PREGNANCY AND DELIVERY IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

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Objective. To analyze the course of pregnancy and delivery that occurred before and after surgical correction of idiopathic scoliosis with instrumented fixation of the spine.

Material and Methods. The paper presents a retrospective randomized study of 100 patients of reproductive age (18–35 years) with Lenke type 2–6 idiopathic scoliosis. The following aspects of pregnancy were analyzed: the possibility of independent conception, the pain severity according to VAS during each of the three trimesters of pregnancy, and the mode of delivery (naturally or by C-section). A comparative analysis of the data of patients operated on for the spine deformity correction before and after pregnancy and delivery was carried out. Data was collected using a questionnaire survey of patients. Detection and analysis of differences between groups were carried out using the χ^2 criterion.

Results. A statistical relationship was found between the presence of instrumentation installed before delivery (during or before pregnancy) and the need for C-section. It was revealed that the lower the caudal end of instrumentation within the L3–S1 region, the higher the C-section occurrence. Predominantly thoracic scoliosis (Lenke types 2–4) is characterized by higher likelihood of independent conception and lower lumbar pain intensity during pregnancy than predominantly lumbar scoliosis (Lenke types 5–6). There are also certain difficulties in conducting spinal anesthesia in patients with installed instrumentation, which negatively affects the possibility of its use.

Conclusion. The issue of the course of pregnancy and delivery in idiopathic scoliosis continues to be very significant for both patients and spine surgeons who supervise them. The solution to this issue is impossible without cooperation with obstetrician gynecologists and anesthetists planning and administering anesthetic management during delivery (which is especially important in case of impossibility or significant restriction of spinal anesthesia use in such patients).

Key Words: pregnancy, scoliosis, pain syndrome, back pain, pregnancy outcome.

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In recent decades, there have been some significant changes in the technique for correcting idiopathic scoliosis, which have made it possible to improve the quality of patients' life [1, 2]. The advent of segmental instrumentation played the key role in this event.

The incidence of idiopathic scoliosis in adolescents ranges from 0.3 % to 5.2 %. It is a well-known fact that these deformities develop very slowly during a long period of time [3], with the patients usually becoming adults during this period. Thus, the epidemiology of idiopathic scoliosis in adolescents largely reflects the epidemiology in adults. According to the available data [2], the sex ratio (female : male) ranges from 1.5 : 1 to 3 : 1 and gradually increases with age. Furthermore, more severe scoliosis is more common in women than men: the ratio is 1.4 : 1 for deformities with the Cobb angle of 10° to 20° and exceeds 7.2 : 1 for scoliosis with a curve over 40° [2].

The annual number of surgeries for scoliosis reaches 29,000 only in the USA, while the number of people with similar clinically significant deformities (30° or more) is about 500,000 [4].

Patients often ask spinal surgeons about the further prognosis of their life from the standpoint of clinical and social outcomes, including the possibility of carrying a pregnancy and delivering a baby. This issue has not been studied well enough yet, and there is a need for a multicenter research and analysis with the involvement of obstetrician-gynecologists. To date, the medical community does not have data on the course of pregnancy and delivery in patients with spinal deformities that occurred before or after deformity correction and instrumented fixation of the spine.

The aim of the study is to analyze the course of pregnancy and delivery that occurred before and after surgical correction of idiopathic scoliosis with instrumented fixation of the spine.

Material and Methods

This study included patients with grade IV idiopathic scoliosis who had a successful delivery.

The inclusion criteria were as follows:

1) thoracic or lumbar idiopathic scoliosis (Lenke types 2–4);

2) the age of 18–35 years at the time of delivery (international standard of reproductive age, 15–49 years);

3) the absence of chronic gynecological and therapeutic diseases;

4) Cobb angle of ⩾40°.

We selected patients with Lenke type 2–6 scoliosis for the study due to the fol-

lowing reasons: patients with Lenke type 1 scoliosis have less pronounced deviations in the biomechanics of the spinal column in the lumbar and lumbosacral segments, while the compensatory lumbar curve, as a rule, is not structural and characterized by a relatively small angle of deformity; type 1 scoliosis is expected to have the smallest effect on the biomechanics of the lumbar spine during pregnancy and delivery.

The strategy for patient selection and inclusion in the study is schematically presented in the Figure.

