■ REVIEW ARTICLE

Total hip replacement in patients with neurological conditions

J. M. Queally,
A. Abdulkarim,
K. J. Mulhall

From Cappagh National Orthopaedic Hospital, Dublin, Republic of Ireland

Neurological conditions affecting the hip pose a considerable challenge in replacement surgery since poor and imbalanced muscle tone predisposes to dislocation and loosening. Consequently, total hip replacement (THR) is rarely performed in such patients. In a systematic review of the literature concerning THR in neurological conditions, we found only 13 studies which described the outcome. We have reviewed the evidence and discussed the technical challenges of this procedure in patients with cerebral palsy, Parkinson's disease, poliomyelitis and following a cerebrovascular accident, spinal injury or development of a Charcot joint. Contrary to traditional perceptions, THR can give a good outcome in these often severly disabled patients.

Total hip replacement (THR) is one of the major successes of modern medicine.[1] As the design of implants and surgical techniques evolve, the indications for this procedure are continually expanding with replacement now being performed in children[2-4] and in patients with complex conditions which would previously have been managed by salvage procedures.[5,6] Neurological conditions affecting the hip pose a particular challenge for the replacement surgeon with associated paresis, spasticity, contractures and tremors potentially leading to poor or imbalanced muscle tone across the hip. Altered muscle tone in the dynamic hip stabilisers leads to abnormal forces acting across the hip which can result in subluxation and osteoarthritis.[7,8] In addition to contributing to the underlying degenerative process, abnormal muscle tone predisposes patients who undergo THR to early failure because of dislocation and aseptic loosening.[9-15] As a result, end-stage osteoarthritis in this group of patients has traditionally been treated by salvage procedures such as resection arthroplasty[5,10] and arthrodesis.[6,7]

When replacement is undertaken in these patients it is usually as a tertiary referral in specialist centres with a low volume of such patients.[3,9,16] The outcome is often not amenable to assessment using the usual methods. These factors contribute to a lack of clinical data regarding the outcome of THR in these patients. In order to determine the current evidence regarding the outcome in patients with neurological conditions which affect the hip we carried out a systematic review of the literature, with a structured search of Medline, EMBASE and the Cochrane databases for articles published between 1970 and 2009 containing the following terms: total hip arthroplasty, total hip replacement, cerebral palsy, spina bifida, poliomyelitis, Parkinson's disease, paralytic hip disease, multiple sclerosis, cerebrovascular accident, spinal injury, Charcot hip and neuromuscular disease. Only 13 studies dealt specifically with this group in terms of functional outcome, rates of complications, surgical techniques and post-operative management. All these studies (Table I) were reviewed and the references from the articles also retrieved to identify any additional studies of interest. Our review confirmed a lack of clinical data regarding the outcome of THR in these patients with no prospective long-term outcome studies being identified. This review presents the information available and includes our own observations regarding the outcome and management of these patients.

Cerebral palsy

Pain in the hip is common in patients with cerebral palsy and affects 25% to 75% depending on the severity of their condition.[17] It occurs as a result of a complex interplay of a variety of conditions including dysplasia, subluxation and osteoarthritis. The primary underlying pathological mechanism is muscle imbalance with the strong hip flexors and adductors overpowering the weaker abductors and extensors, resulting in contractures. Bony abnormalities include excessive valgus of

■ J. M. Queally, MRCS I, Registrar in Trauma and Orthopaedics
Cappagh National Orthopaedic Hospital, Finglas, Dublin 11, Ireland.

■ A. Abdulkarim, MRCS, Research Fellow
Sports Surgery Clinic, Santry Demesne, Dublin 9, Ireland.

■ K. J. Mulhall, FRCS I(Trauma & Orth), Associate Professor
Mater Misericordiae University Hospital, Eccles Street, Dublin 7, Ireland.

Correspondence should be sent to Mr K. J. Mulhall; e-mail: kjmulhall@eircom.net

doi:10.1302/0301-620X.91B10.22934 $2.00

J Bone Joint Surg [Br] 2009;91-B:1267-73.

