

Controversies with nonoperative management for adolescent idiopathic scoliosis: Study from the APSS Scoliosis Focus Group

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Abstract

Purpose: To determine consensus among Asia-Pacific surgeons regarding nonoperative management for adolescent idiopathic scoliosis (AIS). **Methods:** An online REDCap questionnaire was circulated to surgeons in the Asia-Pacific region during the period of July 2019 to September 2019 to inquire about various components of nonoperative treatment for AIS. Aspects under study included access to screening, when MRIs were obtained, quality-of-life assessments used, role of scoliosis-specific exercises, bracing criteria, type of brace used, maturity parameters used, brace wear regimen, follow-up criteria, and how braces were weaned. Comparisons were made between middle–high income and low-income countries, and experience with nonoperative treatment. **Results:** A total of 103 responses were collected. About half (52.4%) of the responders had scoliosis screening programs and were particularly situated in middle–high income countries. Up to 34% obtained MRIs for all cases, while most would obtain MRIs for neurological problems. The brace criteria were highly variable and was usually based on menarche status (74.7%), age (59%), and Risser staging (92.8%). Up to 52.4% of surgeons elected to brace patients with large curves before offering surgery. Only 28% of responders utilized CAD-CAM techniques for brace fabrication and most (76.8%) still utilized negative molds. There were no standardized criteria for brace weaning. **Conclusion:** There are highly variable practices related to nonoperative treatment for AIS and may be related to availability of resources in certain countries. Relative consensus was achieved for when MRI should be obtained and an acceptable brace compliance should be more than 16 hours a day.

Keywords

adolescent idiopathic scoliosis, AIS, bracing, nonoperative

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Introduction

The majority of patients with adolescent idiopathic scoliosis (AIS) undergoes nonoperative treatment in the form of observation, bracing, and/or exercises. Only a small subset of these patients eventually require spinal fusion surgery.¹ The main aim of nonoperative treatment is to prevent curve progression and adulthood progression.^{2,3} However, the options of nonoperative treatment are highly variable without clear consensus.^{4,5} Standardization of care is important to improve overall healthcare efficiency as well as for comparative research.

Despite the proven benefits of brace treatment for AIS,⁶ various nuances of bracing have yet to be well-understood. Specifically, the indications, follow-up imaging, and timing of weaning should be clarified. The Scoliosis Research Society (SRS) criteria for initiating bracing includes Risser stage 0–2, major curve Cobb angle 20–40°, and no later than post-menarche 1 year. Despite this well-quoted guideline, many consider bracing to be useful even for large curves >50°. ^{7,8} The indications may expand further than simply preventing surgery as bracing has potential to drive vertebral remodeling and curve regression.^{9,10} At the other end of the spectrum is brace weaning. One article suggests brace weaning at Risser 4, 12 months post-menarche and lack of height gain.¹¹ Another recommended weaning at Risser stage ≥4, more than 2 years post-menarche and no height gain between two visits of unknown duration.¹² Despite using these criteria, the curve progression rate after weaning has been reported to be as high as 29.2%.¹³ Most surgeons are moving toward standardized bone age parameters such as Sanders staging¹⁴ and the distal radius and ulna classification (DRU)^{15–17} due to the limitations of Risser staging.¹⁸

Given the lack of consensus regarding various aspects of nonoperative treatment for AIS, it is appropriate at this stage to identify the variations in practice. As an initiative by the Asia Pacific Spine Society (APSS) Scoliosis Focus Group, we are tasked to understand the trends in nonoperative treatment for AIS in the Asia-Pacific region. Moreover, we grab this opportunity to study the diagnostic methods of AIS, use of scoliosis-specific exercises, and follow-up criteria.

Methods

Study design

An online REDCap questionnaire (Online Appendix A) consisting of 51 questions was circulated to members of the Asia Pacific Spine Society (APSS). The questionnaire was constructed based on a Delphi method panel discussion between members of the APSS Scoliosis Focus Group. The experts were asked for their opinions on the topics of diagnosis, use of scoliosis-specific exercises, and bracing. Three rounds of modifications of the questions were circulated within the focus group and a final questionnaire

(Online Appendix A) was distributed electronically during the period of July 2019 to September 2019 to surgeons in the Asia-Pacific region on their practice of nonoperative treatment for AIS.

