Chiari pelvic osteotomy in the treatment of adolescent hip disorders: possibilities, limitations and complications

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Received: 10 July 2010 / Revised: 17 August 2010 / Accepted: 6 September 2010 / Published online: 28 September 2010
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Abstract Ninety-nine hips treated by the Chiari pelvic osteotomy were included in this study designed as a retrospective review. The group consisted of 36 male and 50 female patients, with mean age of 15.6 years. Each was diagnosed with developmental dysplasia of the hip (DDH) or avascular necrosis of the femoral head—Legg-Calve-Perthes disease (LCP)—and postreduction avascular necrosis (PAN). Five hip parameters (the acetabular angle of Sharp, the center-edge (CE) angle of Wiberg, the percentage of femoral head uncoverage, the acetabular depth ratio, and the Shenton-Menard arch continuity) were evaluated. Functional outcome was assessed according to Harris hip score (HHS) and McKay criteria for clinical evaluation. The postoperative results showed improvement in all the radiographic parameters. The angle of Sharp showed a decrease of 8.62° ($p<0.01$). The CE angle of Wiberg showed an increase of 28.76° ($p<0.01$), and the uncoverage of the femoral head showed a decrease of 51.51%

($p<0.01$). The improvement of HHS was 11.93 ($p<0.05$). The patients' satisfaction was indicated by grade 4.1 ± 0.94 and the doctor's satisfaction by grade 3.7 ± 1.16 . The Chiari pelvic osteotomy, in spite of the development of biologically better procedures, has retained its position in the treatment of adolescent hip disorders.

Introduction

Chiari medial displacement osteotomy has been used for several decades in the treatment of various pathological conditions of adolescent and young adult hips [1–3]. But since the introduction of triple pelvic osteotomy, it has rarely been used. It returned into everyday usage once we were confronted with limited possibilities of the triple pelvic osteotomy [1–5].

The aim of this paper was to analyse our medical records and to evaluate the results of Chiari pelvic osteotomy in the treatment of adolescent hip disorders.

Materials and methods

From 1994 to 2006, 99 Chiari pelvic osteotomies in 86 patients were performed: 46 left hips, 27 right hips, 13 patients bilaterally. All patients had complete records, and all the charts were reviewed by a senior consultant. There were 36 male and 50 female patients. The mean age at surgery was 15.6 ± 10.57 years, ranging from ten years and four months to 19 years and two months.

The preoperative diagnoses were developmental dysplasia of the hip (DDH) in 41 hips, and avascular necrosis of the femoral head - Legg-Calve-Perthes disease and post-reduction avascular necrosis in 58 hips. Based on Mose

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Fig. 1 **a** Postreduction avascular necrosis of the left hip in a 14-year-old female, previously surgically treated; preoperative anteroposterior (AP) view. **b** The same patient four years postoperatively (Chiari pelvic osteotomy done); AP view

classification criteria, the femoral head was deformed (coxa magna, i.e. normally shaped but more than 4 mm wider than contralateral normal hip; or coxa plana, i.e. contour of the head lies within more than two concentric Mose circles) in 58 cases [6]. Relative overgrowth of the greater trochanter was present in 32 cases.

Previously, 50 (50.5%) hips had been treated nonoperatively, and the remaining 49 hips (49.5%) had been treated surgically. Surgery involved open reduction with Salter and corrective femoral osteotomies in 22 hips, Salter with corrective femoral osteotomy in five hips, isolated Salter osteotomy in 18 hips and isolated corrective femoral osteotomy in four hips.

The inclusion criteria in the study were age 10–20 years, the uncontained hip due to developmental dysplasia of the hip or avascular necrosis of the femoral head. Exclusion criteria included a history of hip infection.

The typical patient was a young female (10–20 years old) with at least one uncontained hip.

The original operative technique was used in all cases [5]. The isolated Chiari osteotomy was performed in 57 (57.6%) hips (Fig. 1), with acetabular augmentation in 23 (23.23%) hips, with corrective femoral osteotomy in eight (8.07%) hips, and/or with the great trochanter translocation in 11 (11.1%) hips (Fig. 2). The dislocation was fixated with Kirschner wires in seven hips, while in 92 hips we used screws to allow firmer fixation. Intraoperative imaging was not necessary in any case.

