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Appendix

TABLE E-1 Summary of Literature Analyzing Total Hip Arthroplasty in Patients with Cerebral Palsy*

Study†	Patients	LOE	Age‡	Surgical Approach§	Additional Procedures§	Postoperative Immobilization§	Implants§	Follow-up‡	Complications	Outcomes	Survivorship	Conclusions
Koffman[18] (1981)#	5 primary THAs in 4 patients with CP (3 non-ambulatory, 1 ambulatory), 10 PFRs in 6 patients with CP	IV	Median, 33 (21 to 57)	NA	None	NA	Sevash (1), LeGrange-Letournel (2), T-28 (2)	Median, 4 (3 to 6)	Early dislocation with revision 11 yr postop. and subsequent acetabular component loosening (1), limited range of motion requiring THA resection (1), HO with pain and no range of motion (1)	0 THAs with no pain or stiffness	2 of 5 THAs revised	Constrained liners will likely loosen, surgical indications include pain and disability
Root[14,19] (1982 and 1986)#	15 primary THAs in 15 patients with CP (6 non-ambulatory, 9 ambulatory), 8 arthrodeses in 8 patients with CP	IV	31 (16 to 52)	Trochanteric osteotomy (13), posterolateral (2)	Adductor or hip flexor releases (11), structural femoral-head autograft (2)	Hip spica cast (13)	Charnley-Muller (8), T-28 (2), Harris cup with custom stem (3), Triad (1), CAD with Charnley-type computerized design rod (1)	6.75 (2.5 to 12)	Proximal greater trochanteric migration with femoral component bending and persistent pain (1), femoral component loosening (1), dislocation requiring revision (2)	No pain, and functioning at level before developing hip pain (13)	2 revisions for dislocation (1 femoral and 1 acetabular revision)	THA recommended for bilateral disease or in older, ambulatory patients; arthrodesis recommended for unilateral disease or in young, active patients
Skoff[20] (1986)#	12 primary THAs in 9 patients with CP (unknown ambulatory status), Down syndrome, or mental retardation	IV	42 (16 to 65)**	Anterior (9), lateral or posterior (3)**	Adductor release (NA)**	None**	T-28 (NA), DF-80 (NA), HD-2 (NA), Autophor ceramic (NA)**	3.5 (0.33 to 7.1)**	Loosening (1), partial peroneal nerve palsy (1), HO (3), trochanter pain (1)**	100% pain relief with improved range of motion and maintenance of function; wheelchair sitting improved; no dislocations**	1 revision at 4.5 yr postop.**	THA is a good option for this group of patients**
Buly[15] (1993)	19 primary THAs in 18 patients with CP (6 non-ambulatory, 12 ambulatory)	IV	30 (16 to 52)	Trochanteric osteotomy (14), posterolateral (5)	Adductor or hip flexor releases (12), structural femoral head autograft (4)	Hip spica cast (16)	Femur: Charnley (7), Mueller (3), T-28 (3), custom (3), Triad (2), CAD-type Charnley (1); acetabulum: Charnley (8), Mueller (3),	10 (3 to 17)	Proximal greater trochanteric migration with femoral component bending and persistent pain (1), femoral component loosening (1),	No pain in 16 of 18 patients, improvement in functional level in 12 patients, improved range of motion in all patients	86% survivorship at 10 yr postop.	THA is an effective treatment for pain relief and functional improvement; recommended postoperative spica casting

