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Anterior vertebral body tethering for idiopathic scoliosis in growing children: A systematic review

Bizzoca D *et al*. AVBT in growing children

Abstract

BACKGROUND

The management of idiopathic scoliosis (IS) in skeletally immature patients should aim at the three-dimensional deformity correction, without compromising the spinal and chest growth. In 2019, the Food and Drug Administration approved the first instrumentation system for anterior vertebral body tethering (AVBT), under a Humanitarian Device Exception, for skeletally immature patients with curves having a Cobb angle comprised between 35° and 65°.

AIM

To summarize the current evidence about the efficacy and safety of AVBT in the management of IS in skeletally immature patients. Particular attention will be also addressed to surgical indications, clinical and radiological outcomes, postoperative complications, re-intervention rate, conversion rate to posterior spinal fusion (PSF), learning curve and future developments.

METHODS

From January 2014 to January 2021, OVID-MEDLINE®, EMBASE, Cochrane Library, SCOPUS, Web of Science, Google Scholar and PubMed were searched to identify relevant studies. The methodological quality of the studies was evaluated, relevant data were extracted.

RESULTS

Seven clinical trials recruiting 163 patients were included in the present review. Five studies out of seven were classified as high-quality studies, whereas the remaining two studies were classified as moderate-quality studies. 151 out of 163 AVBT procedures were performed in the thoracic spine, whereas the remaining 12 tethering in the lumbar spine. Only 117 patients out of 163 (71.8%) carried out a non-progressive curve at skeletal maturity. 23 patients out of 163 (14.11%) required unplanned revision surgery

within the follow-up period. Conversion to PSF was performed in 18 patients out of 163 (11%).

CONCLUSION

AVBT is a promising growth-friendly technique for the treatment of IS in growing patients. However, it currently has a moderate success rate and is endowed with relevant perioperative complication rate, revision rate and conversion to PSF rate.

Key Words: Idiopathic scoliosis; Spinal growth modulation; Anterior spinal instrumentation; Curve correction; Anterior vertebral body tethering; Pediatric spine; Growing spine; Skeletally immature patients; Growth-friendly spinal implants

Bizzoca D, Piazzolla A, Moretti L, Vicenti G,. Anterior Moretti B, Solarino G vertebral body tethering for idiopathic scoliosis in growing children: A systematic review. *World J Orthop* 2022; In press

Core Tip: Although anterior vertebral body tethering (AVBT) is a promising growth-friendly technique for the treatment of idiopathic scoliosis in growing patients, it has a moderate success rate and is endowed with relevant perioperative complication rate, revision rate and conversion to PSF rate. Future level I studies, with long-term follow-ups, are needed to best define the limits and potentials of this emerging surgical technique.

INTRODUCTION

The management of idiopathic scoliosis (IS) in skeletally immature patients should aim at the three-dimensional deformity correction, without compromising the spinal and chest growth and the complete lungs development[1-3].

In order to achieve all these goals, besides the classic conservative treatments for IS in growing children - *i.e.*, bracing[4-6] and serial casting - several growth-friendly surgical

procedures have been introduced in clinical practice, in recent years[7]. These include growing rods[8,9], the Shilla procedure[10], vertebral body stapling[11], posterior dynamic deformity correction device[12] and anterior vertebral body tethering (AVBT)[11-22].

AVBT rationale for IS correction, in skeletally immature patients, relies on the asymmetric inhibition of vertebral growth, by applying Hueter-Volkmann principle[15]. Each vertebral body grows both in length, *via* endochondral ossification, and in circumference, *i.e., via* endochondral ossification[25]. The subsequent compression of the growth plate on the curve convexity will inhibit the vertebral body growth, while the concomitant distraction on the curve concavity will promote the vertebral body growth[15]. This dynamic phenomenon will finally limit the curve progression and, ideally, reduce the deformity without affecting the spine growth and mobility.

