

Controversies in Cervical Discectomy and Fusion: Practice Patterns Among Canadian Surgeons

Gwynedd E. Pickett, Jessica Van Soelen, Neil Duggal

ABSTRACT: Objective: Optimal fusion technique and peri-operative management of patients undergoing anterior cervical discectomy (ACD) is unclear. We document current practice patterns among Canadian spinal surgeons regarding the surgical management of single level degenerative cervical spondylosis. **Methods:** We conducted a web-based survey of neurosurgeons and spinal orthopedic surgeons in Canada. We asked questions pertaining to the management of single level cervical degenerative disc disease causing radiculopathy and/or myelopathy, including frequency of fusion following single-level discectomy, preferred fusion technique, indications and frequency of use of anterior plating, and use of an external cervical orthosis following surgery. Demographic factors assessed included training background, type and length of practice. **Results:** Sixty respondents indicated that their practice involved at least 5% spine surgery and were included in further analysis. Neurosurgeons comprised 59% of respondents, and orthopedic surgeons 41%. Fusion was employed 93% of the time following ACD; autologous bone was the preferred fusion material, used in 76% of cases. Neurosurgeons employed anterior cervical plates in 42% of anterior cervical discectomy and fusion cases, whereas orthopedic surgeons used them 70% of the time. External cervical orthoses were recommended for 92% of patients without plates and 61% of patients with plates. Surgeons who had been in practice for less than five years were most likely to be performing spinal surgery, using anterior cervical plates, and recommending the postoperative use of cervical orthoses. **Conclusion:** Practice patterns vary among Canadian surgeons, although nearly all employ fusion and many use instrumentation for single-level ACD. Training background, and type and length of practice influence practice habits.

RÉSUMÉ: Controverses au sujet de la dyscectomie cervicale avec arthrodèse: pratiques courantes chez les chirurgiens canadiens. Objectifs : La meilleur technique d'arthrodèse et de prise en charge des patients qui subissent une dyscectomie cervicale antérieure (DCA) n'est pas bien établie. Nous rapportons les pratiques courantes parmi les chirurgiens canadiens concernant la chirurgie pour spondylarthrose cervicale dégénérative unique. **Méthodes :** Nous avons effectué une enquête électronique auprès des neurochirurgiens et des orthopédistes pratiquant des chirurgies spinales au Canada. Le questionnaire comprenait des questions sur le traitement de la discopathie dégénérative cervicale unique causant une radiculopathie et ou une myélopathie, sur la fréquence de l'arthrodèse après une dyscectomie unique, la technique d'arthrodèse de choix, les indications et la fréquence d'utilisation d'une plaque d'ostéosynthèse antérieure et d'une orthèse cervicale externe après la chirurgie. Les facteurs démographiques recueillis comprenaient la formation du chirurgien, son type de pratique et la durée de celle-ci. **Résultats :** Soixante répondants qui ont indiqué que la chirurgie spinale constituait au moins 5% de leur pratique ont été inclus dans l'étude. Parmi eux, 59% étaient des neurochirurgiens et 41% des orthopédistes. L'arthrodèse était utilisée chez 93% des patients après une DCA; le matériau de choix était l'os autologue utilisé chez 76% des cas. Les neurochirurgiens utilisaient des plaques d'ostéosynthèse dans 42% des dyscectomies cervicales antérieures et des cas d'arthrodèse alors que les orthopédistes l'utilisaient chez 70% des cas. Chez 92% des patients qui n'avait pas reçu de plaque d'ostéosynthèse, on recommandait une orthèse cervicale externe de même que chez 61% des patients qui en avaient reçu une. Les chirurgiens qui étaient en pratique depuis moins de cinq ans étaient ceux qui avaient le plus souvent recours à la chirurgie spinale, utilisaient une plaque d'ostéosynthèse cervicale antérieure et recommandaient l'utilisation d'une orthèse cervicale après la chirurgie. **Conclusion :** Bien qu'il existe des variations dans les techniques utilisées par les chirurgiens canadiens, presque tous utilisent l'arthrodèse et plusieurs utilisent l'instrumentation pour la DCA unique. La formation du chirurgien, son type de pratique et la durée de celle-ci influencent ses choix.