							Harris (3), T-28 (3), Triad (2)		trochanteric bursitis (3, with 1 requiring wire removal), dislocation requiring revision (2), HO (11)			and selective tendon releases
Ries[21] (1994)#	2 primary THAs in 2 patients with CP (unknown ambulatory status), 2 hemiarthroplasties in 2 patients with CP, 7 other hip arthroplasties in 7 patients with mental impairment (schizophrenia, seizures, Down syndrome), 244 arthroplasties in mentally competent patients	III	62 (57 to 67)	NA	NA	NA	NA	NA	Femoral periprosthetic fracture requiring internal fixation with subsequent failure of implant requiring revision internal fixation, and UTI (1)	Improved function in 1 patient who sustained a periprosthetic fracture, and decreased function in the other patients	No implants removed	THA should only be performed when conservative measures have failed because of the high complication rate##
Gabos[13] (1999)	14 prosthetic arthroplasties in 11 non-ambulatory patients with CP	IV	17 (11.25 to 20.67)	Anterolateral (14)	Iliopsoas release (14)	Hip abduction pillow (NA) or modified Petrie broomstick cast (NA)	Custom THA femur (NA), standard shoulder prosthesis (NA), glenoid component in acetabulum (NA)	4.75 (2 to 6.33)	Dislocation (4, left dislocated), osteolysis (1), periprosthetic fracture (2, healed nonoperatively), bilateral fixed abduction contractures requiring abductor and hamstring releases and heterotopic bone excision (1), HO (5)	10 patients (13 arthroplasties) had complete pain relief, whereas 1 patient (1 arthroplasty) had persistent pain	NA	Hip implant stability does not contribute to pain relief or sitting tolerance in non-ambulatory patients with CP, rather removal of bone-on-bone contact does; this type of prosthetic interposition is an effective surgical option in this population and a good alternative to more expensive custom prostheses
Weber[22] (1999)	16 THAs in 16 patients with CP (3 non-ambulatory, 12	IV	48.5 (22 to 79)	Anterolateral (8), trochanteric osteotomy (7),	Tendon releases (2)	Hip spica cast (1), hip abduction orthosis (1)	Cemented (12), hybrid (2), uncemented (2)	9.7 (2.5 to 21)	Intraoperative fracture (2), trochanteric avulsion	11 of 16 patients had no pain, 2 patients had slight pain,	NA	THA is an excellent option in this patient population for

	ambulatory, 1 unknown)			posterolateral (1)					requiring surgical fixation (1), adductor spasticity requiring tenotomy (1), heel ulcer in the casted patient (1), ileus (1), urinary retention (1), aseptic loosening of both components requiring revision (1), and painful HO requiring resection (1)	and 1 patient had moderate diffuse pain; ambulatory status was known in 14 patients postop.; it improved in 9 patients and remained unchanged in 5 patients		pain relief, with often improved ambulatory status and reasonable longevity despite young age
Blake[23] (2006)	2 THAs in 1 patient with non-ambulatory CP	V	16	Left: anterolateral approach with trochanteric osteotomy; right: the proximal part of the femur was resected above the subtrochanteric level before implanting the THR	Psoas and adductor tenotomy (left)	NA	Cemented Exeter stem with third-generation cementing and Osteonics uncemented Secur-Fit HA-coated acetabular shell with a constrained liner	2	None	Can sit without pain	100%	THA can greatly improve quality of life in this patient population
Schörle[26] (2006)††	19 THAs, unknown patient number	IV	NA	NA	NA	NA	NA	4.5 (NA)	Aseptic femoral loosening (1), periprosthetic fracture requiring revision (1)	84% pain-free, walking ability improved in all patients	1 revision for periprosthetic fracture	THA is effective for pain relief and improved walking
Queally[37] (2009)	6 THAs in patients with CP (unknown ambulatory status) reviewed during review of literature	IV	NA	NA	NA	NA	Constrained acetabular components (4), standard acetabular components (2), stem-and-sleeve femoral components (4), standard proximally coated femora (2)	NA	NA	NA	NA	THA associated with good pain relief and improved function
Root[24] (2009) and	65 THAs in 62 patients with CP (all able to stand-transfer or walk)	IV	30.7 (14 to 61)	Trochanteric osteotomy (14),	Adductor tenotomy (28), structural	Hip spica cast (46), abduction orthosis (10),	First 20 patients had cemented	9.7 (2 to 28)	5 isolated acetabular revisions (1	100% pain relief and return to preoperative	95% at 2 yr postop. and	Patients with CP can expect to experience

