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SYSTEMATIC REVIEW

NEW PERSPECTIVES IN SCOLIOSIS AND SPINAL DEFORMITIES: AN UPDATE FROM THE 2023 ANNUAL SOSORT MEETING

The impact of pregnancy on women with adolescent idiopathic scoliosis: a scoping review

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ABSTRACT

INTRODUCTION: Adolescent idiopathic scoliosis is the most common spinal deformity encountered in adolescents and larger curves are more prevalent in girls. For females with scoliosis, women's health issues are of particular concern, especially pregnancy. The aim of this review was to summarise the best available evidence to determine the influence of pregnancy on scoliosis-related outcomes in women with scoliosis and whether scoliosis affects maternal-health outcomes, differentiating between patients who have been managed conservatively and/or surgically.
EVIDENCE ACQUISITION: A search was conducted using CINAHL, Scopus, Cochrane Database, MEDLINE, and EMBASE from inception to May 2023 to identify relevant articles in any language. The scoping review followed the PRISMA-ScR guidelines. Studies were eligible if they included pregnant women (primiparous or multiparous) with a diagnosis of scoliosis of unknown aetiology. The results were summarized by outcomes, including pregnancy and scoliosis-related outcomes and type of management.
EVIDENCE SYNTHESIS: Our comprehensive search strategy identified 6872 articles, of which 50 articles were eligible for this review. Back pain appears to be more prevalent in this population during pregnancy and associated with the major curve and the decrease of lumbar lordosis. There have been reports of failed attempted spinal anaesthesia among patients with instrumented scoliosis correction and minor complications related to epidural anaesthesia at a higher rate compared to non-instrumented patients and healthy controls, however successful spinal analgesia can be achieved in patients with instrumented scoliosis correction. Overall, the caesarean section rate was similar in scoliosis patients compared to controls without scoliosis and to national averages. Curve progression occurs in some but not all patients during pregnancy, and this phenomenon occurs irrespective of the treatment received.
CONCLUSIONS: Higher-quality prospective longitudinal research is needed to understand the relationship between pregnancy and adolescent idiopathic scoliosis. Further, the patient's perspective, concerns and fears surrounding pregnancy with scoliosis are yet to be explored. Exploring the impact of pregnancy on women with adolescent idiopathic scoliosis would have clinically relevant outcomes and could help provide pertinent answers to patients and healthcare workers and help guide future research.

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KEY WORDS: Pregnancy; Adolescent; Scoliosis; Parturition; Epidural anesthesia; Caesarean section.

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that arises in otherwise healthy children at or around the time of puberty.[1] Idiopathic scoliosis is the most common spinal deformity seen in this age group, with a prevalence ranging from 0.47-5.2%.[2] The condition is more common in female patients, and the observed sex predilection becomes more marked in severe forms of the disease.[3] The cardinal features of AIS, which are typically identified during parent/patient-initiated clinical assessment or *via* scoliosis screening programs, include abnormal spinal curvature and asymmetries of the trunk.[3] A definitive diagnosis of scoliosis is made by measuring Cobb angles from standing coronal plane radiographs. A diagnosis of scoliosis is confirmed when the observed Cobb angle/s measure ≥10° with accompanying vertebral rotation.[3] Common treatment options for patients with AIS include watchful waiting; physiotherapeutic scoliosis-specific exercise (PSSE); bracing; and surgery.[1] The aim of treatment in AIS is to prevent/alleviate pain, reduce future mortality and morbidity rates; minimise/halt curve progression; and address the psychosocial impact of the condition.[1, 4] Treatment decisions are based on a variety of factors, including sex; curve magnitude; curve location, curve pattern, growth potential, cosmetic appearance, and psychosocial factors.[5]

Due to the strong sex predilection seen in AIS,[2] women's health issues, specifically maternal health, are of particular concern in this population. Patients and their families are keen to understand the impact that scoliosis, and the related treatment, has on conception, pregnancy, labour, and the risk of developing future back pain.[6] Pre-treatment informed decision-making, patient satisfaction and treatment expectations could be optimised if patient-practitioner discussions are based on robust and contemporary data. Yet, there is a paucity of scientific literature regarding the impact of scoliosis on maternal health and also the influence that pregnancy and childbirth have on health outcomes in patients with AIS. Previous studies reviewed by Dewan *et al.*[7] have provided valuable information on a variety of maternal, psychological, social, and somatic health outcomes in AIS patients *versus* healthy controls. However, most of this literature is retrospective in nature and focuses predominantly on cohorts who have been managed using a very finite group of surgical techniques or bracing approaches. This literature is therefore not reflective of the depth and breadth of the different approaches to management in AIS.

The mean maternal age for the initial pregnancy is increasing worldwide, and this phenomenon is accompanied by an increased risk of negative maternal health outcomes.[8, 9] It is imperative that our understanding of the natural history and the long-term outcomes associated with the different forms of management in AIS is based on contemporary data. Much of what is known regarding the long-term outcomes in treated and untreated AIS patients is based on research that was conducted on cohorts from the twentieth-century.[10-12] While pivotal for our understanding of AIS, it could be argued that these studies no longer reflect the social milieu of the modern patient, nor do they reflect current advances in patient management. Moreover, the most recent systematic literature review on the influence of pregnancy on women with AIS does not include data beyond 2015.[7] We, therefore, felt that a more encompassing review of the literature on this topic would be valuable.

Due to the diverse nature of the potential study outcomes and the type of studies that could be included, we undertook a scoping review to summarise current evidence. The aims of this scoping review were 1) to map the current literature regarding the influence that pregnancy has on the spines of women diagnosed with AIS; 2) to explore the impacts of AIS on maternal health outcomes; and 3) determine how these spine-related changes and maternal health outcomes differ between AIS management (conservative or surgical).

Evidence acquisition

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).[13] A review protocol was not included in a registry as PROSPERO does not currently accept registration for scoping reviews. As this was a scoping review, we did not formally rate the quality, including risk of bias of each article.

Eligibility criteria

Studies were included that reported on pregnant women (primiparous or multiparous) with a diagnosis of AIS. Studies were excluded if they were not related to idiopathic scoliosis, such as neuromuscular, congenital, and degenerative scoliosis, or if the women were diagnosed with kyphoscoliosis. Included were original full-text peer-reviewed articles, including prospective and retrospective studies, case-control studies, cohort studies, case reports,

and clinical trials. Review articles and letters to the editor were excluded. We did not exclude studies based on the language of publications.

Search strategies

A comprehensive literature search was performed using the bibliographic databases CINAHL, Scopus, Cochrane Database, MEDLINE (OVID) and EMBASE (OVID) from database inception to May 2023. The search strategy included two key concepts (scoliosis and pregnancy) and used a combination of the following MeSH and non-MeSH terms: "scoliosis"; "spinal curvature"; "Cobb angle"; "spinal deformity"; "adolescent idiopathic scoliosis"; "idiopathic scoliosis"; "adolescent scoliosis"; and "pregnant"; "pregnancy"; "childbearing"; "childbirth"; "pregnancy complications"; "birth"; "antenatal"; "perinatal"; "postpartum"; "caesarean"; "pregnancy disorders'; 'labor", "delivery'; 'obstetric complications'. The final electronic search strategy for each database is available in the Supplementary Digital Material 1 (Supplementary Text File 1). Search results were imported into a bibliographic management software (EndNote X20.5) and duplicates were removed. Results of the search were reported as per the PRISMA flow diagram (Figure 1).

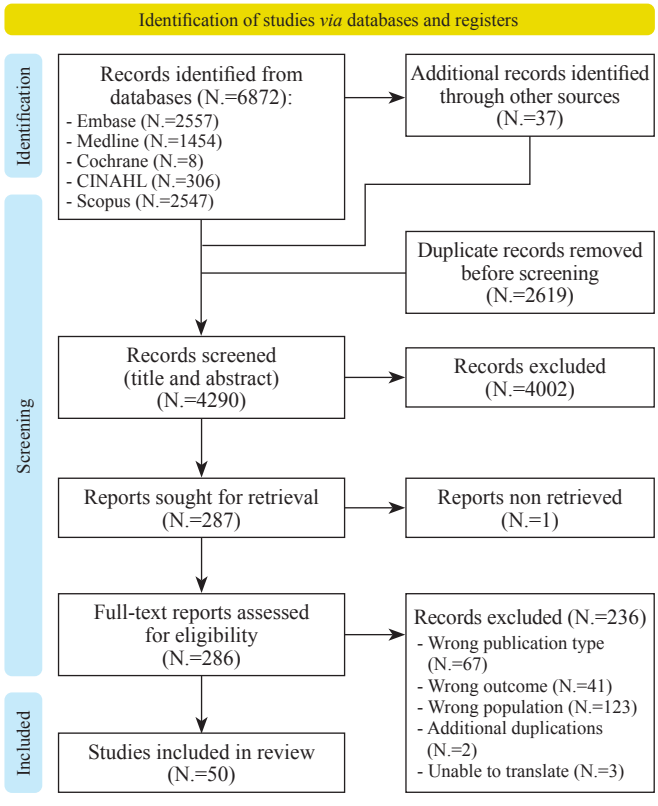

Figure 1.—PRISMA flow diagram.

