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CHANGES IN THE SPINO-PELVIC BALANCE AFTER HIP REPLACEMENT IN PATIENTS WITH CONGENITAL HIP DISLOCATION

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Objective. To analyze the features of the sagittal spino-pelvic balance formation in patients with congenital hip dislocation and its changes after total hip replacement with restoration of the rotation center.
Material and Methods. A retrospective analysis of medical documentation of 47 patients with congenital hip dislocation was performed, a total of 62 total hip replacements were performed. Patients were divided into two groups: Group I with unilateral congenital hip dislocation (n = 26) and Group II – with bilateral hip dislocation (n = 21). The processing and study of statistical correlation were carried out using the Spearman method at $p \leq 0.05$.
Results. Patients with congenital hip dislocation had average preoperative value of the global lumbar lordosis of 64.1°, and the excess value of the sacral slope angle of 46.4°, which led to hyperlordosis. After surgery, the average value of the global lumbar lordosis was 57.2°, the sacral slope – 41.5°. There was a close relationship between these parameters (r = 0.787).
Conclusions. Restoration of the hip rotation center in patients with congenital hip dislocation contributes to a decrease in the sacrum incidence, pelvic anteversion, and lordosis.
Key Words: sagittal spino-pelvic balance, hip displasia, Crowe IV.

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Patients with congenital hip dislocation often complain of lumbar spine pain. In case of bilateral dislocation, these sensations are more troubling than hip joint pain [1]. The combination of complaints is called hip-spine syndrome (HSS). Offierski et al. [2] described the complexity of diagnosing the underlying cause of pain and suggested the classification of HSS by identifying 4 categories: simple, secondary, complex and misdiagnosed. In 1989, Funayama et al. reported a spinal pathology that develops in response to changes associated with a hip joint pathology, for example, coxarthrosis [3]. The authors noted that lumbar spondylolisthesis can develop in coxarthrosis combined with the anterior inclination of the sacrum.

Recently, the relationship between the parameters of the spino-pelvic balance and the development of degenerative spinal changes has been actively studied. Sagittal spino-pelvic relationships have been studied in detail in the group of conditionally healthy patients [4, 5]. Duval-Beaupere et al. [6] were among the first researchers who described biomechanical features of the spine in 1992. Having performed barycentremetric studies they concluded that, due to a regular change in the spatial configuration of the pelvis and spine, the partial centers of gravity in an upright position are located in such a way that the coordinates of the common center of gravity, part of the body located above the hip joint are constant, while the gravity axis is always slightly posterior to the bicoxofemoral axis. This position reflects the balance of the spino-pelvic relationship, which provides minimal energy loss when maintaining a vertical posture.

Pelvic incidence (PI) on the sagittal radiograph of the spine is an anatomical constant, while all other spino-pelvic relationships depend on the position of femoral heads [4, 7]. In case of congenital hip dislocation, femoral heads are strongly displaced cranially and posteriorly. For this reason, the spino-pelvic balance adjusts to the situation to maintain a vertical posture. Balance changes in patients with bilateral congenital hip dislocation have been described by Matsuyama et al. [1], while sagittal spino-pelvic balance disorders in unilateral congenital hip dislocation have not been investigated yet. Observations in non-operated patients allowed scientists to conclude that, in order to maintain a vertical posture, excessive pelvic anteversion and hyperlordosis are formed, which lead to lumbalgia. In addition, the PI angle can both decrease and open up in the opposite direction, i.e. become negative, provided that the perpendicular line to the superior surface of the sacrum that crosses point O is considered zero (Fig. 1). In this case, we can determine the functional PI, since the support and rotation of the pelvis occur not immediately but via soft tissues surrounding the femoral heads. Identification of true (anatomical) angles, including PI, in congenital hip dislocation requires positioning of hip joints and is much more complicated because normally femoral heads are well visualized due to hyaline cartilage between the femoral heads and acetabulum, and this orienting point is absent in patients with dislocation. Dissociation between femoral heads and acetabular cavities does not allow one to determine the true PI. Therefore, in cases classified as Crowe type IV, the spino-pelvic balance is established relative to the dislocated femoral heads (functional PI) located at the maximum distance from the acetabulum. The initial anatomical PI and calculations of the expected balance changes after surgery are important for indications for hip arthroplasty for unilateral and bilateral congenital hip dislocation.

