B-Scan Ultrasonic Measurement of the Lumbar Spinal Canal as a Predictor of Industrial Back Pain Complaints and Extended Work Loss

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B-scan ultrasonic measurements of lumbar spinal canal diameter were examined as predictors of industrial back pain complaints and extended work loss. Baseline data were collected on 3,020 Washington State aircraft manufacturing workers, and over a mean 3.7-year follow-up period 352 subjects reported industrial back pain complaints. Mean canal measurements of subjects with industrial back pain complaints were smaller at all spinal levels than in subjects without complaints. The mean differences between the groups, however, were extremely small (0.07 mm to 0.51 mm), and not all levels were statistically significant. The relative risk for an L5-S1 measurement 2 standard deviations below the mean was 1.4, yet the measurement explained less than 1% of the uncertainty in predicting complaints. No association was found between canal measurements and claims with extended work loss of greater than one month. The imprecision of the measurements and poor predictive ability indicate that B-scan ultrasonography, as used in this study, is of dubious screening value.

Among the first to study the relationship between the size of the lumbar spinal canal and clinical symptoms were Sarpyener[1] and Verbiest.[2-5] They concluded that relatively narrow canals were associated with symptoms such as neurogenic intermittent claudication and disturbances from potentially compressive agents, such as herniated intervertebral discs. Since then interest in the clinical relevance of spinal stenosis has grown, and it is now the most common diagnosis associated with spinal surgery in Americans over 64 years of age (R. A. Deyo, personal communication).

When Verbiest and Sarpyener began studying the association between canal size and symptoms, diagnostic technology did not allow measurement of the canal through non-invasive, radiation-free means. Thus, measurements were practical in the diagnostic examinations of some patients, but not for general population studies or screening. In 1978, Porter et al[7] introduced a technique for measuring spinal canal diameter with ultrasonography, which overcame several disadvantages of earlier techniques.

Using ultrasonography, Porter and coworkers[8] found that 55% of patients with symptomatic lumbar disc herniations had canal measurements below the fifth percentile of asymptomatic subjects. They concluded that the risk of developing symptomatic disc problems was inversely related to the size of the canal. On this basis, they suggested that consideration be given to screening adolescents, and that indi-

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0096-1736/93/3512-1250$03.00/0

viduals with narrow canals could be offered vocational counselling and ergonomic assistance.

Macdonald and colleagues[9] were the first to study the effect of canal diameter on workplace absenteeism due to back problems. They reviewed absenteeism records for 204 miners and for the 3 years before and 3 years after ultrasonographic measurement of canal diameter. They reported a significant relationship between smaller canals and previous back symptom reports and greater resultant absenteeism. Subjects with canals in the lowest tenth percentile had a history of significantly more absenteeism than did subjects with larger canals. Unfortunately, a significant reduction in the labor force hampered analysis of the prospective portion of the study. The investigators concluded that preemployment measurement of the spinal canal by ultrasound might identify workers at risk for significant back problems. They recommended, however, that further prospective study of the significance of canal size in back problems be undertaken before using such measurements in the selection of workers.[9] Later, Anderson, Chovil, and colleagues,[10,11] using a similar ultrasound technique, found an association between canal diameter and a history of work loss because of back problems in a small group of hospital employees. The view that spinal canal size has implications for back problems among workers has been voiced by others.[12] One author went so far as to term lumbar stenosis "an occupational hazard."[13]

The studies previously reported have been cross-sectional or retrospective. The present study is a prospective investigation into the effect of spinal canal diameter, as measured through B-scan ultrasonography, on the occurrence of industrial back pain complaints and related disability of one month or greater.

Materials and Methods

Subjects

All employees receiving hourly wages at one of the Boeing Company's aircraft plants in Washington State were invited to participate in a prospective study of risk factors for back pain. The 3,020 volunteers represented 75% of employees solicited. The subjects included 2,350 men and 670 women, from 21 to 67 years of age. No one who volunteered to participate was excluded for any reason.