After preclinical studies performed in animal models[26-28], in 2010 Crawford and Lenke[16] reported the first case of an eight-year-old child, with a 40° right thoracic curve successfully managed through AVBT. In the following years, based on these encouraging results, different spine surgeons started the use of "off-label" devices and the first cases series describing the use of AVBT were published by Samdani *et al*[24,29].

In 2019, the Food and Drug Administration (FDA) approved the first instrumentation system for AVBT, under a Humanitarian Device Exception, for skeletally immature patients with curves having a Cobb angle comprised between 35° and 65°[30]. Since then, a relevant number of clinical trials focusing on AVBT has been published[8-18;25]. However, some controversies still exist about this emerging surgical technique and little data are available about the long-term results.

This systematic review aims to summarize the current evidence about the efficacy and safety of AVBT in the management of IS in skeletally immature patients. Particular attention will be also addressed to surgical indications, clinical and radiological outcomes, postoperative complications, re-intervention rates and conversion rates to posterior spinal fusion (PSF).

MATERIALS AND METHODS

The study was conducted with methods described in the PRISMA[31]. It was registered in PROSPERO (ID: CRD42020183915) before the data extraction and analysis.

Literature search and study eligibility

SCOPUS, Web of Science, Springer Link, OVID-MEDLINE®, EMBASE, Cochrane Library, Google Scholar and PubMed were searched from January 2014 to January 2021 to identify relevant papers for further analysis.

The main keywords were: "Anterior Vertebral Body Tethering (AVBT)" or "Tethering" and "scoliosis" and "growing spine" or "growing child" or "immature patients". A manual search of the reference lists of the selected publications was also performed, to identify additional studies for potential inclusion.

Due to the paucity of studies on AVBT, both retrospective and prospective studies were included in the present systematic review. The following exclusion criteria were applied: (1) Less than twenty-four months of follow-up; (2) Lack of surgical intervention description; and (3) Drop-out greater than 20% at the final follow-up. The review was restricted to articles published in English. When multiple papers from the same centre or trial were depicted, the most thorough publication was selected.

Two review authors (Bizzoca D, Piazzolla A) analysed the titles and abstracts. Potentially relevant articles were acquired for full-length text and aAuthors were contacted when the full-text was not available.

Data extraction

Information was extracted from each study by two review authors (Bizzoca D, Piazzolla A) and finally checked by other two Authors (Moretti B, Solarino G), including: (1) Characteristics of study participants (age, gender, preoperative Cobb); (2) Study inclusion; (3) Surgical approach; (4) Clinical outcome; (5) Radiological outcome; (6) Percentage of successful AVBT procedures; (7) Perioperative complication rate and type; (8) Reintervention-rate; and (9) Number of conversions to PSF. Disagreements were resolved by discussion between them.

Study quality assessment and bias risk of the included studies

The quality of the analysed paper was evaluated following the American Academy of Orthopaedic Surgeons (AAOS) clinical practice guideline and review methodology version 2[32]. We assessed the following features: Inclusion end exclusion criteria description; sample size and features; the number of lost to follow-up; prognostic factors evaluation; outcome evaluation; appropriate statistical analysis; references of the study; data evaluation; the presence of bias; the presence of confounding factors; follow-up length.

Based on the study design and the depicted flaws, the quality of each study included in this systematic review was defined as follows: High-quality study (< 2 flaws); moderate-quality study (≥ 2 and < 4 flaws); low-quality study (≥ 4 and < 6 flaws) and very low-quality study (≥ 6 flaws).

Two Authors (Bizzoca D, Piazzolla A) independently evaluated all the studies. In case of disagreement between them, a new combined evaluation was performed. Two senior authors (Moretti B, Solarino G) finally approved the quality assessment procedure.

Publication bias could not be assessed by a funnel plot considering the very low number of patients in each study.

Primary, secondary and tertiary outcome

The primary outcome was to assess the success of AVBT at skeletal maturity, with a minimum 24-mo follow-up, in patients managed with this growth-friendly technique.