Raphael[25] (2010)				posterolateral (45)	femoral-head autograft to superolateral acetabulum (4)	knee immobilizer (2)	THAs, next 39 patients had hybrid THA (35) or uncemented THA implanted (4, 2 S-ROM components and 2 fully porous-coated stems); early THAs utilized 22-mm heads, whereas more recent THAs utilized 32-mm heads; no constrained liners		anteverted cup with recurrent dislocations, 2 retroverted cups with recurrent dislocations, 2 painful acetabular loosenings [1 with osteolysis]), 2 isolated femoral revisions (1 short neck with recurrent dislocation, 1 periprosthetic fracture), and 2 both-component revisions (1 with infection and 1 with infection and recurrent dislocations)	function; 52 (88%) returned to GMFCS functional status before experiencing hip pain	85% at 10 yr postop.	long-term pain relief and improved function after THA; recommended 3 wk postop. hip spica cast when questionable compliance; concluded that THA is successful in achieving pain relief and restoring function in patients with CP with painful hip arthritis
Schroeder[27] (2010)	15 THAs in 13 ambulatory patients with CP	IV	42 (32 to 58)	NA	Adductor tenotomy (5), adductor lengthening (1), psoas and rectus release (4), external rotator transposition (1)	Abduction orthosis (5), hip spica cast (2)	Uncemented cup (10, 6 press-fit, 4 threaded), cemented cup (5), uncemented stem (11), cemented stem (4)	10 (2 to 18)	1-time dislocation treated with closed reduction (1), acetabular aseptic loosening requiring revision (3), recurrent dislocations requiring acetabular revision (1), and infection requiring both-component revision (1)	Pain reduced from 8.4 to 1.1; improved hygienic care in 77%, improvement in ambulation in most patients	No stems revised, 3 cups revised	THA can provide durable pain relief and improved function with a relatively high risk of dislocation
Prosser[28] (2012)	20 hip resurfacings with concomitant proximal femoral osteotomy in 19 patients with CP (13 GMFCS V, 6 II-IV)	IV	37 (13 to 57)	Posterior (20)	Proximal femoral osteotomy	Broomstick casts in some (NA)	Birmingham Hip Resurfacing and 6 or 7-hole DCPs	8 (2.7 to 11.6)	Early dislocation (2), revisions of femoral plate because of failure (3), revision arthroplasty (2, 1 for traumatic femoral neck fracture and 1 for extra-articular impingement	89% pain-free at final follow-up; 32% improved GMFCS grade; 60% of patients required a second surgical procedure; no patients required revision for instability and	2 resurfacings revised and 3 osteotomies revised	Authors recommended this treatment for patients with CP and painful subluxated or dislocated hips