Postoperatively, none of the operated patients was immobilized; a post-op skin traction was used in all cases for a period of 46.3 ± 17.75 days. Rehabilitation started 9.9 ± 15.82 days after surgery. Crutch walking without weight bearing on the operated leg was initiated 45.3 ± 10.93 days postoperatively. Crutch walking with touch-down weight bearing on the operated leg was initiated 76.3 ± 11.93 days postoperatively. Full weight bearing was allowed 103.2 ± 7.9 days postoperatively—always after we verified osteotomy healing.

The mean follow-up period was 7.2 ± 6.33 years (ranging from 4–12.5 years).

Pelvic anteroposterior X-rays were taken preoperatively and at the last follow-up, always in a standing position. Five hip parameters (the acetabular angle of Sharp, the CE angle of Wiberg, the percentage of femoral head uncoverage, the acetabular depth ratio, and the Shenton-Menard arch continuity) and three osteotomy parameters (the angle of the osteotomy, i.e. angle between the line parallel to the interteardrop line and the osteotomy line; the distance of the osteotomy from the acetabular edge; and the percentage of medial displacement of inferior pelvic fragment at the level of osteotomy) were evaluated, all performed or supervised by a senior consultant. Severin radiographic classification was also used for assessment of the results [2, 3, 6–9].

Functional outcome was evaluated according to HHS and McKay criteria [2, 10–12]. Any limb shortening as well as gait characteristics (normal gait, limping, waddling and very poor gait) were particularly defined.

An indication for conversion to hip arthroplasty or arthrodesis was considered as the survival end point of these hips after surgery.

The satisfaction of the patients and doctors was indicated by grades 1–5 (Tables 1 and 2).

Statistical analysis was performed using *t*-test, χ^2 test, Z test, McNemar test, Wilcoxon test, Post hoc Tuckey test, and Spearman rank correlation test.

Results

The angle of the osteotomy averaged $13 \pm 8.27^\circ$, with an average distance of the osteotomy from the acetabular edge of 7.8 ± 4.57 mm. In the final follow-up radiograms, the osteotomy step from the acetabular edge was completely remodelled in 73 hips (73.73%) with a primary distance of ≤ 5 mm; partial remodelling was observed in 22 and no remodelling in four

Fig. 2 **a** Postreduction avascular necrosis of both hips in a 12-year-old female; preoperative anteroposterior (AP) view. **b** The same patient five years postoperatively (Chiari pelvic osteotomy and great trochanter translocation done bilaterally); AP view

patients, with a primary distance of ≥ 7 mm. The average displacement of osteotomy was $43.4 \pm 13.96\%$. There was no significant correlation between the remodelling of the roof step, the displacement of the osteotomy and the final results.

Table 1 Patient's satisfaction scale

Grade	Criteria
1	Ambulation only with crutches, significant pain regardless of activity
2	Ambulation and daily activities significantly impaired, moderate pain during and after activities, infection or neurological impairment
3	Moderate pain during activities, reduced range of motion, reduced walking distance, infection
4	Occasional or slight pain, range of motion slightly reduced
5	Normal functional result, no complications, no pain

Due to a high osteotomy angle in one patient, we found one unwanted osteotomy ending in the sacroiliac joint.

The initial angle of Sharp was $47.2 \pm 6.12^\circ$, and the final was $38.6 \pm 7.78^\circ$. A statistically highly significant decrease of the angle was achieved ($t=1.88006E-29$, $p<0.01$), and with no significant difference to the values in healthy adult hip (Z test, $p>0.05$). This angle did not show a statistically significant influence on the choice of surgical technique.

The initial angle of Wiberg was $10.2 \pm 16.77^\circ$, which increased finally to $38.9 \pm 14.60^\circ$; there were high statistically significant differences both to preoperative values ($t=1.2704E-29$, $p<0.01$) and normal values (Z test, $p<0.01$). This angle had a statistically significant influence on the choice of surgical technique, e.g. in a smaller CE angle of Wiberg the Chiari pelvic osteotomy together with corrective femoral osteotomy was more frequently used than the isolated Chiari pelvic osteotomy ($t=3.208$, $p<0.05$) or the Chiari pelvic osteotomy together with acetabular augmentation ($t=2.706$, $p<0.05$).