Can. J. Neurol. Sci. 2004; 31: 478-483

Anterior cervical discectomy for degenerative cervical disc disease and spondylosis is one of the most common operations performed by the spinal surgeon. Despite the frequency of this operation questions remain regarding the optimal surgical technique and the best peri-operative management of these patients. Controversy still surrounds the issues of whether fusion is required following anterior cervical discectomy (ACD), whether anterior cervical plating is indicated following a single-level anterior cervical discectomy and fusion (ACDF) for

degenerative disc disease, and whether postoperative use of an external spinal orthosis (ESO) is required following ACDF with or without plating.

From the Division of Neurosurgery, London Health Sciences Centre, London, Ontario, Canada.

RECEIVED JANUARY 26, 2004. ACCEPTED IN FINAL FORM JUNE 21, 2004.
Reprint requests to: Neil Duggal, London Health Sciences Centre, University Campus, 339 Windermere Rd., London, Ontario N6A5A5, Canada.

As no formal evidence-based guidelines exist, surgeons must each develop their own opinions and technical habits, based on their individual reading of the literature and influenced by the location, time period, and nature of their training in spinal surgery. Published studies to date describe the experiences of particular individuals and groups, but do not convey an overall sense of practice habits and, more importantly, the logic and reasons on which those practice decisions are based. We surveyed Canadian spinal surgeons to gain an understanding of practice patterns in ACDF for single-level degenerative disc disease, with particular attention given to the issues listed above.

METHODS

E-mail invitations were sent to 159 neurosurgeons and spinal orthopedic surgeons in Canada, asking them to participate in a web-based survey of current practice in the management of patients undergoing ACDF. Surgeons were identified through affiliations with hospitals and academic departments, and registration with relevant professional organizations including the Canadian Congress of Neurological Sciences, the North American Spine Society and the Canadian Spine Society. E-mail reminders and fax versions of the survey were sent in second and third waves, to maximize the response rate.

All questions in the survey related to the management of single level degenerative disc disease in the cervical spine. Practice pattern factors assessed included the percentage of the respondent's practice devoted to spinal surgery, frequency of use of instrumentation in spinal cases, frequency of use of fusion following single-level ACD for degenerative disease, preferred fusion technique (Cloward vs. Smith-Robinson), type of bone graft preferred (bovine bone, allograft, or autograft), frequency of use and indications for anterior spinal plating in the setting of single-level ACD for degenerative disease, and the preferred type of plate and fixation method. We also inquired whether external cervical orthoses were prescribed post-ACDF to patients who had or had not received instrumentation, the type of orthosis preferred, the length of time the patient was required to wear it, and reasons for prescribing orthoses. Demographic factors assessed included training background (orthopedic vs. neurosurgical), type of practice (academic vs. private), and length of time in practice.

Responses were tabulated and summarized using Microsoft Excel. Statistical significance of correlations was calculated with the chi-square test.

RESULTS

One hundred and one responses were received from the 159 surgeons contacted, yielding a total response rate of 63%. Thirty-six surgeons responded that they would not complete the questionnaire, as spine surgery formed no part of their current practice. Sixty-five completed questionnaires were received and reviewed. Sixty surgeons indicated that their practice involved at least 5% spine surgery, and they comprised the population of respondents analyzed.

Neurosurgeons represented 59% of respondents, and orthopedic surgeons 41%. Seventy-two percent of respondents were in academic positions. Eighteen percent had been in practice for five years or less, 27% from six to ten years, 33%

Table 1: Length of time in practice

Years in Practice	Neurosurgery (%)	Orthopedics (%)	Total (%)
0-5	8	10	18
6-10	17	10	27
11-20	18	15	33
21-30	14	8	22

from 11-20 years, and 22% from 20-30 years (Table 1). Spinal surgery was responsible for 54% of surgical practice for the responding neurosurgeons, and for 70% of practice of the responding orthopedic surgeons. Neurosurgeons reported using instrumentation in any type of spinal case (anterior or posterior, anywhere in the spine) an average of 38% of the time, whereas orthopedic surgeons used instrumentation in 59% of spinal cases (Figure 1).

A fusion was performed an average of 93% of the time following single-level ACD for degenerative disease. Neurosurgeons were slightly less likely to fuse than were their orthopedic colleagues (91% vs. 96%, Figure 1). Respondents tended to use one technique near-exclusively (90% of the time), with 13% preferring the Cloward method and 83% the Smith-Robinson method. Only two respondents indicated that they used each technique about 50% of the time. No correlation was found between the type of technique preferred and training background, or length of time in practice.