Using the randomization technique, we selected 100 patients who were asked to undergo a questionnaire survey on the key aspects of the course of pregnancy and delivery (questionnaire questions are presented in the supplementary material). The mean age at the time of delivery was 24.2 ± 4.2 years (range, 18 to 35 years).

Patients were divided into subgroups according to the scoliotic curve type (Table 1): Lenke type 2–4 curves were classified as thoracic scoliosis with lumbar compensatory curve (hereinafter referred to as thoracic scoliosis), Lenke type 5–6 curves were classified as lumbar scoliosis with thoracic compensatory curve (hereinafter referred to as lumbar scoliosis).

The patients were divided into two groups based on the time point of delivery relative to the time of surgery. Group 1 (n = 42) included patients who had delivery before surgical treatment. Thoracic scoliosis was diagnosed in 27 (64.28 %) of these individuals, lumbar scoliosis was noted in 15 (35.72 %) cases. The mean age was 22.50 ± 3.67 (18–31) years at the time of delivery and 26.10 ± 4.12 (20–33) years at the time of surgery. The mean curve angle was 87.9° ± 15.7° (57–113°) for thoracic scoliosis and 65.3° ± 18.1° (49–98°) for lumbar scoliosis. Group 2 (n = 58) included patients who had delivery after surgery (instrumented fixation of the spine). Mean age at the time of delivery was 25.80 ± 2.48 (21–35) years; mean age at the time of surgery was 21.30 ± 3.10 (18–24) years.

The patients were divided into two groups in order to assess the effect of the installed instrumentation on the severity of pain during pregnancy and mode of delivery. Accumulation of such data will make it possible to provide patients with recommendations on the preferred time of surgery for scoliosis (before pregnancy and delivery or after, with taking into consideration some other factors).

The following parameters were considered to be most important during questionnaire survey:

– mode of delivery (vaginal or C-section);

– non-orthopedic comorbidities (gynecological and endocrinological disorders preventing conception) and concomitant orthopedic diseases (severe spinal pain);

– presence or lack of epidural anesthesia.

In addition to the questionnaire, patients were asked to evaluate the severity of pain in the lumbar spine, which was presumably associated with increased load and known from empirical medical practice. No biomechanical studies on determining the nature and severity of this load have been carried out yet; this field remains open for further study. Evaluation was carried out according to the VAS score in each trimester of pregnancy; the average value, standard deviation, and range were calculated. The presence of significant pain was defined as 4 or more VAS score.

The search for a possible relationship between the deformity score (Cobb angle) and the mode of delivery was not a part of the current study.

Statistical processing was performed using the SPSS Statistics 22 software. The χ^2 method was used to find differences between the groups in the possibility of independent conception and the mode of delivery; the data are presented in the tables in the "Results" section. A relationship between the position of the lower level of instrumentation in Group 2 patients and the mode of delivery was also revealed using the χ^2 method.

Pain severity was compared according to VAS scale in patients of the same group in different trimesters of pregnancy using the Wilcoxon test for paired samples and in patients of different groups in the same trimesters of pregnancy using the Mann – Whitney test.

Other data were processed and presented using descriptive statistics.

Literature for the period of February 2019 to March 2019 was analyzed using the keywords "scoliosis" and "pregnancy" in the PubMed and other databases with inclusion of English- and Russian-language results. Articles on the topic of the current study were included in analysis.

Results

Comparison of the modes of delivery between the groups using the χ^2 criterion revealed statistically significant ($p < 0.01$) differences. The exact quantitative data are presented in Table 2.

The following conclusion can be made: cesarean section was more often performed in Group 2 patients who had instrumented fixation (operated on before delivery), while patients without fixation (operated on after delivery) are more likely to have vaginal delivery.

When discussing this issue, it should be noted that traumatology and orthopedic management of pregnant patients with spinal instrumentation, including the lumbar spine, is currently based mainly on the empirical practice of an orthopedic traumatologist.

Patients were informed by the attending physician about the possibility of delivery both vaginally and by C-section.

Appeals from obstetricians to orthopedic doctors on this issue were repeated and did not have the nature of a formal consultation. The main issue was the possibility of vaginal delivery itself in the presence of spinal instrumentation. This possibility was confirmed by the experience of successful pregnancy outcomes in patients who had been previously treated at the department. The high frequency of C-section in patients may be associated with a fear of birth injury due to severe pain in the last trimester of pregnancy (which is to be discussed below), as well as little knowledge on this topic on the part of obstetrician-gynecologists due to the absence or rarity of highly reliable data.

