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Research Article

Three different techniques for pelvic fixation in the management of neuromuscular scoliosis in nonambulatory spastic cerebral palsy: A comparative study of Galveston Rod, iliac screw, and sacroiliac screw

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ABSTRACT

Objective: This study aimed to compare the clinical and radiographic results of three different pelvic fixation techniques, i.e., Galveston Rod, Iliac Screw, and Sacroiliac Screw, in managing neuromuscular scoliosis in nonambulatory children with spastic cerebral palsy (CP).

Methods: This retrospective study included nonambulatory children aged < 18 years with neuromuscular scoliosis secondary to CP, undergoing a spinal fusion and pelvic fixation by either Galveston rod, iliac screw, or sacroiliac screw techniques. The primary outcome variable was to determine the stability of the major curve angle and pelvic obliquity over timeline intervals for each pelvic fixation technique. The two radiographic parameters were measured at five timeline intervals and were compared to define stability among the groups.

Results: One hundred and one patients (54 females [53%]) with spastic nonambulatory CP met the inclusion criteria; the mean age at surgery was 13.5±3.1 years. Mean follow-up intervals were first-year (12.9±1.5) and second-year (25.8±2.5). Forty-one patients had minimum five-year (81.5±23 months) postoperative follow-up. Groups were based on pelvic fixation techniques: 25 patients with the Galveston rod, 24 with the iliac screw, and 52 with the sacroiliac screw. Of the 41 patients with a minimum five-year follow-up, 10 had the Galveston rod, 11 had an iliac screw, and 20 had sacroiliac screw fixation. Gross Motor Function Classification System level, medical comorbidities, intrathecal baclofen pump, and vitamin D level were compared with each pelvic fixation technique ($P > .05$). Major curve angle parameters were measured at the five timelines as 70.5°±21.1°, 15.7°±13°, 15.7°±12°, 17.5°±12.7°, and 15.1°±9.6°, and pelvic obliquity as 14.8°±10.4°, 4.9°±4.2°, 5.7°±4.6°, 5°±4.4°, and 7.2°±4.4°, respectively. After the surgery, corrected major curve angle and pelvic obliquity showed no statistically significant difference between pelvic fixation techniques ($P > .05$) and remained stable over timeline intervals ($P > .05$). Fifteen patients had complications requiring additional surgery. The iliac screw group (nine patients) had the highest rate of complications.

Conclusion: All three pelvic fixation techniques can provide equivalent correction for major curve angle and pelvic obliquity in managing neuromuscular scoliosis in nonambulatory CP children. Pelvic obliquity after surgery may remain stable regardless of pelvic fixation type. A higher rate of postoperative complication can be encountered with the iliac screw.

Level of Evidence: *Level III*, Retrospective Study

Introduction

Scoliosis is the most common spinal deformity in the cerebral palsy (CP) population[1] and instances of curve progression increase with age and Gross Motor Function Classification System (GMFCS) level.[2-4] Prevalence of scoliosis in GMFCS IV and V is 71% and 79%, respectively.[5] Scoliosis in nonambulatory patients with CP may cause pain and imbalanced sitting, which generates challenges for patients and caregivers.[6] Hence, surgery of scoliosis targets correction of scoliotic curve and pelvic obliquity to improve sitting balance and personal care.[7,8]

In the surgical treatment of neuromuscular scoliosis, pelvic fixation acts as a "distal anchor" to reduce pelvic obliquity, which helps with upright sitting positioning. Various techniques have been described to achieve pelvic fixation.[9] Recently, Galveston rod, iliac screw, and sacroiliac screw have been the most commonly utilized.[10] There is no clear evidence regarding the superiority of any of these techniques. Complications have been reported more commonly with iliac screw techniques than with Galveston rod or sacroiliac screw techniques.[11]

This study aimed to evaluate 3 different pelvic fixation techniques in 101 patients at intervals of a minimum of 2-year/5-year periods and determine the best technique for initially reducing and maintaining the major curve angle and pelvic obliquity. Also, we intended to assess complications with each pelvic fixation technique and the need for requiring additional surgery. We hypothesized that all 3 pelvic fixation techniques provided similar maintenance of major curve angle correction and pelvic obliquity stability; however, complication rates may vary among techniques.

