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Surgical Results in Hidden Lumbar Spinal Stenosis Detected by Axial Loaded Computed Tomography and Magnetic Resonance Imaging

An Outcome Study

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Study Design. An outcome study of patients with neurogenic claudication and/or sciatica with hidden stenosis, detected only by axial loading of the lumbar spine (ACE) but not at the traditional unloaded examination (psoas relaxed position) during computed tomography (CT) myelography or magnetic resonance imaging (MRI), followed up after surgery.

Objective. To estimate the clinical effect of decompression with or without fusion in patients with hidden stenosis in the lumbar spine.

Summary of Background Data. A number of patients with neurogenic claudicatio with or without sciatica do not have corresponding imaging abnormalities. Axial loaded CT and MRI have disclosed hidden stenosis in certain cases. The surgical effect in patients with hidden stenosis has never been described.

Methods and Materials. Axial loading of the lumbar spine during CT and MRI was performed in 250 patients with neurogenic claudication and sciatica. All fulfilled the inclusion criteria for ACE, *i.e.*, suspected but not verified spinal stenosis in 1 to 3 levels. In 125 patients (50%), a significant narrowing of the spinal canal occurred. Out of these 125 patients, 101 had a clear stenosis besides the stenosis only detected at ACE. In 24 patients, a hidden stenosis was detected in 1 to 3 levels only at the ACE. These patients were observed for 1 to 6 years after decompression with or without fusion regarding subjective improvement of leg and back pains, walking capacity, satisfaction, and health related quality of life.

Results. At follow-up, 76% of the patients had leg pain less than 25/100 on a VAS scale and 62% had back pain less than 25/100. Ninety-six percent were improved or much improved regarding leg and back pains The ability to walk increased significantly after surgery. Walking capacity to more than 500 m increased from 4% to 87%. Twenty-two patients were subjectively satisfied with the surgical results. The ODI score, the SF-36 and the EQ-5D score corresponded well to the above mentioned improvements at follow-up.

Conclusion. According to this study, the results of surgery in hidden lumbar stenosis only detected by axial compression in extension during CT or MRI, are convincing and comparable with the results of surgical treatment for stenoses diagnosed by unloaded examinations.

Key words: MRI, axial loaded, lumbar spine, stenosis, sciatica. **Spine 2008;33:E109–E115**

Individuals with lumbar spinal stenosis frequently report clinical symptoms such as neurogenic claudication or sciatica with or without low back pain. These symptoms are regularly induced by walking, standing, or hip extension. Typically the symptoms decrease during forward flexion, squatting, or lying supine with flexion in hips and knees. In certain patients with clinical signs of spinal stenosis, no corresponding imaging abnormalities can be shown at the traditional unloaded computed tomography (CT) myelographic or magnetic resonance imaging (MRI).

To increase the diagnostic sensitivity in such patients, a device (DynaWell L-spine, DynaWell Inc. Las Vegas, USA) was developed by which the lumbar spine could be loaded to simulate the upright standing position[1–3] *i.e.*, the position in which the spinal stenosis symptoms regularly occur.

A study on healthy individuals has shown that a load of 50% of the subjects' body weight applied by this compression device in supine position can morphologically simulate the lumbar spine in upright position.[4]

The use of the device (DynaWell L-spine) might cause a significant narrowing of the spinal canal, *i.e.*, an apparent accentuation of a suspected but not verified spinal stenosis in several patients when compared with the routine CT and MRI techniques.[1–3,5–8] However, no study has attempted to determine the influence of these imaging findings on the surgical results after decompression with or without fusion. Outcome studies with axial loading at imaging have been looked for to evaluate the full clinical value of this technique.[9]

The purpose of the present study was to evaluate if a hidden lumbar spinal stenosis in patients with neurogenic claudication and/or sciatica only detected by axial loaded CT myelography or MRI can be successfully treated with decompression with or without fusion.