Parameters

Participants reported on their demographics and experience, use of diagnostic and assessment tools, availability of services in their country, bracing regimens, maturity assessment parameters, and method of follow-up. For demographics, questions included their country of practice and years practicing spine surgery. When MRIs were obtained for patients was included. Choices included: “all cases,” “neurological problems,” “right-sided lumbar curve,” “left-sided thoracic curve,” “short angular curves,” and “any male patient”. Participants reported on whether they used objective quality-of-life assessments including the 22-item SRS (SRS-22), 36-item short form, and Euro-QoL 5-dimension (EQ-5D) questionnaires which were scores well-established for studying AIS.^{19–24}

Availability of services included any screening program available and type of program (hospital-based, government-based, country-wide), scoliosis-specific exercises, and designated orthotists to fabricate braces. Additional conceptual questions including the potential cause for scoliosis and its deterioration were also included. Choices included “poor sitting posture,” “sleeping on a side,” “single arm sports,” “not enough exercises,” “inadequate sleep,” and “family history of scoliosis”. Participants were also asked whether scoliosis would cause pregnancy complications.

Bracing questions included its availability, brace initiating criteria, and brace weaning criteria. Participants were asked the frequency of prescription per month; type of brace used such as Boston, Milwaukee, Rigo-Chêneau, and Charleston bracing; how brace fabrication was planned; and how the brace was made. Fabrication planning methods included standing radiograph, supine radiograph, side-bending radiographs, and traction radiographs. Brace fabrication methods included molding, computer-aided design and manufacturing systems (CAD/CAM), and 3D printing. Questions regarding the Cobb angle in which bracing would be initiated and specifically for 50° curves and proximal thoracic curves were also included. The use of night-time or full-time bracing was elucidated. Brace compliance methods included patient reporting, thermal sensor, or pressure sensor. The daily acceptable brace wear and follow-up duration were reported. Participants disclosed whether patients removed their braces during exercise, whether explanation was provided to teachers and whether their cooperation was requested to prevent teasing by other students, and whether preferences such as sitting near a fan/air-conditioning and extra time during classes for brace wear were given to the patient. Indication for brace discontinuation and skeletal maturity parameters used to decide