Materials and Methods

This study was reviewed by our institutional review board and deemed exempt based on all regulatory statutes. We evaluated nonambulatory patients with spastic CP with severe scoliosis who underwent a spinal fusion and pelvic fixation by either Galveston rod, iliac screw, or sacroiliac screw techniques between

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Table 1. Comparison of patients' demographic, medical comorbidities, presence of intrathecal baclofen (ITB) pump, and vitamin D level

	Type of pelvic fixation			Statistical analysis (*P**)		
Variable	Galveston rod (n)	Iliac screw (n)	Sacroiliac screw (n)	Galveston rod vs. iliac screw	Galveston rod vs. sacroiliac screw	Iliac screw vs. sacroiliac screw
Sex						
Female	10	9	35	0.858	**0.023**	**0.014**
Male	15	15	17			
GMFCS level						
IV	4	6	9	0.435	0.886	0.434
V	21	18	43			
Gastrostomy						
Yes	19	14	40	0.187	0.929	0.097
No	6	10	20			
Tracheostomy						
Yes	2	3	5	0.603	0.817	0.703
No	23	21	47			
Intractable epilepsy						
Yes	10	8	34	0.628	**0.035**	**0.009**
No	15	16	18			
Vitamin D level						
<30	6	6	25	0.825	0.739	0.933
>30	12	14	27			
ITB pump						
Yes	7	5	8	0.56	0.191	0.558
No	18	19	44			

GMFCS, Gross Motor Function Classification System.
Bold type indicates statistical significance.
*Chi-square test.

2005 and 2019. A retrospective review of clinical and radiographic records from our institutional electronic medical record was performed. Inclusion criteria consisted of diagnosis of nonambulatory spastic CP (GMFCS IV-V), under 18 years of age, scoliosis treated by posterior spinal fusion from upper thoracic to sacrum with pelvic fixation, radiographs (preoperative, immediately after surgery, first-year, and second-year), and minimum 5 years of clinical follow-up. Exclusion criteria consisted of neuromuscular disorders other than CP, posterior spinal fusion without pelvic fixation, and incomplete follow-up. Demographic data were obtained from medical records and sitting scoliosis radiographs were analyzed at 5 timelines: preoperative, immediately postoperative, first year, second year, and more than 5 years after surgery. According to pelvic fixation techniques, patients were separated into Galveston rod, iliac screw, or sacroiliac screw groups. Written informed consent was obtained from all participants who participated in this study.

The primary outcome variable was to determine the stability of the major curve angle and pelvic obliquity over timeline intervals for each pelvic fixation technique. These 2 radiographic parameters were measured at 5 timeline intervals and were compared to define stability (change of magnitude between postoperative to follow-up time intervals). Secondary outcome variables were associated with demographics (sex, GMFCS level, topography, age at surgery), medical comorbidities (presence of gastrostomy and/or tracheostomy, intractable epilepsy, total vitamin D level (<30 ng/mL or >30 ng/mL), occurrence of lower limb contractures, and intrathecal baclofen (ITB) pump), and surgical complications (wound dehiscence, infection, and/or pseudoarthrosis).

HIGHLIGHTS

- Various techniques have been described to achieve pelvic fixation in surgical treatment of neuromuscular scoliosis. Galveston rod, iliac screws, and sacroiliac screws are commonly used however, there is no clear evidence regarding the superiority of any of these techniques. This study aimed to evaluate these three methods in nonambulatory patients with spastic CP.
- The results showed that corrected major curve angle and pelvic obliquity were not significantly different and remained stable over the follow-up duration. However, complication rates were the highest(9 out of 24 patients) in the iliac screw group. Additionally, iliac screws also failed to stabilize the major curve angle after 2 years.
- The results indicate that despite these techniques can provide similar correction for major curve angle and pelvic obliquity, Galveston rod technique appears to be the safest option when complication rates are considered in managing neuromuscular scoliosis in nonambulatory patients with cerebral palsy.