■ Materials and Methods

At our clinic, 250 individuals with clinical signs of neurogenic claudication and/or sciatica, *i.e.*, a disabling leg pain with or

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Figure 1. Patient in a supine slightly extended position (with a small pillow under the lumbar spine) during axial compression. The device consists of a harness attached to a nonmagnetic compression part by nylon straps which are tightened to axially load the lumbar spine. By tightening or loosening the adjustment knobs on the foot plates, the load can be regulated and equally distributed on the legs.

without back pain that worsened at walking and standing, fulfilled the inclusion criteria for axial loaded imaging in extension (ACE)[3] and were examined between 1996 and 2002. The inclusion criteria for ACE have previously been decided as: A dural sac cross sectional area of less than 110 mm^2 in one or more levels with a suspected but not verified central and/or lateral canal stenosis during unloaded imaging [psoas relaxed position (PRP)]. The indications also included situations where a suspected nerve root compression by thickening of the ligamentum flavum, a bulging disc, or a suspected synovial cyst were noted. These criteria were, according to our previous experience, mandatory to follow to get optimal results at the ACE examination.[3]

Every examination of a patient with a suspected encroachment of the spinal canal started with a conventional investigation in PRP to avoid loading of an osteoporotic or fractured spine or a spine with skeletal malignancy representing contraindications for loading.

The CT examinations were performed on a Somatom Plus S unit (Siemens, Erlangen, Germany). Before the CT examination, 3 to 6 mL of iohexol (180 mg/mL) (Omnipaque; Nycomed, Amersham) was injected intrathecally. The CT examination was performed approximately 30 minutes after the contrast injection.

The MRI was performed on a 1-T system using a surface coil. Routine MRI consisted of axial T2-weighted (4200–8249/119–130/2–3 [TR/TE/number of excitations]) and/or T1-weighted (583–960/12–15/2–3) turbo spinecho sequences, with an imaging matrix of 210–256 × 256, field of view of 188–285 × 188–285 mm, and section thickness of 4 mm with an intersection gap of 0.4 mm. For the routine CT and MR imaging, the patient was placed supine with slight hip flexion and with a small pillow under the knees.

After the routine imaging, axial loading was applied by using a United States Food and Drug Administration approved commercially available device (DynaWell L-spine) (Figure 1). This device comprises of a nonmagnetic harness or jacket with straps connected to a footplate and a compression mechanism. The harness or jacket was applied to the patient before he or she entered the CT or MRI unit, but no loading was applied during the routine imaging.

At the axial loaded imaging (ACE) shown in Figure 1, the patient was lying in a supine position with a small pillow under the lumbar spine to retain the lumbar lordosis. The feet were

Table 1. Preoperative Data

			CSA (mm^2) Diff PRP-ACE			Lateral Recess Stenosis at ACE				
EM and Pat. No.	Symptom CL/SCI	Walk Distance (Grade)	L3–L4	L4–L5	L5–S1	L3–L4	L4–L5	L5–1	Syn. Cyst	Disc Hern
CT 9	1/0	1	80–60	80–60		1	1			
CT 10	0/1	2			110–70					1
CT 11	1/1	1		80–45			1			
CT 12	1/1	1		70–45			1			
MR 2	0/1	2					1			
MR 3	1/1	1	110–90	110–90		1	1			
MR 4	1/0	2		80–50			1			
MR 6	0/1	2					1			
MR 7	1/1	1		100–70			1			
MR 8	0/1	1		85–65			1			
MR 13	1/1	1	80–60	80–60		1	1			
MR 14	1/0	2		80–50			1			
MR 15	1/1	2		75–55			1			
MR 16	1/1	2	−105	−100		1	1			
MR 17	1/0	1		80–55			1			
MR 18	1/1	2	90–60	70–45		1	1			
MR 19	1/1	1	90–50	90–50		1	1			
MR 20	0/1	1		95–75			1			1
MR 21	0/1	2					1	1		
MR 22	1/1	1	−100				1		1	
MR 23	1/1	1		80–60		1	1			
MR 24	0/1	1							1	
MR 25	0/1	3	−110				1		1	
MR 26	1/1			75–50			1			

Walk distance: <100 m = 1, 100–500 m = 2, 500–1000 m = 3, >1000 m = 4.
EM indicates examination method; NCL, neurogenic claudication; SCI, sciatica; CSA, dural sac cross-sectional area; PRP, unloaded psoas-relaxed position; ACE, axial loading in extension; Syn cyst, synovial cyst; Disc hern, disc herniation.

placed against the footplate and axial load was applied by stretching the side traps by turning adjustment knobs on the foot plate. We applied a load corresponding to 40% to 50% of the patient's body weight distributed equally to both legs according to recommendations in previous studies.[10,11] The load was applied for 5 minutes, and then sagittal T1 and axial T1- and T2-weighted MR images were obtained. The patients were instructed to take their regular pain medication, and we routinely did not use additional pain medication.

