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A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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Pelvic osteotomy in the neurogenic unstable hip

Key words: *cerebral palsy, meningomyelocoele, hip dysplasia*

SUMMARY

Background. *The purpose of our study was to evaluate treatment outcome in pelvic osteotomy for neurogenic hip instability, mainly in combination with soft tissue procedures, open reduction in dislocated hips, and proximal femoral osteotomy.*

Material and methods. *19 patients with neurogenic hip instability were treated from 1996 to 2005, with 29 pelvic osteotomies: 23 for cerebral palsy (15 patients), 5 for meningomyelocoele (3 patients), and 1 for sciatic nerve palsy. There were 19 subluxated and 10 dislocated hips.*

Results. *In the CP patients, 13 patients reported improvement, one patient reported no change, and one patient reported deterioration. In objective assessment, improvement in gross motor function was found in 13 patients, in one patient unchanged, and in one patient walking ability deteriorated. In radiological evaluation, normal or dysplastic hips were achieved in 15 hips (66%). Eight hips (34%) progressively subluxated in follow-up with no redislocation. The subluxations led to repeated surgery in 2 patients. Avascular necrosis of the femoral head occurred in 2 hips (8%). All the MMC and paralytic patients improved in their movement activities. In radiological criteria, all hips were initially improved, but in the follow-up, 3 hips remained dysplastic and 3 hips resubluxated, leading to repeated surgery in one patient.*

Conclusions. *Different types of pelvic osteotomies should be chosen in neuromuscular hip instability according to the hip deformities in order to achieve a stable and congruent hip. The combination with soft tissue release and femoral varus derotation osteotomy offer satisfactory outcomes mainly in the early stage of instability.*

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BACKGROUND

The incidence of hip dysplasia in patients with cerebral palsy (CP) varies with the severity of neurological involvement and the ability of the patients to walk [1]. The patients with more severe neurological impairment (spastic diplegia and quadriplegia and nonambulatory patients) are at greater risk for hip instability than patients with spastic hemiplegia and those who can walk. Hip subluxation and dislocation develops gradually in response to muscle imbalance due to contracture of the adductors and flexors of the hip, which overpower the hip extensors and abductors. Bony deformities occur later in response to the spasticity. Hip instabilities in neurogenic conditions represent a common problem, and up to 75% of patients with a severe form of CP suffer from hip dislocations [2]. These conditions lead hip pain, restriction of motion, and difficulties with perineal hygiene and problems in sitting. The goal of treatment is to provide a painless hip that allows for stable sitting and positioning in nonambulatory patients, and to reduce the hip so that ambulatory patients can walk stably without pain. For these reasons, early surgical treatment of these conditions is indicated, according to the recent literature reports [1,2]. According to our experience and the opinions of many other authors [3,4,5,6], instabilities of the hip in neurogenic conditions, when the acetabular index exceed 25 degrees and the migration index is more than 33%, should be treated by pelvic osteotomy.

Pelvic osteotomy is seldom performed as a single procedure, but is very often combined with soft tissue procedures and proximal femoral osteotomy. Pelvic osteotomies can be generally divided into the following categories:

1. Osteotomies that redirect the acetabulum;
2. Osteotomies that reshape the acetabulum;
3. Salvage osteotomies, which increase the area of the acetabulum with non-articular cartilage.

Various different factors must be considered to choose the type of pelvic osteotomy for the unstable hip, including:

– the patient's age, in view of basic technical principals and remodelling activity;
– the location of acetabular insufficiency
– the degree of instability;
– the direction of dislocation;
– proximal femoral morphology;
– hip congruency;
– muscular function (balanced, imbalanced, spasticity, paralysis);
– the position of the pelvis (pelvic obliquity).

The location of acetabular insufficiency in neurogenic conditions is mostly superior and posterior; it may be global (complex), but seldom anterior. We use the common radiological criteria of hip instability, namely CCD angle, Shenton's line, Wiberg's CE angle, Reimer's migration index (MI) and acetabulum index (AI), and a modified classification according to Sharrard and Shea [7,8]. In CP patients, in prolonged spasticity, the acetabulum becomes dysplastic, with erosion of the lateral lip by the progressively subluxated femoral head (Fig. 1). The acetabular index increases, and finally the capacity of the acetabulum is reduced. In the beginning, the changes are reversible, but the bony deformities develop with persistent spasticity, and include also some changes

Fig. 1. Dislocated hip in CP – diplegic girl 7 years old (W. S.). Dysplastic acetabulum with erosion of lateral lip is present

of the proximal femur. The anteversion of the proximal femur persists to adulthood, the neck-shaft angle increases, and coxa valga develops. The trochanter minor becomes elongated due to pulling from the iliopsoas muscle. Finally, the femoral head is deformed superomedially and superolaterally due to the pressure of the capsule and caput reflexum of the rectus femoris muscle, the rim of the acetabulum, the abductors, and the ligamentum teres (Fig. 2). These deformities also lead to pain.