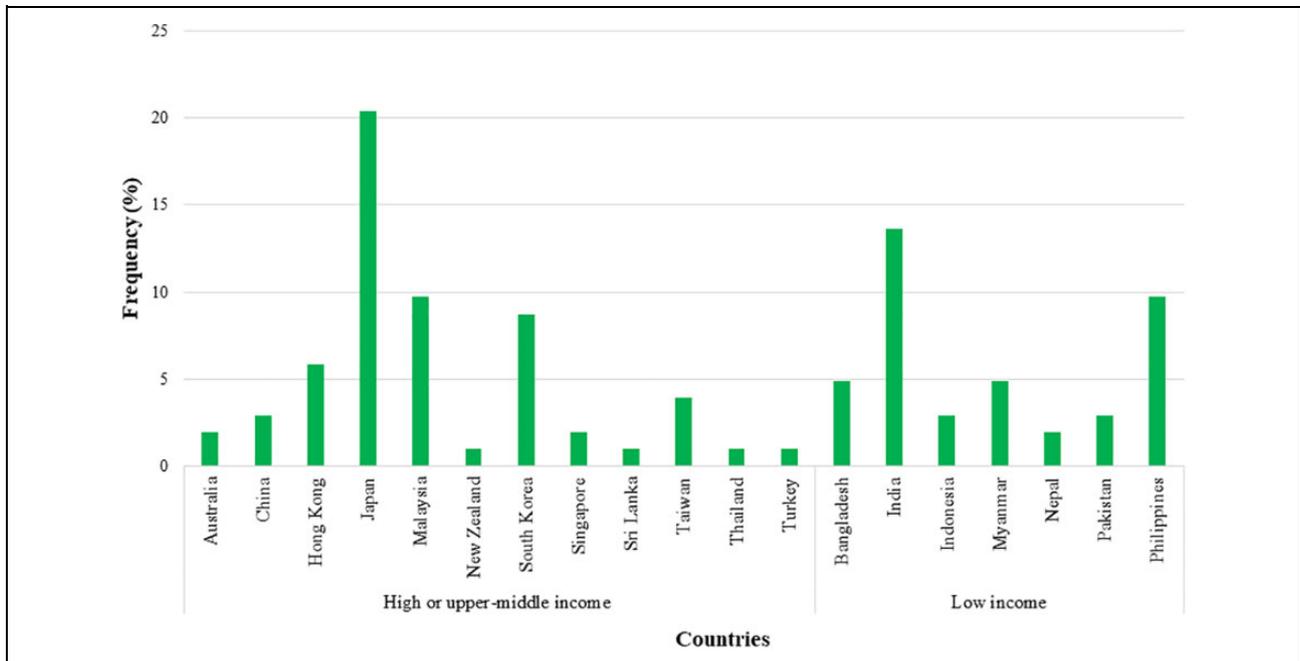


Figure 1. Distribution of participants by country.

was included. The method of weaning included gradual, nocturnal, or off immediately.

Maturity parameters used included choices of chronological age, change in body height, arm span and sitting height, Tanner staging, Menarche status, Risser staging, open or closed triradiate cartilage, olecranon staging, DRU, Sanders staging, Tanner and Whitehouse staging, and Greulich and Pyle atlas.

Statistical analysis

The main determinants of practice in the heterogeneous Asia-Pacific region were the availability of resources and experience with nonoperative care for AIS. For analysis, countries were divided into middle–high income (Australia, China, Hong Kong, Japan, Malaysia, New Zealand, South Korea, Singapore, Sri Lanka, Taiwan, Thailand, Turkey) and low-income (Bangladesh, India, Indonesia, Myanmar, Nepal, Pakistan, Philippines) groups based on the World Bank classification. Years of experience with AIS was divided into less experienced (≤ 10 years), medium experience (11–20 years), and more experienced (> 20 years). Comparisons between countries and various parameters were conducted with Fisher's exact or Fisher–Freeman–Halton tests. The Fisher–Freeman–Halton test was also used for comparing the number of braces fabricated with various bracing parameters such as fabrication method and follow-up protocols. Stratified analysis for years of experience was compared with Mantel–Haenszel test, which assessed categorical predictors with categorical outcomes. SPSS version 26.0 (IBM, Armonk, New York,

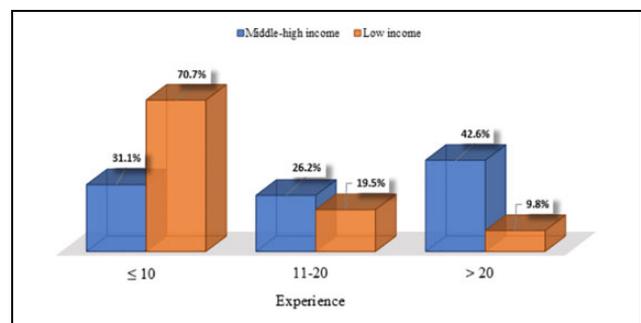


Figure 2. Experience per income group.

USA) was used for analysis. The value of $p < 0.05$ was considered statistically significant.

Results

From the 103 responses (61 middle–high income and 42 low income) collected, most were from Japan (20.4%), followed by India (13.6%) (Figure 1). Most responders have been practicing for 6–10 years (26.5%; Figure 2). About half (52.4%) of the responders had screening programs where they worked and most are government-based (46.3%). Only 22.2% had hospital-based screening programs. Higher income countries were more likely to have screening programs (75.4% vs. 19.0%; $p < 0.001$) and government-based programs (67.2% vs. 2.4%; $p < 0.001$).