Physical Examination and Questionnaire Data

After informed consent was obtained from the volunteers, each was taken through a standardized physical examination by one of three physical therapists. In addition to ultrasonography to determine the diameter of the lumbar spinal canal, the examinations included assessments of basic anthropometric measures, lifting strength, flexibility, and estimated aerobic capacity. A general low back examination also was performed, including assessment of lower extremity reflexes and straight leg raise testing. After the physical examination, subjects were given a take-home packet of questionnaires that requested medical history, demographic, and psychosocial information. Analyses of these data as predictors of back pain reporting have been published elsewhere.[14-19]

Determining Canal Diameter (B-Scan Ultrasonography)

The technique used to obtain the ultrasound images of the lumbar spinal canal was similar to that described by Porter et al,[7] with the exception that measurements were obtained directly from a B-scan rather than an A-scan. A General Electric Dataline portable ultrasound real-time scanner was used. The 3.5-MHz transducer was placed 1 cm from the midline of the back and was angled approximately 15° medially to obtain the clearest image possible. Measurements were obtained from the images by two of the investigators (TH, MCB).

We conducted an investigation of the B-scan technique used in this study, which was reported earlier,[22] and found measurement errors to be approximately double those previously reported for the technique using A-scan.[7,20,21] The two readers in the present study were among the three readers who participated in the earlier investigation of measurement reproducibility. The mean error due to interobserver variations ranged from 0.9 mm to 1.5 mm depending on spinal level, with reproducibility greater at the higher levels. Interobserver error was responsible for most of the variation in readings. Ultrasound images of the lower levels also were more frequently deemed unreadable than the upper lumbar levels. The variability in readings due to differences between subjects, however, was consistently greater than the variability due to measurement error. Thus, if even moderate associations exist between low back symptom reports and canal size, they should be revealed when studying large groups of subjects, such as in the current study.

Monitoring Back Pain Reporting and Absenteeism

The subjects were tracked from the time of their intake physical examinations, from July of 1982 through September of 1983, until the end of December of 1987, for reports of back pain via the company medical and safety departments or the filing of an industrial insurance claim. Subjects were tracked for a mean 3.7 years, only during their employment with the Boeing Company's aircraft division. During this period 352 subjects reported back pain complaints. The ultrasound measurements then were examined as predictors of back pain complaints in industry.

The baseline data also were examined as predictors of extended work loss back injury claims. Independent recording systems used by the Boeing Company and their insurance carrier to monitor industrial insurance back injury claims occurring during the follow-up period were cross-referenced to identify claims resulting in 1 month or more of time loss. Forty-eight such claims of extended work loss occurred.

Data Analysis

The occurrence of an industrial back pain complaint is complicated

by a variable exposure time for different study subjects. This variation occurred because of subject enrollment over time, layoffs, resignations, and so forth. Thus, the statistical methods of time to event or survival analysis were used.[23] The univariate predictive value of continuous variables, such as the ultrasound measurements, was analyzed using the Cox proportional hazards regression model. Discrete variables were tested by comparing subsets with life tables and log-rank statistics.

Multivariate predictive models were constructed using Cox step-up stepwise proportional hazards regression. Age was included in the analysis because it correlated with the ultrasound measurements, and younger employees were more likely to file industrial back pain complaints.[16] The straight leg raise test (SLR), recording whether or not symptoms were elicited, also was included because in previous analyses it was the only physical examination variable to show a strong association with subsequent reporting.[17,19] Use of information theory made it possible to quantify the amount of information for predicting a back pain report from each variable considered.[6] From these estimates, Venn diagrams were constructed to display graphically the relative amounts of predictive power of the variables, and the amount of overlap in predictive information.

Results

Similar to an earlier study of the ultrasound technique,[22] the upper lumbar levels were more frequently deemed readable than the lower levels (Table 1). For this reason, only 47% of subjects had measurements recorded for the L5-S1 level, which was read the least frequently. Conversely, measurements were available for 82% of subjects at the L2-L3 level. The incidence of industrial back pain complaints was similar for subjects with and without available measurements ($P = .70$, L5-S1 level).

Measurements of each spinal level, as obtained from both the right and left sides, were considered univariately as predictors of industrial back pain complaints. At all spinal levels measured, the mean canal measurements were smaller for subjects filing back pain complaints than for subjects without complaints. These mean differences, however, were extremely small, ranging from 0.07 mm to 0.51 mm. The differences reached statistical significance only for levels L3-L4, L4-L5, and L5-S1, as measured from the left side (Table 2). The difference at L1-L2, as measured from the right side, had the same magnitude and significance as the L3-L4 difference shown in Table 2.