Hip instability in MMC and paralytic conditions represents a common problem, and treatment strategy remains very controversial [1,9,10,11,12]. The dislocation may be developmental, teratologic, or spastic, but the most common type is paralytic. In our opinion, surgery is indicated in patients with unilateral or bilateral hip subluxation or dislocations in lower lumbar lesions (below L4) and sacral lesions, where quadriceps muscle function is present. Surgical treatment should correct capsular laxity, soft tissue contractures, misalignment of the proximal femur, and acetabular dysplasia. There is overall global deficiency of the acetabulum in most patients with MMC, which is more severe posteriorly. Acetabular augmentation can be obtained with different osteotomies, but possible posterior insufficiency of the acetabulum must be considered.

The aim of our study was to evaluate the different types of pelvic osteotomies in these neurogenic hip instabilities.

MATERIAL AND METHODS

Pelvic osteotomy was mostly combined with femoral varus-derotation osteotomy and/or open reduction, in order to correct all present deformities in one stage. We evaluated 19 patients with neurogenic hip instability treated in our institution from 1996 to 2005 (Table 1). The patients underwent 29 pelvic osteotomies, mostly for cerebral palsy (15 patients, 23 pelvic osteotomies), as well as for MMC (3 patients, 5 pelvic osteotomies) and sciatic nerve palsy (1 girl, 1 pelvic osteotomy). Soft tissue release (adductor tenomyotomy, lengthening of the hip flexors) represents the basic surgical procedure in muscle contractures, and it is provided before, or in combination with, pelvic and femoral osteotomies, respectively.

Unstable hip in cerebral palsy

Pelvic osteotomies were used in 15 patients (23 pelvis osteotomies), ranging in age from 5 to 17 years (10 girls, 5 boys). Most of these patients were quadriplegic (13 patients), 2 patients were diplegic, and only one patient was hemiplegic. Most of the patients were nonambulatory, i. e. wheelchair dependent (10 patients), 3 patients were ambulatory dependent on a standing frame or walking with a walker or crutches, and only 2 patients were ambulatory non-dependent in walking. There were 16 subluxated hips and 8 dislocated hips. In these conditions, the following ostetomies were used for treatment.

Osteotomies that redirect the acetabulum

In reducible and congruent hips, when 5 well-known Salter's prerequisites are fulfilled, the redirection pelvic osteotomy of innominate bone according to Salter is performed for patient in the age up to 11 years old with mild dysplasia of the acetabulum (AI<35°). These osteotomies were used in 10 hips, mostly subluxated (9 hips).

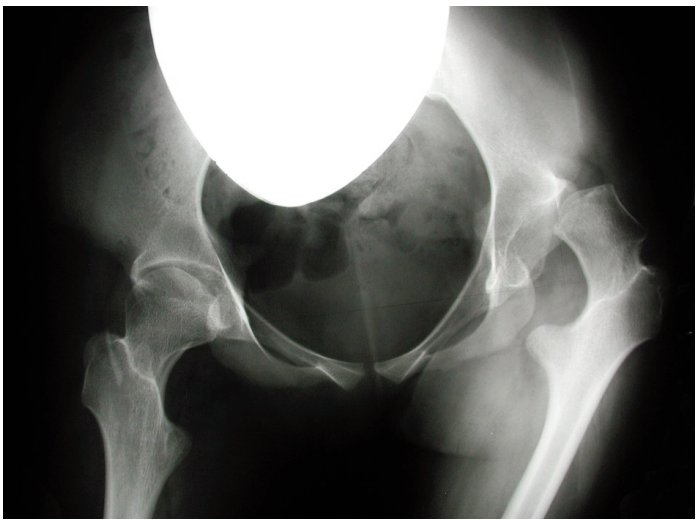

Fig. 2. Dislocated hip in CP – a diplegic girl 16 years old (D. K.). Dysplastic acetabulum and deformed femoral head in superomedial and superolateral aspect and elongated trochanter minor are obvious

