

Evaluation of the effectiveness of surgical treatment using the one-level ACDF method based on changes in the parameters of the sagittal balance of the cervical spine

Ocena skuteczności leczenia operacyjnego metodą jednopoziomowej ACDF na podstawie zmian parametrów balansu strzałkowego odcinka szyjnego kręgosłupa

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Słowa kluczowe: NDI, jednopoziomowa stabilizacja przednia szyjna, szyjny balans strzałkowy.

Abstract

Introduction: Anterior cervical fixation is one of the most effective methods of treating cervical discopathy. The following parameters are distinguished to assess cervical sagittal balance: cervical lordosis angle, T1 slope, and sagittal vertical axis.

Aim of the research: To assess the impact of the increase in the cervical lordosis angle on the other parameters of sagittal balance and on the effects of surgical treatment.

Material and methods: Thirty patients were qualified for surgical treatment with the method of a single-level ACDF. An X-ray examination was taken before and 3 months after surgery. The following parameters were analysed: T1 slope, sagittal vertical axis, and cervical lordosis angle. The perceived pain was assessed by analysing the results of the NDI questionnaire and the VAS scale.

Results: After surgical treatment, the Cobb angle changed statistically significantly ($p = 0.001$), on average 11.79° . The SVA C2-7 distance did not change significantly ($p = 0.697$), with a mean of 22.82 mm after surgery. The value of the T1 slope angle increased to 27.38° ($p < 0.001$). There was a significant reduction in the NDI scale ($p < 0.001$) and in the VAS scale ($p < 0.001$), but no correlation with changes in the sagittal balance parameters was demonstrated.

Conclusions: The change in cervical sagittal balance seems to be an important prognostic factor in the assessment of the effectiveness of surgical treatment. The individual parameters showed mutual dependencies. The correction of balance parameters after single-level ACDF stabilization does not significantly affect the result of surgical treatment (NDI, VAS). However, this issue requires further research.

Streszczenie

Wprowadzenie: Stabilizacja przednia szyjna jest jedną z najskuteczniejszych metod leczenia dyskopatii szyjnej. Wyróżnia się następujące parametry służące ocenie szyjnego balansu strzałkowego: kąt lordozy szyjnej, kąt nachylenia trzonu Th1, strzałkowa oś pionowa. Zaburzenia spowodowane zmianą parametrów balansu mogą powodować dolegliwości bólowe i zmiany zwyrodnieniowe tego odcinka.

Cel pracy: Ocena wpływu wzrostu kąta lordozy szyjnej na pozostałe parametry balansu strzałkowego oraz na efekty leczenia operacyjnego.

Materiał i metody: Przeprowadzono prospektywne badanie, do którego włączono 30 pacjentów zakwalifikowanych do operacyjnego leczenia choroby zwyrodnieniowej kręgosłupa szyjnego metodą jednopoziomowej przedniej stabilizacji. Każdy pacjent miał wykonane badanie rentgenowskie przed leczeniem i 3 miesiące po leczeniu operacyjnym. Przeanalizowano następujące parametry: kąt nachylenia Th1, strzałkowa oś pionowa, kąt lordozy szyjnej. Oceny odczuwanych dolegliwości bólowych dokonano, analizując wyniki kwestionariusza NDI i skali VAS.

Wyniki: Po leczeniu operacyjnym kąt lordozy szyjnej uległ statystycznie istotnej zmianie ($p = 0,001$), średnio $11,79^\circ$. Odległość SVA C2-7 nie zmieniła się istotnie ($p = 0,697$), po operacji średnio o 22,82 mm. Wartość kąta nachylenia Th1 wzrosła do $27,38^\circ$ ($p < 0,001$). Uzyskano istotną redukcję w skali NDI ($p < 0,001$) i w skali VAS ($p < 0,001$), jednak nie wykazano związku ze zmianami parametrów balansu strzałkowego.

Wnioski: Wydaje się, że zmiana balansu strzałkowego odcinka szyjnego jest istotnym czynnikiem prognostycznym w ocenie skuteczności leczenia operacyjnego. Poszczególne parametry wykazały wzajemne zależności. Korekcja parametrów balansu po stabilizacji jednopoziomowej ACDF nie wpływa istotnie na wynik leczenia operacyjnego (NDI, VAS). Zagadnienie to wymaga jednak poszerzenia badań.