										no patients experienced HO		
Sanders[29] (2013)	10 THAs performed in 8 patients with CP (all GMFCS II-IV)	IV	54 (43 to 61)	Posterolateral (10)	Adductor tenotomy (1)	None	Biomet Avantage dual-mobility implant with an unspecified stem (10)	3.33 (1.83 to 4.67)	1 reoperation for periprosthetic fracture	Improvement in SF-36 scores	No revisions	Dual-mobility implants have the potential to have an improved outcome because of decreased instability with reasonable quality of life compared with conventional THA, but larger studies are needed
Tudor[30] (2013)#	11 resurfacing arthroplasties in 9 patients with CP (4), CNSI (2), or other neuromuscular conditions (3)**	IV	33.1 (13 to 49)**	Posterolateral (11)**	Osteotomy and bilateral adductor tenotomy (1); extensive releases (1); gluteus maximus and adductor releases (1); adductor lengthening (1)	Abduction pillow (3), broomstick cast (1)	Unspecified resurfacing**	63.7 (41 to 89)**	Acetabular loosening and dislocation (1)	1 had severe pain (remained stable at GMFCS level IV) and 3 had no pain (improved GMFCS level)	No revisions	Hip resurfacing is a viable option that confers greater stability compared with THA
Alosh[31] (2014)#	30 primary THAs** in patients with CP (12, unspecified ambulatory status) or acquired spasticity (15)	IV	48.6 (29.1 to 75.0)**	Posterolateral (30)**	Adductor tenotomy (7), flexor lengthening (5), HO excision (1), split tibialis anterior transfer (1)	Abduction pillow and knee immobilizer (30), abduction brace (5)**	Uncemented THA (30)**	2.7 (2.1 to 12.1)**	Calcar fracture (1), sacral decubitus ulcer (1), wound drainage requiring incision and drainage (2)	Most patients improved GMFCS level	100%	THA can markedly improve pain, function, and mobility in patients with upper motor neuron disorders, with low rates of instability even without constrained liners
Yoon[32] (2015)	5 primary THAs in 5 ambulatory patients with CP	IV	35.9 (20.2 to 55.6)	Posterolateral (5)	Adductor tenotomy (1)	Abduction orthosis (5)	Third-generation ceramic heads and liners (5, Biolox Forte) with either a Plasmacup SC cup and BiContact stem (4, Aesculap) or	6.8 (5.8 to 8.3)	Dislocation treated with closed reduction and abduction brace for 2 mo (1), intraoperative calcar fracture treated with	All patients had pain relief and no decrease in function	100%	This type of THA is a good option for ambulatory patients with CP

							a Trident cup and DDH stem (1, Stryker)		intraoperative wiring (1)			
King[33] (2016)	389 primary THAs in 387 patients with CP compared with 425,813 THAs in 423,707 controls from National Joint Registry for England and Wales**	III	53 (NA) for CP vs. 69 (NA) for controls**	NA	NA	NA	Cemented (72), uncemented (163), hybrid (85), reverse hybrid (14), resurfacing (55)	NA	22 revisions (10 within 1 yr postop.); increased rate of UTI and readmission in CP group (p = 0.01 to 0.03)	Revision for periprosthetic fracture (7), aseptic loosening (6), pain (5), and dislocation (4); equal satisfaction to controls on PROM data, equal improvement of OHS and EQ-5D scores	6.4% revision at 5 yr postop. vs. 2.9 for controls (p < 0.001); revision lowest at 5 yr with cemented (1.5%) and hybrid (1.2%) components, highest with uncemented (7.1%) and resurfacing (11.5%) prostheses	THA is a safe and effective treatment in this population despite a higher revision rate; cemented and hybrid implants have lowest revision rate
Morin[36] (2016)	40 THAs in 33 patients with non-ambulatory CP	IV	19.16 (13.5 to 31.67)	Trochanteric osteotomy (40)	Upper femoral shaft shortening (40, 35 fixated with cement and 5 supplemented with a 4-hole plate with unicortical screws)	Hip spica cast (23)	Hybrid total hip arthroplasty (37), uncemented total hip arthroplasty (3), dual-mobility articulation (40)	5.25 (0.75 to 12.25)	Pneumonia (1), mesenteric artery syndrome (1), acetabular loosening with HO (1), metaphyseal fractures managed in traction (2), femoral cortex resorption (1), HO (1), deep periprosthetic infection requiring reoperation (3), femoral osteotomy nonunions requiring bone-grafting and internal fixation (2), greater trochanteric nonunion requiring fixation (1), HO requiring resection (1), disassembly between the	Pain greatly improved and range of motion somewhat improved; functional status remained the same	6 revisions	THA combined with femoral osteotomy in this population led to excellent pain relief

