SACRAL FIXATION WITH THE VARIABLE ANGLE SCREW- PRELIMINARY RESULTS

N. ANAND * C. E. SUTTERLIN **

Study Design: *Retrospective review of the first 25 consecutive cases with sacral fixation.*

Objectives: *To report an easy technique of S1 and S2 fixation with the variable angle screw and the TSRH instrumentation system.*

Summary of Background Data: *Sacral Fixation with most instrumentation systems has always been a challenge, especially so at the end of long constructs. The senior author introduced the Variable Angle Screw (VAS) in 1992, as a modification of the original TSRH bone screw. The screw has since been used routinely in all TSRH constructs.*

Results: *The first 25 consecutive cases with sacral fixation have been reviewed with an average follow-up of 12 months. To date there have been no implant failures, screw loosening or demonstrable pseudarthroses.*

Conclusions: *We feel no other screw allows variability in all degrees of freedom as the Variable Angle Screw. It consequently minimizes the need for complicated or complex rod contouring and allows for easy attachment of the rods, while at the same time achieves safe and optimum fixation at both S1 and S2 levels.*

Key Words: *(Sacral fixation, pedicle, variable angle screw)*

INTRODUCTION

Pedicle screw fixation has been gaining in popularity, however fixation to the sacrum continues to be the weak ling in with most constructs. Anatomic and biomechanical studies have defined safe and efficacious techniques of sacral fixation. Most systems allow for some variability in the site and angle of screw insertion, but constraints within the system often compromise optimum position or make rod contouring and screw insertion an arduous task. The aim of this aper was to report an easy technique of S1 and S2 fixation with the variable angle screw and the TSRH instrumentation system.

METHODS

Variable Angle Screw: The senior author introduced the Variable Angle Screw (VAS) in 1992 as a modification of the original fixed angle screw on the TSRH instrumentation system. Since then both screws are available on the TSRH implant set. The screws connect to the rod using eyebolt/nut assemblies. The variable angle screw differs from the original screw in that it use eyebolt/nut assemblies with a serrated spacer attached. The spacers are available in 3 mm, 6 mm and 9 mm widths allowing the screw to be laterally displaced from the rod. The serrations further allow thi variable angle screw 360° of rotation at 6° increments. Hence the variable angle screw offers many degrees of angulation and displacement from the rod. The fixed angle screw, on the other hand must be placed perpendicular to the rod and this can make contouring of the rod more difficult. The availability of top tightening eyebolts and titanium implants have made this system more versatile than ever.

Technique of Sacral Fixation: Standard posterior approach was performed allowing adequate exposure of the sacrum. The sites of screw insertion were selected and marked. The entry point for the S1 screw was just medial and inferior to the first sacral foramen. The entry hole was made with a high speed burr, drill or sharp trocar. Next a T-handled probe was gently rotated down the cancellous bone of the pedicle of S1 angling 25° caudally in the sagittal plane to parallel the sacral end plate and converging 25-30° in the axial plane towards the promontory. The appropriate length of the screw was determined by the markings on the probe. The probe for the S2 screw was angled caudally to parallel the S1 screw in the sagittal plane and 45° laterally in the axial plane towards the sacral ala taking care not to enter the sacroiliac joint. The probe on reaching the anterior cortex was gently tapped till the soft feel of cortical penetration was noted at both S1 and S2 levels. Each hole was probed again to ensure that no pedicle wall fracture has occurred and the surrounding walls were entirely bony. The appropriate length screw was then inserted. Other pedicle screws were inserted in the standard fashion and the rods were contoured and attached with the suitable eyebolt spacers.

* Fellow, Florida Fellowship in Reconstructive Spinal Surgery,
** Director, Fellow, Florida Fellowship in Reconstructive Spinal Surgery, Spinal Associates of North Central Florida, Gainesville, Florida

Table 1:

				# of Previous Lumbar Surgery	Levels Fused	#	YEARS post-op
1	HA	29	M	1	L5-S1	1	0.51
2	SA	53	M	NONE	L3-S1	3	0.46
3	BB	42	F	2	L5-S1	1	0.98
4	KC	24	F	4	L3-S2	4	0.94
5	KC	24	F	4	L3-S2	4	0.94
6	PC	61	M	2	L4-S1	2	0.82
7	LE	32	F	1	L5-S1	1	0.51
8	DF	38	F	NONE	L2-S1	4	0.44
9	AF	57	F	2	L2-S1	4	1.52
10	CH	53	F	2	L3-S1	3	1.99
11	MH	53	F	NONE	L3-S1	3	1.01
12	WM	60	M	2	L3-S1	3	0.24
13	HM	61	F	NONE	L1-S1	5	1.11
14	HN	69	F	NONE	L2-S1	4	1.37
15	LP	45	M	1	L4-S1	2	0.35
16	DR	32	F	1	L3-S2	3	0.75
17	PR	56	M	5	L1-S2	6	1.29
18	GR	38	F	1	L5-S1	1	1.07
19	BS	68	F	3	L4-S1	2	1.02
20	ES	68	F	2	T10-S1	8	0.79
21	RT	53	M	1	L2-S1	4	1.83
22	CT	32	F	1	L5-S1	1	1.10
23	JT	31	M	NONE	L5-S1	1	0.92
24	LT	62	F	2	L4-S1	2	1.10
25	GW	50	M	NONE	L5-S1	1	1.11