Autologous bone was the preferred fusion material, used in 76% of cases. Thirty-six respondents (60%) indicated that they always used autograft. Only 15% of respondents reported using allograft in any of their cases, and a further 15% used bovine bone; no surgeon used allograft or bovine graft exclusively. There was a correlation between number of years in practice (>10 years) and the use of bovine graft ($P < 0.05$).

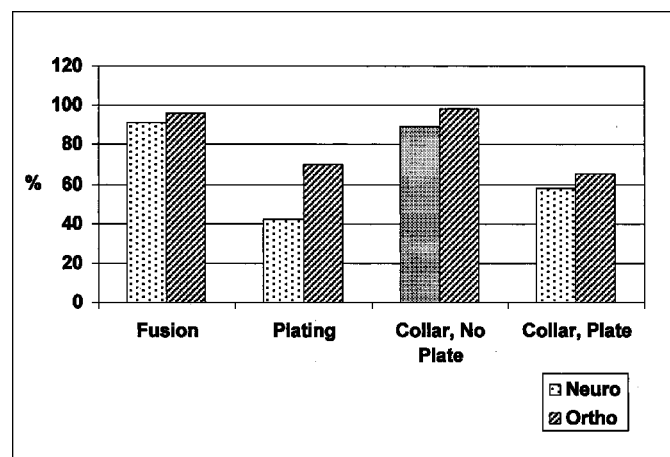


Figure 1: Percentage of spinal surgeons who perform fusion following ACDF, employ anterior cervical plates, and recommend cervical collars in the setting of ACDF with and without plating, compared by training background.

Table 2: Plate system preference

Commercial Plate System	Frequency of Use (%)
Atlantis	37
Cervical Spine Locking Plate	24
PEAK Polyaxial Anterior Cervical Plate	17
Codman	15
Cervical Spine Locking Plate (small)	4.5
ABC	2.3
Orion	0
Premier	0
DOC	0
Other	0.2

On average, neurosurgeons employed anterior cervical plates in 42% of their ACDF cases, whereas orthopedic surgeons used them 70% of the time (Figure 1). Twenty-eight percent of neurosurgeons and 38% of orthopedic surgeons indicated that they always used a plate. Reasons for plating included avoiding the use of a collar, concern that patients would be noncompliant with the collar, improving early mobility and return to work, the presence of patient risk factors for nonunion including diabetes and smoking, prior anterior decompressive surgery, motion demonstrated on preoperative dynamic radiographs, and "routine".

Respondents tended to use one type of plate exclusively. Of 41 respondents who indicated that they used a plate for single-level ACDF for degenerative disease, 42% always used constrained plates, 42% always used semi-constrained plates, and only 16% indicated that they used both types. Semi-constrained systems with transitional screws, which allow for translational motion of the screw heads along a rail or slot, were rarely used. Of the 24 respondents who used semi-constrained plates, only four employed systems with transitional screws, and then only for 5-10% of their cases. The Atlantis plate system (Atlantis Anterior Cervical Plate System, Medtronic Sofamor-Danek, Memphis, TN) was the most popular cervical plate, used in 37% of cases (Table 2). The CSLP system (Cervical Spine Locking Plate, Synthes Spine, Paoli, PA) ranked second, chosen in 24% of cases, with the small version of CSLP used in a further 4.5%. PEAK (PEAK Polyaxial Anterior Cervical Plate, DePuy Acromed, Raynham, MA) and Codman (Codman Anterior Cervical Plate System, Codman & Shurtleff Inc., Raynham, MA) plates were used in 17% and 15% of cases respectively. The ABC plate (Aesculap, Center Valley, PA) was used only rarely, in 2.3% of cases. Orion (Medtronic Sofamor-Danek, Memphis, TN), Premier (Medtronic Sofamor-Danek, Memphis, TN), and DOC (DePuy Acromed, Raynham, MA) systems were not used in any cases by any of the responding surgeons, although respondents did indicate using "Other" (nonlisted) systems in 0.2% of cases.