Tab. 1. List of patients and diagnosis, surgical procedures and results of treatment

Pat.	Sex	Birth	Diagnosis	Side	DATE	Surgical procedure	Hip	RTG			Gross motor function	RTG-After surg.			Gross motor function
		year			SURG.			AC	CE	MI %	Before surgery	AC	CE	MI %	After surgery
D.G.	F	1985	Quadriplegie	L	2001	Steel + 0R	subluxation	48	-40	94	NONAMB,wheelchair	22	40	0	AMB-DEP-walker
W.S.	F	1992	Quadriplegie	R	1997	Salter+VDO+OR	dislocation	32	-40	100	NONAMB,wheelchair	15	25	4	AMB-DEP-canes
W.S.	F	1992	Quadriplegie	L	1999	Salter+VDO	subluxation	31	0	46	AMB-DEP-stand. frame	16	25	14	AMB-DEP-canes
H.K.	F	1991	Diplegie	R	2000	Salter+VDO	subluxation	28	0	49	AMB-NONDEP,limping	42	15	37	AMB-NONDEP
H.K	F	1991	Diplegie	L	2001	Salter+VDO	subluxation	28	0	50	AMB-NONDEP	38	10	37	AMB-NONDEP
K.M.	M	1993	Quadriplegie	RL	1998	VDO bilat.	subluxation	24	-30	100	NONAMB,wheelchair	24	20	34	AMB-DEP-walker
K.M.	M	1993	Quadriplegie	R	2000	Salter+VDO	subluxation	32	-20	70	NONAMB,wheelchair	28	0	50	AMB-DEP-walker
K.M	M	1993	Quadriplegie	L	2002	Salter+VDO	subluxation	26	-30	90	NONAMB,wheelchair	46	20	25	AMB-DEP-walker
K.M.	M	1993	Quadriplegie	R	2004	Chiari+VDO+OR	subluxation	50	-20	75	NONAMB,wheelchair	38	35	0	AMB-DEP-walker
K.L.	M	1984	Quadriplegie	R	1998	Salter+VDO	subluxation	28	0	48	NONAMB,wheelchair	48	20	17	AMB-DEP-walker
K.L.	M	1984	Quadriplegie	L	1997	Pemberton+VDO+OR	subluxation	62	-20	71	NONAMB,wheelchair	50	0	44	AMB-DEP-walker
M.M.	M	1989	Quadriplegie	L	2002	Chiari+VDO+OR	dislocation	54	-45	100	NONAMB,wheelchair	44	10	36	AMB-DEP-walker
S.J.	F	1982	Diplegie	R	1998	Steel	subluxation	50	0	42	AMB-NONDEP,limping	40	20	26	AMB-NONDEP-1 crutch
S.J.	F	1982	Diplegie	L	1997	Steel	subluxation	50	0	42	AMB-NONDEP,limping	38	22	25	AMB-NONDEP-1 crutch
K.M	M	1988	Quadriplegie	L	2004	Chiari+VDO+OR	dislocation	52	-46	100	NONAMB,wheelchair	40	25	23	AMB-DEP-walker
H.A	F	1988	Quadriplegie	L	2005	Chiari+VDO	subluxation	54	-30	85	NONAMB,wheelchair	44	0	53	NONAMB,wheelchair
D.K.	F	1984	Quadriplegie	R	1995	Chiari+VDO+OR	dislocation	53	-20	100	NONAMB,wheelchair	40	15	25	AMB-DEP-walker
P.A.	F	1991	Quadriplegie	R	2004	Chiari +VDO+OR	dislocation	60	-30	100	NONAMB,wheelchair	40	10	34	NONAMB,wheelchair
V.A.	M	1995	Quadriplegie	R	2004	Salter+VDO	subluxation	36	0	52	AMB-DEP-stand. frame	18	15	22	AMB-DEP-walker
A.A.	F	1995	Quadriplegie	L	2005	Pemberton+VDO	dislocation	36	-30	100	NONAMB,wheelchair	15	20	23	NONAMB,wheelchair
A.A.	F	1995	Quadriplegie	R	2005	Pemberton+VDO	dislocation	38	-20	100	NONAMB,wheelchair	14	22	23	NONAMB,wheelchair
K.S.	F	1985	Hemiplegie	R	1996	Pemberton+VDO+OR	dislocation	58	-30	100	NONAMB,wheelchair	40	0	50	AMB-NONDEP-1 crutch
S.N	F	1998	Diplegie	R	2004	Salter+VDO	subluxation	33	0	36	AMB-DEP-crutches	16	13	24	AMB-NONDEP
S.N.	F	1998	Diplegie	L	2004	Salter+VDO	subluxation	30	0	36	AMB-DEP-crutches	17	15	25	AMB-NONDEP
R.J.	M	1986	MMC	R	1998	Pemberton+VDO	subluxation	52	-20	67,4	AMB-DEP-walker	50	0	47,2	AMB-DEP-canes
R.J.	M	1986	MMC	R	1999	Chiari+VDO	subluxation	54	-20	84	AMB-DEP-walker	38	26	22	AMB-DEP-canes
R.J.	M	1986	MMC	L	1998	Chiari+VDO	subluxation	46	10	39	AMB-DEP-walker	42	10	44	AMB-DEP-canes
S.L.	M	1994	MMC	R	2001	Salter	subluxation	34	12	40	AMB-DEP-walker	24	20	28,9	AMB-DEP-walker
A.K	M	2000	MMC	R	2002	Salter+OR	dislocation	34	-30	100	NONAMB,wheelchair	20	20	27	AMB-DEP-walker
S.J.	F	1986	Ischial palsy	L	1998	Pemberton+VDO+OR	dislocation	42	-24	100	AMB-DEP-crutches	62	-12	64	AMB-NONDEP-1 crutch