									femoral neck and inner head (1)			
Houdek[34] (2017)#	39 THAs in 39 patients with CP (all GMFCS I-IV) and 78 matched controls**	III	49 (21 to 74)	Anterolateral (19), posterior (20)	Adductor (7) and psoas (2) tendon releases, femoral head structural allograft for acetabular augmentation (4)	NA	Dual-mobility articulations (5), lipped liners (2), cemented femur (17), uncemented femur (22), uncemented acetabulum (39)	3 (0.33 to 8)**	CP vs. control cohort: dislocation (3 vs. 3; p = 0.66), infection (1 vs. 2; p = 1.0), acetabular loosening (2 vs. 3; p = 1.0), wound complications (1 vs. 3; p = 1.0), HO (1 vs. 4; p = 0.66), DVT (1 vs. 0; p = 0.33), and periprosthetic fracture (0 vs. 7; p = 0.09)	All patients had severe or moderate pain preoperatively and none did postop. (p < 0.0001); all 9 patients with CP with preoperative hip flexion contractures of ≥15° had correction of their flexion contractures, and 22 of patients with CP had improvement in ability to walk; both groups had large improvements in their Harris hip scores	CP group vs. control: 92% vs. 97% at 2 yr, 88% vs. 95% at 5 yr, 81% vs. 90% at 10 yr, and 81% vs. 68% at 15 yr postop. (p = 0.80)	THA provides a durable option for pain relief and functional improvement for patients with CP who are ambulatory
Molenaers[35] (2017)	37 complex THAs in 29 patients (9 with CP of unknown ambulatory status)	IV	35 (15 to 85)**	Direct anterior (37) with proximal extension of acetabular exposure (24)**	NA	NA	Uncemented acetabulum (37), cemented femur (24), uncemented femur (13)**	3.3 (1 to 5)**	Early anterior dislocation requiring open reduction (1), deep infection requiring irrigation and debridement with liner exchange (1)	Harris hip scores: good (4), excellent (13); 84% satisfied or very satisfied**	100% survivorship	Complex THAs in this population can safely be performed by the DAA, with extension of the approach if needed

*LOE = Level of Evidence, THA = total hip arthroplasty, CP = cerebral palsy, PFR = proximal femoral resection, NA = not available, HO = heterotopic ossification, CAD = computer-assisted design, UTI = urinary tract infection, HA = hydroxyapatite, THR = total hip replacement, GMFCS = Gross Motor Function Classification System, DVT = deep venous thrombosis, DCP = dynamic compression plate, CNSI = central nervous system injury, PROM = patient-reported outcome measure, OHS = Oxford Hip Score, EQ-5D = EuroQol-5 Dimension, and DAA = direct anterior approach. †Studies are in order of the year of publication; the data presented are specific to study subpopulations with CP undergoing THA if multiple subpopulations or surgical procedures were studied and data were presented separately. ‡The values are given as the mean in years, unless otherwise noted, with the range in parentheses. §The values in parentheses are given as the number of patients or hips. #These studies contained additional patients without CP. **These studies included patients without CP. ††Only the abstract for this article was reviewed, as the article was in German.

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TABLE E-2 Summary of Literature Analyzing Total Hip Arthroplasty in Patients with Parkinson Disease*

Study	Patients	Reason for THA†	LOE	Age‡	Surgical Approach†	Additional Procedures†	Implants†	Follow-up‡	Complications†	Outcomes	Survivorship	Conclusions
Cabanela[45] (2000) and Weber[46] (2002)	107 THAs (74 primary and 33 revision) in 98 patients with PD	Primaries: osteoarthritis (58), femoral neck fracture (7), femoral neck nonunion (5), osteonecrosis after femoral neck fracture (4); revisions: failure of femoral endoprosthesis (19), aseptic loosening (10), prosthetic femoral neck failure (2), failed cup arthroplasty (1), and failed resection arthroplasty (1)	IV	72 (57 to 87)	Anterolateral (56), transtrochanteric (36), posterolateral (12), and direct lateral (3)	Adductor tenotomy (7), psoas tenotomy (1)	16 types of acetabular and 17 types of femoral component designs were used; cemented stem (103), cemented cup (94)	7.1 (2 to 21)	Dislocation (6, all within 3 mo postop., only 1 treated operatively, and all were after revision THA), trochanteric nonunion (4), DVT (3), hematoma (1), UTI (8), pneumonia (3), transient peroneal neuropathy (2), cerebrovascular accident (2), postoperative confusion (4), ileus (1), gastrointestinal hemorrhage (1), pulmonary emboli (2), and deep infection (1). 4 patients died of pneumonia (2), cerebrovascular accident (1), and massive pulmonary embolus (1)	Function improved 1 yr postop. but then declined by final follow-up with increased limping and use of gait aids in conjunction with worsening PD; 51 patients had died and 57% of patients progressed to stage IV or V; pain relief present in 93% of patients	93% at 5 yr	THA in patients with PD is indicated for painful hip arthritis for pain relief but is associated with higher rate of medical complications and postop. mortality with low rate of dislocation in primary THA and inevitable deterioration of functional status due to progression of PD
Meek[44] (2006)§	THAs from the Scottish National Arthroplasty Project, 1,467 with follow-up data on patients with PD#	NA	IV	NA	NA	NA	NA	NA	Dislocation (2)	No association between PD and postop. dislocation, with only 2 dislocations recorded in 1,467 THAs performed on patients with PD with available follow-up data, for an annual dislocation	NA	THA is a good option for patients with PD; constrained articulation should not be the first treatment

