain but that smoking does not decrease the perception of pain [14, 16, 29, 33-35]. Health status reporting after spinal surgery did not show progressive improvement as in the non-smokers[16]. After surgery, wound healing is adversely effected[7, 13]. Post-operative rates of wound infections [7, 13, 36-38], and non-union of spinal fusions are substantially higher in tobacco use patients [7, 13, 38].

Achieving fusion at multiple levels in the cervical spine is more difficult than at a single level. The more levels of fusion the more likely a surgical nonunion will occur. Hilibrand et al. clearly shows an increased rate of 50% surgical nonunion of multilevel cervical interbody fusion in smoking patients.[6]. It is more difficult to achieve fusion with allograft bone than with autograft bone in multi-level cervical fusions.—Bishop et al. demonstrated that cigarette smoking significantly delays the healing of interbody allograft in the cervical spine.[39] Autograft was used exclusively for the anterior and posterior fusions in this study. Our fusion rate was 100%, confirmed by radiography including flexion-extension films in 49 patients, and surgical exploration in 15 patients. We contend the negative influence of tobacco use on multilevel cervical interbody fusion healing is additive with other factors such as multiple involved levels, and the use of allograft bone [6, 39-42].

Anterior cervical plating in multi-level fusions has decreased the rate of non-union. However longer constructs have been shown to be less stable causing increased posterior strain, particularly in flexion or distraction[43]. Anterior plating with locking fixation screws and unicortical fixation is the most recent design and is more stable than the conventional unlocked plate and screws [44, 45]. The anterior plate does restore the normal lordosis and preventing kyphosis in the operated cervical spine. Katsuura, et al. reported the plated cervical spine can maintain cervical lordosis whereas anterior cervical fusion without plating could not[46].

Posterior lateral mass screws and plating are biomechanically superior in all loading modes to anterior plating with locked fixation screws[18, 21]. This series had interbody grafting and anterior cervical plating to restore and maintain the normal cervical lordosis, and posterior instrumented lateral mass fusion to give the maximal stability to allow the fusion to proceed.

The diagnosis of symptomatic cervical discogenic pain is elusive with radiographs, Computerized tomography, myelography and most recently M.R.I. In fact, a significant number of asymptomatic patients will have false positive abnormalities on these tests. False positive levels preclude using these tests alone as routine selection of involved levels for surgical treatment in the chronic axial cervical pain patient. Provocative cervical discography has been the technique of choice when the history and physical examination suggest the patient may be an operative candidate. This diagnostic workup is as described recently by Garvey et al[22], and Palit et al [47], and is similar to the diagnostic evaluation described by authors over the past 50 years of cervical surgical intervention [48-55] . The use of provocative cervical discography to select involved levels is controversial, but recent studies have demonstrated improved functional outcome results in patients where discography was used in the pre-operative surgical evaluation[22]. Our study group of HTU patients had an average of three levels damaged. Our hypothesis is that the number of involved levels and the damage at each level may be greater in the HTU because of decreased healing potential associated with nicotine. A partial-thickness annular tear that would usually heal in a normal disc may not heal and may continue to deteriorate in the tobacco user. This group may be more prone to have permanent full thickness annular tears develop from small, accumulative trauma. In our patients with a provocative discogram of classical pattern there was an improved patient-perceived outcome after successful fusion. Our improved outcomes are the result of the selection of involved levels with discography. These results are similar to those reported by authors in the past [22, 47].

Our patients reported a significant 84% self-perceived beneficial outcome ($P=0.003$). There was a significant 30% improvement in PAS ($P<0.001$). The ODI score significantly improved 24% ($P<0.001$). Our results in tobacco use patients are similar to authors reporting on the treatment of axial dominant neck pain over the past decades. These improved results are important because the tobacco use patient would expect a less satisfactory outcome with anterior fusion alone. The use of anterior and posterior fusion in this difficult treatment group allows a 100% fusion rate and outcome results similar to those achieved in the previous reported series of treatment of axial neck pain.

Conclusions

Combined anterior and posterior fusion in tobacco use patients gave a 100% fusion rate. The patients reported a high percentage of self-perceived improvement of pain and function. This improvement with surgical management in this difficult patient group, as compared with the dissatisfaction before surgery because of their neck pain, documents that this surgical treatment is a reasonable option.

Table 1. Number of Cervical Vertebral Motion levels Fused

Levels Fused	N=49	%
2	10	20%
3	21	43%
4	16	33%
5	2	4%

Table 2. Pain Analog Scale (PAS)* and Modified Oswestry Disability Index (ODI

Population	PAS			ODI		
	Initial	Final	p-value	Initial(median)	Final(median)	p-value
All N=49	9±1	5±2	<0.0001	61±10(64)	40±14(40)	<0.0001
1-2 Levels n=10	9±1	4±2	<0.0001	60±7(61)	36±13(35)	0.0008
3 Levels n=21	9±1	5±1	<0.0001	60±12(64)	43±11(40)	<0.0001
>3 Levels n=18	9±1	5±2	<0.0001	64±8(62)	43±16(43)	<0.0001

* Values shown reflect patient pain levels on a scale of 0 (no pain) to 10 (pain so severe that it cannot be tolerated for more than a few minutes).

**A paired t-test was performed to gain correlation. The assumption of normality was verified using normality tests and quantile plots.

(±) standard deviation

Table 3. If You Had to Spend the Rest of Your Life With Your Neck Condition as It Was before Your Surgery, How Would You Feel About It?*

Population	Dissatisfied %	Satisfied %
All n=49 *	92	8
<3 Levels n=10	90	10
3 Levels n=21	95	5
> 3 Levels n=18	89	11

*Based only on the follow-up questionnaire

Table 4. How Has Your Neck Pain Been Affected by the Surgery?*

Population	Improved %	Same %	Worse %
All n=49 *	78	14	8
<3 Levels n=10	80	20	0
3 Levels n=21	67	24	9
> 3 Levels n=18	89	0	11

*Based only on the follow-up questionnaire

*p-value for all population is 0.01. Other p-values are not significant.

Table 5. Would You Have the Same Treatment Again If You Had the Same Condition?*

Population	Yes %	Not Sure %	No %
All n=49 **	66	22	12
<3 Levels n=10	70	10	20
3 Levels n=21	58	28	14
> 3 Levels n=18	72	22	6

*Based only on the follow-up questionnaire

**p-value for all population is <0.001. Other p-values are not significant. A nonparametric sign test (Wilcoxon signed rank test) using paired data was performed.

Table 6. How Would You Rate the Overall Results of Your Treatment for Your Neck or Arm pain?*

Population	Excellent/Good %	Fair %	Poor %
All n=49 **	84	8	8
<3 Levels n=10	90	0	10
3 Levels n=21	82	9	9
> 3 Levels n=18	83	11	6

*Based only on the follow-up questionnaire.

**p-value for all population is 0.003. Other p-values are not significant. A nonparametric sign test (Wilcoxon signed rank test) using paired data was performed.

Table 7. Results related to Discography*

Population	Excellent/Good %	Fair %	Poor %
Classic n=34	85	3	12
Non-Classic n=7	100	0	0
Not Done n=8	63	37	0

*Based only on the follow-up questionnaire.

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