Study selection, data charting, and synthesis of results

Records were screened independently by title and abstract for topic relevance by two pairs of authors (J.T., A.B., B.B. or R.M.). The full text of potentially eligible articles was then assessed independently by two pairs of authors (J.T., A.B., B.B. or R.M.) against the eligibility criteria for inclusion. Any disagreements regarding inclusion were resolved by consensus. If consensus could not be reached, disagreements were resolved by an arbiter (V.C.). Forward and reverse citation tracking was conducted on the eligible articles to identify studies that may have been missed by the primary search.

Calibration of the data charting forms was conducted by the research team prior to the final data extraction, with the data charting form being piloted on four studies. This was an iterative process in which there were many changes during each round. Two pairs of reviewers (J.T., A.B., B.B. or R.M.) independently charted the data. Any relevant discrepancies were resolved by consensus. Information extracted from each study related to female participants only and included: author; year of publication; study design; country; data collection period; participant and curve characteristics; treatment characteristics; maternal health outcomes; and other relevant health outcomes.

Data were synthesised by outcomes, including pregnancy-related outcomes (*i.e.*, success, number and duration of pregnancies), delivery-related outcomes (*i.e.*, epidural/anaesthesia use, C-section rate, and complications), scoliosis-related outcomes (*i.e.*, curve progression), and any other related outcomes (*i.e.* pain, and quality of life).

Evidence synthesis

Study selection

We identified 6872 records through searching databases and 37 additional records through other sources. After duplications were removed, 4290 records remained. The title and abstract screen reduced the potential number to 286 for full-text review. After the full-text review, 50 articles met the eligibility criteria (N.=7959 participants) and are included in this review (Figure 1).

Study characteristics

Of the 50 included studies, 70% (N.=35) were retrospective studies[6, 11, 12, 14-45] and 18% (N.=9) were case re-

ports.[46-54] Only six studies were prospective (12%).[10, 55-59] Most were North American (40%)[6, 10, 12, 16, 17, 19, 22, 23, 25, 26, 35, 38, 41, 42, 45, 46, 49, 52, 55, 57] or European (44%) studies.[11, 14, 15, 20, 21, 24, 28-34, 37, 44, 47, 50, 51, 53, 56, 58, 59] The study population of all included publications was recruited from hospitals or medical centres, except for two studies, where participants were recruited from the Gothenburg Scoliosis Database.[20, 21]

While more than half of the studies were published prior to 2010 (N.=30),[10-12, 14, 16, 17, 20-23, 25, 28, 31, 33, 34, 36-38, 45-49, 51-54, 56-58] some were published in the last decade (2011-2023) (N.=20)[6, 15, 18, 19, 24, 26, 27, 29, 30, 32, 35, 39, 41-44, 50, 55, 59, 60] including 14 published post-2015.[6, 15, 18, 19, 26, 27, 32, 35, 39, 41-44, 59] The mean age of participants was difficult to estimate as some studies provided the mean age of the entire population, which included both male and female participants. In contrast, others reported the mean age at the end of the scoliosis treatment, whether conservative or surgical. When reported, the mean pregnancy age ranged between 16 to 42.7 years. Most studies looked at pregnancy in surgical cases (N.=34),[6, 11, 17-20, 22-27, 29, 33-39, 41-44, 46, 48, 49, 51-56, 58, 60] while fewer looked at pregnancy in conservatively managed patients (N.=17).[11, 12, 14-17, 19, 21, 28, 29, 31, 32, 35, 41, 43, 44, 57] The characteristics of all included studies are reported in Supplementary Digital Material 2 (Supplementary Table I).[6, 10-12, 14-39, 41-60]

Pregnancy-related outcomes

Twenty-seven studies examined pregnancy-related outcomes explicitly looking at the success and number of pregnancies.[10-12, 15, 17, 18, 20, 21, 24, 25, 27-30, 32, 33, 35, 36, 38, 39, 42-44, 55, 56, 58, 60] From these studies, seven reported outcomes in the conservatively managed patients,[10, 15, 21, 28, 29, 32, 43] 11 in surgically managed patients,[18, 20, 24, 27, 33, 36, 39, 42, 55, 56, 60] and nine in mixed patient groups (*i.e.*, managed conservatively (brace) or surgically).[11, 12, 17, 25, 35, 38, 43, 44, 58] In conservatively managed patients, Aulisa *et al.*[15] reported no significant differences in the number of pregnancies in braced participants regardless of the size of the curve which was also reported by Cochrane and Nachemson[21] who found a pregnancy rate similar to the country's national norm (Sweden). Conversely, compared to a healthy population, Misterska *et al.*[32] reported a significant difference regarding the rate of pregnancy and the mean number of children. Close to 100% of patients had delivered one or more babies with a mean number of children of 2.0, contrary to 79% and 1.5 in the healthy population.

In surgically managed participants, the number of women that had never been pregnant (nulliparous women)[20, 27, 55] and the number of children born per woman (pregnancy rate)[27, 36, 39] were not significantly different compared to a healthy control group or the Japanese national norm. In studies where researchers compared surgically managed participants to participants managed conservatively,[11, 17, 35, 43, 44, 58] Danielsson and Nachemson[11] reported no significant difference in the number of childless persons and the number of people with children, where the mean number of children in surgically treated participants was 1.8, 1.9 in brace-treated participants, and 2.0 in the healthy group. This was also reported by Swany *et al.*,[35] who found minimal differences in the average number of live births and pregnancies. The mean number of live births was 2.1 for conservatively and 2.3 and 2.7 for surgically (fused above L2 and fused below L3, respectively) managed participants. The authors reported that this rate aligned with the country's national average.[35] Lander *et al.*[42] also reported similar findings where fusion levels did not impact the number of children. These findings contrasted with the recent study by Ohashi *et al.*,[43] where the authors reported a significantly lower number of children, even after they adjusted for age, in AIS patients (1.3) compared to healthy control (1.7) (P=0.001).

Three studies examined the need for fertility treatments.[24, 30, 44] In women surgically managed, Falick-Michaeli *et al.*[24] report a 17% rate of fertility treatment which was higher than the expected general population (3-7%) at that time. Similarly, Lebel *et al.*[30] reported higher use of fertility treatments in AIS patients (7%) compared to a non-scoliotic population (2%). Both studies were conducted in the same country (Israel) and published around a similar period (2012 and 2015). Snetkov *et al.*[44] reported the rate of medical assistance for conception. The authors mentioned that more than one-third of patients managed conservatively (35.7%) or surgically (37.93%) required fertility treatments to become pregnant.

The duration of pregnancy was examined in seven studies, either surgically managed[6, 18, 26, 55] or compared between management groups.[19, 30, 58] Studies report an average gestational period of 39 weeks, similar to the comparison group.