RESULTS

Since February 1992, 26 patients have had sacral fixation with the Variable Angle Screw for lumbosacral fusion in degenerative spinal disease. The average age of the patients was 48 years (range: 24 to 69) with 10 males and 15 females. The average lenght of follow-up was 12 months (range: 3 to 24). Six patients have had both S1 and S2 instrumentation while the remaining 20 patients had only S1 fixation. All patients with S2 fixation had 3 or more levels fused. Eighteen out of the 25 patients had undergone previous lumbar spinal surgeries, with 10 having had 2 or more previous surgeries. The sacral screws have shown no evidence of loosening, breakage, bending or any form of failure. Fusion seems to be progressing uneventfully and there are no signs of demonstrable pseudarthrosis at present. One patient had postoperative wound infection following L3-S2 posterior spinal fusion and instrumentation. It was salvaged with early wound debridement and antibiotics, but he presented 4 months later with destruction of L2-3 disc and collapse of L2 on L3. He underwent revision with anterior lumbar interbody fusion from L1 to S1 followed by extension of posterior instrumentation and fusion to L1. At the patient's recent 22 month follow-up fusion seems to be progressing uneventfully at all 5 levels.

DISCUSSION

A number of techniques of sacral screw fixation have been described. There exist differences as to the location and safety of these sacral screws, with regard to the anatomy and rigidty of the construct.

Harrington and Dickson, Krag and Magerl advocated S1 screws inserted along the pedicle (anteromedially). Edwards, Louis and Cotrel et al preferred lateral placement into the sacral ala (anterolaterally). Roy-Camille et al, Steffee et al, and Guyer et al proposed a double screw method, one oriented along the S1 pedicle and the other laterally towards the sacral ala. The variety of clinically based recommendations bare testimony to the fact that sacral fixation poses particular difficulties, because of both the unique and variable anatomy and the great difficulty in intraoperative visualization, including radiographic.

Asher and Strippgen suggested that an anteromedial orientation of the S1 screw would provide a stronger fixation than an anterolateral orientation because the former provided longer screw path length. They did not perform biomechanical studies to test this hypothesis. Dohring and Krag noted that the anterolateral screw path was longer than the anteromedial in female patients and the reverse was trues in male patients. Zindrick et a on performing pullout strengths reported greater loads to failure for anterolaterally directed screws were loaded in tension along the screw axis, in contrast to in vivo loading which probably is

predominantly perpendicular to the screw axis (flexion loading). Dohring and Krag applied flexion loads about a fixed transverse axis near the dorsal cortex. They noted that anteromedially oriented screws required significantly more load to produce a 1 degree rotation than anterolaterally oriented screws. Carison et al. also showed that the anteromedial screw orientation resulted in the greatest maximum load to failure and the least screw rotation.

Anatomical studies of the human sacrum have further corraborated that S1 screws directed anteromedially towards the sacral promontory enter the medial safe zone and therefore carry minimal risk of injury to the neurovascular structures anterior to the sacrum.

Steffee et al, suggested that two points of sacral fixation were necessary in cases of severe spondylolisthesis and in long lumbar fusions (i.e. over three segments) as the S1 screw though quite strong would not be able to hold the weight of the entire spine. The S2 pedicle has been shown to have the least holding power as it is insufficient in bone quality and depth to obtain adequate purchase with the screw. Consequently, the ala of the sacrum which has excellent bone seems a better alternative. Steffee recommended buttress clamps that were fixed with screws driven over the plate into the ileum (overshooter) or under the plate into the ala of the sacrum at the S2 level (undershooter). Puno et al showed biomechanically that the Steffee plate with S2 fixation was be most rigid system and there was a dramatic decrease in rigidty when the S2 fixation was removed. This need for S2 fixation is probably explained by the fact that the lumbosacral junction is exposed to shear stresses in compression and anterior bending. This tends to cause forward displacement of L5 on S1 which in turn causes increased stress on the S1 screws when used alone. The S2 screws help in acting as a tether distally and dissipate the shear forces by providing additional fixation points. We also feel that the divergence of the screws in both planes further increases the rigidty of the construct.