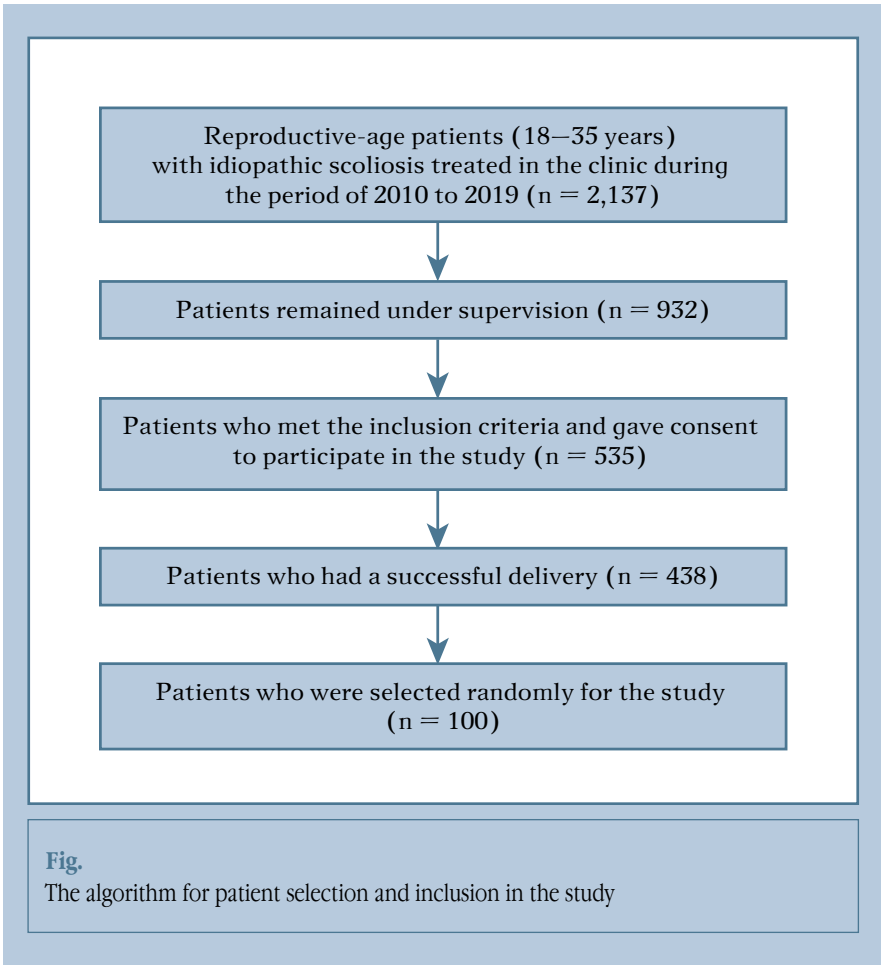

Fig.
The algorithm for patient selection and inclusion in the study

Table 1
Distribution of the studied patients by the type of scoliosis (n = 100)

Lenke type	Patients, n (%)
Thoracic scoliosis	
Type 2	38 (38.00)
Type 3	4 (4.00)
Type 4	0 (0.00)
Lumbar scoliosis	
Type 5	58 (58.00)
Type 6	0 (0.00)

Scientific justification for the need for a C-section in the presence of lumbosacral spine fixation is beyond the scope of this study because the opinions and data provided not by orthopedic traumatologists but obstetrician-gynecologists are of prime importance on this issue, considering the specifics of their work and that they are the ones determining the mode of delivery. This is a promising area for future research.

An additional task was set during the study, namely to analyze the pregnancy outcome in the low level of instrumentation placement in Group 2 patients. The data are presented in Table 3.

The χ^2-based evaluation revealed a high ($p < 0.01$) degree of statistical significance for the relationship between the level of spinal fusion and the need for a C-section. The following conclusion can be made: the lower the caudal end of instrumentation within the L3–S1 region is, the higher the risk of the C-section is, and, conversely, the higher the lower end of the instrumentation is, the higher the patient's chance for a vaginal delivery is.

The possibility of independent conception was also evaluated. In addition, the relationship between independent conception, deformity localization and the chronological ratio of delivery to surgical treatment was analyzed using the χ^2 method. In this case, no statistically significant relationship was noted ($p > 0.05$). However, it is noteworthy that a total of 48.57 % (17 out of 35) of the patients with the major lumbar curve and only 30.77 % (20 of 65) of women with the major thoracic curve required medicated help for conception. Complete data are presented in Table 4.

