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Clinical Studies

Pelvic fixation in surgical correction of neuromuscular scoliosis

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ABSTRACT

Background: Surgical correction of neuromuscular scoliosis can be associated with high complication rates, including such associated with pelvic fixation. Up to now it is debated whether and when to include the pelvis into the fusion construct. Therefore, we aimed to illuminate when pelvic fixation is beneficial in surgical correction of neuromuscular scoliosis.

Methods: A prospective cohort of 49 patients (mean age 13 ± 3 y, 63% females, follow up 56 months, range 24–215) who underwent correction of neuromuscular scoliosis including S1/the ileum ($n = 18$) or without ($n = 31$) pelvic fixation were included. The outcome was measured with analysis of radiological parameters, clinical improvement and complication/revision rates. Subgroup analysis was performed to find if non-ambulatory patients with gross motor function classification system (GMFCS) levels >III, with larger scoliotic curves (>60°) and moderate pelvic obliquities up to 35° benefit from pelvic fixation.

Results: There was no significant difference in complications when comparing patients with (9 out of 18 patients, 50%) or without (9 out of 31 patients, 29%) fixation to the pelvis ($p = .219$). Wheelchair bound patients (GMFCS >III) with cobb angles greater than 60° and pelvic obliquity less than 35° ($n = 20$) revealed no differences in amount of clinical improvement of ambulation with ($n = 9$) or without ($n = 11$) pelvic fixation (p: n.s.). And even complication or revision rates where not different in those two groups.

Conclusion: Pelvic fixation does not seem obligatory in wheelchair bound patients per definition. Even with pelvic obliquities up to 35° and large scoliotic curves >60°, avoiding pelvic fixation does not result in higher revision rate or worse clinical outcomes.

Background

Surgical correction of neuromuscular scoliosis is associated with high complication rates ranging from 17 to 74% [1,2]. Revision surgery and readmissions range up to 25% [3]. Despite high complication rates, neuromuscular scoliosis correction is thought to be beneficial since scoliosis with Cobb angles above 40° tend to deteriorate if managed conservatively [4–6], even in adolescent spines with underlying neuromuscular disorders.

The risk of complications leading to revisions can be partially counteracted by adequate surgical decision making [7]. Among such, the need of fixation to the pelvis is debated and clear criteria to assist with such a decision are lacking [8–10]. Generally, pelvic fixation is avoided in ambulatory patients [7,9] and recommended in wheelchair bounded patient (e.g. with gross motor function classification system GMFCS levels >III) [9,11]. However, pelvic fixation is also associated with higher blood loss, increased surgical time, higher costs, increased lumbosacral cavity, limited iliac bone harvesting ability, greater implant prominence with the risk of skin ulcerations and even higher pseudoarthrosis rates [8,9,12,13].

The main challenging question remains in which situation is pelvic fixation clinically beneficial to such patients. With this research question in mind, we hypothesized that pelvic fixation is not needed in all wheelchair-bound neuromuscular scoliosis patients.

Methods

Study population

Approval from the local ethics review board was given before starting this retrospective analysis. Patients primarily operated for neuromuscular scoliosis from 2000 until 2018 were identified using a single center electronic patient file system (Fig. 1). Only patients with a minimal follow-up of two years were included to document baseline characteristics such as age, gender, surgeon, surgical procedure, diagnosis (Table 1). All electronically archived files were screened pre- and postoperatively to obtain GMFCS impairment levels, sitting balance, ambulatory status, complications and surgical revisions.

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Table 1
Patient demographics, preoperative and postoperative measures.

