Three-staged correction of severe rigid idiopathic scoliosis using limited halo-gravity traction

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Abstract

Introduction Despite the advantages of modern instrumentation techniques, the treatment of severe rigid idiopathic scoliosis could be very demanding. Traction can provide better, safer correction and minimize complications related to forceful intra-operative maneuvers; however, several side effects are associated with prolonged periods of traction. The aim of this work is to review the clinical and radiographic results of limited perioperative halo-gravity traction in severe rigid curves analyzing its efficacy, advantages and possible complications and comparing it to classic two staged corrections performed without traction.

Methods A retrospective case control study including 47 adolescents with severe rigid idiopathic scoliosis divided into two groups; a consecutive series of 21 patients who had a three-staged correction by an anterior release, 2 weeks of halo-gravity traction then posterior instrumentation (TRN group); compared to an earlier series of 26 consecutive patients treated without traction (SAP group). The average age was 18 years + 1 month and 16 years + 2 months, respectively. The average preoperative dorsal and lumbar

curves for (TRN) group were 106.5° and 87°, respectively, and for (SAP) group were 102° and 81°, respectively.

Results Patients were followed up for an average of 6 years (range 3–8 years). A significantly better correction was achieved in (TRN) group (average 59%) compared to (SAP) group (average 47%). At final follow-up, the loss of correction had an average of 8° for (TRN) group and 11° for (SAP) group. A shorter hospital stay was found in (SAP) group; a shorter operative time was found in (TRN) group and there was no significant difference in blood loss, early or delayed complications.

Conclusions Limited halo-gravity traction is an efficient, safe modality in the treatment of severe rigid adolescent scoliosis. The application of gradual traction over a limited period of 2 weeks led to better correction, shorter operative time with no significant complications.

Keywords Severe rigid · Idiopathic · Scoliosis · Halo-gravity traction

Introduction

The management of severe rigid deformities has always been a major challenge to spine surgeons. The halo device was first introduced by Perry and Nickel [1]. Later, Cotrel and Morel [2] introduced the use of preoperative traction with a head halter and a pelvic sling. However, this type of traction did not improve correction achieved by Harrington instrumentation for adolescent idiopathic scoliosis (AIS) patients with curves up to 90°–100° [3–5].

The halo also allowed other forms of skeletal traction including halo-femoral [6] and halo-tibial traction [7]. Stagnara [8] popularized halo-gravity traction using the weight of the body as a counterforce and thus traction

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forces can be transferred between the patients' bed, a wheelchair, and a walking frame. Gradual increase in traction over a period of time allowed for partial improvement of severe curves; thus surgical correction was performed on a less prominent deformity yielding better correction and minimizing neurological complications.

The use of third generation segmental instrumentation systems and the development of several correction maneuvers have resulted in improved correction of spinal deformities; combined with perioperative traction, this should allow for a better overall correction of severe rigid deformities with fewer complications.

The purpose of our study was (1) to evaluate the safety and efficacy of halo-gravity traction and (2) to compare the clinical and radiological outcome of surgical correction of severe rigid deformities in adolescents with idiopathic scoliosis with and without 2 weeks of traction.

Patients and methods

This study was approved by the ethics committee and the Institutional Review Board; it included 47 patients with severe rigid scoliosis who gave their informed consent to be included in this research. It is a retrospective case control study consisting of a consecutive series of 21 patients treated from 2005 to 2007 with traction; compared to an earlier series of 26 consecutive patients treated from 2001 to 2004 without the use of traction.

All patients had severe rigid curves and flexibility less than 30%. Patients within each group were evaluated including personal data (age, sex), perioperative data (operative time, blood loss, instrumentation, complications, hospital stay), clinical data (SRS—24 questionnaire) and radiographic data (coronal and sagittal plane deformities, flexibility, amount of correction, and loss of correction). In addition, patients within the traction group were evaluated for the time on traction and traction related complications.