										rate of 0% to 0.46%		
Mathew[47] (2013)	12 primary THAs in 11 patients with PD	Proximal femoral fracture (9), osteonecrosis (2)	IV	76 (66 to 83)	Anterolateral Watson-Jones approach (12)	NA	Cemented acetabulum (12), cemented stem (10), uncemented stem (2)	3 (1 to 5)	UTI (5), cognitive impairment (3), pressure ulcers (2), periprosthetic fractures (3), and death (3)	Of 12 THAs, 10 were completely painless and 2 were mildly painful; 8 of 11 patients had progression of PD	No revisions	THA implantation is possible in patients with PD, but hemiarthroplasty may be indicated in patients with higher degree of debility
Jämsen[43] (2014)§	857 primary THAs (297) or TKAs (560) in patients with PD matched 3:1 with 2,571 controls using the nationwide Finnish health registers#	NA	III	72 (NA)	NA	NA	Cemented THA (165), others not specified	6	18 (6.1%) of 297 of THAs in patients with PD sustained a dislocation, with 10 of these occurring within 1 yr postop.	Patients with PD had longer hospital stays and increased risk of dislocation ($p < 0.05$), but there was no difference in infection, revision rates, or 1-yr mortality rates ($p > 0.05$); >65% mortality rate at 10 yr postop.	96.8% at 3 yr postop.	Patients with PD do not have increased perioperative mortality; perioperative hospitalization is longer and the rates of complications are higher, with poorer long-term prognosis
Park[48] (2014)§	19 THAs in 19 patients with PD (4) or other causes of neuromuscular weakness#	Femoral neck fractures (19)#	IV	72.6 (62 to 81)#	2-incision (19)#	NA	Uncemented acetabulum (19, M2a-Magnum, Biomet), uncemented femur (19, M/L Taper, Zimmer)#	1.5 (1 to 1.5)#	UTI (2), pneumonia (1), postoperative delirium (3), HO (2)#	Mean HHS of 81.0 and mean WOMAC score of 42.9#	100%#	THA using MoM articulation can lead to early recovery and low complications in this population#
Woelber[49] (2016)	2 staged THAs in 1 patient with PD diagnosis after THA	Osteoarthritis	V	46	NA	NA	MoM THAs	1.67	Worsening of underlying PD with metallosis (serum Co 116 μg/L) necessitating DBS placement and revision of bilateral	Patient's PD symptoms improved dramatically following revision THA	0%	Because of family history of PD, response to levodopa, and results of testing, patient likely had underlying PD