Two studies compared lung function in participants with scoliosis.[34, 47] Manning *et al.*,[47] who published their findings in the 60s, reported on nine patients with severe scoliosis (>90°). Of those patients, five were pregnant. Despite the lung capacity of these five participants being decreased, this did not contribute to late pregnancy, parturition or post-partum issues. Similarly, Siegler and Zorab[34] reported on 35 patients with AIS, comparing scoliotic curves greater and smaller than 60°. The authors observed

TABLE I.—*Pregnancy-related outcomes.*[6, 10-12, 15, 17-21, 25-30, 32-36, 38, 39, 42-44, 47, 55, 56, 58, 60]

Study	Year	Management	Findings*
Success and Number of pregnancies[10-12, 15, 17, 18, 20, 21, 24, 25, 27-30, 32, 33, 35, 36, 38, 39, 42-44, 55, 56, 58, 60]			
Akazawa *et al.*[60]	2012	Surgery	Mean number of birth per female was 1.6
Akazawa *et al.*[39]	2023	Surgery	The childbirth rate is reported to be 2.0 similar to the Japanese national average.
Aulisa *et al.*[15]	2017	Conservative-brace	21 out of 87 females experience pregnancy. No significant difference in pregnancy numbers between the groups (Cobb degrees <30° and >30°)
Bauchat *et al.*[55]	2015	Surgery	Nulliparous: AIS 68% and control 44% (not statistically significant)
Betz *et al.*[17]	1987	Conservative (observation/ brace), Surgery	Nulliparous: 51% of women with scoliosis, 69 pregnancies ended in either spontaneous or elective abortions (29%)
Bjerkreim *et al.*[56]	2007	Surgery	24 women had delivered a baby (31.58%)
Cao *et al.*[18]	2020	Surgery	Of the 32 women with AIS 30 were nulliparous and 2 were parous (total of 34 pregnancies), of the 80 controls all were nulliparous.
Cochrane *et al.*[20]	1983	Surgery	30 women with 46 pregnancies delivering 46 full term, healthy infants, stated as similar to Swedish norm.
Cochrane and Nachemson[21]	1985	Conservative-brace	28 women out of 85 had been pregnant at least once, with a total of 40 healthy children, stated as similar to the Swedish norm.
Danielsson and Nachemson [11]	2001	Conservative (observation/ brace), surgery	No significant difference between groups (control, surgically treated AIS, and brace treated AIS) in terms of childless persons and number of children. Surgically treated AIS group: 245 children (mean 1.8 children per person), brace treated AIS group: 209 children (mean 1.9 children per person), control group: 180 children (mean 2.0 children per person). Age at first delivery significantly higher in brace group (28 years) compared to control group (25.9 years) but not surgically treated group (26.6 years).
Falick-Michaeli *et al.*[24]	2015	Surgery	39 pregnancies from 17 women in AIS group, with an average maternal age of 31 years (first pregnancy an average 7.3 years after AIS-surgery), 9 pregnancies from 6 women in control group, with an average maternal age of 29 years. In AIS group 17% (N=3) needed fertility treatments (higher than compared to stated general population 3-7%).
Goldberg *et al.*[12]	1994	Mixed, 36% women surgically treated	AIS group women 663 (51.3%) one or more children. Control group: 687 (60.6%) with one or more children)
Goldberg *et al.*[25]	1998	Unclear- mixed	Higher rate in AIS group of unsuccessful attempts of pregnancy (odds ratio = 1.3; 95% CI: 0.84-2.13); spontaneous abortions (OR: 1.35; 95% CI: 1.02-1.73). Fewer stillbirths in AIS group (OR: 0.38 95% CI: 0.15-0.97).
Kino *et al.* [30.]	2020	Surgery	No significant difference between the AIS and control group in terms of parous or nulliparous, the number of children (1.75 for AIS and 2.08 for healthy control), and the average age at first childbirth (AIS: 30.6, Healthy control: 28.6). In the AIS group: 1 case of premature birth, 1 miscarriage, In the control group: 1 case of premature birth, 2 cases of miscarriage, and 1 stillbirth.
Lander *et al.*[42]	2022	Surgery	The number of children for those with lowest instrumented vertebrae L3 or proximal compared to L4 or distal was not statistically different (P=0.71)
Lange *et al.*[28]	2009	Conservative-brace	88 women (87%) had delivered at least one baby (102 born babies)
Lange *et al.*[29]	2011	Conservative-brace	87% of women had delivered a baby
Lebel *et al.*[30]	2012	Not reported	Mean maternal age similar in AIS group (29 years) and cohort population (28 years). Higher nulliparity in AIS group (41%) compared to cohort population (20%), and high percentage of patients in AIS group used fertility treatment (7%) compared to cohort population (2%).
Misterska *et al.*[32]	2018	Conservative-brace	Of 30 female patients with AIS 29 (97%) had delivered one of more babies (mean number of children: 2), 33 females in the control group (79%) had delivered one of more babies (mean number of children: 1.48). Mean age of 1st pregnancy similar in both groups (25 years).
Ohashi *et al.*[43]	2023	Conservative (observation/ brace) Surgery	The average number of children per married women did not differ between AIS patients (S-AIS:1.5 ((1)/0-3); N-AIS: 1.4 ((1)/0-4). The curve severity did not appear to impact childbirth (P=0.008). Nulliparity in the 30-39 years married women was significantly higher (26.2%) in the AIS group (surgically/non-surgically managed) compared to the control group (13%) (P=0.012) (AIS group common OR: 1.88 (95% CI, 1.08-3.29; P=0.026). This was not significant for the 40-49 group (Japanese National Data) (P=0.58). The mean number of children per married woman: AIS (surgically and non surgically managed): 1.3 ((1)/0-4); Control: 1.7 ((1)/0-8), which was statistically different (P=0.001) even after adjusting for age strata (P=0.001).
Orvomaa *et al.*[33]	1997	Surgery	Of 146 female patients with AIS 79 (54%) had had one or more deliveries (total of 142 pregnancies). 13 patients had miscarriages, none were related to scoliosis, 21 patients had undergone induced abortions, none because of scoliosis.

(To be continued)

TABLE I.—*Pregnancy-related outcomes.*[6, 10-12, 15, 17-21, 25-30, 32-36, 38, 39, 42-44, 47, 55, 56, 58, 60] *(continues).*

Study	Year	Management	Findings*
Smith *et al.*[58]	2003	Conservative (observation/ brace), Surgery	28 women (70%) were nulliparous.
Snetkov *et al.*[44]	2020	Conservative (observation/ brace), Surgery	48.57% (17/35) with a main lumbar and 30.77% (20/65) with a main thoracic curve needed fertility treatments
Swany *et al.*[35]	2020	Conservative (observation/ brace), Surgery	Minimal differences between groups for average live births and average number of pregnancies. Non-operative patients: mean 2.3 pregnancies, 2.1 live births, Spinal fusion for AIS L2 of above: mean 2.3 pregnancies, 2.0 live births, Spinal fusion for AIS L3 of below: mean 2.7 pregnancies, 2.2 live births, stated as similar to US national averages.
Takayama *et al.*[36]	2009	Surgery	Mean number of children in AIS group 1.78 similar to the population norm (2005)
Visscher *et al.*[38]	1988	Mixed	608 women had 1733 pregnancies, average of 2.85 per pregnant woman, 1413 livebirths (including 12 sets of twins). Spontaneous abortion: 264/1733 (15.2%) pregnancies, stillbirth: 14/1733 (0.8%): both are lower than the expected USA rate of 15% of spontaneous abortion and 1.1% stillbirth.
Weinstein *et al.*[10]	2003	Conservative	Median number of children in AIS group and control group was 3.
Duration of pregnancy[6, 18, 19, 26, 30, 55, 58]			
Bauchat *et al.*[55]	2015	Surgery	Similar gestation periods in AIS and control groups = 39 weeks.
Cao *et al.*[18]	2020	Surgery	Average period of gestation for AIS group: 20.2 weeks (SD: 0.6), control group: 39.4 weeks (SD: 1.0)
Chan *et al.*[19]	2017	Conservative (observation/ brace), Surgery	21.4% preterm births (<37 weeks), not significantly associated with curve severity (rate stated as slightly higher than national average).
Grabala *et al.*[6]	2019	Surgery	Average period of gestation was 39 weeks for both AIS group and control group.
Grabala *et al.*[26]	2020	Surgery	Average period of gestation was 39 weeks.
Lebel *et al.*[30]	2012	Not reported	Average period of gestation was 39 weeks for both AIS group and cohort population. No significant difference in preterm deliveries.
Smith *et al.*[58]	2003	Conservative (observation/ brace), Surgery	Gestational age ranged from 35 to 42 weeks.
Other[34, 47]			
Manning[47]	1967	Not reported	Based on 9 cases of severe scoliosis (90° or more) lung function may be impaired without any troubles during late pregnancy and parturition, no respiratory failure.
Siegler and Zorab[34]	1981	Conservative (observation/ brace), Surgery	Increased breathlessness reported in 17% of pregnancies, no serious cardiorespiratory problems were encountered.