The secondary outcome was to identify the rate of perioperative complications, re-interventions and conversions to PSF, in patients who underwent AVBT. The tertiary outcome was to depict the correct indications for AVBT and the correct preoperative workup, as well as to describe the main feature of the surgical procedure.

RESULTS

Study selection

The SCOPUS, Springer Link, Web of Science, OVID-MEDLINE®, EMBASE, Cochrane Library, Google Scholar and PubMed database searches provided a total of 396 studies for potential inclusion in the review (Figure 1). After adjusting for duplicates, 107 studies remained. Of these, 91 studies were discarded after reading titles and reviewing abstracts.

The full text of the remaining 16 studies was examined in greater detail. Of these, 10 studies did not meet the inclusion criteria. Additional one study was identified through a bibliographic cross-reference of obtained articles. A total of 7 articles were finally included in this systematic review.

Study quality

The process of quality assessment, performed according to the AAOS clinical practice guideline and review methodology version 2, depicted the following results: 5[14,20-23] studies out of 7 (71.43%) were classified as high-quality studies, whereas the reaming 2[17,24] studies out of 10 (28.57%) were classified as moderate-quality studies (Table 1).

Study characteristics

The features of the included papers are summarized in Table 1. Seven clinical trials, *i.e.*, one retrospective comparative study (Level III)[22], two prospective observational studies (Level IV)[21,23] and four retrospective studies[14,17,20,24], recruiting 163 patients were included in the present review. Only one of the included studies (14.3%) has compared the outcomes between patients managed with AVBT and a matched cohort of patients treated with PSF and instrumentation[22].

The number of patients, gender, age, minimum follow-up length, clinical and radiological outcomes at the final follow-up and the successful AVBT rate are reported in Table 1.

The patients undergoing AVBT had the following scoliosis pattern distribution, according to Lenke's classification: Lenke 1 (n = 140; 85.9%), Lenke 2 (n = 10; 6.13%), Lenke 3 (n = 3; 1.84%), Lenke 5 (n = 9; 5.52%) Lenke 6 (n = 1;0.61%). 151 out of 163 AVBT

procedures were performed in the thoracic spine, whereas the remaining 12 tethering in the lumbar spine.

Perioperative complications, number of tether revisions and conversion to PSF of the AVBT procedures are reported in Table 2.

Main indications for AVBT

Currently, there is still not a universal consensus on AVBT indications, about Lenke type, curve size and remaining skeletal growth at the time of surgery. Clinical trials depict the features of the ideal patient for vertebral tethering, but the rate of postoperative complications and the lack of long-term results should be carefully considered when recommending AVBT. Interestingly, Krakow *et al*[30], in a retrospective analysis of 359 patients treated between 2016 and 2019 at a large paediatric centre, showed 75 patients (20.9%) could have been tethered in the years preceding approval FDA approval of AVBT device, by applying the FDA IDE criteria.

Nonetheless, all the following points should be carefully assessed before considering this growth-friendly surgical procedure.

Age and skeletal maturity

AVBT has been used in boys and girls aged mainly from eight to sixteen years old. Besides biological age, however, skeletal maturity should be carefully evaluated, to estimate the potential curve progression entity, as well as, to allow the asymmetrical modulation of the spinal growth *via* the Hueter-Volkmann principle.

The ideal skeletal age for AVBT is defined by a Risser score[33] of ≤ 2 and a Sanders score[34] of 3-4. It is important to note Sanders score has shown a strong correlation with the probability of curve progression[35], hence it should be always performed in children eligible for AVBT. Indeed, if the vertebral tethering is performed too early, a higher risk of curve overcorrection should be considered. On the other hand, if it is performed in an almost skeletal mature patient, there will not be enough remaining growth, thus leading to the lack of a relevant curve correction and relevant risk of tethering rupture[36].