									THAs to ceramic on polyethylene			exacerbated by MoM implants; link is speculative
Lazennec[50] (2018)	Primary (42) and revision (21) THAs in 59 patients with PD	Primary: osteoarthritis (42); revision: recurrent dislocation (11), severe acetabular polyethylene wear (6), femoral loosening (4)	IV	72.5 (55 to 79)	NA	NA	Cementless THA with dual-mobility articulation (all primaries), cemented stem (4 revisions)	8.3 (4 to 14)	Complications included cognitive impairment in 12 patients, pneumonia in 3 patients, UTIs in 7 patients, 1 sacral pressure ulcer, 1 intraprosthetic hip dislocation requiring revision, and 4 periprosthetic femoral fractures requiring internal fixation	Good to excellent pain relief in 53 of 57 patients; disability had increased in 68% of patients	1 revision; survivorship free of revision, reoperation, and dislocation was 79.7% at 5 yr postop.	Primary and revision THA using this technique has satisfactory outcomes, although PD symptoms do increase over time
Newman[51] (2018)§	10,528 THAs in patients with PD matched 1:3 with controls from the Nationwide Inpatient Sample (NIS) database#	NA	IV	73 (NA)	NA	NA	NA	Inpatient stay only	Patients with PD more commonly had postoperative delirium ($p < 0.0001$), altered mental status ($p = 0.007$), UTI ($p = 0.007$), and blood transfusion ($p < 0.0001$)	Patients with PD had more medical complications (OR, 1.54; $p < 0.0001$), longer length of stay ($p < 0.0001$), and higher charges per admission ($p < 0.0001$)	NA	Orthopaedic surgeons and neurologists should be involved in preoperative counseling of patients with PD before THA to help optimize care
Rondon[52] (2018)	52 THAs and 71 TKAs in patients with PD matched 1:2 with control group	NA	III	68.7 (NA)	NA	NA	NA	5.3 (NA)	THA in patients with PD failed because of periprosthetic fracture (4), dislocation (4), aseptic loosening (4), deep joint infection (1), and wear (1)	Patients with PD had 11.05 times higher odds of undergoing THA revision ($p = 0.0003$) than their matched controls, with increased risk of periprosthetic fracture (7.7% vs. 0%,	Survivorship free of revision for THA in patients with PD was 94.3% at 2 yr, 85.3% at 5 yr, and 78.7% at 10 yr postop., which was worse than for patients	Patients with PD can demonstrate appropriate postop. functional improvements after THA but not as high as patients without PD and with a higher complication and revision rate

										p = 0.0013) and dislocation (7.7% vs. 0.0%, p = 0.0013); postop. SF-12 scores improved in both groups but improved more in non-PD group (p = 0.029), with better mean preop. (p = 0.001) and postop. scores in non-PD group (p = 0.001 to 0.004)	without PD (p = 0.0024)	

*THA = total hip arthroplasty, LOE = Level of Evidence, PD = Parkinson disease, DVT = deep venous thrombosis, UTI = urinary tract infection, NA = not available, TKA = total knee arthroplasty, HO = heterotopic ossification, HHS = Harris hip score, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, MoM = metal-on-metal, DBS = deep brain stimulator, OR = odds ratio, and SF-12 = Short Form-12. †The values in parentheses are given as the number of patients or hips. ‡The values are given as the mean in years, with the range in parentheses. §These studies contained additional patients without PD. #This includes patients without PD.

TABLE E-3 Summary of Literature Analyzing Total Hip Arthroplasty in Patients with Central Nervous System Injury*