Statistical analysis

The collected data were analyzed using both descriptive and inferential statistics. Since this was a retrospective chart review without any sample size calculation, inferential statistics were performed on an exploratory basis. Descriptive statistics, including mean and standard deviation for outcome variables within 3 pelvic fixation techniques, were tabulated. The change in data of radiographic parameters between each time interval was analyzed by paired *t*-test to compare 2 pelvic fixation techniques. One-way analysis of variance was used for continuous variables (major curve angle, pelvic obliquity). A Chi-square test was conducted for categorical variables (GMFCS level, topography, presence of ITB pump and/or gastrostomy, tracheostomy, lower limb contracture, intractable epilepsy, vitamin D level). A P value $< .05$ was determined to be statistically significant. Statistical Package for the Social Sciences version 27 (IBM Corp., Armonk, NY, USA) was used for the analysis.

Results

One hundred one patients (54 females, 47 males) met our inclusion criteria, and mean age at scoliosis surgery was 13.5 ± 3.1 years. The mean time intervals at first-year and second-year follow-ups were 12.9 ± 1.5 and 25.8 ± 2.5 months, respectively. Additionally, 41 patients had a minimum 5-year postoperative follow-up, and the

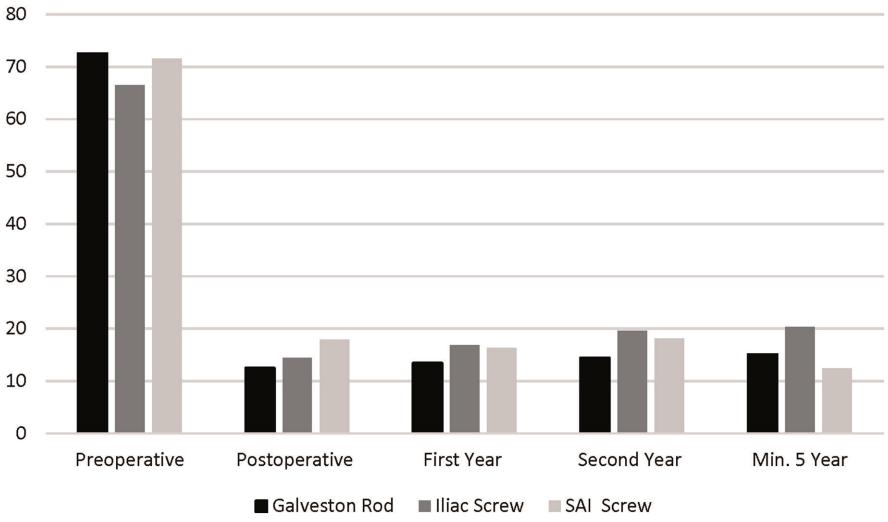

Figure 1. Graph denoting the major curve angle change over timelines. SAI, sacroiliac joint.

mean time interval was 81.5 ± 23 months. Sex, GMFCS level, medical comorbidities, presence of ITB pump, and vitamin D level were compared for each pelvic fixation technique (Table 1). All variables were similar except intractable epilepsy and female sex were more common in the sacroiliac screw group.

Of 101 patients who underwent surgery from the upper thorax to sacrum with pelvic fixation, 25 were with Galveston rod, 24 with iliac screw, and 52 with sacroiliac screw. Of 41 patients who had a minimum 5-year follow-up, 10 patients had Galveston rod, 11 had iliac screw, and 20 had sacroiliac screw fixation. Major curve angle and pelvic obliquity parameters measured at 5 timelines (preoperative, immediately after surgery, first-year, second-year, and minimum 5-year follow-up) were 70.5° ± 21.1°, 15.7° ± 13°, 15.7° ± 12°, 17.5° ± 12.7°, and 15.1° ± 9.6°, respectively (Figure 1). Pelvic obliquity at 5 timelines (preoperative, immediately after surgery, first-year, second-year, and minimum 5-year follow-up) was 14.8° ± 10.4°, 4.9° ± 4.2°, 5.7° ± 4.6°, 5° ± 4.4°, and 7.2° ± 4.4°, respectively (Figure 2). After the surgery to the last follow-up, the major curve angle and pelvic obliquity remained stable ($P > .05$). Major curve angle and pelvic obliquity degrees at each timeline after surgery were similar and remained stable, which was not statistically significant between the 3 pelvic fixation techniques ($P > .05$) (Table 2). When comparing timelines with each pelvic fixation technique, the iliac screw technique did not stabilize the major curve angle as an increase was statistically significant at the second-year follow-up ($P = .012$) (Table 3).