The study included 37 females and 10 males. Twenty-one patients had a three-staged correction by an anterior release, 2 weeks of halo-gravity traction followed by posterior instrumentation, (TRN) group; and 26 patients had an anterior release simultaneously followed by posterior instrumentation, (SAP) group. The average age was 18 years + 1 month and 16 years + 2 months, respectively.

Radiographic studies included preoperative standing AP, lateral and supine side-bending radiographs. Curves were classified according to Lenke's classification system; curve flexibility was initially assessed using the supine side-bending films in all patients and calculating the percentage of curve correction on these views. In (TRN) group, AP views were repeated while patients were on traction, in the supine position, a day before posterior instrumentation.

After final correction, immediate postoperative radiographs were done and repeated every follow-up. All patients were viewed at 6, 12, 24, 36 weeks and 1 year postoperatively and afterwards were followed up at yearly intervals.

Anterior release (both groups)

It included as many levels as possible with an average of 5 (range 4–7 levels). It was performed through an open thoracotomy/thoracoabdominal approach; the parietal pleura overlying the vertebrae was incised longitudinally and every effort was made to spare the segmental vessels; if any of them needed to be cauterized, this was performed away from the intervertebral foramen. The head of each rib was removed to allow visualization of the posterior one-third of the intervertebral disc. The disc was excised back to the posterior longitudinal ligament. A piece of gel foam was temporarily placed at each level till all the discs were removed. The end plates were then sequentially removed and each level was packed with small pieces of morselized bone from the excised rib. A chest tube was then placed and the wound was closed in a standard fashion.

Halo-gravity traction, (TRN) group

Immediately following the anterior release, six to eight halo pins were placed; the halo was placed resting slightly below the equator of the skull just above the eyebrows and the cephalad portion of the earlobes.

Traction was started instantly with a small weight (2–4 kg). It was gradually increased at a rate of 1–3 kg/day as tolerated to reach a final maximum of 30–50% of body weight. Patients were carefully monitored and neurologic examination was performed every time the weight was increased. Full traction was applied for a minimum of 12–14 h/day while patients were in the wheelchair (Fig. 1); the weight was reduced by 50% for the rest of the day when the patient was in bed or asleep. In the wheelchair, traction was increased as tolerated by the patient until they were barely touching the wheelchair seat. After maximum traction was achieved, patients were instructed to immediately report any unusual symptoms and daily full neurologic examination was performed.

The duration of preoperative halo traction was 2 weeks. Routine pin care was performed with daily hydrogen peroxide and water. Antibiotics were used in cases of pin track infection, and pins were exchanged as necessary because of loosening or infection.

Posterior correction and instrumentation were performed with halo traction maintained intraoperatively; the head of the operating table was slightly elevated to allow the counter effect of gravity and half the final weight was used. The halo was removed immediately after performing this stage.

Fig. 1 Halo-gravity traction with wheel-chair modification

Posterior instrumentation (both groups)

Hybrid instrumentation included three to six pedicle screws distally and a claw, consisting of opposing transverse process and facet hooks, on either side proximally. Instrumentation usually extended proximally to D3 or D4 while the distal extent of instrumentation was determined individually according to the side bending and traction radiographs but usually extended to L3 or L4. In between both anchors, sublaminar wires were passed and multiple aggressive facetectomies were performed especially at the apex of the deformity. Meticulous decortication was performed to the posterior elements through out the whole instrumented segment. Correction was gradually achieved with a combination of maneuvers including derotation, translation and the application of cantilever forces. A thoracoplasty was performed and an average of 5 ribs (range 4–7 ribs) was removed, thoracoplasty included removal of 4–6 cm of those ribs including the remains of the rib heads and dislocating the costo-vertebral joints. Ribs were morselized to be used as an autograft generously placed over the entire construct. A wake-up test was performed and was positive in all patients.

All patients were allowed full ambulation by the second postoperative day and were braced for an average of 3 months then gradually weaned off the brace.