Table I. Details of studies retrieved reporting the outcome of total hip replacement (THR) in patients with neurological conditions

Study author/s	THR (number)	Neurological condition*	Mean age (yrs, range)	Length of follow-up (yrs)	Implant type/surgical technique	Outcome
Buly et al[9]	19	CP	30 (16 to 52)	10 (3 to 17)	Cemented components	2 dislocations (11%)
					12 tenotomies	3 revisions (16%)
					Hip spicas post-operatively	94% painfree
					Anteverted acetabular component for sitters	95% survivorship at 10 years for aseptic loosening, 86% for any reason
Weber and Cabanela[21]	16	CP	48.5 (22 to 79)	9.7 (2.5 to 21)	12 all cemented	1 revision (aseptic loosening)
					2 all cemented	87% significant pain relief
					2 hybrid	
Weber et al[29]	107	PD	72 (57 to 87)	7.1 (2.0 to 21.0)	Uncemented and cemented components used	93% pain relief
					7 tenotomies	6 (6%) dislocations (all revisions)
						3 (3%) aseptic loosening
						26% post-operative medical complication rate
Meek et al[14]	2394	PD	N/A†	N/A	N/A	0.0 to 0.46 annual dislocation rate
	1499	CVA	N/A	N/A	N/A	0.0 to 0.3 annual dislocation rate
DiCaprio et al[37]	31	CVA	68 (43 to 84)	2 (1 to 6)	Uncemented acetabulum, cemented femur	No dislocation Heterotopic dislocation 36%
Becker et al[38]	6	Spinal injury	39.4 (23.0 to 57.0)	1.0 (0.5 to 2.0)	N/A	No dislocation
Weber et al[29]	3	Myelomeningocele	45 (28 to 54)	7.6 (5.0 to 10.0)	1 all cemented	3 dislocations
					1 all cemented	2 revisions
					1 hybrid	Poor pain relief
Case Reports						
Spinnickie and Goodman[35]	1	Poliomyelitis	71	5 months	Cementless components Constrained liner	Dislocation
Blake et al[3]	2	CP	14	2.25	Constrained hybrid prosthesis	Painfree
					No hip spica	No dislocation
Cameron[36]	1	Poliomyelitis	N/A	3	Uncemented constrained components	N/A
Laguna and Barrientos[16]	1	Poliomyelitis	38	3	Uncemented components	Painfree
						No dislocation or loosening
Robb et al[40]	1	Charcot joint *Tabes dorsalis*	58	N/A	Cemented components	Multiple dislocation
Sprenger and Foley[41]	1	Charcot joint *Tabes dorsalis*	61	7	N/A	No dislocation

* CP, cerebral palsy; PD, Parkinson's disease; CVA, cerebrovascular accident
† N/A, not available

Fig. 1a

Fig. 1b

Radiographs of the dislocated degenerative hip of a 20-year-old man with cerebral palsy a) pre-operative anteroposterior view showing complex anatomy including a dysplastic acetabulum and coxa valga. He had severe pain and was confined to a wheelchair. b) Post-operative view, one year after a constrained uncemented total hip replacement. Bulk autografting of the acetabulum was performed using the resected femoral head. At the last follow-up he was walking independently and was free from pain.

the femoral neck and persistence of fetal anteversion. As a result, the femoral head tends to sublux onto the superior acetabular margin (Fig. 1) resulting in considerable deformity of the head and degenerative changes.[7,8,18] Pain accompanies this process from an early stage giving rise to decreased mobility, with difficulty in sitting, perineal hygiene, transferring and overall care.

The management of early-stage hip disease in cerebral palsy has been discussed extensively in the literature,[7,19] but there is little information on the treatment of advanced disease.[9] Options for the treatment of a painful, degenerative and/or subluxed hip include arthrodesis, resection arthroplasty and THR.[7] Arthrodesis is often contraindicated because of a high incidence of deformities of the spine and contralateral hip.[8,20] Resection arthroplasty, with or without interpositional procedures, has been associated with mixed results, does not reliably provide relief from pain in all cases and typically gives a poor functional outcome in young patients.[5,10] THR has traditionally been reserved as a last resort because of a perceived high risk of dislocation and early aseptic loosening if undertaken in younger patients. Consequently, there are few studies reporting the outcome of THR in these patients.[3,9,21]

Buly et al[9] described the long-term results of 19 THRs carried out between 1972 and 1986 in patients with cerebral palsy with a mean follow-up of ten years (Table I). The indication for surgery in all the patients was painful osteoarthritis in a hip which was either subluxed or dislocated. They described modifications to the standard surgical techniques including the use of custom-made femoral implants, tenotomies, hip spicas and placing the acetabular component in anteversion for sitters (Table I).