Ultrasound measurements within subjects were strongly correlated, with pairwise correlations between levels ranging from 0.76 to 0.87 at the lower levels. For subjects to be included in the multivariate analysis, measurements were required at every level considered, so it was desirable to select a representative ultrasound measurement. The L5-S1 level measurement was chosen because it was the only ultrasound variable to enter into a predictive model, when included in a preliminary multivariate analysis of age, SLR, and ultrasound data. Men and women were analyzed together because there were no effects of gender or interactions with other variables of interest. The final multivariate analysis was performed on a subset of 1,339 subjects (44% of study population, 153 subjects with back pain reports and 1,186 without) with valid data for all variables of interest, including SLR, age, and L5-S1 measurement. In this analysis, back pain elicited on SLR ($P = .003$), younger age ($P = .002$), and narrower canals ($P = .05$) were associated with future reporting.

The relative risk of reporting an industrial back pain complaint for a person with an L5-S1 measurement 2 standard deviations below the mean, as compared with someone at the mean, was 1.4. Yet, the L5-S1 canal diameter measurement explained less than 1% of the uncertainty in predicting who would or would not go on to report an industrial back pain complaint. The predictive information provided by age or SLR was slightly greater (Fig. 1). There were canal diameter measurements available for 21 to 42 of the subjects with extended work loss, depending upon the level considered. Canal measurements were

TABLE 1
Spinal Canal Measurements (cm) Acquired from B-Scan Ultrasonography

	Level	Subjects*	Mean	S.D.	10th Percentile	90th Percentile
Men (n = 2,350)						
Right side	L1-L2	1643	1.57	0.18	1.35	1.80
	L2-L3	1937	1.54	0.20	1.28	1.78
	L3-L4	1793	1.52	0.21	1.25	1.75
	L4-L5	1413	1.45	0.23	1.15	1.73
	L5-S1	1054	1.45	0.25	1.13	1.75
Left side	L1-L2	1681	1.57	0.18	1.35	1.80
	L2-L3	1921	1.53	0.20	1.28	1.78
	L3-L4	1771	1.51	0.20	1.25	1.75
	L4-L5	1401	1.45	0.23	1.15	1.75
	L5-S1	1016	1.46	0.24	1.15	1.75
Women (n = 670)						
Right side	L1-L2	468	1.63	0.17	1.40	1.83
	L2-L3	554	1.58	0.19	1.33	1.80
	L3-L4	534	1.56	0.19	1.30	1.80
	L4-L5	390	1.47	0.21	1.20	1.75
	L5-S1	352	1.44	0.23	1.10	1.73
Left side	L1-L2	466	1.62	0.17	1.40	1.83
	L2-L3	553	1.58	0.19	1.33	1.80
	L3-L4	537	1.56	0.19	1.30	1.80
	L4-L5	401	1.47	0.22	1.17	1.75
	L5-S1	343	1.44	0.24	1.11	1.74

* The number of subjects were those from the total study population of 2,350 men and 670 women who had readable B-scans at the level noted.

TABLE 2
Spinal Canal Measurements (cm) for Subjects with and without Industrial Back Pain Reports

Level	No Reports			Back Pain Reports			Mean Difference	No Reports vs Back Pain Reports (95% CI)	P
	Mean (cm)	SD	No.	Mean (cm)	SD	No.			
L3-L4	1.53	0.20	2,031	1.50	0.21	277	0.03	0.001, 0.054	0.035
L4-L5	1.46	0.23	1,599	1.42	0.23	203	0.04	0.004, 0.070	0.031
L5-S1	1.46	0.24	1,204	1.41	0.24	155	0.05	0.011, 0.091	0.012