Study	Patients†	LOE	Age‡	Surgical Approach†	Additional Procedures†	Postoperative Immobilization†	Implants†	Follow-up‡	Complications†	Outcomes†	Survivorship	Conclusions
Becker[56] (2003)	6 THAs in 5 patients with paraplegia due to spinal cord injury with Brooker stage-IV HO	IV	41.3 (23 to 57)	Anterior incision for partial HO excision and separate lateral incision to complete HO resection and implant THA (6)	HO prophylaxis (6, 6-Gy preop. radiation and 6 wk postop. indomethacin)	NA	Cemented THA with "semi-captive cup"	1 (0.5 to 2)	None	Brooker grade I and II HO at final follow-up	100%	Authors recommended HO prophylaxis and the use of THA for treatment of hips ankylosed by HO with degenerative joints in this population
DiCaprio[57] (2004)	31 primary THAs performed for osteoarthritis in 22 patients with previous CVA	IV	68 (43 to 84)	Modified anterior exposure	7 patients with risk factors for HO received HO prophylaxis in the form of 700 cGy radiation within 36 hr postop.	NA	Hybrid THA (24), uncemented (4)	2.9 (1 to 6.7)	36% of patients had HO with severe Brooker III and IV HO in 22% of patients; 0 patients receiving HO prophylaxis developed HO	High HHS (86) and no functional limitations except in the patients sustaining Brooker stage-IV HO	100%	Patients with previous CVA are at potentially increased risk of HO after total hip arthroplasty and HO prophylaxis with either radiation or nonsteroidal anti-inflammatory drugs should be considered in this population
Meek[44] (2006)§	THAs from the Scottish National Arthroplasty Project, 7,795 with follow-up data on patients with CVA#	IV	NA	NA	NA	NA	NA	NA	Dislocation (11)	No association between CNSI and postop. dislocation, with only 11 dislocations recorded in the 7,795 THAs performed on patients with previous CVA and available follow-up data, for an annual dislocation	NA	THA is a good option for patients with CVA; low dislocation rate is perhaps due to lower rate of mobilization postop.; constrained articulation should not be the first treatment

										rate of 0% to 0.4%		
Tudor[30] (2013)§	11 resurfacing arthroplasties in 9 patients with CP (4), CNSI (2), or other neuromuscular conditions (3)#	IV	33.1 (13 to 49)#	Posterolateral (11)#	Adductory tenotomy (1)	Abduction pillow (1), broomstick cast (1)	Unspecified resurfacing#	63.7 (41 to 89)#	None	Slight pain with improvement in GMFCS level from IV to III (1), no pain with maintenance of GMFCS level IV (1); high satisfaction (2)	No revisions	Hip resurfacing is a viable option that confers greater stability compared with THA
Alosh[31] (2014)§	30 primary THAs in patients with CP (12) or acquired spasticity (15: TBI [9], CVA [3], spinal cord injury [1], and multiple sclerosis [2])#	IV	48.6 (29.1 to 75.0)#	Posterolateral (30)#	Adductor tenotomy (4), flexor lengthening (1), HO excision (6), split tibialis anterior transfer (5)	Abduction pillow and knee immobilizer (30), abduction brace (5)#	Uncemented THA (30)#	2.7 (2.1 to 12.1)#	Wound drainage requiring irrigation and debridement (1), recurrent HO requiring resection (1), periprosthetic infection requiring resection arthroplasty (1)	Most patients improved GMFCS level	1 revision	THA can markedly improve pain, function, and mobility in patients with upper motor neuron disorders, with low rates of instability even without constrained liners
Park[48] (2014)§	19 THAs in 19 patients with CVA (15) or other causes of neuromuscular weakness#	IV	72.6 (62 to 81)#	2-incision (19)#	NA	NA	Uncemented acetabulum (19, M2a, Magnum, Biomet), uncemented femur (19, M/L Taper, Zimmer)#	1.5 (1 to 1.5)#	UTI (2), pneumonia (1), postop. delirium (3), HO (2)#	Mean HHS of 81.0 and mean WOMAC score of 42.9#	100%#	THA using MoM articulation can lead to early recovery and low complications in this population#

*LOE = Level of Evidence, THA = total hip arthroplasty, HO = heterotopic ossification, NA = not available, CVA = cerebrovascular accident, HHS = Harris hip score, CNSI = central nervous system injury, CP = cerebral palsy, GMFCS = Gross Motor Function Classification System, TBI = traumatic brain injury, UTI = urinary tract infection, HHS = Harris hip score, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, and MoM = metal-on-metal. †The values in parentheses are given as the number of patients or hips. ‡The values are given as the mean in years, with the range in parentheses. §These studies included additional patients without CNSI. #This included patients without CNSI.