Curve aetiology

AVBT has been proposed for idiopathic curves only, since patients with syndromic scoliosis may not respond as predictably, compared with IS. In this kind of patient, the growth of the untethered portion of the spine may be unpredictable, thus potentially increasing the re-intervention rate.

Similarly, left-sided thoracic curves are not an absolute contraindication for AVBT, but the surgeon must rule out the presence of a syndromic condition, before recommending AVBT.

Finally, the surgeon should be aware the left-sided approach might be high-demanding, from a technical point of view, since segmentary vessels lie closer to the aorta, compared with the right side, thus ligation could be more difficult.

Curve location, size, flexibility and three-dimensional features

AVBT has been largely studied in idiopathic flexible thoracic curves, Lenke type 1, with a Cobb angle comprised between 35° and 65°, according to FDA IDE criteria[37]. Published and ongoing clinical trials have also focused on other Lenke types, *i.e.*, type 2, 3C and 5[38]; the Cobb angle for lumbar curves should be < 35°.

Although lumbar curves are not contraindications to AVBT, this technique has been described for thoracic curves, consequently, particular caution should be taken when performing surgery of the lumbar spine (*i.e.*, open laparotomy or mini-laparotomy could be needed to access the lumbar spine)[39].

Furthermore, as suggested by Newton, tethering more than one curve potentially reduces the predictability of the outcome[15].

Curve flexibility should be preoperatively assessed on supine bending radiographs; a curve showing a 50% flexibility is an ideal candidate for AVBT[15].

Thoracic kyphosis greater than 40°[29] is a relative contraindication to AVBT, since this growing-friendly technique, by involving the tethering of the most anterior portion of the spine, could improve the patient's kyphosis[39].

Finally, a careful preoperative evaluation of the patient's sagittal profile, spinopelvic and three-dimensional parameters can help reduce the risk of flat back or decreased lordosis[39].

Preoperative planning

The preoperative workup for patients undergoing AVBT includes upstanding and supine full spine films in anteroposterior and lateral projections, supine bending films and full spine and brain magnetic resonance imaging.

Buyuk *et al*[13], in a retrospective study recruiting 51 patients, confirmed preoperative bending radiographs provide a reasonable estimate of postoperative correction for patients undergoing AVBT. An increase of the major Cobb angle, however, is expected on first upstanding spine radiographs, compared to intraoperative X-rays.

Spine levels are typically instrumented from upper end-vertebra to lower-end vertebra; tension should be applied on the tether, to bring the tilted discs into neutral alignment where possible[14].

Surgical technique

AVBT should be carried out using a strict lateral decubitus position, with the convex side of the thoracic deformity facing upward, on a radiolucent table. The patient is induced under general anaesthesia, using a double-lumen endotracheal tube, thus allowing the anaesthesiologist to deflate the right lung (or left lung, in presence of left-sided thoracic curves) during the procedure, to access the anterior thoracic vertebral bodies. Care should be taken to protect the brachial plexus by placing a soft gel roll under the axilla[39]. The right arm should be placed on an armrest; a soft gel pad should be used to protect the ulnar nerve. The patient is finally secured with tape. Intraoperative neuromonitoring, with somatosensory evoked potential and transcranial motor evoked potentials should be used to monitor spinal cord function during surgery and assess upper and lower extremities.

All the vertebral bodies to be instrumented should be identified under fluoroscopic guidance and marked on the skin. The right lung (left lung in left-sided thoracic curves) should be deflated by the anaesthesiologist before starting surgery. After standard skin preparation and draping, an anterior surgical access is performed; thoracoscopic, mini-open and traditional open access have been described.

Although Video-assisted thoracoscopy surgery (VATS) usually allows vertebral instrumentation from T4 to L2, in some cases, the diaphragmatic attachments may make the instrumentation of the vertebrae distally to T12 more technically demanding. An additional open or mini-open retroperitoneal approach is usually needed to instrument the vertebrae distally to L2. VATS is generally performed using two anterior viewing portals of 1 cm in length, placed on the anterior axillary line, and two/three posterior instrumentation portals of about 3 cm in length, placed on the posterior axillary line, overlying the vertebral bodies.