The initial uncoverage of the femoral head was $53.4 \pm 20.99\%$, and the final was $1.9 \pm 70.67\%$; which is within a normal range (less than 25%) and presents a high statistical decrease of the femoral head uncoverage achieved ($t=5.51519E-38$, $p<0.01$). This parameter had a high statistical significance on the choice of surgical procedure; in a larger femoral head uncoverage the Chiari pelvic osteotomy together with corrective femoral osteotomy was more often performed than the isolated Chiari pelvic osteotomy ($t=3.545$, $p<0.01$), the Chiari pelvic osteotomy together with acetabular augmentation ($t=4.341$, $p<0.01$) or the Chiari pelvic osteotomy together with translocation of the great trochanter ($t=2.992$, $p<0.05$).

The initial acetabular depth ratio was 20 ± 7.52 , finally it was 23.8 ± 7.38 ; a high statistically significant increase of the acetabular depth ratio was achieved ($t=2.17972E-07$, $p<0.01$), without statistical difference in normal values (Z test, $p>0.05$).

Table 2 Doctor's satisfaction scale

Grade	Criteria
1	Hip coverage less than 70%, inability to walk without crutches
2	Hip coverage from 80–70%, chronic infection or permanent neurological impairment, limited walking distance
3	Negative Wiberg CE angle, hip coverage from 90–80%, nonunion of osteotomy, limp or waddling gait
4	Wiberg CE angle $<25^\circ$ but positive, or hip coverage from 90–95%, delayed osteotomy union, infection or neurological impairment completely healed, implant failure, slight limp or waddling gait
5	Wiberg CE angle $>25^\circ$ and hip coverage $>95\%$, with healed osteotomy, without infection or implant failure, and with normal functional range of motion and normal gait

Regarding the Shenton-Menard arch, initially it was interrupted in 70 hips (70.71%) and this remained unchanged during the entire follow-up period.

There were 62 (62.63%) excellent, 18 (18.18%) good, nine (9.09%) fair and ten (10.10%) poor results according to the Severin classification.

Before the surgery 31 patients (31.31%) complained of pain, as compared to 18 patients (18.18%) at the final follow-up; the difference was not statistically significant ($p>0.05$).

Initially HHS was 76 ± 15.15 , and at the final follow-up it was 87.9 ± 9.42 , showing high statistical significance in regard to the improvement of functional condition ($W+=803$, $W-=3,853$, $N=96$, $p<0.01$).

McKay clinical classification was assessed preoperatively with four excellent, 24 good, 32 fair and 39 poor cases, while at the final follow-up there were 26 excellent, 24

good, 29 fair and 20 poor results; according to such evaluation a high statistically significant improvement of the functional condition was achieved ($W+=1,711$, $W-=434$, $N=65$, $p\leq 3.057e-05$).

Limb shortening of the affected side equalled 0.9 ± 1.94 cm before the treatment and 1 ± 2.04 cm at the end. The difference in the amount of shortening of the affected limb was not statistically significant ($p=0.412093252$).

Finally, 42 patients (42.42%) walked normally, 21 (21.21%) had limping, 34 (34.34%) had a waddling gait, and two (2.03%) patients had a very poor gait.

Regarding complications, three patients had signs of infection, there was one unwanted osteotomy ending in the sacroiliac joint, nonunion of osteotomy was present in three patients, nonunion of osteotomy with implant failure occurred in seven patients, while early arthrosis developed in 14 patients (in total 28 patients, 28.28%) (Fig. 3). None of patients have been reoperated.

The survival of these hips at four years was 100%.

The preoperative diagnosis did not influence the outcome. However, the femoral head deformity did, e.g. nonspherical femoral head (coxa plana) formed nonspherical congruency of the hip in all 22 (22.22%) cases.