Following ACDF for single level degenerative disc disease, cervical orthoses, typically Aspen (Aspen Medical Products, Long Beach, CA) or Philadelphia (Philadelphia Cervical Collar Co., Thorofare, NJ) collars were recommended for 92% of patients who did not receive plates and for 61% of patients who did receive plates. The most common reasons for recommending

an ESO were multilevel pathology, concern regarding bone strength or screw placement, patient comfort, and "routine". Recommended length of ESO use varied between one and twelve weeks, with six weeks being the most commonly reported time period. The length of ESO use did not vary significantly depending on whether or not anterior cervical plating had been performed. Half of the respondents reported that they required the ESO to be worn day and night, regardless of whether plating was performed.

Surgeons who had been in practice for five years or less devoted 70% of their practice to spinal surgery, whereas their colleagues who had been in practice for 20 years or more spent 53% of their time on spinal cases. The newer surgeons reported using instrumentation in 66% of their spinal cases; this percentage was 39% for surgeons with 6-10 years in practice, 45% for those with 11-20 years, and 42% for those over 20 years. Surgeons in practice for five years or less were more likely (72%) to use anterior cervical plates following ACDF for single level degenerative disc disease, as compared to 40%, 51%, and 43% for the other practice length categories respectively (Figure 2). Finally, newer surgeons were also slightly more likely to recommend the use of an ESO in the setting of instrumentation.

DISCUSSION

Variations in clinical practice were evident from the results summarized above, although certain common practices and trends became apparent. Canadian spinal surgeons typically perform a fusion following ACD, and are almost certain to recommend the use of an ESO for 6-12 weeks if instrumentation of the spine is not performed. However, the specific fusion technique and bone substrate used vary from surgeon to surgeon, as do the recommendations regarding how long to wear the ESO.

Despite numerous publications suggesting that fusion is not necessary following ACD,¹⁻⁶ responding surgeons performed a fusion in 93% of cases. Watters and Levinthal⁵ reported that although clinical outcomes for ACD and ACDF were similar at

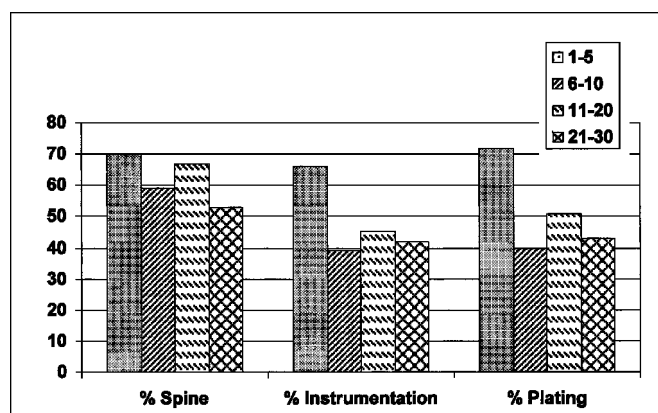


Figure 2: Volume of practice devoted to spine surgery, and frequency of cases in which spinal instrumentation and specifically anterior cervical plates are used, as a function of number of years in practice. Values are expressed as percentages.

three months, fusion resulted in more rapid postoperative resolution of pain. Others have reported that although ACD and ACDF produce similar results in the short-term, longer follow-up demonstrates higher levels of function and patient satisfaction among patients who undergo ACDF than patients who have discectomy alone.^{5,7} This may relate to movement at the operated level in patients who do not develop spontaneous bony fusion. An ACDF may also be used to restore normal cervical lordosis in patients with abnormal alignment at the operative level, as such patients are at risk of further kyphosis if no interbody graft is placed.⁶

Autogenous bone, typically a tricortical graft from the iliac crest, is generally felt to produce higher rates of arthrodesis than grafting with bovine bone or with allograft,⁸⁻¹⁰ although dissenting opinions have been published.¹¹ However, obtaining autologous bone requires a separate incision with distinct morbidity. Harvesting autograft from the iliac crest is associated with decreased mobility in the postoperative period and may produce long-term donor site pain.¹²⁻¹⁵ For a single-level fusion in a nonsmoking patient, similar fusion rates have been reported using autograft and allograft,¹⁶ and the donor site morbidity of autograft may not be justified. Nonetheless, over half of the responding surgeons use autograft exclusively. This may relate to both health care costs and availability of allograft in the universal Canadian health care system. Most respondents indicated that they used a particular technique or choice of bone graft 90-100% of the time, suggesting that each surgeon decides on their preferred method, and subsequently performs ACDF in the same manner for each case, with only minor variations. The correlation between length of time in practice and the use of bovine bone may reflect the period of its introduction and popularization in the 1970s, followed by disillusionment regarding fusion rates and concern about infectious transmission in the 1990s.¹⁷