Preoperative	***n* = 49**	**Postoperative**	***n* = 49**
Age, y, mean (SD)	13 (3.4)	Follow up, m, median (IQR)	36 (35)
Cobb angle, °, mean (SD)	70 (19.0)	Cobb angle postoperative, °, mean (SD)	29 (17.2)
		Cobb angle latest follow up,°, mean (SD)	37 (20.5)
Pelvic obliquity, °, mean (SD)	20 (14.3)	Pelvic obliquity, °, mean (SD)	13 (13.8)
CL4, °, mean (SD)	16 (9.7)	CL4,°, mean (SD)	7 (9.6)
Mobility		***Improvement in sitting or walking***	
No sitting balance	28	Yes	30
Sitting balance	21	No	19
Not walking	37		
Walking	12		
GMFCS		GMFCS Improvement, mean (SD)	0.5 (0.61)
I	3	***Complications***	
II	5	Yes	18
III	4	Consequence A	3
IV	13	Consequence B	1
V	24	Consequence C	14
Sex		No	31
Female, n	31	***Revisions***	
Male, n	18	Yes	14
		No	25

Consequences in complications are rated according to Farshad et al. [16]

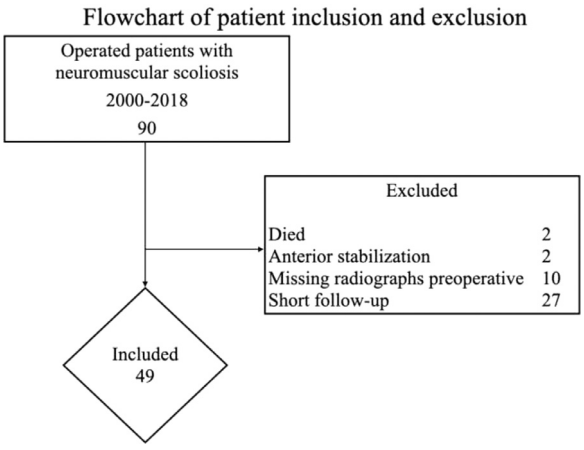

Fig. 1. Flow chart for patient inclusion.

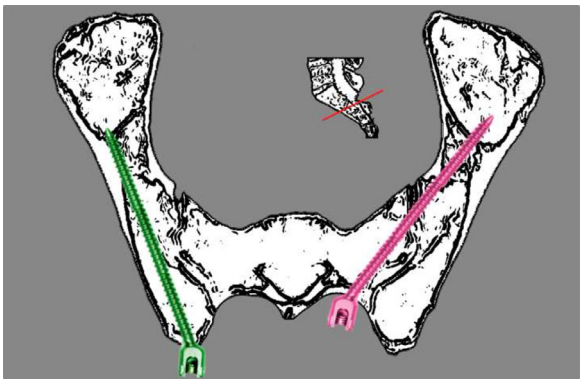

Fig. 2. Axial illustration for pelvic screw placement, the viewing angle of the axial cut is shown in the miniature picture. At the patient's right side in green an alar iliac screw and on the patients left side in pink a S2 alar iliac screw.

Surgical approach

Surgery was performed through a standard posterior midline approach. Pedicle screws were used for scoliosis correction. Pelvic fixation was achieved with pedicle screws in S1 ($n = 2$) or alar-iliac screws ($n = 16$). Fixation of the pelvis was achieved with different techniques according to surgeon preference. If the fixation with S1 screws was not expected to provide sufficient hold, the pelvis was included into the stabilization. Depending on patient anatomy and stability different screw and fixation constructs were used (Fig. 2) [14]. All these constructs were summarized into the group of alar-iliac screws.

In one patient, an anterior release at the apex level T11 was performed prior to posterior stabilization due to insufficient curve flexibility on preoperative bending radiographs. The decision toward pelvic fixation among the wheelchair bound patients (only with GMFCS levels >III) was based on pelvic obliquity and sitting imbalance.

Radiographic follow up

Whole spine radiographs were reviewed, and Cobb angles were measured pre-, postoperatively and at final follow up (Figs. 3 and 4). The angle between L4 upper endplate and the connection of the most cranial part of the iliac crests was measured (CL4) in antero-posterior (AP) whole spine radiographs (Fig. 5). Pelvic obliquity was measured as described by Maloney [15] with preoperative radiographs and at latest follow up (Fig. 6).