Additional valuable information (AVI) obtained from the axially loaded examination was defined as (1) a significant reduction of the dural sac cross sectional area of more than 15 mm^2 to an area less than 75 mm^2 (the border-line value for canal stenosis according to Schönström *et al*[12]) from unloaded to loaded examination or (2) a suspected central or lateral recess stenosis caused by a bulging disc, thickening of the ligamentum flavum, a synovial cyst, or a disc herniation at the unloaded examination that changed to an obvious manifestation at the loaded examination.

AVI was found in 125 out of 250 patients fulfilling the inclusion criteria for axial loading (ACE). In 101 of these 125 individuals, a previously hidden stenosis was disclosed in 1 to 2 disc levels, in addition to apparent stenoses present at the unloaded examinations. These patients were excluded from the study.

In 24 patients (9.6% of all 250 patients), a hidden stenosis was disclosed in 1 to 3 disc levels, whereas no stenosis was detected at any level on the unloaded PRP examination.

There were 12 males and 12 females. Age range was 31 to 76 years (mean 55 years). Four patients were examined with CT myelographic technique and 20 patients with MRI.

Among the 24 patients studied, 16 predominantly had neurogenic claudication and 8 had mainly sciatica (Table 1). Fourteen of the 16 patients with neurogenic claudication showed a significant decrease of the DCSA below 75 mm^2 at ACE (Figures 2A, B and 4A, B). Among the other 8 patients with sciatica, an increased disc herniation were noted in 2, an increasing synovial cyst were noted in 3 (Figure 3A, B) and a lateral recess stenosis due to thickening of the ligamentum flavum were noted in 3 patients (Figure 2A, B). Before surgery, there were no differences in walking capacity between patients with neurogenic claudication and patients with sciatica (Table 1).

Seven patients were operated with decompression and fusion and 17 with only decompression in 1 to 3 levels. The history of pain before surgery was 1 to 10 years. The patients were observed for 1 to 6 years after surgery.

Follow-up questionnaires were filled out by all patients. These included information regarding change in leg and back pain, respectively, at walking and standing compared with before surgery on a 4-graded scale [much improved (2), improved (1), not improved (0) and worse (−1)]. The patients were also asked to describe their remaining leg and back pains accordingly on a VAS scale.(0–100) Walk distance before surgery and at follow-up were consecutively described in the patients files (Table 2). Patient satisfaction with the surgical result was rated yes or no.

Health related quality of life was measured by the disease specific Oswestry Disability Index (ODI),[13] and the generic measures SF-36[14] (compared with the results in the Swedish Spine Register[15]) and EQ-5D.[16]

The axially loaded images were considered to be part of the clinical imaging protocol at our institution (Sahlgrenska University Hospital, Göteborg, Sweden), and institutional review board approval was not obtained. The methods used in the current study have previously been approved by the ethical committee at the University of Göteborg.