Canadian surgeons are similar to their colleagues in the United Kingdom with regards to fusion technique and choice of bone graft. A 1998 survey of 118 surgeons in the United Kingdom and Eire who performed ACD found that 96% performed interbody fusion, with most (63%) using autologous bone.¹⁸ Bovine graft was used in 25% of cases, but 15% of surgeons reported abandoning artificial graft materials, including bovine graft, because of concerns about nonunion. The use of anterior cervical plating was not addressed in that survey. It is our impression that surgeons in the United States have notably different practice habits, with allograft and cervical plating being used much more frequently. However, no paper has surveyed or analyzed these trends among American surgeons.

With the advent of instrumentation for the anterior cervical spine, an increasing number of surgeons are electing to place internal fixation routinely following ACDF. Anterior cervical plating is frequently utilized for multilevel discectomies or corpectomies to provide immediate immobilization, buttress the bone graft, reduce the rate of pseudoarthrosis, and improve and maintain cervical alignment.¹⁹⁻²² However, the benefit of plate fixation in single-level degenerative disorders of the cervical spine remains unproven. Several retrospective studies have shown no difference in clinical outcome or rates of successful fusion between patients treated with single-level discectomy and fusion with or without anterior cervical plating.^{19,23,24}

Troyanovich et al²⁵ recently reported that plating preserved overall cervical lordosis following single-level ACDF, but the radiographic findings were not correlated with significant clinical benefit. However, Caspar et al²⁶ reported that in a series of 356 patients, the addition of anterior cervical plating resulted in a lower reoperation rate, presumably due to a stabilizing effect on the bone graft.

Rapoff et al²⁷ showed that in a cadaveric calf spine model, an anterior cervical plate served as a load-sharing device, reducing the magnitude of load transmitted through the bone graft; they contended that this would improve graft consolidation and thereby increase the chance of arthrodesis. This view is supported by a recent retrospective review.²⁸ Kaiser et al²⁸ assessed radiographic evidence of fusion following one- or two-level ACDF with cortical allograft and plate stabilization in 251 patients with cervical disc herniation or spondylosis, as compared to an historical cohort of 289 patients treated with ACDF using cortical allograft without anterior fixation. They found a statistically significant increase in radiographic fusion rates for single-level fusion, from 90% to 96%. The graft-related complication rate was reduced from 6% to 0%, while the plate-related complication rate was only 1.3%. Although this is a retrospective study of consecutive series, and fails to correlate the radiographic evidence of nonfusion with clinical symptoms, it does suggest that anterior cervical plating improves single-level fusion rates. A randomized, double-blinded, controlled study is required to determine the true effect of plating on arthrodesis and clinical outcomes, and the relative benefit with different types of bone graft. Use of allograft and anterior cervical plates raises the cost of ACDF substantially. In a publicly funded health care system such as Canada, it is difficult to justify major additional operative costs without evidence of significant improvement in clinical outcomes.

Despite the lack of definitive clinical or radiographic evidence, many surgeons choose to place an anterior cervical plate following single-level ACDF for degenerative disc disease, with the rationale of avoiding an external spinal orthosis (ESO) in the postoperative period. It is assumed that this will correlate with greater levels of patient satisfaction and an earlier return to activities of daily living or work. However, the cost and potential operative complications associated with cervical plating²⁹ should be weighed against any theorized benefits. Respondents typically had specific indications for placing an anterior cervical plate, although a subgroup of surgeons indicated that they plate as a matter of routine. Training background appears to influence practice in this regard. For orthopedic spinal surgeons, spine surgery accounted for a greater percentage of their practice than it did for their neurosurgical colleagues, and they were also more likely to use instrumentation in their spinal cases. This may result from greater exposure to instrumentation in general during their orthopedic training. Interestingly, although orthopedic surgeons were more likely to employ anterior cervical plating, they were also more likely to recommend ESOs to their patients postoperatively.