Complications

Complications were assessed using radiographs and electronic patient files and classified as A (mild), B (moderate), C (severe), D (life-threatening) and E (death) [16]. Wound healing problems were coded as prolonged wound discharge and postoperative wound dehiscence. Infection was diagnosed if there was purulent discharge, an open sinus to the implant or if, in case of revision, at least two tissue probes presented the same germ. Screw loosening was checked on follow up radiographs and in revision cases according to surgeon's description. Patient files and

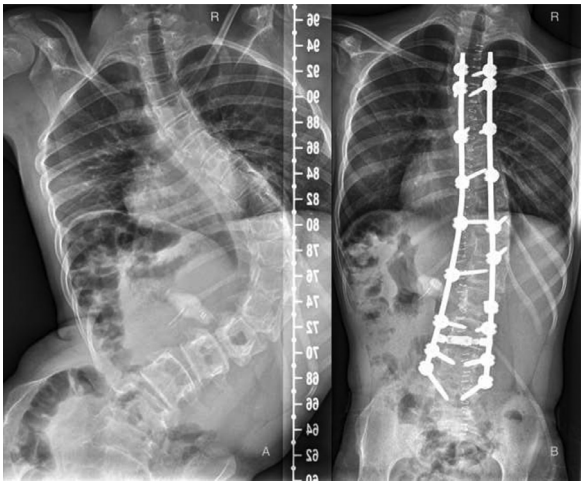

Fig. 3. A: 13-year-old patient with a cerebral palsy related scoliosis. Preoperative whole spine radiograph with a scoliotic deformity of 113° cobb angle between Th8 and L3. Pelvic obliquity (Maloney) of 25°
B: Postoperative radiograph after posterior correction from Th4 to L5 not including the pelvis. Cobb angle: 24°, Pelvic obliquity: 6°.

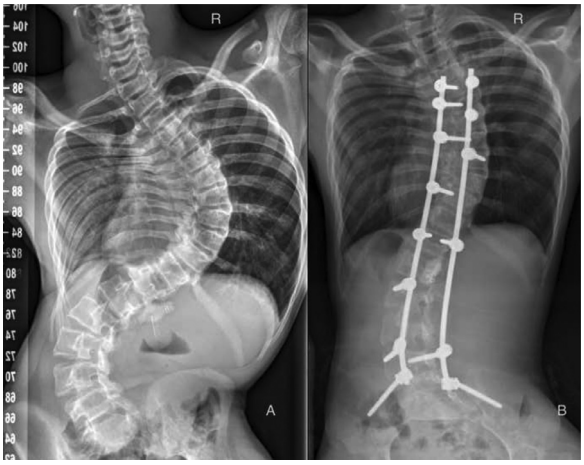

Fig. 4. A: 15-year-old patient with a cerebral palsy related scoliosis. Preoperative whole spine radiograph with a double curved scoliotic deformity of 95° cobb angle between Th12 and L5 and 105° between Th3 and Th12. Pelvic obliquity (Maloney) of 13°
B: Postoperative radiograph after posterior correction from Th5 to the ilium including the pelvis. Cobb angles: 43° and 54°, Pelvic obliquity: 5°.

radiographs were identified for revision surgeries and implant failures (screw/rod breakage, disconnection screw/rod) were registered.

Subgroup analysis of with GMFCS >III patients

A subgroup analysis among wheelchair bound GMFCS >III patients was performed to find a pelvic obliquity cut off value which still allows secure scoliosis correction without pelvic fixation. The subgroup was further limited to patients with a preoperative cobb angle above 60° since this cobb angle is associated with an elevated complication risk compared to patients with lower cobb angles [4]. Furthermore, a pelvic obliquity angle of 35° was chosen as the upper limit for inclusion since this was the greatest pelvic obliquity angle, which was not fused to the pelvis. This resulted into two homogenous groups of patients with (wp) and without (wop) pelvic fixation which were then compared in terms of radiological and clinical outcome.