In deep dissection, the parietal pleura is opened over the spine and segmental vessels should be ligated on the convex side. Once vertebral dissection and exposure are completed, under fluoroscopic guidance, a staple and a bicortical screw are implanted in each instrumented vertebra. The entry point for the staple and the screw is just anterior to the rib head in the vertebral body. After completing all levels instrumentation, the polyethylene cable is installed. Tension on the cable is applied on each instrumented level; care should be taken to maximally tighten the tether at the curve apex, while minimal tension should be applied at the upper and lower instrumented vertebrae, to avoid screw plough and adding-on. However, there is no consensus about the exact amount of tension to be applied.

Before wound closure, the thoracic cavity should be irrigated with saline and accurate haemostasis should be performed. Then the lung is reinflated, and a chest drainage tube is typically placed and set to suction. All wounds finally undergo layered sutures.

The chest tube should be put on suction for 48 h with daily radiographic control; on the postoperative day third, if there is no residual pneumothorax, the tube should be put off suction and then removed on postoperative day four.

Clinical outcome and complication rates

Clinical success of AVBT is defined as the achievement of a non-progressive scoliosis curve - *i.e.,* Cobb angle < 35° - at skeletal maturity, avoiding PSF. Patients who needed one or more revision procedures were considered successful if they finally presented a stable curve at skeletal maturity.

Only 117 patients out of 163 (71.8%) carried out a non-progressive curve at skeletal maturity, in the trials included in this systematic review. The success rate of AVBT also showed a wide heterogeneity in the analysed studies, ranging from 52%[22] to 95.24%[21].

Moreover, a relevant postoperative complication rate (17.8%) was observed in the analysed studies; such a kind of complication was also observed in patients that achieved a successful outcome at skeletal maturity. Among the postoperative complications observed in the analysed studies, pulmonary complications played a central role (n = 12; 7.4%), including atelectasis (n = 5; 3.07%), pneumonia (n = 2; 1.23 %), pneumothorax (n = 4; 2.45%) and chylothorax (n = 1; 0.6%). All these complications were successfully conservatively managed.

In the included studies, 23 patients out of 163 (14.11%) required unplanned revision surgery within the follow-up period. The main indications for AVBT revision were: Curve overcorrection (n = 11; 6.75%); broken tether with curve progression (n = 8; 4.9%); adding-on (n = 2; 1.23%) and progression of the untethered curve (n = 2; 1.23%). Overcorrection is defined by a reduction of the preoperative Cobb angle progressing beyond the neutral axis, it is therefore recorded as a negative number. Broken tethers, identified as a change in screw angulation of > 5° on consecutive standing spine radiographs, are not an indication to revision surgery. A re-intervention is needed when a curve progression is detected because of the tether breakage. Adding-on, *i.e.,* the postoperative loss of correction due to curve progression, was managed with tether extension.

Untethered curve progression is another big concern of AVBT. Interestingly, Hoernschemeyer *et al*[20] described the combined use of thoracic tether and lumbar brace

in eight patients with larger main thoracic curves and smaller lumbar curves. In this subset of patients, a significant decrease in all the three measured curves, from preoperatively to the latest postoperative follow-up was observed[20]. This therapeutic strategy, combining thoracic AVBT with a lumbar brace, could be useful in the management of scoliosis in growing children.

Conversion to PSF was performed in 18 patients out of 163 (11%), during the follow-up period in the included studies. In these patients, AVBT gave no significant advantages, since they could not avoid PSF surgery, within 24-mo after tethering.