Good outcomes were reported in terms of pain, dislocation, rates of revision and functional improvement (Table I). As regards function, five patients (26%) regained the ability to walk and seven (37%) improved enough to walk independently. Malposition of a component gave rise to recurrent dislocation in two patients who required revision of a retroverted acetabular component and a short femoral neck. One femoral component became loose after five years and one acetabular component was loose at 15 years.

Weber and Cabanela[21] found a successful outcome for THR in cerebral palsy in a retrospective review of 16 patients (Table I). Blake et al[3] treated a painful dislocated hip in a 14-year-old patient with cerebral palsy with a constrained hybrid prosthesis consisting of an uncemented acetabular component with acetabular screws, a constrained liner and a cemented femoral component. At two years and three months, he was still free from pain with a good posture.

These studies illustrate the complexity and difficulties involved in treating the degenerative dislocated hip in these patients, but with appropriate modifications to the surgical technique and choice of implant, good outcomes are achievable with THR.

A review of the last six consecutive THRs with a minimum follow-up of one year performed by the senior author (KJM) in patients with cerebral palsy, showed that four had required uncemented constrained acetabular components because of soft-tissue imbalance (Fig. 1), while two had standard unconstrained uncemented acetabular components. Standard proximally-coated femoral components were used in two patients (Fig. 1) and four had 'stem-and-sleeve' design uncemented femoral components, which we prefer when dealing with abnormal proximal femoral anatomy.

We manage dysplastic acetabula on their merits by bone grafting and other techniques as indicated. Each patient is assessed individually in terms of bony abnormalities and soft-tissue tensioning and careful templating and pre-operative planning are mandatory. Contractures are released when necessary. We do not use a hip spica post-operatively and mobilise the patient on the day after the surgery. In one case, soft-tissue tension imbalance was encountered post-operatively and was treated by combined injections of botulinum toxin and formal surgical release. We advise a low threshold for such interventions in order to preserve movement and stability. We have found that an experienced multidisciplinary team including nurses, social workers, physiotherapists, care-givers and good facilities for rehabilitation are critical in the effective management of these patients. Our results mirror those of previous studies,[3,9,21] and despite differences in the type of implant and in post-operative management, we have found that THR has given reliably good results for relief from pain, improved function and walking ability in the medium term.

Parkinson's disease

This disease occurs in 1% of people over the age of 60 years.[22] The musculoskeletal effects include rigidity, contractures, tremor, bradykinesia, dystonia and postural instability which theoretically predispose patients to dislocation of the hip.[23,24] The outcome in these patients after surgery for fractures of the hip is poor, mainly because of medical complications with high rates of morbidity and mortality.[25-28] Reports on the outcome of THR in these patients are limited.[14,29]

Several studies have discussed the outcome of hemi-arthroplasty in fractures of the hip in patients with Parkinson's disease.[25,26,28,30] Although these studies are not strictly applicable to an elective THR, some inferences can be taken in terms of rates of dislocation and post-operative complications. Some authors have reported a rate of dislocation of 37%,[25] but other studies have found better outcomes,[24,28] with Staeheli et al[28] reporting one dislocation in a series of 49 hemiarthroplasties at a mean follow-up of 7.3 years (minumum two years). Eventov et al[26] also noted a low rate of dislocation of 3%. These studies, however, found a high rate of mortality in the early post-operative period, up to 47% within six months.[25] This was mainly due to increased medical complications, with up to 20% of patients developing a urinary track infection and 10% pneumonia in the immediate post-operative period.[28] Aggressive medical management was advised in terms of antibiotic prophylaxis, with an extended period of coverage, respiratory physiotherapy, early mobilisation and prevention of pressure sores.[28]