The aim of the study is analysis of the features of sagittal spino-pelvic balance formation in patients with unilateral and bilateral congenital hip dislocation in HSS and changes in the spino-pelvic balance after hip replacement using the proposed method of determining anatomical PI.

Material and Methods

A retrospective analysis of medical documentation of 47 patients with congenital hip dislocation was conducted, a total of 62 total hip replacement surgeries were performed using corrective osteotomy for congenital hip dislocation [8].

The average age of patients was 42.4 (range, 19 to 74) years, there were 5 men and 42 women. The patients were divided into two groups: group I included patients with unilateral congenital hip dislocation (n = 26), and group II consisted of patients with bilateral hip dislocation (n = 21). A total of 15 patients were operated on bilaterally, and 6 patients refused surgery on the opposite side due to decreased back pain after the first surgery. Difference in the length of the lower limbs was compensated by corrective insoles.

All patients underwent radiography of the spinal column at the level of C1–S1 in step mode with capturing of the femur bones prior to surgery, before discharge (day 10) and after 24 or more (24 to 46) weeks. The spino-pelvic relationships were evaluated based on the obtained radiographs using the Surgimap software (Version 2.2.1). The following parameters were analyzed: global lumbar lordosis (GLL) value according to Cobb from the superior surface of L1 vertebral body to the superior surface of S1; PI, which is the angle between the perpendicular line joining the middle of the cranial endplate of S1 and the line drawn from this point to the center of the femoral heads; sacral slope (SS), defined as the angle between the horizontal line and the superior surface of the sacrum; pelvic tilt (PT), the angle between the vertical line and a line connecting the midpoint of the superior sacral surface with the center of the femoral heads; sagittal vertical axis (SVA), defined by the distance between a plumb line drawn from the vertebral body of C7 and a parallel line drawn from the posterior superior edge of the cranial endplate of the S1 vertebral body (anterior displacement of the plumb line is denoted by “+”, posterior displacement of the plumb line is denoted by “-”); hip axis (HA), which is a vertical line drawn from a point located in the middle of the segment between the centers of the femoral heads parallel to SVA (Fig. 1) [1].

All descriptive statistical data are presented as mean (M) and standard (SD) deviations. Statistical correlation was processed and studied using Spearman method for $p \leqslant 0.05$ (SPSS 12.0.2 software).

In 22 patients, a method for predicting correction of sagittal spino-pelvic balance in congenital hip dislocation was used to determine true PI value [9]. At stage 1, functional PI (rotation point at position of hip dislocations) was determined using radiographs as described above. The 2nd stage included identification of true PI (verification of the acetabular cavities without femoral heads, sites of the proposed implantation of acetabular components with identification of the center of rotation). Next, spino-pelvic balance was calculated using known formulae. The approach included the method of X-ray diagnostics (MSCT), image examination and processing using “K-PAKS” software, determination and calculation of the true PI angle. Images of the pelvis and lumbar spine were viewed and processed in the mode of two parallel windows, one of which displayed an image in the frontal plane, and the other window displayed an image in the sagittal plane. For calculation of the true PI angle, the center of the symphysis 1 was determined on the image in the frontal plane with simultaneous selection of the center of the sacral promontory 2. On the image in the sagittal plane, line 3 was drawn through the S1 endplate, and the perpendicular line 5 was drawn from its center 4 towards the coccyx (Fig. 2).

Next, rudimentary acetabulum on the right hip joint was determined on the frontal plane image based on the teardrop view, and line 6 was drawn to its outer edge. Rudimentary acetabulum on the right hip joint on the sagittal plane image was determined based the teepee view, point 7 was placed on its top (Fig. 3).

Then, rudimentary acetabulum on the left hip joint was determined in a similar way on the frontal plane image. Focusing on the acetabular teardrop view, line 6 was drawn to the outer edge of the teardrop. On the image in the sagittal plane, rudimentary acetabulum was determined on the left hip joint based the teepee veiw, point 8 was placed on its top (Fig. 4).