*Results statistical significance as stated by the study
AIS: adolescent idiopathic scoliosis; S-AIS: surgical-AIS; N-AIS: non surgical-AIS; SD: standard deviation; OR: odds ratio.

an increase in breathlessness in 17% of pregnancies, however, no serious cardiorespiratory problems were encountered (Table I).[6, 10-12, 15, 17-21, 24-30, 32-36, 38, 39, 42-44, 47, 55, 56, 58, 60]

Delivery-related outcomes

Twenty-one studies reported results on epidural and anaesthesia during delivery *via* vaginal or caesarean section for AIS patients.[6, 17-19, 22-24, 30, 37, 41, 46, 48-55, 58, 59] Patients included in these studies had various treatments for scoliosis prior to pregnancy: surgery,[6, 18, 22-24, 37, 46, 48, 49, 51-55] conservative management,[50] and a combination of surgery or conservative management.[17, 19, 41, 58] Two studies failed to report the type of management.[30, 59] Of the 18 studies which included surgical or a combination of surgical and conservative management patients, nine reported more frequent attempts at epidural and/or spinal analgesia procedures in these patients compared to healthy controls. However, epidural success was eventually achieved.[18, 22, 23, 37, 46, 49, 54, 55, 58]

Difficulty in attempting or achieving analgesia was reported in two studies with surgical patients,[22, 55] and one study reported one failed attempt at spinal anaesthesia;[17] however, this patient's AIS treatment history was unclear. Four studies including surgical patients reported successful spinal analgesia.[19, 48, 51, 52] Falick-Michaeli *et al.*[24] reported that refusal of epidural anaesthesia, by anaesthesiologists, occurred in 70% of AIS surgical patients from this single centre study location. The main reason being the perception of an absence of access to a site for catheter placement. Grabala *et al.*[6] reported no significant difference between the use of a spinal block for analgesia between the AIS group (surgical) and the control group. There is a lack of evidence regarding us-

ing spinal analgesia or anaesthetics in conservatively managed AIS patients. Piosik *et al.*[50] reported no problems with analgesia or anaesthetic in conservatively managed patients.

There is no substantial evidence of a reported difference in rates of caesarean sections in patients with AIS. This statement appears to hold true for those treated surgically and conservatively. Twenty-two studies reported outcomes related to caesarean section rates.[6, 10, 11, 17-21, 24, 27, 30, 32-37, 41, 44, 45, 55, 58] Four of these studies with surgical patients reported higher rates of caesarean sections in patients with surgical instrumentation.[6, 20, 33, 35] While Kino *et al.*[27] reported that two caesarean sections were necessary in the AIS group and none in the healthy group, the authors note that one caesarean section was performed at the doctor's discretion while the other was secondary to a twin-twin transfusion syndrome. Similarly, Villevieille *et al.*[37] reported a caesarean section rate of 33% (five patients out of 15) but did not compare this rate to the country's national average or a control group. Three studies omitted to provide the type of management.[30, 34, 58] Lebel *et al.*[30] reported a higher caesarean section rate in the AIS group than control. Siegler *et al.*[34] and Smith *et al.*[58] only reported the caesarean section rate in the AIS participants, respectively 17% and 41.4%.

Four studies compared the caesarean section rate between surgically and conservatively managed patients.[11, 17, 35, 44] Three studies[11, 17, 35] reported no significant differences, while one[44] found an increased rate. Snetkov *et al.*,[44] on the other hand, reported a significant rate difference in surgically managed participants. Finally, four studies examined the caesarean section rate in conservatively managed patients only.[10, 21, 32, 45] Two reported the rate without comparison[10, 45] while the other two reported a rate similar to the country's national average[21]or the control group.[32]

Five studies reported outcomes related to complications

TABLE II.—*Delivery-related outcomes.*[6, 10, 11, 17-24, 27, 30, 32-38, 41, 44-46, 48-55, 58, 59]

Study	Year	Management	Findings*
Epidural/anaesthesia[6, 17-19, 22-24, 30, 37, 41, 46, 48-55, 58, 59]			
Bauchat *et al.*[55]	2015	Surgery	More epidural procedures performed in the spinal instrumentation group (39%) than in the control group (5%). Longer time required to complete the neuraxial technique: spinal instrumental group (6.5 ± 2.0 min), matched control subjects (4.6±1.8 min). Neuraxial analgesia failure occurred in 5 (12%) the spinal instrumentation group, 0 in the control group. No significant difference in anaesthesia consumption.
Betz *et al.*[17]	1987	Conservative (observation/brace), surgery	One patient (1.2%) had a failure of attempted spinal anaesthesia
Cao *et al.*[18]	2020	Surgery	Rate of successful neuraxial anaesthesia was significantly higher in the control group: AIS group 3.1% and control group: 81.25%. Epidural anaesthesia successful in 1 out of 3 attempted vaginal-delivery AIS patients, unsuccessful in 5 C-section AIS patients, not attempted in other 6 C-section patients.
Chan *et al.*[19]	2017	Conservative (observation/brace), surgery	Spinal anaesthesia was successful in 99% of deliveries in which it was attempted (70 of 71). In the remaining cases (N.=13) no anaesthesia was attempted: patients' choice (3.6%), rapid labour progression (3.6%), emergency C-section (3.6%), anaesthesiologist choice (3.6%), unknown (1.1%).
Chapek *et al.*[41]	2023	Conservative (type not reported) Surgery	Participants who received a PSIF were less likely to have an epidural anesthesia compared to scoliosis participants without PSIF (RR: 0.62; 95% CI 0.49-0.80) P=0.001) Scoliosis participants had a significantly higher rate of epidural analgesia compared to control (RR: 1.08; 95% CI 1.02-1.13, P=0.004) The epidural rate among those with PSIF level L3 or above compared to L4 or below was not statistically different (P=0.42)
Chaudhuri *et al.*[59]	2022	Not reported	Difficulty in spinal anaesthesia was found in 23% of cases and scoliosis spinal anaesthesia was found to be more difficult in the presence of scoliosis (2 out of 3 patients) (aOR 1.7;95%CI 1.1-2.4 P=0.001) warranting an increase in the number of attempts and need of different gauge needle.
Crosby and Halpern[22]	1989	Surgery	8 out of 16 patients' epidural analgesia was attempted (twice for 1 patient). 3 patients chose general anaesthesia for elective C-section, and 3 declined regional anaesthesia. 5 (out of 9) epidural analgesia were uncomplicated and successful on the first attempt. 4 were complicated including multiple attempts prior to successful insertion, blood in the catheter, a dural puncture, able to define the epidural space, and/or failure to obtain analgesia. There were no reported sequelae related to the epidural insertion.

(To be continued)

TABLE II.—*Delivery-related outcomes.*[6, 10, 11, 17-24, 27, 30, 32-38, 41, 44-46, 48-55, 58, 59] *(continues).*