Therefore biomechanically and anatomically anteromedial S1 screws with anterolaterally oriented S2 screws appear to be the most efficacious.

Bicortical sacral purchase has been shown to provide the most secure fixation, but this is associated with potental risk to vital neurovascular structures anterior to the sacrum. Fortunately, our clinical experience and other reports indicate a low frequency of complications from bicortical sacral screws. We feel several steps can be taken to avoid injury to the lumbosacral trunk and iliac vein. First the anterior sacral cortex is very gently perforated by tapping on a blunt probe. The probe it self serves as a depth gauge thereby avoiding inadvertent plunging of a depth gauge anterior to the cortex. No tap is ever used across the anterior sacral cortex and the screw length should exactly match bone length. When in doubt a shorter screw should be used.

We feel that where fusion is attempted for spondylolisthesis, pseudarthroses, instability following previous laminectomy or when 3 or more segments are included a second sacral fixation point is justified. The Variable Angle Screw is unique in that it is not restricted by the constraints of the system and hence complete attention can be given to the anatomy of the sacrum thereby achieving safe and optimum fixation. Contouring of rod becomes extremely easy as the screw need not be perpendicular to the rod and further the lateral spacer allow for the rod to be connected even at a distance. No other system allows for this variability in all degrees of freedom.

REFERENCES:

1. Asher MA, Strippgen WE: Anthropometric studies of the human sacrum relating to dorsal transacral implant design. Clin Orthop 203: 58-62, 1986.
2. Carlson GD, Abitbol JJ, Anderson DR, et al: Screw Fixation in the Human Sacrum. an In Vitro Study of the Biomechanics of Fixation.
3. Cotrel Y, Dubousset J, Guillaumat M: New universal instrumentation in spinal surgery. Clin Orthop 227: 10-23, 1988.
4. Edwards CC: Spinal Screw Fixation of the Lumbar and Sacral spine: Early results treating the first 50 cases. Proceedings of the 21st Annual Meeting of the Scoliosis Research Society, p. 99, 1986a.
5. Esses SI, Botsford DJ, Huler RJ, et al: Surgical Anantomy of the sacrum. A guide for Rational Screw Fixation. Spine 16 (6S): S283-S288, 1991.
6. Guyer DW, Wiltse LL, Peek RD: The Wiltse pedicular system. Orthopaedics 11: 1455-1460, 1988.
7. Harrington PR, Tullos HS: Reduction of severe spondylolisthesis in children. South Med J 62: 1-7, 1969.
8. Krag MH, Beynnon BD, Pope MH, et al: An internal fixator for posterior application to short segments of the thoracic, lumbar, or lumbosacral spine, design and testing. Clin Orthop 203: 75-98, 1986.
9. Krag MH: Biomechanics of thoracolumbar spinal fixation: A review. Spine 16 (3S): S84-S99, 1991.
10. Louis R: Fusion of the lumbar and sacral spine by internal fixation with screw plates. Clin Orthop 203: 18-33, 1986.

11. Magerl F: External spinal skeletal fixation, The External Fixator. Edited by BG Weber, F Magerl. New York, Springer-Verlag, 1985, pp. 290-365.
12. Magerl FP: Stabilization of the lower thoracic and lumbar spine with external skeletal fixation. Clin Orthop 189: 125-141, 1984.
13. Mirkovic S, Abitbol JJ, Steinman CC, et al: Anantomic Consideration for Sacral Screw Placement. Spine 16 (6S): S289-S294, 1991.
14. Puno RM, Bechtold JE, Byrd JA, et al: Biomechanical Anaalysis of transpedicular Rod Systems. A Preliminary Report. Spine 16 (8): 973-980, 1991.
15. Roy-Camille R, Salliant G, Mazel C: Internal fixation of the lumbar spine with pedicle screw plating. Clin Orthop 203: 7-17, 1986.
16. Roy-Camille R, Salliant G, Mazel C: Plating of the thoracic, thoracolumbar, and lumbar spinal injuries with pedicle screw plates. Orthop Clin North Am 17: 147-159, 1986.
17. Steffee A, Biscup R, Sitkowski D: Segmental spine plates with pedicle screw fixation. Clin Orthop 203: 45, 1986.
18. Steffee A, Sitkowski D: Posterior lumbar interbody fusion and plates. Clin Orthop 227: 99-102, 1988.
19. Steffee AD, Sitkowski DJ: Reduction and stabilization of grade IV spondylolisthesis. Clin Orthop 227: 82-89, 1988.
20. Zindrick MR, Wiltse LL, Widell EH, et al: A biomechanical study of intrapedicular screw fixation in the lumbar spine. Clin Orthop 203: 99-112, 1986.