The obtained images were combined into one image in the sagittal plane, on which points 7 and 8 were connected by line 9, with its center marked by point 10. Line 11 was drawn from the angle formed by lines 3 and 5 and then connected to point 10, the resulting angle between lines 5 and 11 is the true PI angle (Fig. 5).

Results and Discussion

In patients with congenital hip dislocation, GLL had an average value of 64.1° before surgery. These patients also had an excessive value of the SS angle (46.4°) with an average value of 33–40°, which leads to hyperlordosis of the lumbar spine. A close relationship between these parameters was noted ($r = 0.787$). Pelvic anteversion (PT) is negative (-23.9° ± 32.2°), with a weak negative correlation between SS and PT ($r = -0.22$). The mean value of the PI angle is 38.4° ± 15.8° for group I and 12.9° ± 17.7° for group II,

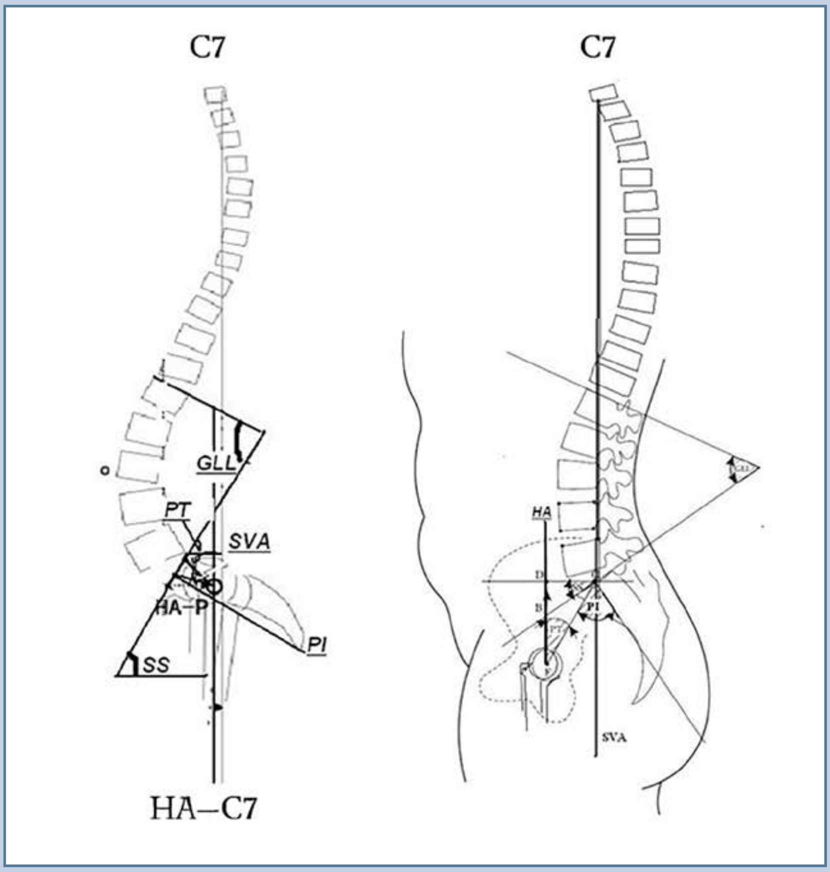

Fig. 1
Schematic representation of measuring the parameters of sagittal spino-pelvic relationships: PI is the angle between the line connecting the midpoint of the superior surface of the sacrum (O) with the midpoint of the femoral heads (F), and a line perpendicular to the superior surface of the sacrum drawn to the point O; SS is the angle between the horizontal line (OD) and the superior surface of the sacrum (OB); PT is the angle between a vertical line (FD) and a line connecting the midpoint of the superior surface of the sacrum (O) with the center of both femoral heads. If the contours of the right and left femoral heads do not overlap, the F point is located in the middle of the bicoxofemoral axis connecting the midpoints of the both femoral heads; GLL is the angle between the superior surface of the L1 body and the superior surface of the S1 body (according to Cobb). Hip axis (HA) is a vertical line drawn from a midpoint of the segment between the centers of the femoral heads parallel to the sagittal vertical axis (SVA)

with the PI value being negative (-12.0°) for all of the three cases in group II.