Fifteen patients had complications requiring additional surgery. One patient (Galveston rod group) had proximal junctional kyphosis. Nine patients in the iliac screw group had complications: 7 had infection, 1 had pseudoarthrosis, and 1 had wire breakage. Five patients in the sacroiliac screw group had complications: 4 had infection and 1 had pseudoarthrosis. The iliac screw technique had the highest rate of complications compared with the other techniques (Galveston rod vs. iliac screw: $P = .004$, sacroiliac screw vs. iliac screw: $P = .008$).

Discussion

Our study reveals that each type of pelvic fixation provided stability for pelvic obliquity in patients with spastic CP who had similar demographic and medical comorbidities. The iliac screw group did not maintain the major curve angle at the second-year follow-up compared with the postoperative result. However, the major curve

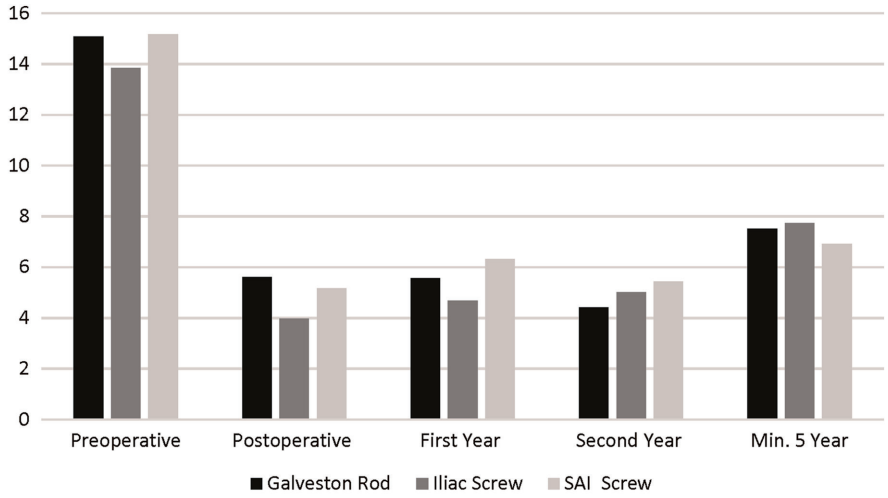

Figure 2. Graph denoting the pelvic obliquity change over timelines. SAI, sacroiliac joint.

Table 2. Types of pelvic fixation compared at each timeline

	Type of pelvic fixation			Statistical analysis (*P**)		
	Galveston rod (n)	Iliac screw (n)	Sacroiliac screw (n)	Galveston rod vs. iliac screw	Galveston rod vs. sacroiliac screw	Iliac screw vs. sacroiliac screw
Major curve angle (°)						
Preoperative	72 ± 19	66 ± 15	71 ± 24	0.943	1	0.988
Postoperative	12 ± 9	14 ± 12	17 ± 14	1	0.28	0.834
First year	13 ± 8	16 ± 11	16 ± 13	1	1	1
Second year	14 ± 8	19 ± 13	16 ± 13	0.475	0.717	1
Minimum 5 years	15 ± 8	20 ± 6.9	12 ± 10	0.61	1	0.082
Pelvic obliquity (°)						
Preoperative	15 ± 10	13 ± 10	15 ± 10	1	**1**	1
Postoperative	5 ± 4	4 ± 3	5 ± 4	1	0.533	0.766
First year	5 ± 4	4 ± 3	6 ± 5	1	1	0.469
Second year	5 ± 4	5 ± 3	6 ± 5	1	1	1
Minimum 5 years	7 ± 4	7 ± 4	7 ± 5	1	**1**	**1**

Bold type indicates statistical significance.
*Bonferroni analysis.