Average satisfaction of patients was graded as 4.2 ± 0.94 . The patients' satisfaction showed a high statistically significant correlation with the percentage of femoral head uncavage ($R=0.2839$, $N=98$, $p<0.01$), HHS ($R=0.8332$, $N=98$, $p<0.01$), McKay clinical classification results ($R=-0.5194$, $N=98$, $p<0.01$), shortening of the operated leg ($R=0.3569$, $N=98$, $p<0.01$) and the presence of complications ($\chi^2=141$, $p<0.01$). The correlation of the CE angle of Wiberg and treatment results according to Severin did not show statistical significance ($p>0.05$).

The satisfaction of doctors was expressed by grades 3.7 ± 1.16 . The doctor's satisfaction showed a high statistically significant correlation with the CE angle of Wiberg ($R=0.4144$, $N=97$, $p<0.01$), the percentage of femoral head uncavage ($R=0.6161$, $N=98$, $p<0.01$), HHS ($R=0.7534$, $N=98$, $p<0.01$), McKay clinical classification of results ($R=-0.4326$, $N=98$, $p<0.01$), and the presence of complications ($\chi^2=48.3$, $p<0.01$). The correlation with treatment results according to Severin did not show statistical significance ($p>0.05$).

Discussion

Although from the very beginning the Chiari pelvic osteotomy has been practically applied both in adolescent and early adult periods, the literature has more often reported results in adults. Nevertheless, there are investigations also studying the adolescent population [1, 2, 13–15]. Regarding the number of patients, operated hips,

Fig. 3 **a** Postreduction avascular necrosis of both hips in a 16-year-old male; preoperative anteroposterior (AP) view. **b** The same patient five years postoperatively (Chiari pelvic osteotomy done bilaterally), bilateral osteotomy nonhealing with break of osteofixation material. *Left*, healing occurring later. The patient was without any complaints and with full hip motion; AP view

gender and age, all these studies are comparable to ours which analysed 99 hips with predomination of the left hip (59.59%) and female gender (63.64%), while mean age was 15.6 years. Other authors have mostly analysed slightly older age groups, also reporting a slightly higher frequency of the affected left hip and female gender [16–18].

As regarding the diagnosis, some authors have only analysed DDH [1, 17, 18], while others have turned their attention to various pathological conditions [2].

Other authors, like us, also applied this method of treatment to solve previously undertreated conditions, both non-operatively and surgically [1, 2, 13–18].

Like other authors, we also use the original operative technique [1, 2, 13–18]. In the presence of ventral/ventrolateral insufficient coverage of the femoral head, bone augmentation of the acetabulum is usually added to the procedure, in a similar manner as we did. We performed acetabular augmentation as the additional procedure in 23.23% and corrective femoral osteotomy in 8.07% of operated hips. There were no reports in the literature on the translocation of the great trochanter which we performed in 11.1% of patients to create better conditions for the medialization in the Chiari pelvic osteotomy, improvement of abduction and tightening of pelvic trochanter muscles. Also, insufficient attention has been paid to the type of fixation.

Although the original technique involves the osteotomy without fixation and with postoperative immobilization, recently this has been generally discarded [1, 2, 13–18]. Postoperatively, like others, we also used skin traction. Crutch walking with touch-down weight bearing was started 76.3 days postoperatively, with full weight bearing on the operated leg 103.2 days postoperatively. The condition for allowing touch-down weight bearing was initial bone healing. The condition for full weight bearing on the leg was good bone healing after the osteotomy.

The follow-up period was 7.2 years in our series. In some series it was shorter [8], while in others longer [1, 13–16].