Up to 34% of all responders obtained MRIs for all cases and was more common for the lower income countries ($p = 0.040$). Most (97.1%) would obtain MRIs (Table 1) for neurological problems, followed by asymmetrical reflexes (85.7%), rapid progression after skeletal maturity (84.4%),

Table 1. Indication for MRI comparing middle–high and low-income countries.

Indication	Middle–high income countries (<i>n</i> = 61)	Low- income countries (<i>n</i> = 42)	Fisher's exact test <i>p</i> value ^a
	Frequency (%)		
For all cases			0.058
No	45 (73.8)	23 (54.8)	
Yes	16 (26.2)	19 (45.2)	
Neurological problems			1.000
No	1 (2.2)	1 (4.3)	
Yes	44 (97.8)	22 (95.7)	
Right-sided lumbar curve			1.000
No	28 (62.2)	15 (65.2)	
Yes	17 (37.8)	8 (34.8)	
Left-sided thoracic curve			0.402
No	12 (26.7)	10 (43.5)	
Yes	32 (71.1)	13 (56.5)	
Short angular curves			0.396
No	12 (26.7)	10 (43.5)	
Yes	33 (73.3)	13 (56.5)	
Any male patient			0.196
No	38 (84.4)	17 (73.9)	
Yes	7 (15.6)	6 (26.1)	
Asymmetrical reflexes			1.000
No	6 (13.3)	6 (26.1)	
Yes	37 (82.2)	17 (73.9)	
Congenital deformities			1.000
No	8 (17.8)	5 (21.7)	
Yes	35 (77.8)	18 (78.3)	
Neurocutaneous stigmata			0.507
No	7 (15.6)	7 (30.4)	
Yes	38 (84.4)	16 (69.6)	
Rapid progression despite maturity			1.000
No	7 (15.6)	5 (21.7)	
Yes	38 (84.4)	18 (78.3)	
Back pain			1.000
No	18 (40.0)	11 (47.8)	
Yes	27 (60.0)	12 (52.2)	

^a*p* Value at exact significance (two-sided).

and congenital deformities (82.8%). Only 67% used quality-of-life assessment tools, and of these, 80.6% utilized the SRS-22 score. These were predominantly in the middle–high income countries ($p = 0.007$). Some surgeons had beliefs that poor sitting posture (6.8%) and not enough exercises (4.1%) were causes of scoliosis. However, more individuals identified poor sitting posture (20.4%), single arm sports (3.7%), and not enough exercises (25.9%) as causes of scoliosis progression. Up to 10.7% noted an association between pregnancy complications and scoliosis.

Only 61.2% of responders have a designated orthotist at their clinic, and only 81.6% of surgeons braced patients. Most prescribed rigid braces (75.5%). Up to 37.9% utilized scoliosis-specific exercises and 25.5% utilized semi-rigid

braces. Middle–high income countries prescribed more braces (93.4% vs. 73.8%; $p = 0.002$). The majority braced 1–5 patients per month (67%) and only 5.8% of surgeons braced 11–20 patients per month. Nearly all individuals braced patients between Cobb angles of 20–40°. The brace criteria were highly variable, but most (80.6%) used more than one maturity parameter for decision-making. The most common tool used was Risser staging (92.8%). Up to 74.7% used the menarche status, 59% utilized chronological age, while 41% utilized the triradiate cartilage appearance, 18.1% utilized the DRU, 16.9% with the Tanner staging, and 7.2% with Sanders staging. Middle–high income countries generally used multiple standardized measurements like the DRU, Sanders staging, and elbow maturity parameters ($n = 28$; $p = 0.036$). Only four individuals from low-income countries used the same parameters. No variations were observed between individuals of different experience levels.