Weber et al[29] reviewed the outcome of THR in 98 patients (107 THRs) with Parkinson's disease at a mean follow-up of 7.1 years (Table I). These accounted for 0.4% of the 28 000 THRs performed in their institution between 1970 and 1994. Both cemented and uncemented components were used. There were six (12%) dislocations in the revision group only which compared reasonably well with the rates of dislocation in revision arthroplasty in non-Parkinson patients (10.6%).[31] The functional outcome improved in the early follow-up period, but deteriorated as the underlying neurological condition worsened, with 57% of patients having progressed to end-stage Parkinson's disease at the latest follow-up. A high rate (26%) of post-operative complications was observed, reflecting the increased incidence of medical comorbidity associated with this disease.

Meek et al[14] studied the dislocation rate in patients with a history of Parkinson's disease who had undergone THR as reported in the Scottish National Arthroplasty Registry. They analysed data from 14 314 procedures between 1996 and 2004 and found an annual incidence of Parkinson's disease of 5% to 8% in patients undergoing THR. They found that the dislocation rate in this group of patients was significantly lower than that in a control group (Table I), suggesting that this unexpectedly low rate may have been due to pharmacological treatment aimed at maintaining muscle tone.

These studies indicated that THR in patients with Parkinson's disease was successful with low rates of dislocation and satisfactory pain and functional outcome scores. The senior author manages all patients with Parkinson's disease in active collaboration with a neurologist in order to maximise the control of their underlying neurological disorder. We place specific emphasis on the medical management of these patients in the early post-operative period to avoid complications such as urinary and respiratory-track infections, sepsis, deep-vein thrombosis and pulmonary embolism.

Poliomyelitis

Poliomyelitis is an infectious disease caused by a neurotrophic virus which targets the anterior horn cells of lower motor neurones resulting in a flaccid paralysis. The lower limbs are most commonly affected in an asymmetrical manner. As a result of worldwide immunisation programmes, poliomyelitis has been virtually eradicated. However, an estimated 650 000 middle-aged patients in the United States still suffer the long-term sequelae of this disease, including lower-limb deformities and degenerative joint disease.[32]

Some of the more common bone and soft-tissue problems of the hip in patients with poliomyelitis include subluxation, dysplastic acetabula, contractures, poor bone quality and leg-length discrepancy. The hip is prone to subluxation in poliomyelitis because of soft-tissue and bony abnormalities, with the primary mechanism being flaccid paralysis of the muscles which cross the joint. The hip flexors and adductors are usually stronger than the extensors and abductors.[33] Coxa valga tends to occur as the iliopsoas muscle is stronger than the gluteal muscles.[33] Dysplastic acetabula develop due to abnormal weight-bearing across the joint as the hip develops throughout childhood.

Pelvic obliquity, if present, may also contribute to subluxation of the hip and arises as a result of lumbar scoliosis or severe adduction or abduction deformities of the contralateral hip.[34] However, THR is rarely used to treat degenerative joint disease in these patients with the evidence in the literature being limited to case reports.[16,35,36] Laguna and Barrientos[16] treated an osteoarthritic dysplastic hip by a THR in a 38-year-old woman with flaccid paralysis secondary to poliomyelitis. Uncemented components and acetabular bulk allograft were used, and by lowering the centre of rotation of the hip a partial correction of the leg-length discrepancy was achieved without neurovascular compromise. The patient was free from pain and walking well when reviewed after three years. Spinnickie and Goodman[35] described the use of a constrained THR to treat nonunion of a fracture of the femoral neck in a 71-year-old man. Dislocation of the femoral head and trunion occurred five months later, requiring revision THR with a non-constrained liner.

Cerebrovascular accident, spinal injury, Charcot joint and other conditions

As with other neurological conditions, there is little evidence in the literature regarding the outcome of THR in patients with a history of cerebrovascular accident. They have traditionally been considered to be at a higher risk of dislocation because of contractures across the joint. However, Meek et al,[14] using the Scottish National Arthroplasty Registry, which has an annual incidence of 2% to 6% of cerebrovascular accidents in patients undergoing THR, found that the rate of dislocation in this group was significantly lower than that in the control group (Table I). They hypothesised that this low rate may have been due to reduced mobility in these patients.