Abreviations: OR:open reduction, VDO: Varus-derotation osteotomy, NONAMB: nonambulatory, AMB-DEP: ambulatory-dependent, AMB-NONDEP: ambulatory nondepenc

Salter osteotomy was used also in one dislocated hip, when other Salter's criteria were fulfilled. Hip dislocation is obvious on the right side (Fig. 1) by this 6-year-old non ambulatory girl with diplegic form of CP. After soft tissue release, open reduction of the hip and Salter's osteotomy and VDO of femur on the right side, the right hip remains stable (Fig. 3).

Double, triple or periacetabular osteotomies are indicated in the juvenile age (older than 11 years) and adolescents, when Salter's criteria are fulfilled. The

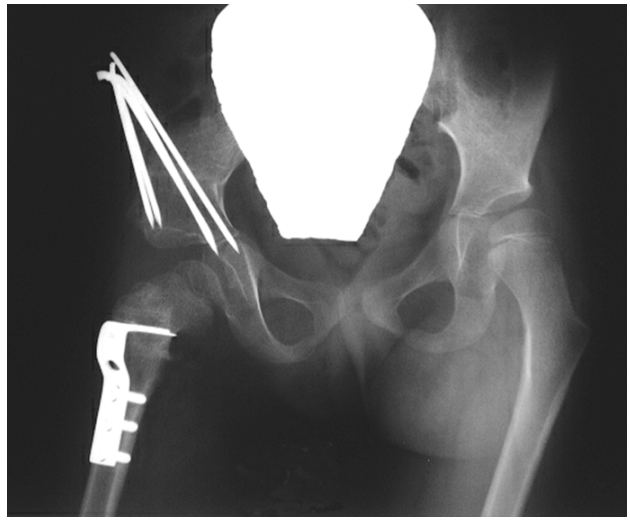

Fig. 3. Stable right hip after soft tissue release, open reduction, Salter osteotomy and VDO was achieved after dislocated right hip in the 6-year-old nonambulatory girl (W. S.) with diplegic CP (see fig. 1)

choice of osteotomy varies according to the experience of the departments. We used the modified Steel's triple pelvic osteotomy (13) in 2 patients (3 hips) and we regularly remove 1.5 cm of the bone segment from the ischial and pubic bone in order to avoid the lateralisation of the hip.

As an example we present a 16-year-old quadriplegic nonambulatory wheelchair dependent girl. The dislocation of the hip on the left side and pelvic obliquity are obvious (Fig. 2). The combined procedures, namely soft tissue release, open reduction, triple pelvic osteotomy and VDO were performed (Fig. 4). 2 years after surgery the hip remains stable (Fig. 5) and allows the gait with crutches, even the deformity of femoral head is present.