The survey results indicated the most severe pain in the presence of the following factors: the last trimester of pregnancy and the presence of spinal deformity in the lumbar spine.

Moreover, pain was more pronounced in Group 1. Complete data are presented in Tables 5 and 6.

Thus, the following conclusions can be made:

– the average pain severity in each separately considered trimester of pregnancy (with the exception of the first trimester) is lower in Group 2 than in Group 1;

– both Group 1 and Group 2 patients with thoracic scoliosis have less pronounced pain than patients with lumbar scoliosis.

In addition, the questionnaire allowed obtaining data on the use of epidural anesthesia: it was used in 4 (9.53 %) out of 42 patients of the Group 1 (all of these individuals had thoracic curve); epidural anesthesia was not used in Group 2.

Discussion

The mutual influence of idiopathic scoliosis and surgical interventions for it, as well as the course of pregnancy and delivery, has not been studied well enough, and the studies available

on this topic are sparse. At the same time, there have been attempts to fill this gap in the literature. One of the first works [5] was on the course of pregnancy and delivery in 146 patients operated on for idiopathic scoliosis using the Harrington's distractor with a follow-up period of up to 19 years after surgery. The authors investigated in detail the nature of complications during pregnancy and delivery, as well as provided their characterization. The authors noted that, out of 146 patients with idiopathic scoliosis, 79 (54 %) had two or more successful deliveries, 90 % of the pregnancies were delivered on time, while premature births (less than 38-week gestation) constituted 10 % of the pregnancies. Complications of pregnancy and delivery were noted in four children: rubella, multiple hereditary anomalies of development (chromosomal disorder), congenital scoliosis due to abnormal spine development, and bilateral congenital hip dislocation (one complication per each child). According to the authors, the indicated frequency rate (about 3 %) corresponded to the incidence of similar complications in the population in general, which illustrates the fact that mother's scoliosis does not affect her child [6]. Severe pain in the lumbar spine was detected in 14 % of the patients, which required their temporary suspension from work in the first trimester of pregnancy. These data do not differ statistically from the general population [7]. The mean residual deformity angle according to Cobb is 44° (range, 21° to 86°). The frequency of caesarean section is 23 %, which is consistent with the previously obtained data on the increased frequency of this mode of delivery in women with spinal deformities [8–13].

Among recent works, studies published by Chan et al. [14] and Dewan et al. [15] in 2017 attract the most attention. The first study included data on 51 patients with < IV scoliosis: the mean deformity angle during surgery was 25°, the median angle was 31°. A total of 55 (65.5 %) patients had vaginal delivery; 29 (34.5 %) women underwent cesarean section. It is noteworthy that the study reported a 99 % success rate of spinal anesthesia. In conjunction with the data obtained, it is possible to assume that grade IV idiopathic scoliosis is associated with significantly greater anesthesiological difficulties compared to similar scoliosis of lesser degrees. Dewan et al. [15] published a review of 22 studies available on this topic, the structure of which confirms the low level of research on the issue: of 22 articles, only 3 (13.6 %) works had level 2b of evidence, 6 (27.3 %) studies had evidence level 3b, while others had evidence level 4. According to the authors, one can state that idiopathic scoliosis (as well as the condition after surgery for it) is accompanied by severe pain in the lumbar spine, and there is no qualitative and quantitative difference in the complications from the fetus/child and mother in the presence of this disease.

In our opinion, the statistical relationship between the low level of instrumentation placement and the incidence of C-section can be explained by the desire of obstetrician-gynecologists and the patients themselves to reduce the potential risks of vaginal delivery. The following aspects and factors are regarded as risk factors due to the extremely little knowledge of them:

– increased load on the instrumentation and the bone-tissue fixation system in general during delivery, which does not exclude the risk of damage to the instrumentation and/or loss of its fixative properties;

– changes in the biomechanics of the lumbar spine compared to that without fixation; it is currently extremely difficult to evaluate the biomechanics of the lumbosacral spine and adjacent muscle groups during delivery in patients with idiopathic scoliosis.

Table 2
Delivery mode in the studied patients

Mode of delivery	Group 1 (n = 42)	Group 2 (n = 58)
Vaginal	27 (64.28 %)	20 (34.48 %)
C-section	15 (35.72 %)	38 (65.52 %)

Percentages are calculated separately for each group.