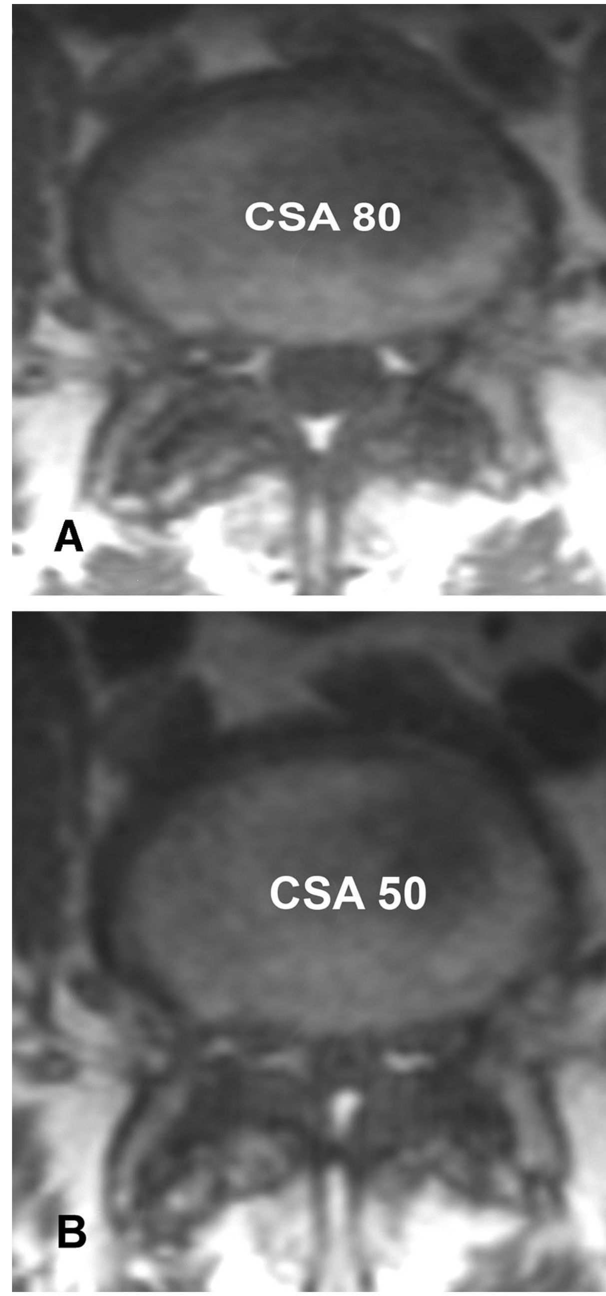

Figure 2. Patient MR14 (Tables 1 and 2). A 55-year-old woman with degenerative changes in L4–L5 level without obvious signs of spinal stenosis at MRI in unloaded position (**A**). She had bilateral neurogenic claudication, and walking capacity was below 200 m. At the loaded MRI examination (**B**) the dural sac cross sectional area decreased from 80 to 50 mm^2 and the L5 nerve roots were compressed in the lateral recesses. She was operated with decompression and posterolateral fusion in the L4–L5 level. At follow-up, 6 years later, her walking capacity was more than 1 km and she was pain free.

■ Results

At follow-up, 16 (of 21 recordings, 76%) patients had very little remaining leg pain (VAS #25 out of 100). The

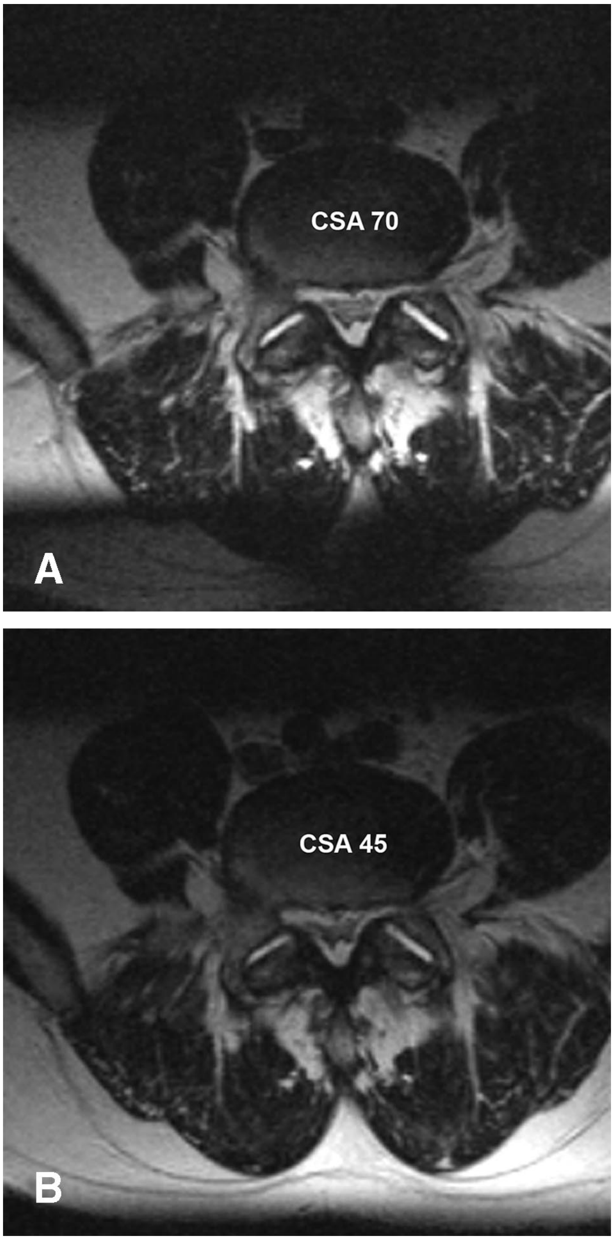

Figure 3. Patient MR18 (Tables 1 and 2). A 55-year-old man with low back pain and severe neurogenic claudication in walking and standing. Axial loaded MRI disclosed a spinal stenosis in the L3–L5 levels. The L4–L5 level is demonstrated in PRP (**A**) and ACE (**B**). Decompression was performed in both levels. One year after surgery, he was much improved regarding his back and leg pains, and he could walk in a normal pace for more than 1 km compared with less than 500 m before surgery.

leg pain was estimated as much improved or improved in 23 of the 24 patients (96%) (Table 2).