Study	Year	Management	Findings*
Daley *et al.*[23]	1990	Surgery	21 attempts at epidural anaesthesia based on 18 patients (3 patients had received epidural anaesthesia in 2 separate pregnancies), 10 were performed easily on first attempt, remaining 11 had excessive and/or patchy analgesia. No long-term complications.
Falick-Michaeli *et al.*[24]	2015	Surgery	Epidural anaesthesia given 30%: AIS group compared to 100%: control group. 12 women (70%) in AIS group were refused epidural anaesthesia: main reason was due to perception of absence of access site for catheter placement.
Grabala *et al.*[6]	2019	Surgery	Most common analgesia for C-section was spinal block (75%: AIS group, 86%: control group, no significant difference). Statistically significant difference in requirements for general anaesthesia in patients fused to L4 (7%) compared to patients fused above L4 (4%).
Kardash *et al.*[54]	1993	Surgery	Multiple unsuccessful attempts at L3/4 interspace, then successful uneventful first attempt at L5/S1 interspace for epidural anaesthesia.
Ho *et al.*[53]	1999	Surgery	In one case: successful insertion on the first attempt in a patient with scoliosis operation (T3 to L2 midline scar) with the need for complementary analgesia (Meperidine and Entonox). No complications reported. However, the patient expresses dissatisfaction with the epidural analgesia.
Lebel *et al.*[30]	2012	Not reported	Similar use of epidural anaesthesia in both groups (AIS group: 17%, cohort population: 13%).
Lee *et al.*[46]	1995	Surgery	In one case: two unsuccessful epidural attempts at L3/4, third attempt at L5/S1 successful using a loss-of resistance technique. Initial dose of 9 mL 0.25% bupivacaine with 1/200,000 epinephrine, patient experienced transient signs and symptoms including hypotension, high sensory block involving trigeminal nerve, difficulty breathing and swallowing, all symptoms subsided. Adequate analgesia was provided and delivery occurred with no complications.
Okutomi *et al.*[48]	2006	Surgery	Successful analgesia of C-section in one case with continuous spinal catheter who had a history of scoliosis operation T3-L3, with no complications.
Pascoe *et al.*[49]	1993	Surgery	In one case: successful spinal anaesthesia of C-section subsequent to an 'inadequate' epidural block in a patient with surgical correction of scoliosis T4-L1.
Piosik *et al.*[50]	2012	Conservative	Epidural catheter carried out without problems in one case report, with sufficient birth analgesia and sufficient epidural anaesthesia for C-section.
Smith *et al.*[58]	2003	Conservative (observation/brace), surgery	Of vaginal deliveries: 9 uncorrected and 2 corrected AIS patients required no anaesthesia, epidural catheter placed in 7 uncorrected AIS patients successfully, unsuccessful continuous spinal analgesia in 1 out of 6 women. Of C-section deliveries: successful combined spinal and epidural anaesthesia in 2 out of 2 uncorrected AIS patients, successful single shot spinal anaesthesia in 2 out of 2 AID patients, continuous spinal infusion in 13 AIS patients in which 8 were successful, 3 had inadequate anaesthesia and 2 failed insertions. Overall, 100% successful analgesia with all technique used for non-surgical cases and 12/19 cases (63%) surgical cases.
Sudanagunta *et al.*[51]	1998	Surgery	In one case: Continuous caudal analgesic success with a vaginal delivery with a history of scoliosis surgery T8-L4. Previously discouraged from having epidural anaesthesia in antenatal clinic but requested analgesia during labour.
Suelto and Shaw[52]	1999	Surgery	In one case: Analgesia successful with a vaginal delivery with a history of scoliosis surgery.
Villevieille *et al.*[37]	2003	Surgery	Epidural: Failed technique 2/9, Failed analgesia 1/9
C-section rate[6, 10, 11, 17-21, 24, 27, 30, 32-37, 41, 44, 45, 55, 58]			
Bauchat *et al.*[55]	2015	Surgery	Similar C-section rate: AIS (12%), control (5%). Similar time to delivery: AIS 231 min (126 to 624 min), control 275 min (170 to 524 min)
Betz *et al.*[17]	1987	Conservative (observation/brace), surgery	C-section rate: 7.4% (all AIS), and two (2.5%) (spinal fusion) but in neither instance was this related to the mother's scoliosis. "The incidence of delivery by C-section and of health problems in the children of women who have scoliosis is no greater than that for the non-scoliotic population."
Cao *et al.*[18]	2020	Surgery	Similar C-section rate: AIS (34.4%), control (31.25%), not significantly different.
Chan *et al.*[19]	2017	Conservative (observation/brace), surgery	Vaginal delivery (65.5%): spontaneous vaginal delivery (54%), forceps assisted delivery (8%), vacuum-assisted delivery (4%). Induction required for 23.8% of deliveries (not significantly associated with degree of curvature). Total of 29 (34.5%) C-sections: 12 (14%) urgent of emergency basis: not significantly associated with curve severity. C-section rate was similar to national average.
Chapek *et al.*[41]	2023	Conservative (type not reported) Surgery	C-section rate was not statistically different in the scoliosis group compared to control (P=0.07) or those who underwent PSIF compared to nonoperative idiopathic scoliosis patients (P=0.26). No significant difference was reported in the C-section rate regarding the fusion level (P=0.38).

(To be continued)

TABLE II.—*Delivery-related outcomes.*[6, 10, 11, 17-24, 27, 30, 32-38, 41, 44-46, 48-55, 58, 59] *(continues).*

Study	Year	Management	Findings*
Cochrane *et al.*[20]	1983	Surgery	12 C-sections in 46 live births, stated as higher than predicted norm in Swedish females. Correlation between decreased lumbar lordosis and increasing C-section rate within in study population.
Cochrane and Nachemson[21]	1985	Conservative- brace	8 (out of 40 deliveries) were C-sections, stated as similar to predicted Swedish norm.
Danielsson and Nachemson [11]	2001	Conservative (observation/brace), surgery	No significant difference between groups (control, surgically treated AIS, and brace treated AIS) for C-section rates. No C-sections were related directly to medical consequences of scoliosis. Vacuum extractions significantly higher in surgically treated AIS group (N.=18) more than control group (N.=4) (brace group N.=8).
Falick-Michaeli *et al.*[24]	2015	Surgery	No significant different in C-section rate between AIS group (N=4, 24%) and control group (N.=1, 17%).
Grabala *et al.*[6]	2019	Surgery	C-section rate was significantly higher in AIS group (64%) compared to control group (33%). As lowest instrumented vertebra moved caudal (L1, L2, L3, L4), the rate of C-sections increased, with most C-section being performed in patients with fusion to L4 (55%) compared with patients fused to L3 and above (45%). Most common reason for C-section: psychological aspects and recommendations by obstetricians (higher in AIS group compared to control group).
Kino *et al.*[3°]	2020	Surgery	Two cases of C-sections in AIS group: 1 performed at discretion of doctor and 1 performed due to twin-twin transfusion syndrome. Zero cases of C-section in control group.
Lebel *et al.*[30]	2012	Not reported	Higher C-section rate in AIS group (21%) compared to cohort population (13%), and higher labour induction rate in AIS (37%) compared to cohort population (26%).
Misterska *et al.*[32]	2018	Conservative- brace	No significant difference in C-section rate between AIS group (30%) and control group (27%).
Orvomaa et at.[33]	1997	Surgery	33 C-sections in 142 pregnancies (rate of 23%), stated as higher than national average (15%).
Siegler and Zorab[34]	1981	Mixed (operative and nonoperative/specific management not reported)	C-section rate was 17%, spontaneous vaginal delivery 65%, forceps or vacuum extraction in 18%. Two cases C-sections performed primarily because of scoliosis, otherwise other cases due to obstetric reasons (pre-eclampsia, failure to progress etc.) Forceps and extraction for obstetric reasons only.
Smith *et al.*[58]	2003	Conservative (observation/brace), surgery	Elective C-sections 17 out of 41 patients (41.4%), 2 patients emergency C-sections (4.9%)
Snetkov *et al.*[44]	2020	Conservative (observation/brace), surgery	In surgically treated AIS patients, more often C-sections were performed compared to AIS patients without fixations. The lower the causal segment fixation the more likely to have a C-section.
Swany *et al.*[35]	2020	Conservative (observation/brace), surgery	Total C-sections in AIS group: 20 out of 60 (33%) compared to state weighted C-section rate of 20.5% (significant difference). C-section rate not significantly different between conservative patients (29%) and arthrodesis patients (38%), also not significantly different between surgical patients fused to L3 or lower (46%) and patients fused L2 or higher (32%). Overall, C-sections were performed at a higher rate in AIS patients compared to national and state averages, and higher in women who had spinal fusions for AIS compared to reported state C-section rates in the general population.
Takayama *et al.*[36]	2009	Surgery	C-section rate 19% (3 out of 16 patients with AIS), stated as equivalent to general population.
Villevieille *et al.*[37]	2003	Surgery	C-section in 5 patients out of 15.
Weinstein *et al.*[45]	1981	Conservative	C-section rate 1.4% (2 patients) attributed to significant complications during pregnancy or delivery to the spinal deformity
Weinstein *et al.*[10]	2003	Conservative	The C-section rate in scoliotic women was 3% compared with 10% in the control group.
Complication[18, 30, 32, 38, 53]			
Cao *et al.*[18]	2020	Surgery	No severe perinatal complications reported in either group.
Ho *et al.*[53]	1999	Surgery	Case study of one patient with Harrinton Rods – no complications reported, even at 6 month follow-up.
Lebel *et al.*[30]	2012	Not reported	Similar rates of preeclampsia, polyhydramnion, premature rupture of membranes compared to cohort population.
Misterska *et al.*[32]	2018	Conservative- brace	No significant difference in complication rate during delivery AIS group (34%) and control group (26%).
Visscher *et al.*[38]	1988	Conservative (observation/brace), Surgery	Pregnancy/delivery complications: 316/1733 (18.2%) lower than the expected Minnesota rate 1970 (21.1%)

*Results statistical significance as stated by the study.
AIS: adolescent idiopathic scoliosis; PSIF: posterior spinal instrumented fusion; RR: risk ratio; aOR: adjusted odds ratio.