The development and evolution of anterior cervical fixation devices has recently been outlined by Haid et al³⁰ who propose a classification system based on the biomechanical properties of the different commercially available systems. Unrestricted plate systems, using nonlocked screws that require bicortical purchase, were the first to be developed but have now become

largely obsolete. The next type of system to be introduced incorporated restricted screw backout by locking the screws to the plate, with a predetermined trajectory and unicortical purchase. These “constrained” systems, including CSLP and Orion, were an improvement in terms of ease of use and decreased screw backout, but the rigidity of the construct decreased the compressive force on the graft, potentially lowering rates of successful fusion.³¹ Most recently, a number of “semi-constrained” plating systems have been developed, in which movement is permitted at the plate-screw interface to allow for controlled graft subsidence. The movement may be rotational in nature, as in the Atlantis, PEAK and Codman systems, translational as in the DOC system, or a combination, as in the ABC and Premier systems.

The respondents in this survey chose constrained and semi-constrained plates in almost equal measure. The popularity of the Atlantis plate may relate to its ability to fulfill multiple biomechanical roles, depending on the choice of screws. It can mimic the fully constrained systems if fixed screws are used throughout; alternately, it can be used as a pivot rotational construct by using variable screws throughout. Finally, a “hybrid” construct can be created, with fixed screws caudally to buttress the plate, and variable screws rostrally permitting some rotational motion as graft subsidence occurs. The system’s flexibility is likely to appeal to surgeons and operating room staff in that purchase and familiarity with only one system still allows for a variety of biomechanical designs to best match the fixation requirements for each individual patient.

Semi-constrained translational devices, in which the screws slide along a rail or slot, were rarely employed. The ABC system, which permits both translational and rotational motion, was the only one reportedly used, and only in 2.3% of cases. No respondents used the similar rotational/translational Premier system, nor the DOC plate which is a true translational system without rotational motion. This may be due to the nature of the survey, with questions pertaining only to the management of single level ACDF for degenerative disease. The relative importance of translation vs. rotation in graft loading and preventing screw backout is unknown.

Traditionally, following either ACD or ACDF, patients have been placed in an ESO for the initial 6-12 weeks of their postoperative course. It is widely believed that such orthoses prevent excessive cervical motion and thereby help to promote bony fusion. However, no biomechanical or clinical evidence validates the need for ESOs following ACDF. A single retrospective study found no significant difference between the rates of fusion in patients who used an ESO postoperatively and those who did not.³² Furthermore, a study comparing various ESOs demonstrated that although cervical-shoulder ESOs restrict some degree of movement in the mid-cervical spine, the amount may be clinically insignificant.³³ The internal stability provided by a plate may be of greater importance. However, this study only weakly supported “avoiding collar use” as a rationale for plating. The presence of a plate did decrease the rate of ESO use, but 61% of the patients who received plates were still required to wear an ESO. A number of surgeons indicated that they routinely required patients to use a collar following ACDF with plating, and the presence of a plate did not significantly reduce the length of ESO use.

All surveys suffer from possible reporting bias, and difficulty in obtaining an adequate response rate. We compiled our list of surgeons from membership information for the North American Spine Society, Canadian Spine Society, and the Canadian Congress of Neurological Sciences. The Canadian Orthopedic Association was not included in the survey, on the assumption that orthopedic surgeons with an interest in spinal surgery would be captured by their membership in the other organizations. It is possible that we thereby missed surveying some spinal surgeons with an orthopedic background, producing a relatively disproportionate sampling of neurosurgeons; however, orthopedic surgeons were still well-represented. Of the 159 surgeons approached, a total of 101 responded, although only 60 indicated that they performed enough spinal surgery (at least 5% of their practice) to provide meaningful data in the questionnaire. The total response rate was thus 63%, while the group analyzed constituted 40% of those approached. This is within accepted limits for a mail survey.