AVBT vs PSF

PSF and instrumentation is the gold standard for the treatment of patients with scoliotic curves > 45°[40,41]. Newton *et al*[22] in a retrospective comparative study, have recently compared outcomes of patients with immature IS, who underwent AVBT, with those of a matched cohort of patients treated with PSF, at a minimum 24-mo follow-up.

Although the post-intervention patient-reported outcomes (PROMs) were similar in both groups, at the final follow-up, the AVBT group had a significantly higher residual deformity, compared with patients receiving PSF ($P < 0.001$). In the AVBT cohort, only 52% of patients were successful in having curves of < 35° at skeletal maturity. In the PSF cohort, no patient needed revision surgery, whereas in the AVBT group 5 patients out of 23 (21.74%) underwent one AVBT revision and the other two patients (8.7%) needed two AVBT revisions procedures. A broken tether was observed in 12 patients out of 23 (52%). Furthermore, 3 patients out of 23 needed surgical conversion to PSF and an additional 3 patients were indicated for PSF, but they had not yet undergone PSF within the study period (overall conversion rate to PSF: 26%).

Finally, the proposed advantages of tethering, including progressive postoperative curve correction and maintenance of spinal motion, were not demonstrated in the AVBT group.

DISCUSSION

AVBT is a promising emerging technique for the surgical treatment of IS in growing patients[36]. It mainly aims to the tree-dimensional correction of the scoliotic deformity, without reverting to spinal fusion or delaying the need for PSF[15,36]. In 2019, the first instrumentation system for AVBT received FDA-clearance, under a humanitarian device exemption, based on the results of a Phase-2A pilot study, performed by Wong *et al*[23]. Although AVBT has shown encouraging results in the treatment of IS in growing patients, there is a paucity of published data about this growth-friendly procedure and long-term results are not yet available.

This systematic review aims to summarize the current evidence about the efficacy and safety of AVBT in the management of IS in skeletally immature patients.

Although there is still not a universal consensus on AVBT indications, clinical trials depict the features of the ideal patient for vertebral tethering, *i.e.*, a skeletally immature patient, with a primary and flexible idiopathic thoracic curve. More recent clinical studies[14,17,20] have also investigated the role of AVBT in scoliosis patterns other than Lenke 1. Baker *et al*[17] in a retrospective study analysing the results of 19 AVBT procedures performed in 17 patients, compared 13 thoracic AVBT procedures lumbar ones. The two groups had comparable demographic features in terms of gender, body mass index and skeletal age. These authors observed in lumbar AVBTs a greater immediate percentage correction ($P = 0.014$) a higher correction rate per level per month ($P = 0.044$) compared with the thoracic cohort. Nonetheless, 1 revision procedure only (8%) was performed in the thoracic group, whereas 3 revision surgical procedures were needed in lumbar AVBT (50%).

Hoernschemeyer *et al*[20] in a retrospective study recruiting 29 patients, identified 5 distinct subgroups of skeletally immature patients, each receiving different treatments. Patients with a single, main thoracic curve received a thoracic AVBT only. In these patients, the structural curve and both compensatory curves demonstrated continued postoperative improvement and achieved good control at the final follow-up[20]. Patients receiving a thoracic AVBT and a lumbar brace also showed postoperative improvement of both curves[20]. Similar findings were observed in patients with left

thoracolumbar curves and those with large main thoracic and lumbar curves treated with a combined thoracic and lumbar AVBT[20]. Finally, patients with a long thoracic curve received a single tether and exhibited a decrease in the main thoracic curve at the latest follow-up[20]. The last subgroup of patients, however, should be monitored over time since they have the largest number of consecutive levels tethered[20].

The anterior approach to the spine needed in the vertebral tethering could be another concern. In the last decades, posterior approaches have largely replaced the anterior access to the spine, therefore several surgeons have not been trained to perform an anterior approach to the spine. However, Baroncini *et al*[18] in a retrospective study that recruited 90 patients, have recently observed AVBT has a quite rapid learning curve. These authors showed intubation time and surgical time per screw decrease by over 50% for each treated patient, the estimated blood loss per screw to decrease by 66% for each surgical procedure, intubation and hospitalization length by 32% for each treated patient.