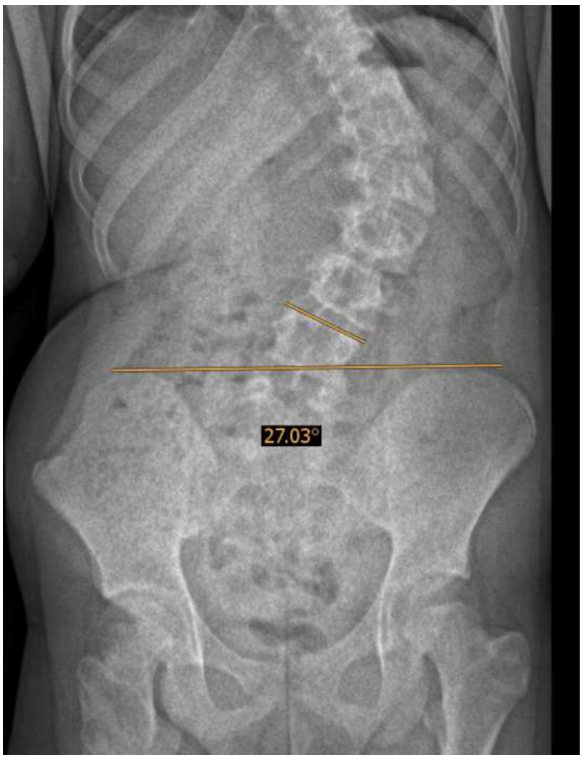

Fig. 5. AP view of the pelvis and the lower lumbar spine. Measurement of the coronal balance of the lower two segments is drawn in yellow (CL4). The angle is measured between the upper end-plate of the L4 vertebrae and a connection between both iliac crests.

Statistical analysis

For normal distributed data means and standard deviations (SD) are reported. For non-normally distributed data medians and interquartile ranges (IQR) are reported. A two-sided unpaired Student t-test was used for normally distributed data and was further specified with 95% confidence interval (CI). Mann-Whitney-U test was used for group comparison with non-normally distributed data. Correlation analysis was performed with Pearson Chi Square test if there were at least five patients in each group, otherwise Fisher's exact correlation test was used. A retrospective analysis including a ROC analysis was performed to evaluate thresholds for pelvic fixation. A p-value < .05 was considered statistically significant. SPSS version 26 (IBM, Armonk, NY, USA) was used for statistical analysis.

Results

The cohort of the 49 patients consisted of patients with cerebral palsy in 38 (78%) patients and other neuromuscular disorders such as syndrome associated in 3 (6%), tumor associated in 2 (4%), spinal muscular atrophy in 1 (2%), myasthenia gravis in 1 (2%), neurofibromatosis in 1 (2%) and unknown in 3 (6%) patients. The mean age was 13 years (SD 3.4). A large fraction of the patients was not ambulatory (Table 1) and had moderate scoliotic curves (mean 70° (SD19°)).

Most commonly ($n = 29$, 59%), the fourth thoracic vertebra (T4) was chosen as upper instrumented vertebra (Fig. 7). Distal fixation included the pelvis in 37% of cased ($n = 18$). Such patients were all with a GMFCS level of IV ($n = 6$) or V ($n = 12$). Nineteen patients (39%) with GMFCS IV ($n = 7$) and V ($n = 12$) were not fixed to the pelvis. No pelvic fixation was performed in GMFCS I-III patients ($n = 12$, 24%).