Conclusion

The issue on the course of pregnancy and delivery in patients with idiopathic scoliosis remains very relevant for both patients and spine surgeons supervising them. The issue cannot be solved without cooperation with obstetrician-gynecologists and anesthetists planning and administering anesthetic management during delivery, which is especially important in case when it is impossible to significantly restrict the use of spinal anesthesia in such patients. Thus, this is a multidisciplinary problem that requires further research.

Based on the data obtained, the following conclusions can be made:

Table 3
Delivery mode in Group 2 patients with the low level of instrumentation placement

Mode of delivery	L3	L4	L5	S1
Vaginal	10 (71.42 %)	5 (83.33 %)	4 (18.18 %)	1 (9.09 %)
C-section	4 (28.58 %)	6 (16.67 %)	18 (81.82 %)	10 (90.91 %)

Percentages are calculated separately for each group.

1) surgical correction of spinal deformity with instrumentation before pregnancy results in increased probability of C-section delivery;

2) the lower the caudal end of instrumentation within the L3–S1 region is, the higher the chance of C-section delivery is;

3) no statistically significant differences were found in the incidence of independent (non-medicated) conception between patients with thoracic scoliosis and patients with lumbar scoliosis;

4) severe (4 VAS score) pain syndrome is more common in patients who have not been operated on for scoliosis, who also have lumbar scoliosis, are in the last trimester of pregnancy, as well as in a combination of these factors;

5) anesthetic management in idiopathic scoliosis (both in the post-operative period and in the absence of surgery) has certain limitations, namely, the difficulty of spinal anesthesia.

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Table 4

Data on conception in the studied patients

Mode of conception	Group 1		Group 2	
	T	L	T	L
Independent	20 (74.07 %)	7 (46.67 %)	25 (65.79 %)	11 (55.00 %)
Medical	7 (25.93 %)	8 (53.33 %)	13 (34.21 %)	9 (45.00 %)

T – predominantly thoracic scoliosis (Lenke type 2–4), L – predominantly lumbar scoliosis (Lenke type 5–6).

Table 5

VAS pain assessment in different trimesters of pregnancy

Group (spine department)	I	II	III
1 (thoracic)	**1.600** ± 0.495 (0–2)	**2.400** ± 1.010 (0–3)	**3.200** ± 1.340 (1–5)
1 (lumbar)	**3.300** ± 1.800 (1–5)	5.500 ± 1.430 (2–7)	6.800 ± 2.150 (4–9)
2 (thoracic)	**1.400** ± 0.500 (0–2)	**1.600** ± 0.950 (0–3)	**2.100** ± 0.931 (1–4)
2 (lumbar)	**2.300** ± 1.380 (0–5)	**2.900** ± 1.830 (1–6)	4.700 ± 2.210 (2–8)

Mean values are marked in bold, data corresponding to severe pain (4 points or more) are indicated in blue color. Data are presentated as follows: M ± σ (min – max), M stands for the average value, σ is the standard deviation, min and max are the minimum and maximum values of the studied parameter.

Table 6

P-values for comparison of pain severity according to the VAS in the groups of patients from the Table 5

	1–T I	2–T II	1–T III	1–L I	1–L II	1–L III	2–T I	2–T II	2–T III	2–L I	2–L II	2–L III
1–T I												
1–T II	0.352											
1–T III	0.089	0.271										
1–T I	0.003											
1–T II		0.016		0.068								
1–T III			0.019	0.004	0.115							
2–T I	0.417											
2–T II		0.389					0.385					
2–T III			0.193				0.124	0.169				
2–L I				0.063			0.089					
2–L II					0.001			0.012		0.098		
2–L III						0.031			0.003	0.002	0.041	

The Wilcoxon test (green frames) was used for comparing patients of the same group (at different time points); the Mann – Whitney test (blue frames) was used for comparing patients of different groups and departments at the same time points. The comparison was carried out either between different trimesters in the same group of patients or between different groups examined during the same trimester. Statistically significant values are highlighted in yellow.

1, 2 – groups; T, L – thoracic and lumbar scoliosis, respectively; I, II, III – the corresponding trimesters of pregnancy.