during delivery[18, 30, 32, 38, 53] with no higher rates of complications noted in patients with AIS: surgical patients,[18, 61] conservatively managed,[32] mixed patients[38] and treatment not reported (Table II).[30]

Scoliosis-related outcomes

There were 10 studies that assessed the impact of pregnancy on curve progression in AIS patients.[11, 14, 16, 17, 19, 21, 26, 31, 33, 57] Of these studies, three assessed the influence of no treatment (*e.g.* observation) or minimal treatment (*e.g.* drugs and/or physical exercise) on curve progression in AIS patients who had experienced one or more pregnancies.[14, 16, 17] Of note, all eligible studies were conducted prior to 1987. Ascani *et al.*[14] found that, on average, in 151 women treated with drugs and/or physical exercise, there was a clinically significant progression (≥5 degrees [Cobb])[62, 63] in all curve types (thoracic, thoracolumbar, lumbar, double major). In this study, the average curve progression was greater in patients who had been pregnant *versus* those who had not, and this finding was more marked in multiparous *versus* primiparous women. Conversely, Berman *et al.*[16] demonstrated that the curves of four AIS patients receiving treatment in the form of observation only either remained stable (two cases) or improved slightly (two cases) after pregnancy. It should be noted, however, that all the cases in the Berman *et al.*[16] study were aged <18 years at the time of their first pregnancy, and all had curves below 30 degrees (Cobb) prior to pregnancy. A study on the effect of pregnancy on curve progression by Betz *et al.*[17] included 158 AIS patients who had been followed without treatment. The data regarding curve progression for the untreated patient group was, however, merged with data from patients who had undergone orthosis treatment. It is, therefore, impossible to comment on curve progression in the untreated cohort in that study.

Five studies assessed the influence of pregnancy on curve progression in AIS patients who had been treated using a brace.[11, 16, 17, 21, 57] A Milwaukee brace was used in four studies[11, 16, 21, 57] included in this review, with Danielsson and Nachemson[11] highlighting that a Milwaukee brace was used to treat all AIS patients seen prior to 1974 and a Boston brace for patients seen between 1974 and 1977. Brace type was not specified in the Betz *et al.* study.[17] All studies reported clinically significant curve progression in some braced AIS patients following pregnancy. Berman *et al.*[16] highlighted either no change or a clinically significant progression in the curves of four young (≤20 years) braced AIS patients after pregnancy. The authors noted that progression was more likely in conservatively managed patients with curves >25 degrees (Cobb) prior to pregnancy. However, the majority of studies found that, when looking at average pre- and post-partum curves, pregnancy did not result in clinically significant changes in curve magnitude in patients who had received brace treatment. Two additional studies[19, 31] reported on the influence of conservative treatment on curve progression in AIS who had experienced one or more pregnancies. However, the specific type of conservative management was not defined.

Regarding surgical intervention, five studies looked at post-partum curve progression in AIS patients who had undergone spinal instrumentation and fusion.[11, 17, 19, 26, 33] A posterior surgical approach was detailed in three studies.[17, 19, 26] Three studies described the instrumentation used: Harrington instrumentation with distraction;[11, 33] and Cotrel-Dubousset instrumentation.[26] The study by Nachemson and Danielsson[11] included 6-12 months of bracing post-surgery. The findings in the surgically managed patients were similar to the braced group in that curve progression was seen in some but not all AIS patients following pregnancy. On average, pregnancy did not lead to clinically significant curve progression in patients who had been managed surgically.

No studies reported on the need for surgical revision in AIS patients who had one or more pregnancies (Table III).[11, 14, 16, 17, 19, 21, 26, 31, 33, 57]

Other outcomes

Fourteen included studies reported on pain during pregnancy, delivery and/or after delivery.[6, 11, 14, 17, 18, 23, 24, 28, 29, 31, 33, 34, 44, 56] Many patients with AIS reported new back pain related to pregnancy or increased back pain during pregnancy, however, the rate and severity of the back pain varied between studies. Four studies found no difference in the prevalence of back pain between AIS patients and control groups.[6, 11, 29, 56] Further, the prevalence of back pain during pregnancy has also been found to be similar between patients surgically treated for AIS and patients who were braced treated,[11] as well as patients who had previous spinal fusions compared to those who have not had spinal fusions.[44] Conversely, other studies found a higher rate of back pain in patients with AIS compared to the control groups.[18, 24] The prevalence of back pain differed depending on the location of the curve,[14] with one study finding that pain was rated lower in patients with thoracic scoliosis compared to lumbar curves,[44] and another noted that back pain during pregnancy was reported more frequently in patients fused to L3-L4 compared to those fused to L1-L2 and T11-T12.[6]

TABLE III.—*Scoliosis-related outcomes.*[11, 14, 16, 17, 19, 21, 26, 31, 33, 57]

Author	Year	Management	Findings*
Curve progression[11, 14, 16, 17, 19, 21, 26, 31, 33, 57]			
Ascini *et al.*[14]	1986	Conservative-(untreated, medication or physical exercise)	Thoracic curves: average curve progression all women 16°, without pregnancy: 13.1°, one pregnancy: 15.6°, more than one pregnancy: 20.1°. Thoracolumbar curves: average progression women without pregnancy: 12°, one pregnancy: 14.6°, more than one pregnancy: 17°. Lumbar curves: average progression women without pregnancy: 10.6°, one pregnancy: 16.2°, more than one pregnancy: 23.2°. Thoracolumbar curves: followed same pattern with curve progression increasing with increased number of pregnancies.
Berman *et al.*[16]	1982	Conservative (observed/brace)	Three of eight reported cases (37.5%) progression of curve greater than 5° (primary curve was greater than 25° prior to pregnancy). No change in 3 cases and a slight improvement in curves after pregnancy in 2 cases.
Betz *et al.*[17]	1987	Conservative (observation/brace), surgery	Average curve progression was 2.2° in both groups with a range of -12° to 25° in group A (previous pregnancy), and -9° to 39° in group B (never been pregnant). Pregnancy did not increase the risk of curve progression, risk of progression was unaffected by age of patient during pregnancy, number of pregnancies, or the stability of the curve. More severe curves (≥50°) had greater curve progression however the risk of progression even with severe curve was the same for both groups.
Blount and Mellencamp[6°]	1980	Conservative- brace	Average curve before pregnancy: 43.7°, after first pregnancy: 46.6°, after second pregnancy 45.9°. Small progression of curve in 3/10 cases after first pregnancy, no change in majority of cases. Stability of curve was unrelated to age and curve progression was found to be not correlated to curve severity.
Chan *et al.*[19]	2017	Conservative (observation/brace), surgery	No significant change in curve progression was demonstrated. The majority of patients (10/11) did not have a clinically significant curve change, 1 patient had a 10° increase after a single delivery (30° to 40°).
Cochrane and Nachemson[21]	1985	Conservative, brace	Out of 85 patients, 10 patients had a curve progression of 5° or more (2 years post bracing), 7 of these patients were pregnancy multiple times. All patients who become pregnant before 23 years of age had progression of their curve.
Danielsson and Nachemson [11]	2001	Conservative (observation/brace), surgery	No correlation between number of pregnancies and curve progression.
Grabala *et al.*[26]	2020	Surgery	No significant difference between loss of correction in AIS pregnancy group (mean loss of correction 3.5°) and AIS non-pregnancy group (mean loss of correction 4.5°).
Miguens-Vazquez[31]	2006	Conservative	No significant relationship found between curve progression and gestation.
Orvomaa *et al.*[33]	1997	Surgery	Pregnancy did not significantly increase fused or unfused scoliotic curvatures.

*Results statistical significance as stated by the study
AIS: adolescent idiopathic scoliosis.