Introduction

The anterior stabilization in the cervical spine was first described by Smith and Robinson in 1955. This surgical technique is one of the most effective methods of surgical treatment of cervical discopathy because it provides safe access to the intervertebral discs from the C3 to the C7 level [1]. It is an effective treatment tool when treating herniated nucleus with compression of the spinal cord and nerve roots, cervical myelopathy, or spinal canal stenosis and calcification of the posterior longitudinal ligament [2–5]. It allows for the correction of deformations of the cervical spine with improvement of the segment alignment in the sagittal projection [6]. In Poland the technique of an anterior approach to the cervical spine was first applied by Jan Haftek in 1967.

The anatomical structure of the vertebrae and the shape of the disc space ensures lordosis of the cervical spine. The cervical lordosis angle, also known as the Cobb angle, is measured between the upper endplate of the C2 vertebra and the lower endplate of the C7 vertebra. Alternatively, it can also be measured between the body of the C1 vertebra and the body of the 7th cervical vertebra. However, when measured this way, the values of the Cobb angle are thought to be often overestimated. The optimal value for the cervical lordosis angle is up to $40 \pm 9.7^\circ$ [7]. So far, the Cobb angle values considered as normal have not been determined.

The parameter corresponding to the lumbar sagittal vertical axis (SVA) parameter assessing sagittal balance in the cervical region is SVA C2-C7. It is a distance drawn from the posterior edge of the upper endplate of the C7 vertebra to a perpendicular line drawn from the centre of the base of the C2 vertebrae. The centre of the axis is at the intersection of the line drawn at the base of the dens and the line of the lower endplate of the C2. The value of SVA C2-7 in asymptomatic patients is up to 20 mm [8, 9]. The T1 slope, analogous to the pelvic incidence parameters, is the angle between the upper endplate of the T1 vertebra and a horizontal line. When it is not possible to visualize the T1 vertebra on lateral X-ray, e.g. due to the high position of the shoulders, it is possible to measure the C7 inclination angle [10]. The T1 vertebra is the connection between the mobile cervical spine and the much less mobile thorax. This is the segment where thoracic kyphosis becomes cervical lordosis. It has been shown that the C2-C7 lordosis angle may increase with the increase of the T1 slope parameter [11]. However, studies show that some T1 slope values increase the risk of initiating degenerative changes. A T1 slope angle lower than

18.5° may result in greater probability of developing cervical myelopathy [12].

Aim of the research

The hypothesis of our work is that an increase in the cervical lordosis angle causes changes in the remaining values of the sagittal balance (Th1 slope, SVA c2-7). Modification of the aforementioned parameters can affect the final outcome of surgical treatment. Based on this assumption, we hypothesized that the improvement of the cervical lordosis angle may have a positive impact on the quality of the patient's functioning after treatment, assessed in the Neck Disability Index (NDI) and Visual Analogue Scale (VAS). Our study was based on the assessment of lateral X-rays assessed before treatment and 3 months after surgical anterior cervical discectomy and fusion (ACDF) treatment of patients operated on at one level.

Material and methods

Group of patients

Thirty patients were included in the study. All of them were treated for cervical discopathy with the method of anterior fixation at one level by the same operator in one department.

Assessment of the sagittal balance parameters of the cervical spine

Sagittal balance parameters were assessed on the basis of a lateral X-ray examination made in a relaxed standing position. The following parameters were measured: the T1 (C7) slope, the sagittal vertical axis (SVA), the distance from the centre of C2 to the posterior edge of the upper endplate of C7, and the angle of cervical lordosis C2-7 – the curvature of the lower part of the cervical spine C2-C7. The parameters of sagittal balance were measured, and the balance was analysed using Surgimap software (version 2.2.15.5 – Os X).

Surgical technique and evaluation of treatment results

All the patients included in the study had an X-ray taken in the lateral projection in a relaxed standing position, providing visualization of the cervical spine with the T1 vertebra. The groups underwent a quality of life test – the Neck Disability Index (NDI) – and the perceived pain was assessed in the visual analogue scale (VAS) before the operation and after the 3-month follow-up period. X-ray examina-

tions were performed before and after treatment during the 3-month observation period.