Table 3. Comparison of timelines at each pelvic fixation technique

	Timeline					Statistical analysis (*P**)			
	Preoperative	Postoperative	First year	Second year	Minimum 5 years	Preoperative vs. Postoperative	Postoperative vs. first year	Postoperative vs. second year	Postoperative vs. minimum 5 years
Major curve angle (°)									
Galveston rod	72 ± 19	12 ± 9	13 ± 8	14 ± 8	15 ± 8	<.001	0.449	0.152	0.204
Iliac screw	66 ± 15	14 ± 12	16 ± 11	19 ± 13	20 ± 6.9	<.001	0.243	**0.012**	0.052
Sacroiliac screw	71 ± 24	17 ± 14	16 ± 13	16 ± 13	12 ± 10	<.001	0.137	0.873	0.722
Pelvic obliquity (°)									
Galveston rod	15 ± 10	5 ± 4	5 ± 4	5 ± 4	7 ± 4	<.001	0.97	0.221	0.581
Iliac screw	13 ± 10	4 ± 3	4 ± 3	5 ± 3	7 ± 4	<.001	0.409	0.313	0.105
Sacroiliac screw	15 ± 10	5 ± 4	6 ± 5	6 ± 5	7 ± 5	<.001	0.105	0.683	0.249

Bold type indicates statistical significance.
*Paired *t*-test analysis.

angle increase is not statistically significant when compared with the other pelvic fixation techniques. In addition, pelvic obliquity after surgery remained stable over timelines regardless of pelvic fixation type, showing equivalent results for correction of pelvic obliquity. Contrary to our study, a multicenter study showed that sacroiliac screw fixation provides better correction for major curve angle and pelvic obliquity and is more stable at 5-year follow-up than iliac screw fixation.[11] This difference may address single vs. multicenter and diverse surgical experiences. Dayer et al[12] reported that surgeon experience influences performing a pelvic fixation technique and they discussed 6 different techniques/criteria of pelvic fixation; however, no statistical variances were given.

In our study, 15 patients (15%) had complications, including infection (n=11) and implant-related complications (n=4). These complication rates were not similar to the literature. Pelle et al[10] indicate a similar complication rate between Galveston rod and iliac screw fixation in neuromuscular scoliosis, which includes other neuromuscular disorders such as Duchenne muscular dystrophy and Rett syndrome. We believe the diversity of neuromuscular diseases may lead to a different result than our study. Lee et al[13] show complication rates between iliac screw and sacroiliac screw fixation were not different. Their study also includes different types of neuromuscular scoliosis. Jain et al[14] report an infection rate in CP scoliosis with sacroiliac screw fixation to be 16%, which is higher than in our study (8%).

Our data were collected retrospectively; therefore, selection bias or misclassification bias could be considered as possibilities. However, we included all consecutive cases of nonambulatory patients with spastic CP undergoing posterior spinal fusion to the pelvis for scoliosis from 2005 to 2019, which helped minimize the effect of missing data selection bias. Possibly, a decision bias for treatment could occur in that the patient/family and surgeon made surgical decisions. The strength of our study was that no cases were lost to follow-up and all treatment was performed in a single, tertiary care pediatric hospital with a specific team-based CP center.

In conclusion, 3 techniques of pelvic fixation (Galveston rod, iliac screw, and sacroiliac screw) provide equivalent correction for major curve angle and pelvic obliquity. When comparing the timelines of each pelvic fixation technique, the iliac screw technique did not stabilize the major curve angle at the second-year follow-up ($P = .012$). However, the major curve angle increase was not statistically significant when compared with the other pelvic fixation techniques. In addition, pelvic obliquity after surgery remains stable over timelines regardless of pelvic fixation type, showing equivalent results with all 3 techniques for correction of pelvic obliquity. Complication rates were the highest in the iliac screw group and the lowest in the Galveston rod group.

Ethics Committee Approval: The study "Pelvic Fixation Loosening in Spastic vs Hypotonic Neuromuscular Scoliosis: Comparison of Cerebral Palsy and Hypotonic Disorders (Duchenne Muscular Dystrophy and Spinal Muscular Atrophy" on which the present manuscript is based received administrative and was deemed exempt (based on the applicable federal regulations and meets all DHHS criteria) by the Nemours Institutional Review Board on April 27, 2022, IRB# 1748798-2.

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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