Drew et al³⁴ have also recently reported on Canadian spinal surgeon preferences in anterior cervical discectomy for both single- and two-level disease. Their survey methodology differed somewhat from ours: they chose a one-page fax survey, which maximized the response rate (70%) but limited the number of questions that could be asked. They surveyed a random sample of 76 surgeons and found fusion was performed by 90.5% of the 53 responding surgeons.³⁴ Orthopedic surgeons were more likely than neurosurgeons to employ the Smith-Robinson technique (94% vs. 64%), use autograft (100% vs. 53%), plate (47% vs. 22%), and recommend postoperative collars (94% vs. 72%). Orthopedic surgeons were also more likely to have undertaken formal fellowship training in spinal surgery. Our survey generally validates the information reported to date, but contributes additional information regarding practice patterns. We obtained responses from a higher proportion of younger surgeons – only 17% of respondents in the previous study had been in practice for over 10 years, as compared to 45% of our respondents. This may account for the fact that a higher percentage of our neurosurgical respondents were placing instrumentation, using the Smith-Robinson technique, and favouring autograft. Due to the different nature of our survey, we were also able to obtain more detailed information regarding collar use as related to the type of fusion performed, the specific plate types and systems used, and most importantly, the reasons underlying such practice choices as instrumenting or using autograft.

Finally, it must be noted that this survey focused on present surgical practice, but made no enquiry into clinical or radiographic outcomes. It presents a “snapshot” of how spinal surgeons in Canada are currently managing single-level degenerative disc disease, but cannot provide information on which methods produce superior results. Common practices do not always reflect the most cost-effective or clinically superior practices. There are no multi-centre, randomized controlled trials available to support one technique over another, nor are any such likely to be undertaken, given that the literature suggests that excellent clinical results may be obtained with any of the different techniques currently in use. Perhaps the most valuable insight gained from this survey is that most surgeons employ a single technique, graft or plate time after time: they choose one

method and use it near-exclusively. In other words, differences in technique persist not because they best address the variability of the disease process or variability among patients, but rather because there is variability among surgeons and their training.

ACKNOWLEDGEMENTS

The authors thank Dr. Volker Sonntag, and Kelly Dadurka for their valuable contributions to the design of the questionnaire.