Osteotomies that reshape acetabulum are Pemberton and Dega osteotomies. They were indicated by more dysplastic acetabulum (AI>35°, shallow and steep acetabulum) but when congruency is still present and concentric reduction is possible, in the age before the closing of triradiate cartilage, optimally up to 10-11 years. We prefer the Pemberton osteotomy. This osteotomy was used in 4 hips, namely three were subluxated and one was dislocated.

Salvage osteotomies are represented by Chiari osteotomy and shelf operations.. These procedures were indicated only if the femoral head cannot be concentrically reduced into acetabulum or if there is a complex acetabular deficiency. We prefer Chiari osteotomy. These osteotomies were performed in 6 patients (6 hips), mostly dislocated (5 hips). As an

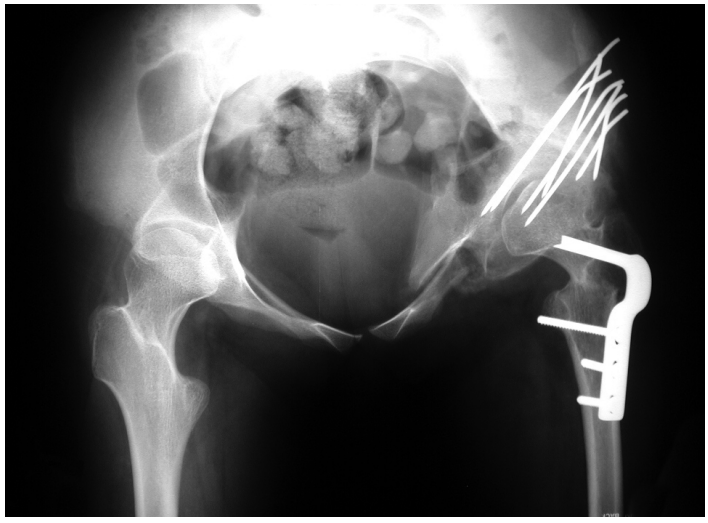

Fig. 4. Reduced left hip 6 months after open reduction, Steel osteotomy and VDO femoris for dislocated hip in diplegic girl 16 years old (D. K.) (see Fig 2)

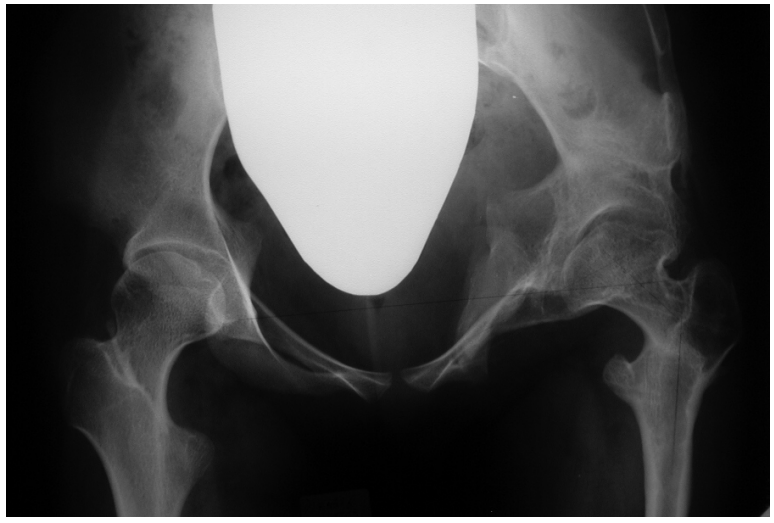

Fig. 5. Stable left hip 2 years after surgery in same girl (D. K.) allows gait with crutches, but deformity of the femoral head is obvious

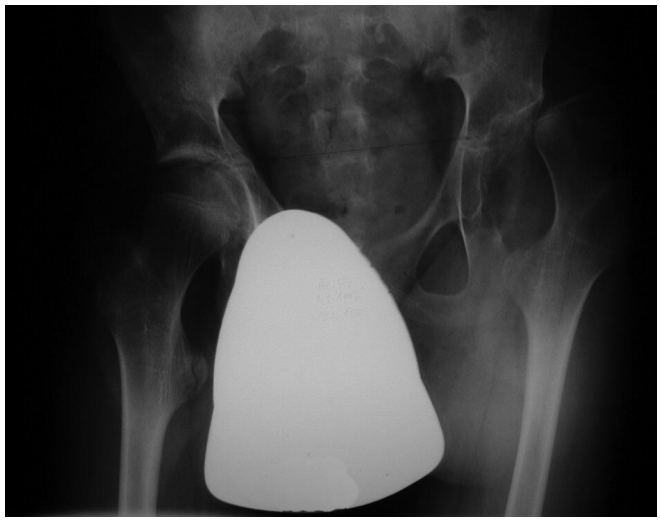

Fig. 6. Dislocation of the left hip in a 13 year-old nonambulatory boy (M. M.) with CP-quadriplegia