Regarding back pain, 13 (of 21 recordings, 62%) had VAS # 25. Back pain was estimated as much improved or improved in 23 of 24 patients (96%) (Table 2).

The ability to walk in normal pace was subjectively improved in all but 1 patient at the follow-up (Tables 1 and 2, Figure 5). Before surgery, 13 patients could walk less than 100 m and nobody could walk more than 500 m. At the follow-up, 16 patients walked more than 1 km and 6 could walk 500 to 1000 m (Figure 5).

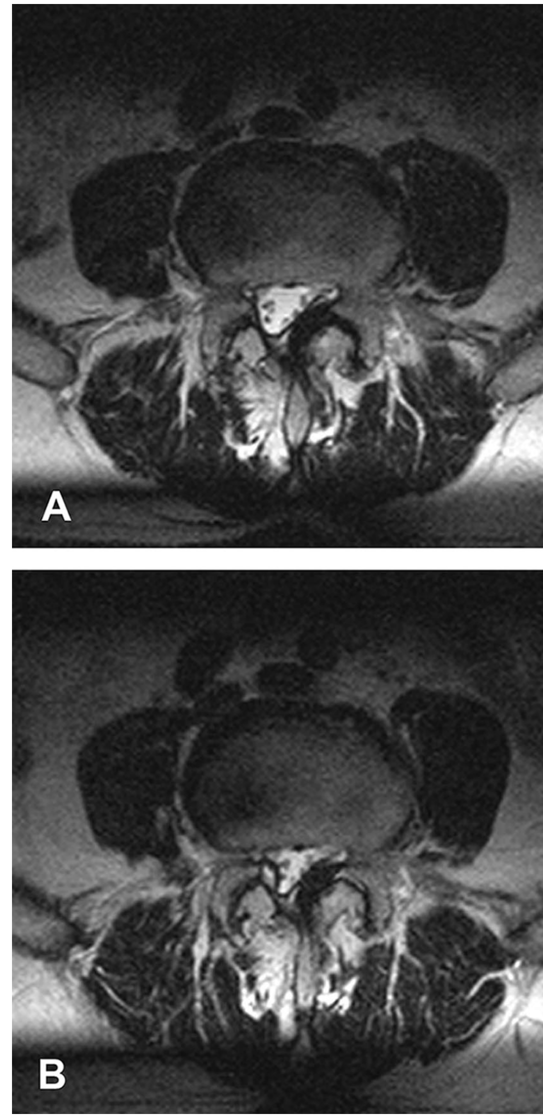

Figure 4. Patient MR25 (Tables 1 and 2). A 79-year-old man with a right L5 rhizopathy. Traditional MRI did not show any significant narrowing explaining his complaints (**A**) (L4–L5 level). Axial loaded MRI showed a synovial cyst compressing the L5 nerve root at the L4–L5 level (**B**). Surgery with removal of the medial part of the L4–L5 joint and the synovial cyst was performed. One year after surgery, he was much improved regarding his leg pain and he could walk 500 to 1000 m.

Eight patients were retired at the time of follow-up. Out of 16 remaining patients, 11 had returned to work (70%) and 5 were on a disability pension. Three patients (12%) used analgesics regularly. Twenty-two patients (92%) were subjectively satisfied with the surgical result. One of the 2 patients in the present study who reported a bad result after surgery suffered from severe diabetes, pectoral angina, and intermittent claudication based on arterial insufficiency.

At the follow-up, mean ODI was 24, EQ-5D was 63, SF-36 PCS was38, and MCS 48. The SF-36 domain profile was very similar to the SF-36 profile in patients surgically treated for central stenosis described in the Swedish Spine Register 2005 (Figure 6).