REFERENCES

- Dowd GC, Wirth FP. Anterior cervical discectomy: is fusion necessary? *J Neurosurg* 1999; 90:8-12.
- Savitz MH. Anterior cervical discectomy without fusion or instrumentation: 25 years' experience. *Mt Sinai J Med* 2000; 67:14-17.
- Savolainen S, Rinne J, Hernesniemi J. A prospective randomized study of anterior single-level cervical disc operations with long-term follow-up: surgical fusion is unnecessary. *Neurosurgery* 1998; 43:51-55.
- Sonntag VK, Klara P. Controversy in spine care: is fusion necessary after anterior cervical discectomy? *Spine* 1996; 21:1111-1113.
- Watters WC 3rd, Levinthal R. Anterior cervical discectomy with and without fusion. Results, complications, and long-term follow-up. *Spine* 1994; 19:2343-2347.
- Yamamoto I, Ikeda A, Shibuya N, Tsugane R, Sato O. Clinical long-term results of anterior discectomy without interbody fusion for cervical disc disease. *Spine* 1991; 16:272-279.
- Thorell W, Cooper J, Hellbusch L, Leibrock L. The long-term clinical outcome of patients undergoing anterior cervical discectomy with and without intervertebral bone graft placement. *Neurosurgery* 1998; 43:268-273.
- Bishop RC, Moore KA, Hadley MN. Anterior cervical interbody fusion using autogeneic and allogeneic bone graft substrate: a prospective comparative analysis. *J Neurosurg* 1996; 85:206-210.
- Floyd T, Ohnmeiss D. A meta-analysis of autograft versus allograft in anterior cervical fusion. *Eur Spine J* 2000; 9:398-403.
- Lofgren H, Johannsson V, Olsson T, Ryd L, Levander B. Rigid fusion after Cloward operation for cervical disc disease using autograft, allograft, or xenograft: a randomized study with radiostereometric and clinical follow-up assessment. *Spine* 2000; 25:1908-1916.
- Savolainen S, Usenius JP, Hernesniemi J. Iliac crest versus artificial bone grafts in 250 cervical fusions. *Acta Neurochir (Wien)* 1994; 129:54-57.
- Aronson N, Filtzer DL, Bugan M. Anterior cervical fusion by the Smith-Robinson approach. *J Neurosurg* 1968; 29:397-404.
- Arrington ED, Smith WJ, Chambers HG, Bucknell AL, Davino NA. Complications of iliac crest bone graft harvesting. *Clin Orthop* 1996; 329:300-309.
- Goulet JA, Senunas LE, DeSilva GL, Greenfield ML. Autogenous iliac crest bone graft. Complications and functional assessment. *Clin Orthop* 1997; 339:76-81.
- Schnee CL, Freese A, Weil RJ, Marcotte PJ. Analysis of harvest morbidity and radiographic outcome using autograft for anterior cervical fusion. *Spine* 1997; 22:2222-2227.
- Malloy KM, Hilibrand AS. Autograft versus allograft in degenerative cervical disease. *Clin Orthop* 2002; 394:27-38.
- Wenz B, Oesch B, Horst M. Analysis of the risk of transmitting bovine spongiform encephalopathy through bone grafts derived from bovine bone. *Biomaterials* 2001; 22:1599-1606.
- Harland SP, Laing RJ. A survey of the peri-operative management of patients undergoing anterior cervical decompression in the UK and Eire. *Br J Neurosurg* 1998; 12:113-117.
- Epstein NE. Anterior cervical discectomy and fusion without plate instrumentation in 178 patients. *J Spinal Disord* 2000; 13:1-8.
- Epstein NE. Reoperation rates for acute graft extrusion and pseudoarthrosis after one-level anterior corpectomy and fusion with and without plate instrumentation: etiology and corrective management. *Surg Neurol* 2001; 56:73-80.
- Katsuura A, Hukuda S, Imanaka T, Miyamoto K, Kanemoto M. Anterior cervical plate used in degenerative disease can maintain cervical lordosis. *J Spinal Disord* 1996; 9:470-476.
- Wang JC, McDonough PW, Endow KK, Delamarter RB. Increased fusion rates with cervical plating for two-level anterior cervical discectomy and fusion. *Spine* 2000; 25:41-45.
- Connolly PJ, Esses SI, Kostuik JP. Anterior cervical fusion: outcome analysis of patients fused with and without anterior cervical plates. *J Spinal Disord Tech* 1996; 9:202-206.
- Wang JC, McDonough PW, Endow KK, Kanim LE, Delamarter RB. The effect of cervical plating on single-level anterior cervical discectomy and fusion. *J Spinal Disord* 1999; 12:467-471.
- Trojanovich SJ, Stroink AR, Kattner KA, Dornan WA, Gubina I. Does anterior plating maintain cervical lordosis versus conventional fusion techniques? A retrospective analysis of patients receiving single-level fusions. *J Spinal Disord Tech* 2002; 15:69-74.
- Caspar W, Geisler FH, Pitzen T, Johnson TA. Anterior cervical plate stabilization in one- and two-level degenerative disease: overtreatment or benefit? *J Spinal Disord* 1998; 11:1-11.
- Rapoff AJ, O'Brien TJ, Ghanayem AJ, Heisey DM, Zdeblick TA. Anterior cervical graft and plate load sharing. *J Spinal Disord* 1999; 12:45-49.
- Kaiser MG, Haid RW, Subach BR, Barnes B, Rodts GE. Anterior cervical plating enhances arthrodesis after discectomy and fusion with cortical allograft. *Neurosurgery* 2002; 50:229-236.
- Bose B. Anterior cervical fusion using Caspar plating: analysis of results and review of the literature. *Surg Neurol* 1998; 49:25-31.
- Haid RW, Foley KT, Rodts GE, Barnes B. The Cervical Spine Study Group anterior cervical plate nomenclature. *Neurosurg Focus* 2002; 12(1):Article 15.
- Lowery GL, McDonough RF. The significance of hardware failure in anterior cervical plate fixation. Patients with 2- to 7-year follow-up. *Spine* 1998; 23:181-187.
- Cauthen JC, Kinard RE, Vogler JB, et al. Outcome analysis of noninstrumented anterior cervical discectomy and interbody fusion in 348 patients. *Spine* 1998; 23:188-192.
- Johnson RM, Owen JR, Hart DL, Callahan RA. Cervical orthoses: a guide to their selection and use. *Clin Orthop* 1981; 154:34-45.
- Drew B, Bhandari K, Orr D, Reddy K, Dunlop RB. Surgical preference in anterior cervical discectomy: a national survey of Canadian spine surgeons. *J Spinal Disord Tech* 2002; 15:454-457.