Statistical analysis of the data was performed using SPSS 17.0 software (SPSS Inc., Chicago, IL, USA). Variables were analyzed using a two sample *t* test and probability values of <0.05 were considered significant.

Results

Patients were followed-up for an average of 6 years (range 3–8 years). Twenty-one patients had a three-staged correction including 2 weeks of halo-gravity and intraoperative traction (TRN) group and 26 patients were traction was not used (SAP) group.

Hospital notes

The total operative time had an average of 455 min; (TRN) group had an average of 420 min, while (SAP) group had an average of 490 min ($P < 0.001$). The total blood loss had an average of 1250 cc; (TRN) group had an average of 1195 cc while (SAP) group had an average of 1305 cc ($P < 0.01$). The total hospital stay had an average of 22 days; (TRN) group had an average of 31 days while (SAP) group had an average of 13 days ($P < 0.001$).

Radiologically

Radiographic measurements were made on AP and lateral radiographs of the spine by a single independent blinded reviewer. The average preoperative dorsal and lumbar scoliosis in (TRN) group were 106.5° (range 92° – 142°) and 87° (range 77° – 110°), respectively, and in (SAP) group were 102° (range 90° – 115°) and 81° (range 75° – 100°), respectively. There was no significant difference in curve magnitude or sagittal plane alignment in both groups. All patients had rigid deformities with a flexibility index on bending films of less than 30%. After 2 weeks, on traction radiographs for (TRN) group patients had an average correction of 45% and the compensatory curve had an average correction of 47%.

Postoperatively, the main curve correction achieved in (TRN) group had an average of 59% (Fig. 2), while (SAP) group had an average of average 47% (Fig. 3) ($P < 0.01$). Correction of the compensatory curve in (TRN) group had an average of 55% while (SAP) group had an average of 44% ($P < 0.01$). At final follow-up, the loss of correction had an average of 8 for (TRN) group and 11 for (SAP) group.

Instrumentation

(TRN) group had an average of 13 levels while (SAP) group had an average of 14 levels ($P > 0.99$).

Fig. 2 A 14-year-old female **a, b** pre-op and follow-up X-rays revealing a 110° and 108° dorsal and lumbar curves corrected down to 32° and 34°, respectively; **c, d** pre-op and 7-year follow-up photographs

Clinical outcome

The Scoliosis Research Society (SRS)-24 questionnaire had an average score of 102 in (TRN) group (range from 90 to 108) and an average of 94 in (SAP) group (range from 84 to 106) ($P < 0.01$).

Complications

(TRN) group

- Three patients had loosening of their halo pins requiring replacement.
- During thoracoplasty, one patient had a pleural tear; a chest tube was placed for 3 days.

- Postoperatively, one patient had a transient mild paraparesis which was missed during her wake up test; it completely recovered at 6 months follow-up examination.

(SAP) group

- Two patients had a deep wound infection which subsided after adequate debridement, lavage and antibiotics.
- During correction, two patients had intraoperative anchor failure requiring proximal extension of instrumentation (1 patient) and distal extension by one level (1 patient).

Fig. 3 A 16-year-old male
a, b pre-op and follow-up
 X-rays revealing a 106° dorsal
 curve corrected down to 30°;
c, d pre-op and 3-year follow-up
 photographs

- One patient had a dural tear that was successfully repaired.

Discussion

The definition of severe scoliosis is yet to be determined. Lenke et al. [9] defined it as a Cobb angle $\geq 70^\circ$;

latter Tokunaga [10] defined it as a scoliotic deformity $>80^\circ$. Greiner et al. [11] reported that AIS patients did not exhibit clinically significant respiratory symptoms until their curves were 60° to 100° , thus defined severe scoliosis as Cobb angle $>60^\circ$. On the other hand, rigid scoliosis was defined as a coronal deformity with less than 40% flexibility index on bending films.

Despite the advantages of modern instrumentation techniques, the treatment of severe rigid scoliosis could be very demanding. Preoperative traction can provide better, safer correction and minimize neurological complications associated with forceful intra-operative maneuvers. On the other hand, intraoperative traction helps by stabilizing the spine and is thought to facilitate curve correction.