The patients were operated on with the method of nucleotomy performed on one level. Interbody cage implants made of PEEK material were used. The front plate was not used during surgery.

Results

Demography

Thirty people (15 men and 15 women) were included in the study, who were operated on with the single-level ACDF method. The distribution of the operated patients depending on their age is presented in Figure 1. Two patients (1 male and 1 female) did not report to the follow-up study.

The most common indication for surgical treatment was cervical discopathy with herniated nucleus pulposus on one level, with symptoms of radiculopathy and pain, and with no improvement after conservative treatment (21 patients). Neurological deficits in the form of upper-limb paresis were found in 10 patients. The single-level stabilization operation was most often performed on the C5-C6 levels (17 patients). There were no permanent postoperative complications in the group of operated patients. The most common postoperative complication was dysphagia (7 patients), which resolved within 14 days of the procedure. Hoarseness occurred in 1 patient and resolved before discharge from the department.

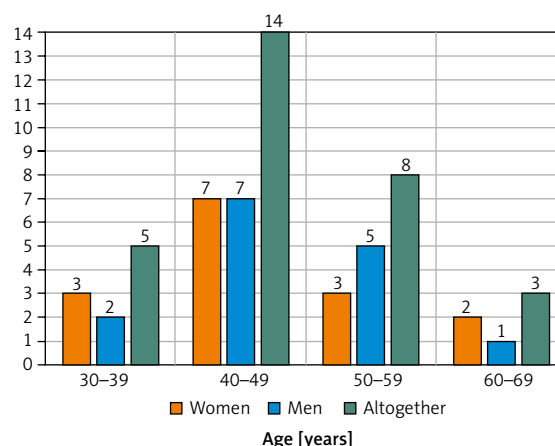


Figure 1. Structure of the study group according to age

Radiography. Assessment of treatment results

Before the operation, the cervical lordosis (C2-7 Cobb) angle was on average 7.97° (Table 1), the angle of T1 slope was 23.79° , and the SVA distance was 22.81 mm. In the control study performed during the 3-month follow-up, the angle of cervical lordosis changed statistically significantly ($p = 0.001$), on average 11.79° (Table 1). The SVA C2-7 distance did not change significantly ($p = 0.697$), with an average of 22.82 mm after surgery (Table 2). The angle of T1 slope increased to 27.38° ($p < 0.001$) (Table 3).

Table 1. Cobb angle (deg) in total and by sex, before surgery versus after surgery

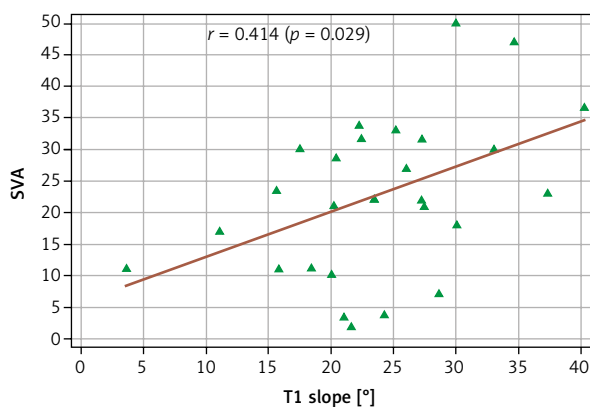
Sex	Research phase	Statistical parameter						
		M	Me	Q ₁ -Q ₃ (IQR)	SD	SE	95% CI	Min.-max.
Women	Before surgery	6.87	4.20	2.00-10.00 (8.00)	7.07	1.83	2.96-10.79	1.10-24.50
	Post-surgery	10.63	9.00	3.30-13.80 (10.50)	8.47	2.19	5.93-15.32	1.80-35.00
Men	Before surgery	9.25	4.30	1.80-15.00 (13.20)	9.73	2.70	3.36-15.13	0.10-31.00
	Post-surgery	13.12	14.00	5.60-19.00 (13.40)	7.81	2.17	8.40-17.84	3.30-25.00
Altogether	Before surgery	7.97	4.25	1.90-12.85 (10.95)	8.33	1.57	4.74-11.21	0.10-31.00
	Post-surgery	11.79	11.00	4.45-17.30 (12.85)	8.12	1.53	8.64-14.93	1.80-35.00