Mean values of the pelvic balance are presented in Tables 1, 2. In both groups, a close correlation between PI and PT values (r = 0.73) was noted before surgery. There is a very weak correlation between PI and SS (r = 0.11) and between PI and GLL values (r = 0.20).

The distance from the SVA line to the sacral promontory is on average 2.7 ± 17.2 mm in group I, and 16.5 ± 37 mm in group II. In addition, it became negative in six patients due to the displacement of the SVA line posteriorly to the sacral promontory, with the distance from SVA to HA reaching 0, which is a sign of the involvement of compensatory mechanisms of the sagittal pelvic balance. Shift in the SVA line anteriorly relative to the sacral promontory, with the HA line being located posterior to the SVA line, served as the sign of decompensation of the sagittal balance (Fig. 6).

The average negative correlation is noted between HA and SVA (r = -0.573) and between SVA and GLL (r = -0.543).

No negative values were obtained for any of the groups during identification of true and functional PI angles in preoperative planning using the developed approach [9] (Table 3).

In three cases, functional PI on sagittal radiographs had a negative value ranging from -1.0 to -12.0°. However, MSCT in the same patients demonstrated that PI did not have negative values and equaled 13 to 41°. True PI (predicted) differs from postoperative value within the range of 3° (Fig. 6). This error is considered acceptable when measuring angles on radiographs.

As in the study by Matsuyama et al. [1], excessive lordosis of the lumbar spine was noted in patients with congenital hip dislocation. Results obtained by Matsuyama et al. are similar to the data we obtained in patients with bilateral pathology: decreased PI angle (12.9° ± 17.7°), increase in SS (51.5° ± 9.2°) and GLL values (71.3° ± 13.0°). Patients with unilateral pathology have the same manifestations but to a lesser extent: PI angle 38.4° ± 15.8°, SS angle 45.0° ± 8.3°, GLL 66.8° ± 7.8°. This proves the importance of each joint in maintaining balance. Once the hip rotation center is restored, patients who have previously had congenital hip dislocation for the first time have to adapt to the reconstructed normal biomechanics they have been unfamiliar with. Non-weight-bearing pelvis was formed in the superjacent regions, which balanced with the spine on the surrounding soft tissues. The lack of support appeared due to the lack of transfer of the load from the dense bone of the acetabulum to the femur bone tissue, which is close in density. This led to the indirect transfer of the load through the surrounding soft tissues. As a result, the pelvis lost its support and tilted anteriorly (pelvic anteversion), compensatory hyperlordosis in the lumbar spine and pronounced pain in the back were formed. At the same time, pain in the hip joint was absent or manifested in case of Crowe type IV dislocation at late stages.

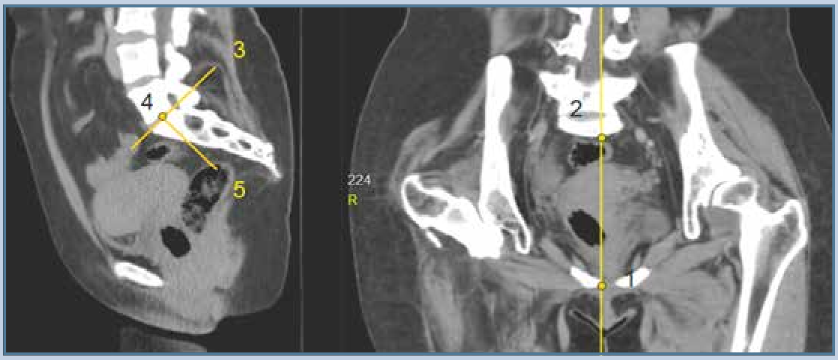

Fig. 2
Frontal and lateral projections of MSCT scans at the level of pubic symphysis