Different methods of traction (halo-femoral, halo-tibial) require extended periods of bed rest [6, 7], while halo-pelvic traction is associated with several long-term complications [4]. Halo-gravity traction is a rather safe alternative that has the benefit of allowing patients to be out of bed to socialize and participate in exercise programs [12]; it can be applied while a patient is in bed or on a wheelchair [5]. On the other hand, halo traction often requires prolonged hospital stays and is not welcomed by all families [13].

Most of the prior studies of halo-gravity traction lack a comparison control group and included only a relatively small number of idiopathic scoliosis patients (Table 1). Sink et al. [14] conducted a retrospective review of 19 children with severe scoliosis who underwent spinal fusion surgery following 6–21 weeks of preoperative halo-gravity traction and some had an anterior release after 6 weeks of traction. Four of the 19 patients had idiopathic scoliosis. For all 19 patients, the Cobb angle had a mean of 84° (range 63°–100°) and was corrected by 39%.

Mehlman et al. [12] presented 24 patients who had halo-femoral traction and a spinal release; 11 of whom had idiopathic scoliosis. The pre-traction curve had an average of 95° and the pre-traction curve in bending had an average of 73°; the final traction curve had an average of 44°. Traction weight was increased to an average of 54% of body weight and final correction had an average of 71%.

Later, Rinella et al. [15] performed a retrospective analysis of 33 patients with severe scoliosis or kyphoscoliosis. The main coronal curve had a mean of 84° (range

22°–158°). Four patients had idiopathic scoliosis, and in those patients the main coronal curve had a mean of 101° (range 84°–131°). The duration of perioperative traction was usually 2–12 weeks depending on their overall medical condition. For all 33 patients, the main coronal curve reduced 38° or 46% after posterior spinal fusion.

Most recently, Sponseller et al. [16] reviewed 53 patients with severe scoliosis or kyphoscoliosis; 23 patients had AIS, 15 received halo-gravity traction (Tx) and 8 (C) did not. The average pretreatment curve magnitudes for the Tx versus C groups were as follows: main curve 97° versus 93°, compensatory curve 64° versus 61°, and kyphosis curve 50° versus 42°. The traction and control groups had mean flexibility of 19 and 20%, respectively. However, those who underwent traction had almost twice the average hospital stay as the control group: 41 versus 21 days. There was no statistically significant difference between traction and control groups in coronal or sagittal curve correction, blood loss, operative time or complications.

Traction without spinal release offers no advantage over immediate spinal fusion with instrumentation [4]. Correction of scoliotic curves under traction is accomplished through two mechanisms. The initial correction is due to the elastic properties (stiffness) of tissues. Since tissues exhibit viscoelastic properties, the initial elastic deformation is followed by a creep phase where most of the correction is achieved. There is a period of primary creep for about 2–4 h, in which the correction is relatively important. A secondary creep period allows a more gradual reduction of the spinal deformity, such that near maximal curve correction can be obtained after about 10–12 days [17].

The previous two facts were a cornerstone in planning our study. It included halo-gravity traction for only 2 weeks during which secondary creep achieved near maximal curve correction in 21 patients (TRN) group. AP radiographs were repeated while patients were on traction a day before posterior instrumentation in the supine position proved that traction increased curve flexibility (compared to the supine side-bending films performed before traction); they provided an approximate estimate on the amount of correction that can be safely achieved and they were also useful in selecting upper and lower instrumentation levels usually resulting in sparing one distal motion segment than initially planned.