There are very few reports on the details of surgical procedure, while its relation to treatment results has been mostly omitted. In our series the mean angle of osteotomy was 13.02°, while it was 12° in a study by Karami et al. [2]; thus, we achieved a larger angle, which is considered a favourable result in the achievement of better coverage and containment of the operated hip. The average distance of the osteotomy from the acetabular edge in our series was 7.85 mm, which is much larger than 3.2 mm as reported by Karami et al. [2]. A possible reason for such a highly positioned osteotomy may be due to the fact that the Chiari pelvic osteotomy was often performed as a reintervention after Salter osteotomy in the extended dysplastic acetabulum with a highly attached capsule when, in cases of low positioned osteotomy, there was danger to enter the joint risking a poor result and severe complications. In our series

the average displacement was 43.41%, similarly to Karami et al. (42%) [2], i.e. slightly lower than 50% as reported by Betz et al. [19]. A relatively marked dislocation was the reason that in 23.23% of our patients we added a bone graft, not only for acetabular augmentation, but also for safer osteotomy healing. This has been also applied by other authors [2, 19]. Roof step remodelling mostly depended on the age and all three listed elements, and it gave better results in younger patients, a higher osteotomy angle, a smaller distance between the osteotomy and acetabular edge and greater displacement, although the dependence was not of statistical significance.

As far as anatomic parameters are concerned, good treatment results were achieved as confirmed by all measurement methods. We verified a statistically significant decrease of the angle of Sharp, increase of the CE angle of Wiberg, decreased percentage of uncovered femoral head and increased depth of the acetabulum. Other authors have also reported similar treatment results [1, 2, 16, 18]. Only the Shenton-Menard arch was disrupted in the same number of patients as preoperatively, primarily because in all cases the Chiari pelvic osteotomy was performed “in situ” (covering without additional corrective femoral osteotomy and hip reduction); the same result has been also reported by other authors [18]. According to the Severin classification of results, there were only 10.1% poor results, which is relatively low if keeping in mind that this method of treatment was mostly applied in cases that were preoperatively the poorest (previously operated, decentralized, with a deformed femoral head).

In our patients surgery proved to be useful to achieve a pain-free condition. Pain complaints were present in 31.31% of patients at the beginning, and at the final follow-up they were present in 18.18% of patients. The so-called analgesic effect of surgery was also reported by other authors [1, 2, 14, 16–18, 20].

As regarding functional parameters, a high statistically significant improvement was also achieved in regard to improved HHS and the change in hip category according to McKay. Other authors have reached similar results as well [1, 2, 9, 14, 16, 20]. The difference in the shortened leg on the side of the affected hip remained unchanged, because in all cases the Chiari osteotomy was performed “in situ”.

Nevertheless, gait improved in a great number of patients, so that at the final follow-up 42.42% of them had a normal gait. Limping due to the shorter leg was possible to correct by heightened footwear. At the final follow-up a relatively large number of patients (34.34%) had a waddling gait due to weak pelvitrochanteric musculature and a positive Trendelenburg sign, which is the basic disadvantage of this operation. This problem is, however, less marked in younger age groups, especially after serious physiotherapy [1, 2, 13–23].

In our patients there was a relatively great number of complications (28.28%). However, half of them developed early arthrosis (14.14%), which is not a high rate, keeping in mind that a great number of our patients came for treatment due to pains in adolescence, which can be considered, even without obvious radiographic findings, a sign of initial arthrosis. The survival of these hips at four years was 100%. The literature mostly reports on the development of early arthrosis and the duration of operated hip survival; in older patients and more advanced degenerative process at operation, the hip survival is shorter [1, 13, 17, 18].

Regarding the patients' and doctors' satisfaction, it did not fully correlate. The patients' satisfaction was higher being graded 4.16, and it mostly depended on pain-free and final functional condition. The doctors' satisfaction was expressed with grade 3.72, and it mostly depended on the final anatomic condition and the absence of complications, and only slightly less on the final functional condition.

Based on our findings, it can be concluded that the Chiari pelvic osteotomy, despite the development of biologically better procedures, has retained its position in the treatment of adolescent hip disorders.

Remodelling possibilities are better in the younger population than in adults; waddling gait is less frequently seen in the young than in adults, and the frequency of important complications is low.

The disadvantage of doing the osteotomy "in situ" is that this excludes the possibility of limb discrepancy correction. There is another possible disadvantage, namely, the narrowing of the pelvic ring, implicating childbirth by Cesarean section [24, 25].

In hips with advanced osteoarthritis the Chiari procedure creates an acetabulum which facilitates later total hip replacement procedure, and may delay the need for this procedure in younger patients [26, 27].

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