Table 2. Follow-up Data

EM and Pat. No.	FU-Time (yr)	Leg Pain: Subj Treatment Effect	Leg Pain: VAS	Back Pain: Subj Treatment Effect	Back Pain: VAS	Walk Distance (Grade)	Satisfaction (Yes = 1; No = 0)	ODI	EQ-5D
CT 9	5	2	17	2	0	4	1	36	62
CT 10	5	2	0	2	0	4	1	0	59
CT 11	3	2	2	2	4	4	1	14	62
CT 12	4	2	9	2	36	3	1	32	
MR 2	2,5	2	2	2	0	4	1	4	100
MR 3	1	2	12	2	12	4	1	4	80
MR 4	2	2	7	2	10	4	1	8	80
MR 6	2	2	7	2	20	4	1	20	80
MR 7	2	2	12	2	12	4	1	14	80
MR 8	2	1	10	2	20	4	1	32	76
MR 13	3	1	54	1	59	3	1	34	69
MR 14	6	2	0	2	0	4	1	0	100
MR 15	4	1	59	2	24	3	1	14	62
MR 16	2	2	10	2	38	4	1	18	6
MR 17	2	2	1	2	1	3	1	22	
MR 18	1	2	5	2	15	4	1	32	
MR 19	2	0	74	0	74	2	0	60	16
MR 20	2	1	53	1	56	4	1	36	
MR 21	1	1	23	1	83	2	0	54	62
MR 22	1,5	1	45	2	30	3	1	30	62
MR 23	1,5	2	25	2	40	3	1	44	22
MR 24	1	1		1		2	1		
MR 25	1,5	2		2		4	1		
MR 26	1	2		2			1		

Subjective treatment effect: much improved = 2, improved = 1, not improved = 0. VAS, visual analogue scale 0–100, 0 = no pain, 100 = maximal pain. Walk distance: <100 m = 1, 100–500 m = 2, 500–1000 m = 3, >1000 m = 4. Satisfaction with surgical result: yes = 1, no = 0.
FU-time indicates follow-up time in years; ODI, Oswestry Disability Index (0–100); EQ-5D, Euroqol 5 dimension quality of life index (−59 to 100).

■ Discussion

The importance of spinal loading and posture during CT and MR examinations in patients with neurogenic claudication and sciatica has been reported in experimental and clinical studies by several authors in recent years.[1–3,5–9,12,17–20] Axial loading decreases the area of the dural sac significantly in a large proportion of individuals with clinical signs of neurogenic claudication if the inclusion criteria for axial loaded imaging are followed.[3] The reason for narrowing of the spinal canal during axial load is probably a degenerative instability in the functional spinal units in the lower lumbar spine with thickening of ligamentum flavum, accentuation of a bulging disc, protrusion of the dorsal fat pad, and enlargements of synovial cysts.

According to our experience there is a considerable risk of failing to detect an essential narrowing of the spinal canal if the examination is performed only in the unloaded traditional positioning.[1–3,5–7,9] Kimura *et al*[4] showed in a study on healthy individuals that a load comprising 50% of a subjects' body weight applied by a

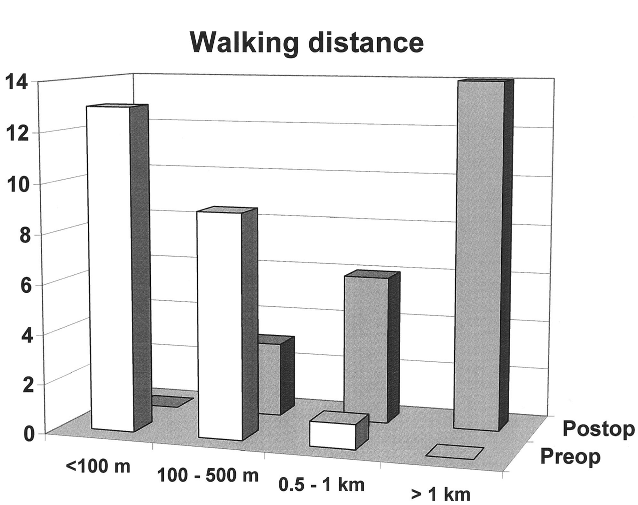

Figure 5. Walking capacity pre- and after surgery. Number of patients (*y* axis). N = 23.