The receiver operating characteristic curve for GMFCS IV and V patients for pelvic obliquity if the pelvis was included showed an area un-

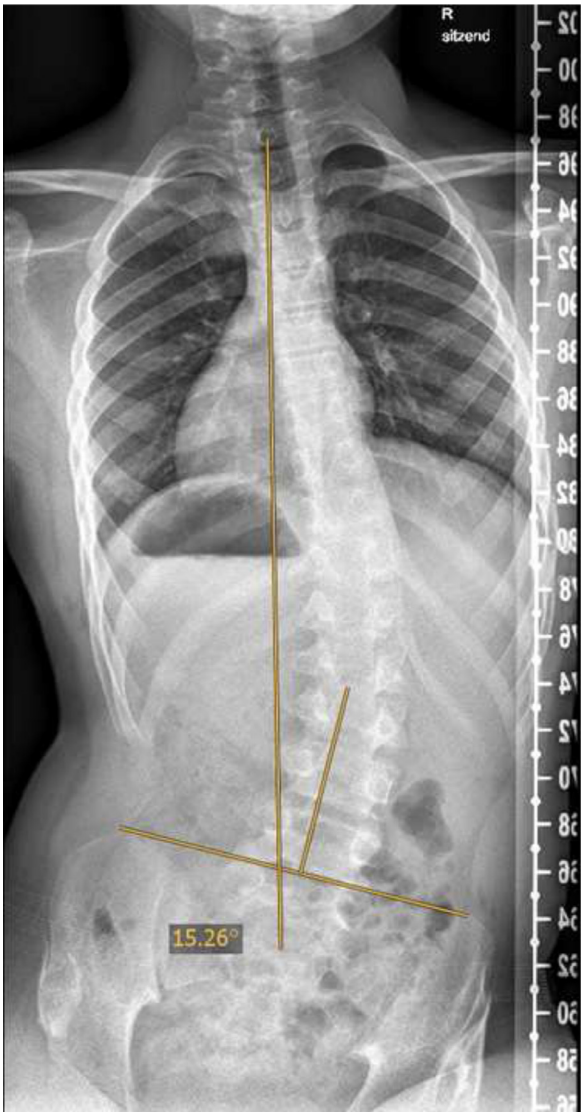

Fig. 6. AP total spine radiograph with pelvic obliquity measurement according to Maloney [15] in yellow. The angle is measured between a perpendicular line to the connection of the iliac crests and T1 to S1.

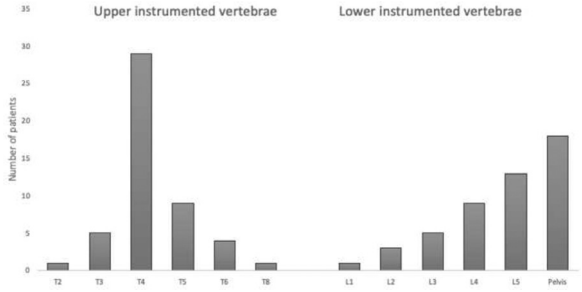

Fig. 7. Number of patients in relation to upper and lower instrumented vertebrae.

der the curve of .756 which is considered a fair correlation. The highest Youden-Index was at 25.5° of pelvic obliquity.

Clinical outcome, complications, and revisions

30 patients (61%) had a postoperative improvement of sitting balance or walking status with GMFCS levels improving by 0.5 ± 0.6 points on average (Table 1).

Table 2
Complications.

	Total $n = 22$	Pelvic base $n = 12$	Lumbar base $n = 10$	Significance (p)
Screw loosening	8 (36%)	5 (42%)	3 (30%)	.124
Implant failure	4 (18%)	1 (8%)	3 (30%)	1
Curve progression	1 (5%)	1 (8%)	0 (0%)	.367
Infection	5 (23%)	2 (17%)	3 (30%)	1
Wound healing	4 (18%)	3 (25%)	1 (10%)	.134

Table 3
Revisions.

Indication for Revision	Revisions ($n = 14$)	Mean Time until first revision (m)
Curve progression	1 (7%)	84
Infection	4 (29%)	34
Prominent screw and skin irritation	1 (7%)	7
Screw loosening	5 (36%)	62
Implant failure	3 (21%)	11

Complications occurred in 18 out of 49 patients (37%) (Table 2). In these 18 patients we counted a total of 22 complications. Of the patients with screw loosening only two patients had a loosening cranial. Both of these patients were lumbar based and both of them needed revision surgery with either implant shortening or complete removal. Both patients only fixed to S1 had radiographic screw loosening but none of them needed revision surgery. Of the implant failures there was one patient with L3 screw dislocation and three patients with rod breakage or dislocation. Complication rate was not significantly different in GMFCS I-III patients (6 out of 12 patients, 50%) compared to GMFCS IV and V patients (12 out of 37 patients, 32%, $p = .540$).