References

1. **Benli IT, Ates B, Akalin S, Citak M, Kaya A, Alanay A.** Minimum 10 years follow-up surgical results of adolescent idiopathic scoliosis patients treated with TSRH instrumentation. Eur Spine J. 2007;16:381–391. DOI: 10.1007/s00586-006-0147-3.
2. **Theis JC, Grauers A, Diarbakerli E, Savyides P, Abbott A, Gerdhem P.** An observational study on surgically treated adult idiopathic scoliosis patients' quality of life outcomes at 1- and 2-year follow-ups and comparison to controls. Scoliosis Spinal Disord. 2017;12:11. DOI: 10.1186/s13013-017-0118-y
3. **Akoume MY, Azeddine B, Turgeon I, Franco A, Labelle H, Poitras B, Rivard CH, Grimard G, Ouellet J, Parent S, Moreau A.** Cell-based screening test for idiopathic scoliosis using cellular dielectric spectroscopy. Spine. 2010;35:E601–E608. DOI: 10.1097/BRS.0b013e3181cf39ff.
4. **Reamy BV, Slakey JB.** Adolescent idiopathic scoliosis: review and current concepts. Am Fam Physician. 2001;64:111–116.
5. **Orvomaa E, Hiilesmaa V, Poussa M, Snellman O, Tallroth K.** Pregnancy and delivery in patients operated by the Harrington method for idiopathic scoliosis. Eur Spine J. 1997;6:304–307. DOI: 10.1007/BF01142675.
6. **Finnish National Malformation Register 1963–1991.** Finnish National Board of Welfare and Health, Helsinki, Finland.
7. **Myllynen L.** Work during pregnancy. Academic dissertation. Helsinki: University Press; 1991.
8. **Betz RR, Bunnell WP, Lambrecht-Mulier E, MacEwen GD.** Scoliosis and pregnancy. J Bone Joint Surg Am. 1987;69:90–96.
9. **Cochran T, Irstam L, Nachemsson A.** Long-term anatomic and functional changes in patients with adolescent idiopathic scoliosis treated by Harrington rod fusion. Spine. 1983;8:576–584. DOI: 10.1097/00007632-198309000-00003.
10. **Dugan RJ, Black ME.** Kyphoscoliosis and pregnancy. Am J Obstet Gynecol. 1957;73:89–93.
11. **Kopenhager T.** A review of 50 pregnant patients with kyphoscoliosis. Br J Obstet Gynecol. 1977;84:585–587. DOI: 10.1111/j.1471-0528.1977.tb12658.x.
12. **Manning CW.** Pregnancy and scoliosis. Lancet. 1967;14:792–795.
13. **Siegler D, Zorab PA.** Pregnancy in thoracic scoliosis. Br J Dis Chest. 1981;75:367–370. DOI: 10.1016/0007-0971(81)90024-3.
14. **Chan EW, Gannon SR, Shannon CN, Martus JE, Mencio GA, Bonfield CM.** The impact of curve severity on obstetric complications and regional anesthesia utilization in pregnant patients with adolescent idiopathic scoliosis: a preliminary analysis. Neurosurg Focus. 2017;43:E4. DOI: 10.3171/2017.7.FOCUS17321.
15. **Dewan MC, Mummareddy N, Bonfield C.** The influence of pregnancy on women with adolescent idiopathic scoliosis. Eur Spine J. 2018;27:253–263. DOI: 10.1007/s00586-017-5203-7.

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Supplementary material

The following questionnaire was offered to the patients participating in the study

1. Pregnancy after surgery for scoliosis. **Yes/no.** No. of pregnancy?_____
2. Pregnancy before surgery. **Yes/no.** No. of pregnancy?_____
   Note. If there were pregnancies both before and after surgery, both questions should be answered.
   If there were more than one pregnancy before or after surgery, they all should be mentioned.
3. Were there any concomitant gynecological or endocrinological disease and/or severe pain in the spine, preventing conception? **Yes/no.**
4. Mode of delivery: vaginal delivery, cesarean section, episiotomy (underline as necessary).
5. Were there any complications, cesarean section, stillbirth, abortions, hormone therapy? **Yes/no**.
6. Was there lumbar pain during pregnancy?_____ (score, 1 to 10 points).
7. Was there lumbar pain in the postpartum period?_____ (score, 1 to 10 points).
8. Was spinal anesthesia performed during delivery? **Yes/no.**
9. Was an orthopedic belt used during pregnancy and in the postpartum period? **Yes/no**.

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