Fig 7. Satisfied coverage and stability of the left hip after open reduction, Chiari osteotomy and VDO of femoris are obvious 1,5 years after surgery in the same boy (M. M.)

example we present a non-ambulatory boy aged 13 years with severe quadriplegia (Fig 6), where osteotomy was combined with soft tissue release, open reduction and femoral varus-derotation osteotomy. 1,5 years after surgery the hip remains stable (Fig. 7) and the boy improved and became ambulatory dependent with the walker.

Myelomeningocoele and other paralytic conditions

There were 3 patients with MMC between 2 and 13 years of age, all boys, in whom 5 pelvic osteotomies were performed, and one girl aged 12 years with unilateral ischial birth palsy. In this group, we performed 1 Salter osteotomy, 2 Pemberton osteotomies, and 2 Chiari osteotomies in combination with varus-derotation intertrochanteric osteotomy of the femur.

RESULTS

Because there are very different pathological conditions in our material, we used the following criteria of evaluation:

– the subjective evaluation of the patients and/or caregivers (unchanged, improvement, deterioration);
– objective evaluation, based on the effect of the surgical procedures on gross motor function, distinguishing the following groups: a) non ambulatory in the wheelchair, b) ambulatory dependent – standing in a standing frame, c) ambulatory dependent – walking in a walker, d) ambulatory dependent – walking with canes/crutches, e) ambulatory non-dependent – walking without any device.

According to the radiological criteria of Sharrard and Shea (7, 8), the hips were evaluated as normal to dysplastic, subluxated, and dislocated. The patients' data have been presented in Table 1.

In CP patients, in the subjective assessment, most patients or caregivers reported improvement (13 patients), in one patient the evaluation was unchanged, and one patient reported deterioration. In the objective assessment, in 13 patients the improvement in gross motor function was obvious, in one patient the status was unchanged, and in one patient walking ability deteriorated. In the radiological evaluation, normal to dysplastic hips were achieved in 15 hips (66%). Eight hips (34%) progressively subluxated in the follow up (MI >33%), but no redislocation was present. These subluxations led to repeated surgical procedures in 2 patients. Other patients with hip subluxation have been observed clinically and radiologically. Avascular necrosis of the femoral head was found in 2 hips (8%), and was similar to Buchholz-Ogden type II necrosis. The previous morphological deformities of the femoral head were not changed. There were no complications concerning wound healing and bone healing or hardware problems in this group, but there were 2 general complications: cardio-respiratory insufficiency in one patient and metabolic dysfunction in another patient. These complications were successfully solved.

In MMC and paralytic patients, the subjective evaluation was superior in all cases by the final follow up. In the objective assessment, all the patients improved in their movement activities. In radiological criteria, initially all hips were improved, but in the final follow-up, 3 hips remained dysplastic and 3 hips resubluxated, with slow progression in one patient, leading to a repeated surgical procedure.

DISCUSSION

There are great controversies regarding the treatment strategy for neurogenic hip subluxation and dislocation, particularly from the neurological and orthopedic point of view. The neurologists recommend mostly conservative methods of treatment and observation, but most orthopedic surgeons recommend early surgical treatment. The release of hip adductors and flexors as a single procedure is an appropriate method only for the hip at risk (a hip with abduction < 30° and flexion contracture of 45° without subluxation, MI<33%, age under 5 years) [3,6,14,15]. Treatment of subluxated hips with soft tissue release is effective for long term prevention of hip dislocation in 67% of patients, according to a recent publication by Presedo et al. [16], and soft tissue release can correct the hip instability permanently if it is performed before the bony changes of the hip [14]. According to some authors [17,18,19], femoral varus-derotation osteotomy as a single procedure is useful only in a hip with subluxation (MI under 70%). In the remaining cases, where femoral osteotomy does not provide adequate coverage or stability of the hip, pelvic osteotomy should be performed [18]. Soft tissue release represents mostly an element in these combined procedures, as well as open reduction in cases of hip dislocation. In our treatment strategy, we recommend pelvic osteotomy in all cases of subluxated hips (MI>33%), when the acetabular index exceed 25°. This treatment strategy is consistent with the literature [2,4,6,8,15,20]. The combination with femoral osteotomy depends on the morphology of the proximal femur. The choice of the type of pelvic osteotomy varies according to the three-dimensional anatomy of the acetabulum and the proximal femur. In mild acetabular dysplasia without posterior insufficiency of acetabulum, we use the redirection osteotomies (Salter or Steel), and we achieve good results, in concordance with the results reported by Root [21] and Brunner [3]. This osteotomy increases anterior and superior coverage of the femoral head, but a disadvantage is the decreased posterior coverage of the femoral head. For this reason, this operation is not indicated in patients having posterior insufficiency of the acetabulum and retroversion of the proximal femur, because it may lead to posterior subluxation/dislocation.