There were no differences in the type of brace used between countries ($p = 0.656$), but Boston bracing was the most popular brace (80.7%) overall. Up to 24.1% of individuals would utilize Milwaukee braces, 8.4% would utilize Rigo-Chêneau braces, and 10.8% would utilize Charleston braces. Up to 52.4% of surgeons elected to brace skeletally immature (Risser 0–2) patients with 50° curves before offering surgery while 19% would also brace these patients at Risser 3–5. Most (84.1%; $p = 0.024$) only utilized standing radiographs for planning brace fabrication, while 24.4% would utilize supine side-bending radiographs, 17.1% with supine radiographs, and 11% with traction radiographs. Only 28% of responders utilized CAD-CAM techniques, while 76.8% utilized molds and 4.9% used 3D printing for brace fabrication ($p = 0.016$). Most utilized full-time brace wear (84.1%) as compared to night-use only (6.1%). The majority (97.5%) would not accept less than 16 hours of brace-wear per day. Patients were usually seen within 6–8 weeks after brace fabrication. Most (95.3%) relied on self-reporting for compliance and only a small percentage used objective compliance monitoring (12.5%) like thermal and pressure sensors. These arrangements were similar between countries ($p = 0.100$) and volume of bracing ($p = 0.523$). Patients were allowed to remove braces during exercise for 91.6% of responders. Not many (45.8%) would actively reach out to patients' teachers to explain the diagnosis and treatment and cooperation to prevent teasing. Few (26.5%) ask for special accommodations for the patient such as sitting near a fan or air conditioning and help to don and doff the brace.

Most follow-up braced patients within 4–6 months (80.7%) and obtained in and out of brace radiographs (44.6%) at alternate follow-up. Up to 27.7% utilized out of brace radiographs and 18.1% utilized in-brace radiographs at every visit. There were no standardized criteria for brace weaning. Most (72%) used Risser stage 4 as the indicator for brace weaning, while some (42.7%) utilized 2-years post-menarche and (22%) chronological age of at

least 14 years for girls and 16 years for boys. Most (49.4%) selected a gradual weaning protocol of brace-wear time reduction over the course of 6 months, while 25.3% switched to nocturnal wear for 3–12 months, and 21.7% selected immediate weaning. Up to 95.2% of responders continue to follow-up patients at skeletal maturity, despite no surgery performed at a 6–12 months duration. There were no differences between countries for follow-up protocols ($p = 0.108$), weaning criteria ($p = 0.284$) or brace weaning protocol ($p = 0.553$).

Discussion

Providing prompt nonoperative treatment, usually in the form of bracing, is important to prevent scoliosis progression and avoid surgery. Despite the proven benefits of bracing, many aspects of its utilization are not standardized. Its indications, implementation, follow-up, and weaning protocols are highly variable.^{4,5} Having a standardization of care is necessary for comparison of outcomes and ultimately the benefit of patients. In the diverse Asia-Pacific region, standard of care is often dependent on cultural aspects and availability of resources.^{25–27} This region-wide survey provided some interesting assessments of the current situation in the Asia-Pacific region, the variabilities and loopholes of certain management principles, and the expected direction of our future research to reach consensus.

It was of interest to the authors to determine the availability of MRI in the large variation of countries of low and middle–high income. To our surprise, up to 34% of responders would acquire MRI in all cases despite being asymptomatic and there were no differences between low- or middle- to high-income countries. The indication for MRIs in AIS is controversial. There is reasonable evidence in the literature regarding the likelihood of neuroaxial abnormalities on imaging and recommendations of its use. In a meta-analysis, the pooled prevalence of abnormalities on MRI of 4746 patients undergoing surgery was 8%. Those that required neurosurgery was 33% usually for syringomyelia and Arnold-Chiari Type 1 malformation.²⁸ One study suggests that MRI is not to be indicated in routine assessment, except for neurological deficits or in pain.²⁹ Nearly all study participants (97.1%) agreed for MRIs in view of neurological deficits. Back pain should be scrutinized for its nature such as its severity and whether it occurs at rest. Obtaining MRIs for back pain is excessive as the prevalence of pain may range from 6% to 14% and are often related to factors such as curve magnitude and psychosocial profiles.³⁰ One aspect not included in this study was the understanding of misbeliefs related to AIS. This may affect the practice of obtaining MRIs considering the relatively high prevalence of participants who identify AIS as caused by poor posture (20.4%) and with increased pregnancy complications (10.7%). Misbeliefs of AIS may be common among inexperienced practitioners and should be addressed by learning platforms. Nevertheless, we observed relative

consensus (>80%) for imaging only in the presence of abnormal neurological examination, neurocutaneous stigmata, and rapid progression despite maturity.