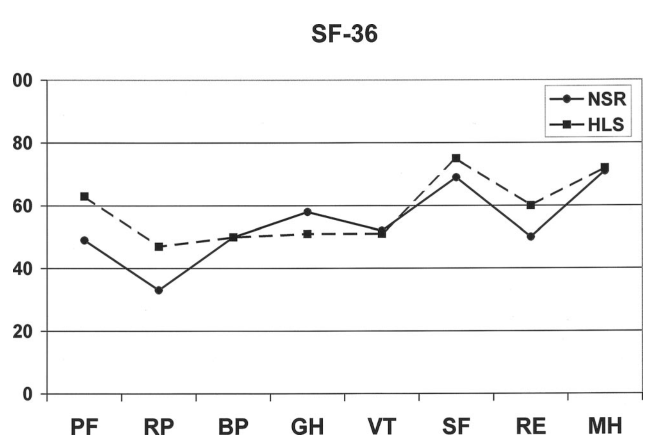

Figure 6. SF-36 domain profile. PF indicates physical function; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, metal health; NSR, National Spine Register (of Sweden) 2005; HLS, hidden lumbar spine stenosis (present study).

compression device can morphologically simulate the lumbar spine in upright position.

Despite continuous development and research, essential problems still arise during attempts to perform examinations in upright posture for patients with spinal disorders.[17,19,20] The examinations in upright position are conducted in a lower magnetic field strength and there are problems to avoid patient motions, which results in movement artifacts influencing the image quality.

In a study by Hiwatashi *et al*,[9] neurosurgeons independently and blinded evaluated images from unloaded and loaded examinations in patients with neurogenic claudication, sciatica or low back pain. According to the results from that study, the additional information gained from axial loading during MRI influenced the neurosurgeons in their treatment decisions changing from conservative to operative treatment in up to 10 out of 20 investigated patients. However, the clinical effect of the axially loaded imaging technique, *i.e.*, the surgical results in hidden stenosis only detected at the axial compression in extension was asked for.

It has been suggested that the only way to prove the clinical effect of axially loaded imaging is to study outcomes of patients treated surgically for hidden stenoses disclosed by imaging at ACE.

The 24 patients included in this study had a hidden stenosis in 1 to 3 levels only detected at the unloaded examination. Individuals with an clear stenosis in any level detected at the unloaded examination had been excluded. At the follow-up, at least 1 year after surgery, most individuals were much improved regarding physical function and satisfaction. The walking capacity in normal pace improved remarkably, and subjectively most patients were without pain or much improved regarding leg and back pain. These findings at follow-up, corresponded well to the scores in ODI,[13] SF-36,[14] and EQ-5D,[16] strengthening the validity of these results despite missing base-line data and incomplete recordings at follow-up (Table 2).

It is possible that the 24 patients in this study would not have been treated surgically if the hidden stenosis had not been detected by the axially loaded CT or MRI technique.

Moreover, in the other 101 patients out of the 125 patients with AVI at the loaded examination, a previously hidden stenosis was disclosed in at least one level at ACE in addition to the stenoses that had been diagnosed at the unloaded examination. It is possible that these hidden stenoses could be of clinical significance and that they could attribute to unsatisfactory results after decompressive surgery in some patients.

In a previous study we have emphasized the importance to follow the recommendations for inclusion criteria for the axial loaded examination to avoid frequent negative examinations. In patients with neurogenic claudication, AVI might be found in a higher percentage if the inclusion criteria are followed.[3]

Following the results of this study, a hidden spinal stenosis in one or more levels might be detected by axially loaded CT or MRI in patients with neurogenic claudication and/or sciatica. Surgery with decompression with or without fusion in these patients seems to be successful. This highlights the importance of performing axially loaded examinations in all patients with relative spinal stenosis findings with or without clear stenoses at other levels.

■ Conclusion

Surgical treatment of central or lateral lumbar spinal stenosis, only detected by imaging in axial compression and extension of the lumbar spine, gives good clinical results that seem to be comparable with the results after traditionally diagnosed and surgically treated stenoses.

■ Key Points

- There is a considerable risk of failing to detect an essential narrowing of the lumbar spinal canal (hidden spinal stenosis) if CT and MRI examinations are performed only in the traditional unloaded position in patients with clinical signs of neurogenic claudication.
- An axial loaded examination should be performed after the unloaded examination to optimize the radiologic diagnosis and to detect an eventual hidden stenosis in any disc level.
- No previous study has been performed to determine the influence of the imaging findings on the surgical results.
- Surgery with decompression with or without fusion in patients with hidden stenosis will to a large extent be successful.

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