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THORACOLUMBAR STABILIZATION SYSTEMS: PRELIMINARY STUDIES

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Spinal cord injury continues to be a problem of epidemic proportions. Efforts to prevent and treat the neurologic consequencies of spinal trauma fall short because of a lack of information regarding the physiologic concomitants and the correlating biomechanical characteristics of spinal cord injury. Previous studies have been directed toward the establishment of a primate model for the investigation of the pathophysiology of spinal cord injury (1,2,4,5,6,7). Additionally, studies have been conducted in more than 40 fresh human cadavers (8). Because of our clinical experience, sixteen of these specimens were used for the evaluation of the thoracolumbar spine and the devices used clinically for stabilization following trauma.

Between 1975 and 1981, 105 cases of thoracic and lumbar spine trauma were managed surgically in our institutions. The lateral extracavitary approach (3) to the spinal cord or cauda equina were performed in most cases. Posterior stabilization procedures were performed utilizing Harrington distraction rods, Weiss springs or Luque rods. Patients were given neurologic grades, both immediately, preoperative and postoperatively according to a VII grade scale. Patients were allowed to plateau neurologically before reconstructive spine surgery was performed. No neurologic

Grade I (complete) patients recovered function below the level of injury. Grade II (motor complete patients) improved an average of 0.7 neurologic grades. Grades III to V (incomplete with varying degrees of deficit) patients improved an average of 1.3 neurologic grades or 49% of possible neurologic recovery, and Grade VI (minimal neurologic deficit) patients recovered an average of 1.8 neurologic grades. Eight of nine patients in this series who had previously undergone emergency re-alignment or stabilization procedures with or without laminectomy were noted to improve significantly following anterior vertebral body resection and reconstruction. There was no correlation between the timing of surgery and neurologic outcome.

These cases and other studies (3) suggest that an important requirement in the treatment of traumatic spinal cord injury is the restoration of an anatomically correct alignment of the spinal cord. The achievement and maintenance of this alignment often requires the application of stabilization instrumentation.

METHODS

Studies were conducted in sixteen unembalmed male human cadavers. In 14, compressive forces were applied to the isolated ligamentous spine. Forces were applied to the upper thoracic spine of two intact cadavers in the flexed sitting position. The methods of force application have been described elsewhere (5-8). Briefly, all specimens were judged to be within normal limits from the medical history and x-ray examinations prior to the tests. All tissues were maintained at 2°C until studied (1-3 days).

A series 810 Materials Test System at rates up to approximately 60 in/s was used to apply the loads. For the isolated spines, the ends of the specimen were mounted in aluminum cylinders with set screws driven into the preparation. The tissue in the cylinder was then fixed using mehyl methacrylate. The forces were applied to the intact specimens using a 4" by 4" steel plate.

Nine of the isolated ligamentous spines and the intact preparation were instrumented using at least one of three stabilization systems (Harrington distraction rods, strengthened Weiss springs and Luque rods). The loads were reapplied until the stabilization system was dislodged or until the specimen was deformed to the original failure point.

RESULTS

The isolated thoracolumbar spines failed at loads from 180 to 1187 pounds (Tables 1 and 2). Two specimens which included the cervical spine failed at 125 and 180 pounds. The intact cadavers were fractured at 350 and 620 pounds. The forces required to fracture the spines varied inversely with the degree of initial flexion and the length of the spines. The fractures were primarily in the low thoracic-upper lumbar spine. However, failure as high as T4 was obtained when the cervical elements were included in the specimen. The posterior ligament complex was routinely disrupted.

The Harrington distraction rods were routinely dislodged at forces from one-third to two-thirds of the failure load (Table 2). In most instances, one or more of the hooks pulled through the lamina. In two cases, one of the hooks for the Weiss springs was dislodged. In all other tests, the springs remained in place and the specimen sustained increasing loads until the spine was deformed to the original failure configuration. The Luque rods were used in two preparations. In one study, the fixation wires pulled through the lamina above the fracture site and in the other, the rods bent at 750 pounds.

DISCUSSION

These preliminary studies illustrate the disadvantage of rigid fixation systems. The Harrington distraction rods fail catastrophically at relatively low force levels while the modified Weiss springs remain in place and continue to bear load. The springs permit increased movement and patient comfort and are less likely to require removal. However, given the primary consideration of restoration of proper spinal alignment, the rigid fixation systems may be better in some cases.

These studies were designed to investigate one aspect of spinal stabilization systems. Further studies are required to determine the load distribution with the various systems, their characteristics under slowly and rapidly applied loads and long term effects, as well as the feasibility of other materials and designs.

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TABLE 1

LIGAMENTOUS SPINE STUDIES

SPECIMEN	MOUNTING	FAILURE LOCATION	MAXIMUM LOAD (lb)	DEFLECTION (in)
S-11 55 y.o 43.1 kg Respiratory arrest	T3-L5 axial compression	T11	255	1.5
S-12 57 y.o. 58.9 kg Pneumonia	T2-Sacrum flexed 30°	T9	220	0.9
S-13 84 y.o. 77.1 kg Respiratory arrest	T3-L5 axial compression	T7	500	1.4
S-17 65 y.o. 68.1 kg Respiratory arrest	T2-Sacrum flexed with force applied 3 inches forward of L1	T9	180	0.3
S-18 41 y.o. 79.4 kg Cardiac arrest	T4-L5 flexed with force applied 1 inch forward of L1	T12	1001	1.2

TABLE 2

STUDIES WITH STABILIZATION SYSTEMS

SPECIMEN	TYPE OF FRACTURE	FAILURE LB LOAD	ANGLE DEGREES	WEISS LB LOAD	WEISS ANGLE DEGREES	HARRINGTON LB LOAD	HARRINGTON ANGLE DEGREES	LUQUE LB LOAD/ANGLE DEGREES
HS 10 (T3-L5)	L1 comp fx	390	40°	--	--	136	27°	--
HS 16 (T2-sacrum)	T11 comp fx	388	32°	116	32°	195 fx lamina-both out	18°	--
HS 27 (C2-L5)	T7 compression	125	30°	60 hook dislodges	26°	50	17°	--
HS 28	T2 fx	180	31°	130	28°	120 rods out/lam fx	20°	--
HS 29	T12-L1 fx	300	40°	200	36°	180 rods out/lam fx		--
HS 31	T10 fx	1150	40°	375	40°	350 severe lam fx/ both out	8°	--
HS 32	T9 fx	450	40°	100 lam fx	15°	150 both upper hooks out	8°	--
HS 33	T11 fx	400	36°	400 one hook out	45°	320 one rod out, other bent	18°	--
HS 38	T11 rotation fracture	950	23° A-P	937	23° A-P	750 Left rod out	30°	750/26° rods bent to angle
INTACT HS 34	T11 comp fx	350	30°	315	23°	40 bilat out - lam fx	12°	--
HS 39	L2 fx	620	28°	280	30°	100 upper hooks out	14°	130/22° rods ripped out T11-T12 lam