DiCaprio et al[37] investigated the incidence of heterotopic ossification (HO) in 31 THRs in 22 patients with a mean follow-up of 35 months. They considered that a history of cerebrovascular accident would predispose patients to HO because of the increased serum levels of growth factors which occur after cerebral injury. Although the primary aim of the study was to document the incidence of HO, they also assessed the functional outcome and complications. No dislocations occurred. The mean Harris hip score improved from 33 pre-operatively to 86 post-operatively. The incidence of HO was significantly higher than that in patients who had undergone THR without a history of a previous cerebrovascular accident (36% *vs* 15%). They recommended routine radiation prophylaxis in patients with a history of cerebrovascular accident undergoing THR.

An increased risk of HO also occurs in patients with spinal injury with tetra- or paraplegia. Becker, Röhl and Weidt[38] reviewed the outcome of THR in six patients with spinal injuries who had undergone THR because of severe HO resulting in ankylosis of the hip. Due to the high risk of recurrence of HO, all had radiation prophylaxis and received indometacin for six weeks after the operation. At 24 months, no dislocation or loosening had occurred. An improvement in functional ability and range of movement was seen in all the patients.

In terms of other spinal conditions, Weber and Cabanela[39] found unsatisfactory results for THR in patients with a myelomeningocele at the lumbar level. All three patients had dislocation. We have also treated a small number of paraplegic patients who presented with functional disability on transferring and atypical pain secondary to osteoarthritis of the hip. We had a good functional outcome and relief from pain in these patients with the use of constrained devices, but one had a dislocation at three months. With such devices dislocation requires an open reduction. In this case acetabular revision was performed using a different constrained design of implant with a good outcome when followed up at three years.

THR has been used in Charcot joints although this is a rare condition and usually a contraindication to arthroplasty.[40,41] Robb et al[40] described multiple dislocations after THR in a 58-year-old woman with a history of *tabes dorsalis*. Surgical attempts at improving soft-tissue tension failed, with the components being removed one year after the initial procedure.[40] Sprenger and Foley,[41] however, described a successful THR in a patient with *tabes dorsalis*. They attributed their success to the fact that the patient was not ataxic.

Discussion

The outcome of THR in patients with neurological conditions is complicated because of the abnormal muscle tone caused by paresis, contractures and tremors.[42] Apart from increasing the risk of dislocation and aseptic loosening, an imbalance in muscle tone across the hip, if present since early childhood, may result in abnormal femoral and acetabular anatomy. This produces complex problems for the arthroplasty surgeon, with modular implants typically required to accommodate the abnormal bony anatomy. As a result of the increased risk of instability, uncertain outcome and abnormal anatomy, THR is rarely performed in these patients and there are few reports of the outcome in the literature (Table I).

Nonetheless, THR can be successful in terms of functional outcome, relief from pain and complications. Post-operative instability is the main complication.[14,15] The availability and improvements in the design of constrained acetabular components have addressed this concern to a certain extent and they may be used to counteract the lack of soft-tissue tension in these patients.[3] Forces which would otherwise cause dislocation are transferred to the locking mechanism and the liner-shell and shell-bone interface. They are valuable in addressing instability with success rates of up to 97.8% seen at 4.8 years.[15] However, re-dislocation and early loosening may occur due to increased forces across the host-implant interface and increased wear.[15] Only two cases in which constrained components were used in patients with cerebral palsy and poliomyelitis have been reported in the literature as discussed above. Redislocation occurred in one requiring revision using a non-constrained component.[35] The introduction of bearings of large diameter has also improved the intrinsic stability achievable in hip replacement but the altered acetabular anatomy frequently encountered can limit the size of the implant.

There appear to be two different groups of patients with neurological dysfunction. In some older patients with neurological conditions such as Parkinson's disease or a history of cerebrovascular accident due to general immobility and pharmacological treatments the risk of dislocation is decreased.[14] This group is best treated using standard unconstrained components. The other group consists of patients with an increased tendency to sublux or dislocate, such as those with cerebral palsy, poliomyelitis or spinal injury. The use of constrained components should be considered in these patients.