Of the acetabuloplasties used for shallow and steep acetabula in congruent hips, the Pemberton osteotomy is used in our institution with good clinical and radiological results in the agreement with the results described in the literature [8,21]. We did not see the deterioration of the posterior coverage of the femoral head reported by some authors [11]. We have no experience with Dega-type acetabuloplasty in CP patients, but these osteotomies are efficient for lateral and also for posterior coverage of the femoral head [5,22]. The advantages of these osteotomies are that they do not significantly reduce posterior acetabular coverage, and provide the greatest amount of immediate correction. In complex deficiency of the acetabulum and hip incongruence, the Chiari osteotomy represents a very good option in children over 11 years of age, as indicated by our own experience and reports in the literature [1,21,23,24,25]. There are also capsular interposition acetabuloplasties, where the capsule undergoes metaplasia to form fibrocartilage. Because of the anti-Chiari effect, this procedure should be used in children over 11 years of age. We do not use shelf acetabular augmentation (shelf plasty), but

the literature reports in CP patients are encouraging [18,26,27]. We have never used the bilateral complete one-stage surgical procedure described in the literature [20]. Our short- and mid-term outcomes in terms of the clinical and radiological parameters are comparable with those from the literature [3,4, 6,21,23,25,28,29,30], but at the same time deterioration of hip stability should be expected, because various factors influence hip stability, including muscle imbalance, femoral head deformation, recurrence of valgus position of the femur, and compliance [5,23, 25,31]. One such problem is also pelvic obliquity, which can be suprapelvic (due to spinal deformity) or infrapelvic (due to asymmetrical contraction of the hips), or both. The timing of surgery (first spinal, then hip surgery or vice versa) is controversial, but there is a consensus to correct both deformities: with spinal-pelvic fusion and with hip surgery [29,32].

Most patients in our group showed improvement of gross motor function. Only one ambulatory non--dependent patient reported subjective deterioration, and walks with one crutch. We attribute this deterioration to the change of pelvic rotation after bilateral Steel osteotomy, and due to changes in the muscle lever arm. This condition needs further evaluation and analysis in the gait laboratory. As far as the walking ability after hip reconstruction is concerned, this depends not only on the surgical procedures, but above all on the severity of the physical and mental involvement. In non-ambulatory patients with positive motivation and the potential to walk, the initial upright positioning represents a very important step towards learning to walk. In these patients we used an individually made standing frame (parapodium, Fig. 19), which is used mainly for patients with myelomeningocoele [1].

Based on our results, we recommend the combined surgical procedure in the neurogenic unstable hip in the early stages of the subluxation as soon as possible (when the diagnosis is made) in order to avoid progression of subluxation and bony deformities. These principles should be accepted also by neurologists, and programs to prevent the dislocation of the hip in neurogenic conditions should be introduced [33,34], because the dislocation of the hip in neurological conditions represents a serious problem.

CONCLUSIONS

According to our experience, the role of pelvic osteotomies in neuromuscular instability of the hip is to achieve stability and congruency of the hip, to reduce pain, to allow for hygienic care and stable sitting in non-ambulatory patients, and to enable standing and walking in potential ambulators, and stable and pain-free walking in ambulators. Pelvic osteotomy is mostly a part of a complex treatment strategy. The best long-term outcomes can be achieved when congruency of the hip before surgery is present and muscle balance was achieved after surgery. Because there are different conditions in neuromuscular instability, different types of pelvic osteotomies according to the actual deformities should be chosen for treatment. We prefer a one-stage procedure to resolve all present deformities in one surgical intervention.

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