The total operative time and total blood loss were significantly less in (TRN) group; this was attributed to more flexibility of the curves and a simpler easier correction which were both the result of pre- and intra-operative traction. There was no significant difference in curve magnitude, sagittal plane alignment or flexibility index in both groups preoperatively; nevertheless, the main curve correction achieved in (TRN) group was significantly better with an average of 59%. The clinical outcome as

Table 1 Comparison between our series and previous studies

	Number of idiopathic scoliosis patients	Average duration of traction	Deformity (°)	Correction (%)
Sink et al. [14]	4/19	6–21 weeks	84	39
Mehlman et al. [13]	11/24	9 days	95	71
Rinella et al. [15]	4/33	2–12 weeks	101	46
Sponseller et al. [16]	23/53	6 weeks	97	62
Our study	21	2 weeks	106.5	59

evaluated by the Scoliosis Research Society (SRS)-24 questionnaire was also significantly better in (TRN) group. Although the hybrid construct had excellent purchase and firm anchorage, we preferred to brace patients postoperatively for a short period of 3 months to protect the good correction achieved in those severe rigid curves till fusion sets in.

Several others reported complications related to the concomitant surgical procedure. Sink et al. [14] reported wound infection after posterior spinal fusion and loss of fixation of the inferior laminar hooks. Several perioperative complications were reported by Rinella et al. [15] including temporary respiratory distress, malignant hyperthermia, coagulopathy, supraventricular tachycardia, triceps palsy, brachial plexus palsy and anterior strut graft dislodgement requiring revision anterior fusion. Long-term complications included superficial wound infections, curve progression, and rod migration. Sponseller et al. [16] reported overall 33% complications in the traction group including 1 reoperation that required 4 rib excisions and revision of a hypertrophic chest scar. In our study, we had a total of 7/46 surgery-related complications, all of which were managed successfully and none of which affected the final outcome of the procedure.

Despite the advantages of halo-gravity traction, several halo-related complications were reported. Wilkins and MacEwen [18] reported that in 6 of 70 patients treated on skeletal traction, cranial nerve complications developed. Ginsburgh and Bassett [19] reported a hypoglossal nerve injury caused by halo-gravity traction using traction that was 40% of the patient's body weight. Avascular necrosis of the odontoid process and cervical spondylosis have been previously reported with spinal traction as a result of prolonged periods of distraction of the odontoid and apophyseal joints, respectively [20]. Several authors have reported pin loosening and superficial pin-tract infections [20–23].

Our patients had shorter periods of traction (2 weeks), which may explain why we did not encounter significant traction-related complications. Only three patients had loosening of their halo pins requiring revision and the overall complication rate was acceptable compared to the magnitude of both the deformity and the surgical intervention. In general, the traction did not exceed 50% of the patient's body weight, a force much lower than those associated with halo-pelvic traction. Furthermore, partial reduction of traction for 8 h/day and the allowance for changes in posture abolished many of the complications associated with high, constant traction. Intraoperatively, traction did not seem to affect bone quality or induce osteoporosis; we found no apparent difference in bone strength or in the holding power of implants between both groups; to the contrary, the two patients who had intraoperative anchor failure were in the SAP group.

Possible limitations of the current study is the use of multisegmental hybrid instrumentation and thus the need for an anterior release; with the recent trend to use all pedicle screw constructs, a better correction was achieved with all screw constructs in scoliotic curves greater than 100° [24]. In our series, all pedicle screw constructs were not used because of their very high cost; hybrid instrumentation yielded a comparably good outcome with a relatively simple inexpensive construct. Although our patients in traction had a longer hospital stay and consequently had a comparatively higher cost, yet this appears justified with their significantly better clinical and radiologic outcomes.

Conclusions

Halo-gravity traction is a safe, well-tolerated modality of applying gradual, sustained traction to maximize correction in patients with severe rigid scoliosis. Complications can be minimized with gradual increases in traction to a maximum of 50% of the patient's body weight and thorough daily neurologic examinations.

The use of halo-gravity traction should be considered in all patients with severe rigid adolescent idiopathic scoliosis, provided that both patient and his family are compliant with the procedure. Limiting traction to a period of only 2 weeks yielded an improvement in surgical correction achieved without the inconvenience of prolonged hospital stay reported in previous halo-gravity traction protocols.

Conflict of interest None.

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