In the presence of abnormal development of the hip there may be excessive femoral anteversion, coxa valga, dysplastic acetabula and a shortened femoral neck with reduced offset.[7] These femoral abnormalities often do not accommodate an off-the-shelf monoblock implant. Custom-made femoral implants were initially used in THR in patients with cerebral palsy.[9] The use of modular femoral implants such as stem-and-sleeve constructs, can be used to address complex femoral anatomy, in particular problems with anteversion, metaphyseal-diaphyseal mismatch and decreased offset.

In patients with neurological conditions THR is rarely used to treat osteoarthritis of the hip because of the perceived complexity and high risk of complications. Nonetheless, favourable outcomes may be encountered. As the medical management of these conditions improves, these patients are living longer and are more likely to develop symptomatic osteoarthritis of the hip. Current evidence suggests that contemporary THR using modular implants, constrained components when required, soft-tissue releases when appropriate, and multidisciplinary management should be considered for these often severely disabled patients.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. **Wroblewski BM, Siney PD, Fleming PA.** Charnley low-friction arthroplasty: survival patterns to 38 years. *J Bone Joint Surg [Br]* 2007;89-B:1015-18.
2. **Scott RD.** Total hip and knee arthroplasty in juvenile rheumatoid arthritis. *Clin Orthop* 1990;259:83-91.
3. **Blake SM, Kitson J, Howell JR, Gie GA, Cox PJ.** Constrained total hip arthroplasty in a paediatric patient with cerebral palsy and painful dislocation of the hip: a case report. *J Bone Joint Surg [Br]* 2006;88-B:655-7.
4. **Jaget M, Begg MJ, Ready J, et al.** Primary total hip replacement in childhood, adolescence and young patients: quality and outcome of clinical studies. *Technol Health Care* 2008;16:195-214.
5. **Castle ME, Schneider C.** Proximal femoral resection-interposition arthroplasty. *J Bone Joint Surg [Am]* 1978;60-A:1051-4.
6. **Root L, Goss JR, Mendes J.** The treatment of the painful hip in cerebral palsy by total hip replacement or hip arthrodesis. *J Bone Joint Surg [Am]* 1986;68-A:590-8.
7. **Flynn JM, Miller F.** Management of hip disorders in patients with cerebral palsy. *J Am Acad Orthop Surg* 2002;10:198-209.
8. **Bleck EE.** The hip in cerebral palsy. *Orthop Clin North Am* 1980;11:79-104.
9. **Buly RL, Huo M, Root L, Binzer T, Wilson PD Jr.** Total hip arthroplasty in cerebral palsy: long-term follow-up results. *Clin Orthop* 1993;296:148-53.
10. **Koffman M.** Proximal femoral resection or total hip replacement in severely disabled cerebral-spastic patients. *Orthop Clin North Am* 1981;12:91-100.
11. **Espehaug B, Havelin LI, Engesaeter LB, Langeland B, Vollset SE.** Patient-related risk factors for early revision of total hip replacements: a population register-based case-control study of 674 revised hips. *Acta Orthop Scand* 1997;68:207-15.
12. **Woolson ST, Rahimtoola ZO.** Risk factors for dislocation during the first 3 months after primary total hip replacement. *J Arthroplasty* 1999;14:662-8.
13. **Paterno SA, Lachiewicz PF, Kelley SS.** The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. *J Bone Joint Surg [Am]* 1997;79-A:1202-10.
14. **Meek RM, Allan DB, McPhillips G, Kerr L, Howie CR.** Epidemiology of dislocation after total hip arthroplasty. *Clin Orthop* 2006;447:9-18.
15. **Su EP, Pellicci PM.** The role of constrained liners in total hip arthroplasty. *Clin Orthop* 2004;420:122-9.
16. **Laguna R, Barrientos J.** Total hip arthroplasty in paralytic dislocation from poliomyelitis. *Orthopedics* 2008;31:179.