Overall, back pain during pregnancy was commonly reported, however, for most patients, the pain was not reported as severe or debilitating. Betz *et al.* found that although 77% of women with scoliosis reported back pain during pregnancy, only 12% considered the pain to be severe.[17] Falick-Michaeli *et al.*[24] found that 35% of AIS patients reported severe back pain during pregnancy and, of these, 76% reported sustained back pain impacting their life after delivery.[24] Similarly, in another study of patients treated with Harrington instrumentation, approximately 10% required sick leave due to their back pain.[33]

Six studies considered measures of quality of life and/or the prevalence of depression.[6, 18, 24, 26, 27, 36] Considering the Scoliosis Research Society Questionnaire (SRS-22),[64] four studies found no significant difference in surgically treated AIS patients and control groups,[6, 18, 26, 36] however, one study found health-related quality of life rated as significantly lower in the AIS group (surgically treated) compared to the control group.[27] The prevalence of depression has been found to be similar in AIS patients compared to control groups.[18, 24]

Based on seven studies, there was no significant difference between the birth weight of the infant between AIS groups and control groups (Table IV).[6, 14, 17, 18, 23-31, 33, 34, 36, 38, 44, 55, 56]

Discussion

• The overall number of women that had never been pregnant and the number of children per woman (pregnancy rate) appears to be similar in all groups of scoliosis

TABLE IV.—*Other outcomes.*[6, 11, 14, 17, 18, 23-31, 33, 34, 36, 38, 44, 55, 56]

Study	Year	Management	Findings*
Pain[6, 11, 14, 17, 18, 23, 24, 28, 29, 31, 33, 34, 44, 56]			
Ascini *et al.*[14]	1986	Conservative (untreated, medication or physical exercise)	16% to 37% of women stated that the onset of the back was related to pregnancy depending upon the location of the curve. The major curve was the site of the pain for the thoracic and thoracolumbar scoliosis. In double major curves, the pain was mostly located on the convexity.
Betz *et al.*[17]	1987	Conservative (observation/brace), Surgery	77% of women with scoliosis reported back pain during pregnancy, 12% considered the pain to be severe.
Bjerkreim *et al.*[56]	2007	Surgery	62% of women had increased back pain during pregnancy. Reported as the same range as for women without AIS.
Cao *et al.*[18]	2020	Surgery	Significantly higher rate of new back pain during pregnancy reported in AIS group (65.6%) compared to control group (15.0%), and also higher rate of back pain after delivery: AIS group (6.2%), control group (0.0%). Among the AIS patients 14 out of 32 reported moderate back pain and 7 reported severe back pain compared to 8 control patients reporting mild back pain and 4 reporting moderate back pain.
Daley *et al.*[23]	1990	Surgery	6 out of 18 patients reported low back pain before labour (during pregnancy or infrequent) and 2 out of 18 patients reported temporary low back pain for two weeks after delivery (might have been associated with epidural anaesthesia).
Danielsson and Nachemson [11]	2001	Conservative (observation/brace), Surgery	No significant difference between groups (control: 28%, surgically treated AIS: 35%, and brace treated AIS: 43%) for low back pain during pregnancy.
Falick-Michaeli *et al.*[24]	2015	Surgery	35% of AIS patients reported severe back pain during pregnancy, of these 76% reported sustained back pain impacting their life after delivery. Minimal back pain reported in control group, with no back pain being attributed to pregnancy in control group.
Grabala *et al.*[6]	2019	Surgery	No significant difference between group (AIS group: 48%, control group: 34%) reporting back pain during pregnancy nor reporting back pain after childbirth (AIS group: 43%, control group 34%). Back pain during pregnancy was reported more frequency in patients fused to L3-L4 (40%) compared to those fused to L1/L2 (32%) and T11/T12 (27%).
Lange *et al.*[28]	2009	Conservative-brace	Back pain was increased in 55% of patients during pregnancy.
Lange *et al.*[29]	2011	Conservative-brace	50% of AIS patients had back pain in pregnancy, similar to age-matched controls
Miguens-Vazquez[31]	2006	Conservative	50% of painful curves in female participants was stated to correspond to women who have had a pregnancy.
Orvomaa *et al.*[33]	1997	Surgery	40% of patients reported low back pain during pregnancy, severe back pain requiring sick leave occurred in 11 of pregnancies.
Siegler and Zorab[34]	1981	Surgery	Increased back pain in 65% of pregnancies, no correlated with the severity of spinal curve. Back pain reported in equal frequency in patients who had previous spinal fusion and those who had not.
Snetkov *et al.*[44]	2020	Conservative (observation/brace), surgery	Pain was reported as more severe in patients in both group (surgically treated AIS or non-surgically treated AIS) in trimester 3 and if a lumbar scoliosis was present. Surgical patients had on average less pain compared to non-operated patients. Pain was rated as lower in patients in both groups with a thoracic scoliosis compared to a lumbar curve.
Quality of life and depression[6, 18, 24, 26, 27, 36]			
Cao *et al.*[18]	2020	Surgery	Based on the total score in the SRS-22 there was no significant differences between the two groups. The prevalence of depression was also similar in both the AIS group (N.=1) and the control group (N.=2).
Falick-Michaeli *et al.*[24]	2015	Surgery	Similar prevalence of depression in both AIS group and control group.
Grabala *et al.*[6]	2019	Surgery	Based on total scores in the SRS-22 there was no significant differences between the two groups (AIS group and control group).
Grabala *et al.*[26]	2020	Surgery	Based on total scores in the SRS-22 there was no significant differences between the two groups (AIS pregnancy group and AIS non-pregnancy group). No significant difference between loss of correction and SRS-22.
Kino *et al.*[3°]	2020	Surgery	Health related quality of life was rated as significantly lower in AIS group compared to control group.
Takayama *et al.*[36]	2009	Surgery	No significant difference in SF-36 questionnaire (measuring physical and mental status) nor SRS-22 questionnaire compared to age-matched healthy controls.
Child factors[6, 11, 18, 25, 30, 38, 55]			
Bauchat *et al.*[55]	2015	Surgery	Infant weight similar in AIS and control group.
Cao *et al.*[18]	2020	Surgery	Average birth weight similar in AIS (3.38kg) and control group (3.21 kg).

(To be continued)

TABLE IV.—*Other outcomes.*[6, 11, 14, 17, 18, 23-31, 33, 34, 36, 38, 44, 55, 56] *(continues).*

Study	Year	Management	Findings*
Danielsson and Nachemson [11]	2001	Conservative (observation/brace), surgery	No significant difference between groups (control, surgically treated AIS, and brace treated AIS) for birth weight of first child.
Goldberg *et al.*[25]	1998	Unclear- mixed	Fewer low-birthweight infants (<2500 grams) in AIS group (OR: 0.84; 95% CI: 0.59-1.21). Slightly higher rate of congenital malformations in AIS group (OR: 1.20; 95% CI: 0.78-1.84).
Grabala *et al.*[6]	2019	Surgery	No significant difference in birth weight of infant between AIS group and control group.
Lebel *et al.*[30]	2012	Not reported	No significant difference in birth weight of infant, congenital malformations and Apgar scores between AIS group and control population.
Visscher *et al.*[38]	1988	Mixed	No significant difference: low birth weight: 80/1413 (5.7%) (expected percent 6.4% Minnesota 1970 rate) or congenital anomalies: 74/1413 (5.2%) (expected percent 6.0% general population) Higher rate of prematurity: 177/1413 (12.5%) (expected percent 7.8% Minnesota 1970 rate)

*Results statistical significance as stated by the study.
AIS: adolescent idiopathic scoliosis; OR: odds ratio; SRS: scoliosis research society.

patients. There does not seem to be a significant difference compared to healthy control or the national average.

• The duration of pregnancy is similar to control groups.

• The need for assisted reproduction technology appears more common in patients with scoliosis.

• Despite decreased lung function, patients with severe scoliosis do not appear to sustain serious cardiorespiratory problems during pregnancy.

• More attempts to achieve epidural analgesia are often needed during vaginal or caesarean section in all patients. However, analgesia is usually successful.

• The caesarean rate appears to be greater in surgically managed, but not in conservatively managed patients.

• There is no difference in the rate of complications (pre-eclampsia, premature rupture, etc.) between different scoliosis management types or compared to national averages.

• Multiple pregnancies may increase the risk of curve progression in observed or minimally treated (medication/physical exercises) AIS patients, but this has not been demonstrated in all studies.

• Post-partum curve progression has been demonstrated in some surgically or conservatively managed AIS populations, however, on average, this group does not appear to experience clinically significant curve progression following pregnancy.

• Overall, back pain was commonly reported in patients with AIS during pregnancy; however, for most patients, pain was not reported as severe or debilitating and typically resolved after delivery. A higher prevalence of back pain was found in patients with lumbar curves compared to thoracic curves.

• Generally, the prevalence of depression and quality of life has been found to be similar in AIS patients compared to control groups.

• There was no significant difference in infantile birth weights between AIS patients and control groups.