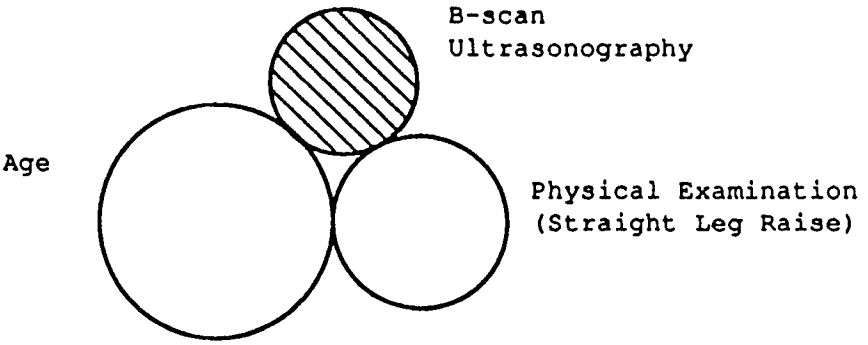

Fig. 1. The size of the circles of this Venn diagram represent the relative amounts of information provided by each variable for predicting industrial back pain complaints.

not predictive of industrial claims resulting in extended work loss (Table 3).

Discussion

It is generally accepted that many factors influence back symptom complaints, and the findings of this investigation support earlier studies indicating that spinal canal diameter may be one such factor.[24,25] The association with industrial back pain complaints identified in this study, however, is very weak, and B-scan ultrasonography demonstrated no practical value in identifying persons at risk. The relatively insignificant information gained from B-scan ultrasonography of the lumbar spinal canal in predicting future industrial back pain reports is put into greater perspective by comparing it to results from a more comprehensive multivariate predictive model previously reported (Fig. 2). This model included the study variables that had been found to be highly associated with back pain reporting[18]: a history of medical treatment for pain problems, psychological distress, job dissatisfaction, and back symptoms elicited on SLR.

This investigation studied industrial back pain complaints, rather than specific clinical pathology, in relation to canal diameter. In the vast majority of back pain reports in industry and in doctors' offices, there is no verifiable pathology.[26] Instead, the problem is defined by symptom complaints. Evidence is growing that psychosocial factors play an important role in such complaints. Cultural norms,[10,27,28] socioeconomic conditions and opportunities for compensation,[29-32] emotional distress,[18] job satisfaction,[18] and the work environment[33-36] are among the many nonmedical factors of likely importance to the onset and persistence of back pain complaints and disability. Such factors may be of even

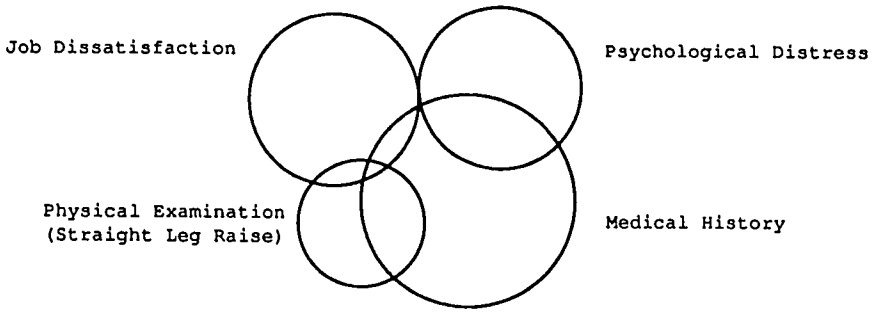

Fig. 2. This Venn diagram displays the relative predictive power of other factors that were found to be of value in predicting back pain complaints in the same study population using a multivariate model. An overlap of circles represents an overlap in predictive information between variables. For comparison of Figs. 1 and 2, the scales are the same.

TABLE 3
Spinal Canal Measurements (cm) for Subjects with and without Extended Time Loss Back Pain Reports

Level	No Work Loss > 1 mo			Back Pain Reports with Work Loss > 1 mo			Mean Difference	No Reports vs Back Pain Reports (95% CI)	P
	Mean (cm)	SD	No.	Mean (cm)	SD	No.			
L3-L4	1.52	0.20	2,266	1.54	0.18	42	−0.02	−.073, .040	0.604
L4-L5	1.45	0.23	1,776	1.49	0.25	26	−0.04	−.132, .059	0.428
L5-S1	1.45	0.24	1,338	1.49	0.22	21	−0.04	−.137, .052	0.415

more importance in disability behavior, as defined through extended work loss. Considering the complex nature of back pain reporting, and the potentially wide spectrum of aging and pathologic processes underlying symptoms, it is not surprising that one physical factor has such a small role in back symptom complaints in industry. The imprecision of the B-scan measurement technique also may dilute the association of canal width to back pain reporting, although it is doubtful that such imprecision would mask a major effect.