There was no significant difference in terms of complications when comparing patients with (9 out of 18 patients, 50%) or without (9 out of 31 patients, 29%) fixation to the pelvis ($p = .219$). Preoperative cobb angles, pelvic obliquity and CL4 angles had no significant impact on complication rates ($p = .589$; $p = .736$; $p = .393$).

Revision surgeries occurred in 14 of 18 patients (78%) most commonly due to screw loosening, followed by infections and implant failures (Table 3). Screw loosening at the pelvic base was solved with revision fusion. A total of 19 revision surgeries were performed in these patients. Median time until revision surgery was 25 months with a range from 1 to 132 months. All six patients with complications in the GMFCS I-III patient group underwent revision surgery whereas in the GMFCS IV and V patient group eight out of 12 patients with complications were reoperated ($p = .082$).

Patients who underwent revision surgery were not significantly different to the other patients in pre- and postoperative radiologic measurements or clinical outcome measures such as pre- and postoperative GMFCS, sitting balance and standing ability (all $p > .112$).

Subgroup analysis of GMFCS >III patients

The subgroup analysis of 20 patients with GMFCS IV and V with scoliosis cobb angles of ≥ 60° and pelvic obliquity < 35° showed two homogenous groups of patients with (wp) and without (wop) pelvic fixation with no significant difference in preoperative cobb angles or pelvic obliquity. Pelvic fixation was performed in 9 of these patients (45%) with equal distribution between GMFCS IV and V patients, respectively ($p = 1.000$, Table 4).

At final follow-up there was no difference in clinical improvement of ambulation ($p = 1.000$), complication ($p = .226$) or revision rate ($p = .668$) between these two groups.

Table 4
Subgroup analysis.

Preoperative	wp $n = 9$	wop $n = 11$	Significance (p)	Total $n = 20$	Postoperative	wp $n = 9$	wop $n = 11$	Significance (p)	Total $n = 20$
Age, y, mean (SD)	13 (2)	13 (2)	.882	13 (2)	Follow up, m, median (IQR)	29 (26–60)	47 (27–60)	.295	51 (31)
Cobb angle, °, mean (SD)	78 (13)	79 (17)	.975	79 (15)	Cobb angle postoperative, °, mean (SD)	43 (12)	29 (12)	.020	35 (14)
					Cobb angle latest follow up, °, mean (SD)	41 (15)	32 (13)	.168	36 (14)
Pelvic obliquity, °, mean (SD)	18 (10)	19 (7)	.681	19 (8)	Pelvic obliquity, °, mean (SD)	10 (10)	14 (7)	.301	12 (9)
CL4, °, mean (SD)	19 (9)	15 (9)	.340	17 (9)	CL4, °, mean (SD)	12 (7)	3 (6)	.005	7 (8)
Mobility					***Improvement in Sitting or walking***				
No sitting balance	7	8	1.000	15	Yes	7	9	1.000	16
Sitting balance	2	3		5	No	2	2		4
GMFCS					GMFCS Improvement, mean (SD)	0.6 (0.5)	0.8 (0.4)	.331	0.7 (0.5)
IV	3	3	1.000	6	***Complications***				
V	6	8		14	Yes	4	2	.336	6
Sex					Consequence A	2	0		2
Female, n	7	8	.604	15	Consequence B	0	0		0
Male, n	2	3		5	Consequence C	2	2		4
wp: Patients with pelvic fixation, wop: patients without pelvic fixation, CL4: Radiographic angle between both iliac crests and upper end plate L4					No	5	9		14
					Revisions				
					Yes	2	2	1.000	4
					No	7	9		16