Bracing is the mainstay nonoperative management of AIS. There are many brace options but the results appear similar.³¹ Various aspects of brace treatment such as indications to start and discontinuing, methods to assess skeletal maturity, and ideal frequency of follow-up and imaging methods are not standardized. One recent best practice guidelines study⁴ based in North America suggested that there is relative consensus for indication of bracing to prevent or limit curve progression, when to prescribe bracing, and the acceptable compliance. However, there is poor consensus for maturity assessment, when radiographs should be taken, duration of follow-up, and when to discontinue bracing. In our study, we observed similar findings which are independent of experience and country of origin. The main difference is the use of skeletal maturity parameters to guide brace treatment. As compared to the study based on North American experience by Roye et al.,⁴ the Asia-Pacific region has comparably much less utilization of Sanders staging and greater reliance on Risser staging and the triradiate cartilage. Similar to the role of Sanders staging in North America, DRU was more commonly used probably due to its development within Asia. There have also been recent developments in understanding two of the poor consensus aspects of brace treatment. Cheung et al.¹³ has identified indicators for brace weaning with DRU (R10 U9) and Sanders staging (SS8) to achieve the shortest period of brace treatment that prevents curve progression. Their group has also identified the likelihood of curve regression (~20% with good brace compliance) and predictors of this outcome (good brace compliance, lumbar curves, high flexibility and correction rates).⁹ This is likely an important component to disclose to patients as it influences brace compliance.

Brace fabrication methods are also highly variable as observed from our participants. Few individuals assessed for curve flexibility before brace fabrication. For those who did, supine side-bending, supine and traction radiographs were most popular. These methods have been shown to predict in-brace correction and the likelihood of curve progression with treatment.^{32–35} Most still utilized molds and a comparably much smaller percentage of responders utilized CAD/CAM and 3D technologies. Brace fabrication using a mold of the patient is a simple to use method that is probably available to most users of different backgrounds. It requires creating a positive cast with modification of edges. Availability of resources dictate the use of more advanced techniques. Molding takes more time and has been criticized for its low accuracy³⁶ unlike CAD/CAM techniques which have been shown to be effective and may increase productivity.³⁷

It is important to note that this study was based on a biased sampling of uncontrolled volunteers and the distribution of participants should be based on population differences between countries. Nevertheless, it was an open

call for participants, and the response rate may be indicative of the number of surgeons actively treating AIS with nonoperative management. Parts of the questionnaire regarding brace treatment can be further explored in depth in future study. Aspects related to how each country encourages brace-wear compliance is also important to understand difficulties faced by clinicians in the Asia-Pacific region.

Conclusion

This is the first study highlighting the variabilities of nonoperative care for AIS in the Asia-Pacific region. In this highly diverse economic and cultural region, it is not unexpected to see variations in practice. We have identified several factors that were consistent among participants. These include obtaining MRIs only with abnormal neurological examination and an acceptable brace compliance of more than 16 hours a day. Many surgeons still predominantly use Risser staging despite its flaws. Recent studies from the region have provided answers for brace fabrication methods, outcomes of bracing and brace discontinuation criteria. Future research should focus on imaging follow-up and the role of physiotherapeutic scoliosis-specific exercises. Without a standardization of management plans, it is difficult to compare the success of nonoperative treatment in our region and to perform cross-country studies. This raises an important incentive to study different nonoperative management options and provide a standardized recommendation of nonoperative care in the society.

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Supplemental material

Supplemental material for this article is available online.

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