Despite AVBT being a promising growth-friendly surgical procedure, endowed with several potential advantages, it has still a lower success rate and a higher complication rate, compared with PSF. Hence, the gathered data of the studies included showed AVBT revealed successful only in 117 patients out of 163 (71.8%). Moreover, 23 patients out of 163 (14.11%) required unplanned revision surgery and 18 patients out of 163 (11%) needed conversion to PSF within the follow-up period. A relevant postoperative complication rate (17.8%) was also observed in the studies included in the present review.

This is, to the best of the authors' knowledge, the first systematic review aiming to investigate the effectiveness and safety of AVBT in the management of IS in growing children. The main limitation of the present study is the low level of evidence of the included studies, since no randomized clinical trials have been still published on AVBT. Currently, six ongoing clinical trials are available on Clinicaltrials.gov[42]: Four prospective clinical trials focusing on AVBT and one prospective comparative non-randomized and one randomized clinical trial aiming to compare AVBT to PSF. The

ongoing and future studies should confirm the surgical criteria for AVBT, prove tethering long-term effectiveness and safeness, focus on PROMs and propose strategies to avoid perioperative complications and long-term implant failures. A more durable, fatigue-resistant cable should be also developed to prevent the high number of broken tethers observed in the published studies.

CONCLUSION

The analysis of the literature included in this systematic review showed AVBT is a promising growth-friendly technique for the treatment of IS in growing patients. However, AVBT has a moderate success rate and is endowed with relevant perioperative complication rate, revision rate and conversion to PSF rate. Future level I studies, with long-term follow-ups, are needed to best define the limits and potentials of this emerging surgical technique.

ARTICLE HIGHLIGHTS

Research background

Anterior vertebral body tethering (AVBT) was originally described in 2010 by Crawford and Lenke[16], who reported the first case of an eight-year-old child, with a 40° right thoracic curve successfully managed with this growth-friendly technique. In 2019, the Food and Drug Administration approved the first instrumentation system for AVBT, under a Humanitarian Device Exception, for skeletally immature patients with curves having a Cobb angle comprised between 35° and 65°. However, some controversies still exist in this emerging surgical technique.

Research motivation

This systematic review was designed to summarize the current evidence about the efficacy and safety of AVBT in the management of idiopathic scoliosis in skeletally immature patients.

Research objectives

The objectives of this systematic review were: (1) To assess the success of AVBT at a minimum 24-mo follow-up; (2) To identify the rate of perioperative complications, re-interventions and conversions to posterior spinal fusion (PSF), in patients who underwent AVBT; and (3) To depict the correct indications for AVBT.

Research methods

The search of electronic databases was performed to identify relevant clinical studies, dealing with AVBT, for further analysis. A total of 107 studies were identified, but only 7 of these were included in the present review.

Research results

The pooled data of seven studies with 163 patients showed AVBT revealed successful only in 117 patients out of 163 (71.8%). Moreover, 23 patients out of 163 (14.11%) required unplanned revision surgery and 18 patients out of 163 (11%) needed conversion to PSF within the follow-up period. A relevant postoperative complication rate (17.8%) was also observed in the studies included in the present review.

Research conclusions

AVBT is a promising growth-friendly technique for the treatment of idiopathic scoliosis in growing patients. However, AVBT has a moderate success rate and is endowed with relevant perioperative complication rate, revision rate and conversion to PSF rate.

Research perspectives

Future studies should confirm the surgical criteria for AVBT, prove tethering long-term effectiveness and safeness, focus on patient-reported outcomes measures and propose strategies to avoid perioperative complications and long-term implant failures. A more durable, fatigue-resistant cable should be also developed to prevent the high number of broken tethers observed in the published studies.

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ORIGINALITY REPORT

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PRIMARY SOURCES

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