The pregnancy rate has been extensively studied in several countries over the last many decades, and although each country has its birth rate, a global birth rate is determined by the United Nations.[61] When considering the global birth rate, our findings align with Dewan *et al.*,[7] where women with scoliosis, managed conservatively or surgically, may be slightly less likely to get pregnant. However, most studies included in this review collated data between 1960 to 2000 and during this period, the global birth rate was much higher than other periods, and was reported to be around 5.0 in the early 60s but steadily declined to 2.6 in late 2010.[65] When examining studies by region, some report a birth rate in the scoliosis populations similar to the national norm.[20, 21, 35] These findings contradict the Dewan *et al.* study.[7] When examining the birth rate in individual countries, scoliosis patients are expected to have a similar number of children. In the USA, Swany *et al.*[35] collected data between 1975 and 1992 and reported a mean number of children of 2.3 and 2.7, respectively, for patients conservatively managed or who had spinal fusion above L3 and patients with spinal fusion below L3. During that period, the country's birth rate varied between 1.9 to 2.0. Similarly, in Japan, Takayama *et al.*[36] collected data between 1976 and 1989 and reported a birth rate of 1.78, which was not different from Japan's birth rate during the same period, reported to vary between 1.95 to 1.61. Similar to Dewan *et al.*,[7] our findings also support a broader use of fertility treatment in scoliotic patients, whether managed with conservative care or spinal instrumentation.

Despite the lack of a clear definition of epidural failure in the literature, Thangamuthu *et al.*[66] conducted a Delphi study in which a working definition was developed. Based on the authors' findings, epidural failure was defined as

"the presence of inadequate pain relief 45 minutes after placement, accidental dural puncture, re-sitting or abandonment of the procedure, and patient dissatisfaction at follow-up." Many technical factors contribute to difficult neuraxial blocks (spinal and epidural blocks), such as BMI, spinal deformities, inability to identify interspinous space, and the distance the catheter is threaded into the epidural space.[67, 68] These factors may contribute to the wide epidural reported failure rate ranging in the literature between 8-23%.[69, 70] Our results showed that more attempts to achieve epidural analgesia are often needed during vaginal or caesarean section in all patients, irrespective of whether they were treated surgically or conservatively for scoliosis. This is similar to the results presented by Dewan *et al.*[7] who concluded that failed attempts and minor, reversible complications occur with greater frequency in surgical than in non-instrumented patients and healthy controls. Despite the reported difficulty to deliver and achieving analgesia, our review found that analgesia can eventually be achieved in most cases.

The World Health Organisation (WHO) suggests that the ideal rate for caesarean sections should vary between 10-15%.[71] When medically indicated, caesarean sections have showed to be effective in saving maternal and infant lives. However, the steadily increasing rate of caesarean procedures, according to the Organisation for Economic Co-operation and Development (OECD), could be accounted for by the increased rate of nulliparous older women, multiple pregnancies as a result of assisted reproduction, time management for both the doctors and the patients, and women's personal preferences.[72] Our findings demonstrated that the rate of caesarean sections is higher in surgically managed patients but not in patients who have been managed conservatively. Notably, however, most examined studies failed to disclose the reason for this choice of intervention. Grabala *et al.*,[6] report significantly higher caesarean section rates in surgically managed AIS patients (64%) compared to healthy control (33%). The most common reason provided was related to psychological aspects and obstetricians' recommendations. Similarly, Swany *et al.*[35] also reported a rate of caesarean sections higher than the expected nationwide averages. The authors speculated that the increase rate could be due to the obstetricians' preferences. This is slightly different to the results presented by Dewan *et al.*[7] who reported that AIS patients can expect similar rates of caesarean delivery as their non-AIS counterparts. However, our findings align with the previous systematic review regarding the non-significant rate of complications (pre-eclampsia, premature rupture, etc.) between different scoliosis management types or compared to the national average.[7]

The literature on the influence of pregnancy on curve progression in AIS patients who have not received any treatment or who have received only minimal treatment is sparse and conflicting. Some patients demonstrate clinically significant curve progression following pregnancy, while others remain stable or even show reductions in curve magnitude. Long-term natural history studies of AIS patients show that curve progression in untreated patients is more common in patients with curves >30 degrees (Cobb) at skeletal maturity, with curve progression more pronounced in severe or very severe curves.[45, 73, 74] Pregnancy is not typically cited as a salient prognostic factor for curve progression in these long-term natural history studies.[4] However, more targeted prognostic research is required to determine if pregnancy is, in fact, a salient prognostic factor, and if so, the strength, precision, and statistical significance of this factor.[75]

On average, clinically significant curve progression after pregnancy does not occur in AIS patients who have received treatment in the form of bracing or surgery. However, some patients will experience significant curve progression after pregnancy irrespective of the treatment that they have received. This finding is also reflected in long-term follow-up studies of braced[76] and surgically[74, 77] managed AIS patients.

There were mixed findings regarding the influence of factors such as curve magnitude prior to pregnancy, the number of pregnancies, and age at the time of pregnancy on curve progression in AIS patients in the included studies of this scoping review.

Pain was treated separately to the pregnancy- and scoliosis-related outcomes. This is because pain could have been related to pregnancy or scoliosis or possibly a combination of both. Back pain is commonly reported during pregnancy in a general population, with between 25% to 68% of healthy, pregnant women reporting back pain.[78-81] Our results have found that AIS patients generally experience higher rates of back pain during their pregnancy. However, it is only a small proportion of those patients with AIS who experience severe back pain that impacts their daily lives.[24, 33] Patients requiring surgical correction for AIS generally did not report back pain at a higher rate compared to patients conservatively treated for AIS.[11] This could be important in providing counselling to female patients with severe curves who are considering treatment options for scoliosis. However, it is worth noting that most studies did not consider the severity of

scoliosis when considering the prevalence of back pain during pregnancy.

The previous systematic review found the same overall finding regarding back pain[7] but classified back pain as a spinal-related change. The review did not report on the outcomes of quality of life nor birth weight of the infant.[7]

Quality of life was not reported in the previous systematic review, as five of the six included studies that reported this outcome were published after 2015 (Table IV). Quality of life during pregnancy was generally similar in AIS patients compared to control groups, but this is only based on a few studies and was commonly measured with the SRS-22 questionnaire. All the studies that considered the quality of life were in AIS populations who were treated surgically therefore, we were unable to compare the quality of life between surgically and conservatively managed AIS patients. Future research should consider more patient-reported outcomes, perhaps with a longer follow-up, such as a long-term prospective cohort study with measures during pregnancy and post-delivery.

Limitations of the study

Out of 50 included studies, only 20 were conducted after 2010, and most were retrospective studies or case reports. Therefore, the findings of this scoping review should be interpreted with caution.

The literature on curve progression in AIS patients who have had one or more pregnancies and have not received treatment or have received only minimal treatment is limited to studies published prior to 1988. Given that the average age of first-time pregnancy is increasing worldwide, it could be argued that the existing literature on this topic lacks relevance to modern-day AIS patients. There is a paucity of literature on curve progression after pregnancy following surgical or conservative management. An examination of the existing studies reveals that only a very finite group of prepartum management strategies have been evaluated in AIS patients. Therefore, this literature is not reflective of the depth and breadth of the management strategies currently available for this group. Furthermore, from a prognostic perspective, much of the information on the influence of pregnancy on curve progression in AIS patients is descriptive in nature. Robust and precise estimates regarding the impact of pregnancy on curve progression in treated and untreated AIS patients are not available. This finding is a product of the vintage of the literature on this topic, in combination with the evolution and increased rigor of prognostic research methods.

Although this scoping review adds to the current body of literature on the potential effects of pregnancy on scoliosis in patients conservatively or surgically managed, one should not forget that the psychological aspect of contemplating pregnancy after receiving or having had scoliosis corrective arthrodesis remains unexplored, and future research should strive to understand this concept better.

Conclusions

Although the results of our scoping review add to the body of the literature, there remains a paucity of information on the effect of pregnancy on scoliosis. More robust longitudinal studies are needed to enhance our understanding and to inform health professionals who manage AIS patients. Our scoping review results may provide important information in counselling female patients with scoliosis who are contemplating pregnancy.

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Conflicts of interest
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Authors' contributions
Conceptualization, investigation: Amber Beynon, Benjamin Brown, Rosemary Marchese, Jean Theroux. Search strategy: Amber Beynon. Formal analysis: Amber Beynon, Benjamin Brown, Rosemary Marchese, Jean Theroux. Writing and writing – review and editing: all authors. All authors read and approved the final version of the manuscript

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