Table 2. The values of the SVA in total and by sex, before surgery versus after surgery

Sex	Research phase	Statistical parameter						
		M	Me	Q ₁ -Q ₃ (IQR)	SD	SE	95% CI	Min.-max.
Women	Before surgery	23.04	22.00	10.90-33.00 (22.10)	13.03	3.36	15.82-30.25	3.30-47.00
	Post-surgery	22.00	22.00	12.00-29.00 (17.00)	11.29	2.91	15.75-28.25	2.80-45.00
Men	Before surgery	22.55	23.00	17.00-28.50 (11.50)	12.49	3.46	15.00-30.10	1.80-50.00
	Post-surgery	23.77	25.00	20.00-29.00 (9.00)	9.75	2.70	17.88-29.66	6.80-40.00
Altogether	Before surgery	22.81	22.50	11.10-31.65 (20.55)	12.55	2.37	17.95-27.68	1.80-50.00
	Post-surgery	22.82	22.25	16.80-29.00 (12.20)	10.45	1.97	18.77-26.87	2.80-45.00

Table 3. Values of the T1 slope (deg) in total and by sex, before surgery versus after surgery

Sex	Research phase	Statistical parameter						
		M	Me	Q1–Q3 (IQR)	SD	SE	95% CI	Min.–max.
Women	Before surgery	23.69	23.40	20.00–27.20 (7.20)	8.64	2.23	18.90–28.47	3.60–40.20
	Post-surgery	27.69	26.60	21.20–34.20 (13.00)	6.72	1.73	23.97–31.41	17.90–40.60
Men	Before surgery	23.91	22.40	20.40–28.60 (8.20)	6.96	1.93	19.71–28.12	11.00–37.30
	Post-surgery	27.03	28.40	24.00–31.00 (7.00)	7.31	2.03	22.61–31.45	10.00–38.80
Altogether	Before surgery	23.79	22.90	20.10–28.00 (7.90)	7.76	1.47	20.78–26.80	3.60–40.20
	Post-surgery	27.38	27.30	23.20–32.10 (8.90)	6.87	1.30	24.71–30.05	10.00–40.60

**Figure 2.** Correlation of the angle of the T1 slope with the SVA in patients before surgery

In the multivariate analysis, with the adoption of the C2-7 Cobb angle as a dependent variable, assuming the time factor and SVA and T1 slope as independent variables, the following results were obtained: in the above multivariate model, the Cobb angle changed, i.e. it increased statistically ($p = 0.010$). This change, at the same time, was statistically significantly modified by a decrease in SVA ($p < 0.001$) and a statistically significant increase in the T1 slope ($p = 0.006$) (Figure 2).

Taking the result of the VAS questionnaire for neck pain as a dependent variable and the Cobb angle C2-7, SVA, the T1 slope, and time factor as independent variables, the following results were obtained: VAS for pain – a statistically significant reduction in the intensity of neck pain in the described time ($p < 0.001$), but no statistical relationship with changes in the Cobb angle ($p = 0.514$), SVA ($p = 0.569$), and T1 slope ($p = 0.706$). The independent variables included in the multivariate model did not determine the reduction in the intensity of neck pain.

Taking the result of the VAS questionnaire for the limb as the dependent variable, and the Cobb angle C2-7, SVA, T1 slope, and the time factor as the independent variables, the following results were obtained: there was a statistically significant reduction in the intensity of pain in the described time ($p < 0.001$), but without a statistical relationship with changes in the

Cobb angle ($p = 0.717$), SVA ($p = 0.269$), and T1 slope ($p = 0.849$). The independent variables included in the multivariate model did not determine the reduction in pain in the limb.

Taking the result of the NDI questionnaire as the dependent variable, and the Cobb angle C2-7, SVA, T1 slope, and the time factor as the independent variables, the following results were obtained: NDI underwent a statistically significant reduction over the reported time ($p < 0.001$), although it was not statistically related to changes in the Cobb angle ($p = 0.372$), SVA ($p = 0.530$), and the T1 slope ($p = 0.467$). The independent variables included in the multivariate model did not significantly reduce symptoms over time.