17. **Bagg MR, Farber J, Miller F.** Long-term follow-up of hip subluxation in cerebral palsy patients. *J Pediatr Orthop* 1993;13:32-6.
18. **Moreau M, Drummond DS, Rogala E, Ashworth A, Porter T.** Natural history of the dislocated hip in spastic cerebral palsy. *Dev Med Child Neurol* 1979;21:749-53.
19. **Spiegel DA, Flynn JM.** Evaluation and treatment of hip dysplasia in cerebral palsy. *Orthop Clin North Am* 2006;37:185-96.
20. **Cooperman DR, Bartucci E, Dietrick E, Millar EA.** Hip dislocation in spastic cerebral palsy: long-term consequences. *J Pediatr Orthop* 1987;7:268-76.
21. **Weber M, Cabanela ME.** Total hip arthroplasty in patients with cerebral palsy. *Orthopedics* 1999;22:425-7.
22. **Adams RD, Maurice V.** *Principles of neurology.* Second ed. New York: McGraw-Hill 1981.
23. **Tolosa E, Compta Y.** Dystonia in Parkinson's disease. *J Neurol* 2006;253(Suppl 7):7-13.
24. **Poewe W.** The natural history of Parkinson's disease. *J Neurol* 2006;253(Suppl 7):2-6.
25. **Coughlin L, Templeton J.** Hip fractures in patients with Parkinson's disease. *Clin Orthop* 1980;148:192-5.
26. **Eventov I, Moreno M, Geller E, Tardiman R, Salama R.** Hip fractures in patients with Parkinson's syndrome. *J Trauma* 1983;23:98-101.
27. **Rothermel JE, Garcia A.** Treatment of hip fractures in patients with Parkinson's syndrome on leveodopa therapy. *J Bone Joint Surg [Am]* 1972;54-A:1251-4.
28. **Staeheli JW, Frassica FJ, Sim FH.** Prosthetic replacement of the femoral head for fracture of the femoral neck in patients who have Parkinson disease. *J Bone Joint Surg [Am]* 1988;70-A:565-8.
29. **Weber M, Cabanela ME, Sim FH, Frassica FJ, Harmsen WS.** Total hip replacement in patients with Parkinson's disease. *Int Orthop* 2002;26:66-8.
30. **Clubb VJ, Clubb SE, Buckley S.** Parkinson's disease patients who fracture their neck of femur: a review of outcome data. *Injury* 2006;37:929-34.
31. **Amstutz HC, Ma SM, Jinnah RH, Mai L.** Revision of aseptic loose total hip arthroplasties. *Clin Orthop* 1982;170:21-33.
32. **Jordan L, Kligman M, Sculco TP.** Total knee arthroplasty in patients with poliomyelitis. *J Arthroplasty* 2007;22:543-8.
33. **Lau JH, Parker JC, Hsu LC, Leong JC.** Paralytic hip instability in poliomyelitis. *J Bone Joint Surg [Br]* 1986;68-B:528-33.
34. **Delaunay CP, Bonnomet F, Clavert P, Laffargue P, Migaud H.** THA using metal-on-metal articulation in active patients younger than 50 years. *Clin Orthop* 2008;466:340-6.
35. **Spinnickie A, Goodman SB.** Dissociation of the femoral head and trunion after constrained conversion total hip arthroplasty for poliomyelitis. *J Arthroplasty* 2007;22:634-7.
36. **Cameron HU.** Total hip replacement in a limb severely affected by paralytic poliomyelitis. *Can J Surg* 1995;38:386.

37. **DiCaprio MR, Huo MH, Zatorski LE, Keggi K.** Incidence of heterotopic ossification following total hip arthroplasty in patients with prior stroke. *Orthopedics* 2004;27:41-3.

38. **Becker SW, Röhl K, Weidt F.** Endoprosthesis in paraplegics with periarticular ossification of the hip. *Spinal Cord* 2003;41:29-33.

39. **Weber M, Cabanela ME.** Total hip arthroplasty in patients with low-lumbar-level myelomeningocele. *Orthopedics* 1998;21:709-12.

40. **Robb JE, Rymaszewski LA, Reeves BF, Lacey CJ.** Total hip replacement in a Charcot joint: brief report. *J Bone Joint Surg [Br]* 1988;70-B:489.

41. **Sprenger TR, Foley CJ.** Hip replacement in a Charcot joint: a case report and historical review. *Clin Orthop* 1982;165:191-4.

42. **Houlden H, Charlton P, Singh D.** Neurology and orthopaedics. *J Neurol Neurosurg Psychiatry* 2007;78:224-32.