The predominant theory as to why spinal canal diameter may be a risk factor for back symptoms relates to the canal's volume, or reserve capacity. If the spinal canal has a relatively small reserve capacity because of soft tissue or bony configuration, then the chances for symptomatic neural or vascular compromise may be greater. For example, in a relatively narrow canal, a space occupying lesion such as a herniated disc may be more likely to cause symptoms. This theory is consistent with the study finding that the lower spinal levels (L3-L4, L4-L5, L5-S1) were most often associated with back pain complaints. Symptomatic disc hernias most frequently occur at the lower lumbar levels. It is puzzling that this association occurs for measurements obtained from the left side of the spine, but not from the right. We have no rational biologic explanation for this discrepancy, which may be related to the technique of acquiring images. In our study, ultrasonography was conducted with subjects lying supine on a pillow-roll to decrease lumbar lordosis, with the examiner standing to the subjects' left. We can only speculate that a subtle variation in the technique, perhaps related to the examiners' position, may have had some effect on the images obtained.

Smaller measures were obtained with the B-scan technique than those reported earlier by Porter, but the difference is systematic and present at all spinal levels. Thus, evaluation of the effects of relative canal size should not have been affected. However, the study had several limitations related to the ultrasound technique. First, measurements were unavailable for a high percentage of subjects because of difficulties with readability. Yet, back symptom reporting was similar among subjects with and without measurements, diminishing concerns that the study sample is biased with regard to the outcome of symptom complaints. However, as this study is prospective, it would still be valid for the population with readable measurements. Second, the measurement technique provides a relative estimate of canal size, but lacks precision. The B-scan technique has a greater mean measurement error than other ultrasound techniques reported in the literature. Reports of inter-reader measurement reproducibility have varied from 0.2 mm to 0.5 mm when images were obtained with the B-mode and actual measurements taken from the A-mode.[7,20,21] Our earlier investigation of measurements obtained directly from the B-mode indicate that measurement reproducibility through this technique is less precise than when the A-mode is used, with B-scan measurement error ranging from 0.9 mm to 1.5 mm.[22] However, if canal size played a major role in back symptom reporting in industry, an association of greater magnitude than that found in the study would have been expected. But it is possible that measurement error may have diluted the association.

In summary, B-scan ultrasonography, as used in this study, would be of no practical value in predicting risk of industrial back pain complaints in workers involved in light to moderate physical activities. Moreover, there was no indication that narrower canal measurements are associated with greater risk of extended work loss claims.

Acknowledgments

This research was supported by The National Institutes of Health (NIH), The National Institute of Occupational Safety and Health (NIOSH), and The Volvo Education and Research Foundations.

We thank Alf Nachemson, Wilbert Fordyce, Jan Lamers, Mark Wortley, and Douglas Mounce for their contributions.

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Only in America

Kavin Gill said he and another employee of DeBest, Inc, had to act quickly to rescue a man buried after a dirt wall collapsed on him. "We could hear muffled screams . . ." Gill said. "His shoulders were pinned. . . . I think he would have died."

But the federal Occupational Safety and Health Administration doesn't see it that way and is fining [DeBest] nearly $7,875 in the . . . incident at a . . . construction site. OSHA said it levied the fines because workers failed to put on hard hats and took no precautions against other trench walls falling on them. . . .

Senator Dirk Kempthorne (R-Idaho) called the citation against DeBest "unconscionable". . . Idaho OSHA director Ryan Kuemichel said it would be "selective enforcement" if he did not cite DeBest. "Rescues must only be attempted after taking proper precautions to ensure that would-be rescuers are not injured in secondary cave-ins," wrote Kuechel. Kempthorne said . . . he is drafting legislation that would exempt acts of heroism from OSHA fines.

From Keeping Up by D. Seligman in *Fortune* 1993;128:5, p 127 (September 6, 1993) (from a news report in the Idaho *Statesman*).