Discussion

The basic parameters of cervical balance associated with the results of surgical treatment of cervical spine osteoarthritis include the Cobb angle, the SVA distance, and the T1 slope [13]. The analysis of changes in the values of the aforementioned parameters and the determination of the sagittal balance allows us to forecast the results of the surgical treatment. Research shows that the Cobb angle and the SVA C2-7 value are correlated with the severity of symptoms in the treatment of cervical myelopathy, and thus they are considered as an indicator of it [14]. Villavicencio *et al.* conducted a study on parallel interbody implants and lordotic cages. In their research, they did not prove any significant differences between the implants used in the results in the correction of cervical lordosis. However, the results of their research prove the existence of a correlation between the improvement of the sagittal balance with the correction of the lordosis angle on the operated segment and the degree of clinical improvement [15].

The parameters of the sagittal balance of the cervical spine, similarly to the lumbar-pelvic parameters, show mutual dependencies. In this study, a statistically significant correlation was demonstrated between the cervical lordosis angle and the T1 (C7) slope, and a negative correlation with the SVA C2-7 distance. After nucleotomy with anterior stabilization at one level

and a 3-month follow-up, both an increase in the C7 cervical lordosis angle and an increase in the value of the T1 slope were found.

In their research, Jun *et al.* proved that the increase of the value of the T1 slope shows a significantly strong correlation with the C2-C7 cervical lordosis angle, both in the group of patients with cervical instability and in those without this pathology. However, it should be noted that higher values of the T1 slope are also a risk factor for degenerative spondylolisthesis in the cervical spine. Changing the angle of cervical lordosis probably acts as a compensatory mechanism in the group of patients with cervical spondylolisthesis. The angle of the T1 slope may be a parameter analogous to the pelvic incidence angle (PI) for the pelvic parameters [16]. However, the study did not evaluate the SVA C2-7 parameter. It can be assumed that the loss of lordosis in cervical spondylolisthesis may increase the length of the SVA C2-7 in the mechanism of shifting the head's centre of gravity forward.

Xu *et al.* evaluated 212 patients treated with the ACDF method, divided into groups operated at one and more than one level. They analysed the interrelationships of the sagittal balance parameters of the cervical spine and showed statistically significant changes in sagittal balance parameters after surgery. The T1 slope was positively correlated with the angle of cervical lordosis ($r = 0.245$) and SVA ($r = 0.184$) [17]. The results obtained by the authors confirm the interdependence of the balance parameters, analogically to the relationships observed in the lumbar spine.

In the case of single-level anterior fixation, significant changes in the cervical lordosis angle, the T1 slope, and the SVA distance were obtained after surgical treatment. However, no influence of the analysed parameters on the treatment results assessed in the NDI and VAS scales was observed. Similar results were obtained by Faldini *et al.*, who, despite a significant increase in cervical lordosis after treatment and during the observation period, did not confirm the relationship between the change of the angle and clinical results after one-level ACDF [18]. It seems that stabilization of one level does not correct the lordosis angle sufficiently to influence the treatment outcome assessed in the perceived pain scales for neck complaints (NDI and VAS). The statistically significant improvement in the VAS scale for limb pain is due to nerve root decompression and is not related to changes in cervical sagittal balance parameters.

Conclusions

The problem of cervical sagittal balance and its impact on treatment outcomes remains unresolved. There are few significant publications confirming the correlation of sagittal balance with the clinical status of patients after single-level ACDF. Similarly to the lumbar spine, the cervical sagittal balance parameters

are interdependent. The change in the cervical sagittal balance seems to be an important prognostic factor in the assessment of the effectiveness of surgical treatment. The correction of balance parameters after single-level ACDF stabilization does not significantly affect the result of surgical treatment (NDI, VAS). It seems reasonable to recommend the assessment of the sagittal balance parameters and the results in long-segment anterior cervical stabilization, and to extend the observation period.

Conflict of interest

The authors declare no conflict of interest.

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