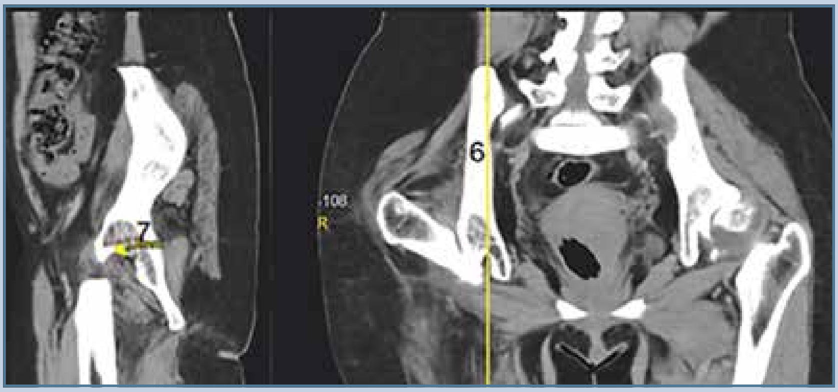

Fig. 3
Frontal and lateral projections of MSCT scans at the level of right acetabulum

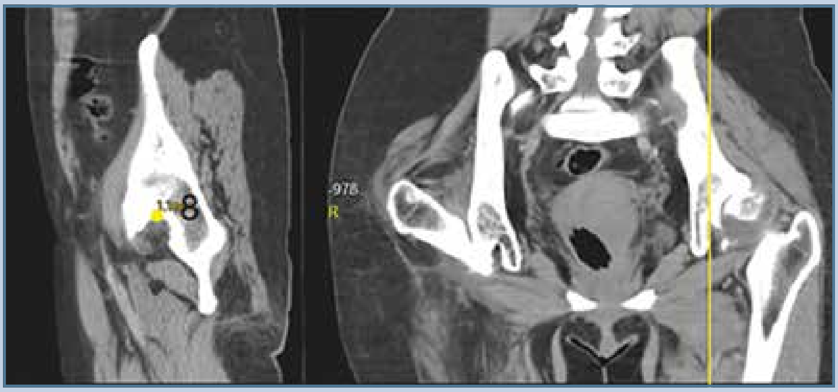

Fig. 4
Frontal and lateral projections of MSCT scans at the level of left acetabulum

Imbalanced sagittal spino-pelvic relationships, as evidenced by the increase in SVA and its even greater dislocation anteriorly to the hip axis (HA), can be noted in group II in the early postoperative period. Nevertheless, signs of decompensation of the pelvic balance decreased and approached the preoperative values by the 2nd stage of surgery, with the 2nd stage of surgical treatment causing the same effect as the 1st stage. The same manifestations were noted in Group I in the early postoperative period. However, they were much less pronounced. This can be associated with the presence of a full support on the opposite lower limb. Functional PI obtained on sagittal radiographs differs greatly from the functional PI obtained by MSCT, including the absence of negative values. We explain this fact by the lability of the structures of the spine and pelvis in the prone or upright position of the patient.

Conclusion

The proposed method for determination of anatomical PI in congenital hip dislocation allows intraoperative reconstruction of anatomical rotation center, which consequently results in normalization of spino-pelvic relationships and global balance.

The study had no sponsorship. The authors declare no conflicts of interest.

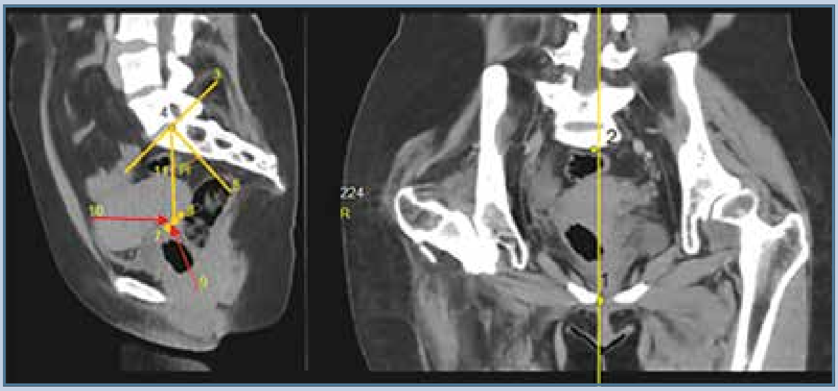

Fig. 5
Frontal and lateral projections of MSCT scans at the level of pubic symphysis