Discussion

The criteria for and potential value of pelvic fixation as adjunction to long construct in the surgical treatment of neuromuscular scoliosis is unclear and debated. We aimed to break the dogma that pelvic fixation must be done in non-ambulatory neuromuscular scoliosis patients [3,9,13]. In our collective, pelvic fixation was mostly performed in patients with high preoperative cobb angles and higher pelvic obliquity (>25°) and not per definition in every non-ambulatory patient. Even with such an approach we found that pelvic fixation was neither associated with superior curve correction nor superior clinical outcome.

We observed a rather high complication rate of 37%, which however seem to be within the range of previous reports (17–74%) [1,2]. The most common complication was screw loosening, which was also the most common reason for revision. Interestingly both patients only fixed to S1 did not need revision surgery although their screws were loose. Furthermore, cranial screw loosening was only seen in lumbar based constructs. The revision of these two patients was relatively mild with implant removal compared to revision fusion in most of the loose screws at the pelvis. Revision rates reached up to 29% and revisions were performed after a maximum of eleven years. Although our revision rate is high it is comparable to recent literature [3] and well explained by the long follow up. We could not find any association between pelvic fixation and the need for revision surgery or complications. In only one revision the pelvis was additionally included. This is in line with a larger series where 5% of revisions were performed with additional pelvic fixation [3].

As preoperative cobb angles ≥ 60° are associated with an elevated complication risk [4], we chose 60° cobb angle as the lower limit to analyze our subgroup of non-ambulating patients (GMFCS IV and V). We furthermore implemented a limitation of 35° of pelvic obliquity as all the patients above this value were fixed to the pelvis. In this subgroup, in terms of complication rate, no significant difference was observed comparing patients with and without pelvic fixation. Postoperative cobb angles and L4 to iliac crest angles (CL4) were even better corrected without pelvic fixation. Concordantly, we found no clinically relevant differences between the two subgroups with and without pelvic fixation. This observation suggests that pelvic fixation might not be necessary, even in non-ambulating patients with cobb angles ≥ 60° and pelvic obliquity ≤ 35°. This would be concordant to older literature advising against pelvic fixation in neuromuscular scoliosis [8, 17]. However, we believe that in higher grades of pelvic obliquities and sitting imbalances, pelvic fixation should be considered.

Further, we aimed to quantify the contribution in the lower two spinal segments with the CL4 angle (Fig. 5). Preoperatively there was no significant difference in terms of CL4 angles comparing patients with or without subsequent pelvic fixation and postoperative CL4 angles were even significantly lower in patients without pelvic fixation. This suggests that the coronal imbalance from L4 to the iliac crest might even better corrected if the pelvis is not included into the fusion.

Limitations

The here documented findings and their interpretation can only be valuable in simultaneous consideration of the limitation of the data. First, the sample size might seem small and might not be representative for a larger collective. However, neuromuscular scoliosis is a rare disease and as such a collective collected over nearly 2 decades years is valuable. Second, the measurement of pelvic obliquity per se has some dependency on standardization of radiographs and sitting position, etc. Third, we retrospectively report findings of a cohort, not randomized to pelvic fixation. This allows to describe the results of our decision algorithm but does not allow randomized comparison.

Conclusion

Pelvic fixation in surgical correction of neuromuscular scoliosis is not obligatory in wheelchair bound patients per definition. Even with pelvic obliquities up to 35° and large scoliotic curves >60° avoiding pelvic fixation does not result in higher revision rate or worse clinical outcomes.

Ethical approval

All procedures performed were in accordance with the ethical standards of the institutional ethics committee and with the 1964 Helsinki Declaration and its later amendments. The study was approved by the cantonal ethics committee of Zurich (KEK-ZH-Nr. 2020-01996).

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There was no external source of funding for this study. The authors declare that they have no known competing financial interests or per-

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Declaration of Competing Interest

None

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100123.

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