Table 1
Sagittal spino-pelvic balance values in Group I patients

Follow-up period	Sacrum incidence, deg.	Pelvic incidence, deg.	Pelvic tilt, deg.	Distance from the sagittal vertical axis to the interfemoral line, mm	Distance from the sacral promontory to the sagittal vertical axis, mm	Lumbar lordosis, deg.
Prior to surgery	45.0 ± 8.3	38.4 ± 15.8	-5.5 ± 21.8	6.3 ± 35.2	2.7 ± 17.2	66.8 ± 7.8
After surgery	46.5 ± 8.9	46.8 ± 8.3	5.2 ± 9.8	-8.8 ± 36.6	19.8 ± 28.3	65.2 ± 16.5
12 months after surgery	40.8 ± 11.1	45.8 ± 7.0	5.8 ± 3.1	22.4 ± 37.8	0.1 ± 31.8	56.6 ± 12.3

Table 2
Sagittal spino-pelvic balance values in Group II patients

Control points	Sacrum incidence, deg.	Pelvic incidence, deg.	Pelvic tilt, deg.	Distance from the sagittal vertical axis to the interfemoral line, mm	Distance from the sacral promontory to the sagittal vertical axis, mm	Lumbar lordosis, deg.
Before stage 1	51.5 ± 9.2	12.9 ± 17.7	41.5 ± 25.8	-14.2 ± 41.3	-16.5 ± 37.2	71.3 ± 13.0
After stage 1	57.4 ± 11.9	33.9 ± 14.2	-3.5 ± 32.8	-66.1 ± 77.7	52.6 ± 56.8	69.6 ± 12.4
Before stage 2	50.9 ± 8.7	16.7 ± 17.5	-38.1 ± 24.7	-20.2 ± 40.8	-7.5 ± 34.9	70.2 ± 12.4
After stage 2	56.6 ± 11.8	35.2 ± 14.2	-1.4 ± 31.2	-53.2 ± 53.0	42.9 ± 32.6	68.9 ± 12.7
After 12 months	42.2 ± 9.5	46.6 ± 7.7	5.9 ± 4.2	25.9 ± 31.7	-4.3 ± 25.1	58.5 ± 8.2

Table 3
True and functional pelvic incidence angles (n = 22), deg.

Pelvic incidence	Group I	Group II
Functional	42.1 ± 16.2	40.0 ± 17.8
True (predicted)	49.6 ± 11.4	48.8 ± 11.6
True (postoperative)	49.9 ± 10.0	46.4 ± 9.7

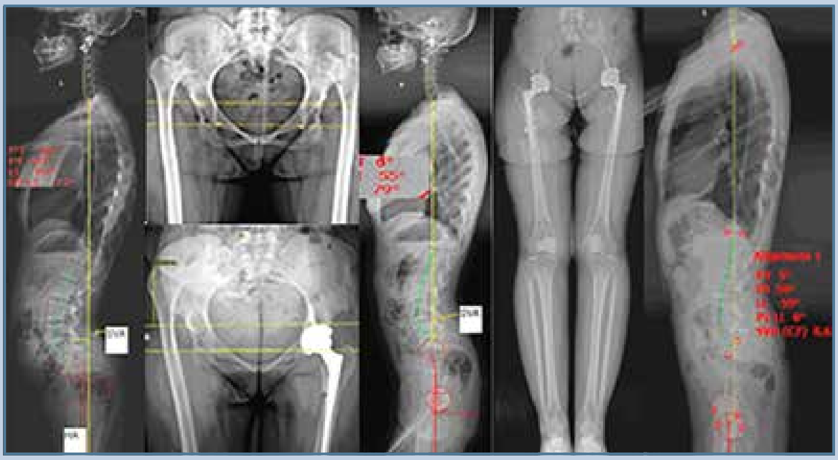

Fig. 6
Changes in the correction of the sagittal balance 12 months after bilateral sequential hip replacement

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