Impact of Movement Disorders on Management of Spinal Deformity in the Elderly

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Spinal deformities are frequent and disabling complications of movement disorders such as Parkinson disease and multiple system atrophy. The most distinct spinal deformities include camptocormia, antecollis, Pisa syndrome, and scoliosis. Spinal surgery has become lower risk and more efficacious for complex spinal deformities, and thus more appealing to patients, particularly those for whom conservative treatment is inappropriate or ineffective. Recent innovations and advances in spinal surgery have revolutionized the management of spinal deformities in elderly patients. However, spinal deformity surgeries in patients with Parkinson disease remain challenging. High rates of mechanical complications can necessitate revision surgery. The success of spinal surgery in patients with Parkinson disease depends on an interdisciplinary approach, including both surgeons and movement disorder specialists, to select appropriate surgical patients and manage postoperative movement in order to decrease mechanical failures. Achieving appropriate correction of sagittal alignment with strong biomechanical instrumentation and bone fusion is the key determinant of satisfactory results.

KEY WORDS: Movement disorders, Parkinson disease, Spinal deformity

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Increasing economic prosperity, improved social welfare, and modern medicine are increasing the average life expectancy in developed nations.[1] Therefore, the prevalence of movement disorders resulting from degenerative brain disease is increasing.[2] The overall prevalence of all common categories of movement disorders has been reported to be approximately 28% in individuals 50 years of age or older, and this prevalence increases sharply with more advanced age.[2,3] The most common of these movement disorders include tremor (14.5%), restless legs syndrome (10.8%), Parkinson disease (PD) (7%), primary and secondary dystonia (1.8%), and chorea and tics (<1% each).[2]

The prevalence of spinal disorders that may warrant surgical treatment is markedly increasing as populations continue to age in developed countries.[4] Substantial advancements have been made in surgical techniques and anesthetic knowledge during the past couple decades; nonetheless, elderly patients continue to face greater risks of morbidity with spine surgery. Furthermore, some procedures may have less favorable outcomes in the elderly as compared to younger patients.[5] Movement disorders are among the many comorbidities that may negatively impact the outcomes of spine surgery in the elderly.[3,6] Previous reports have documented a series of patients with movement disorders treated surgically for spinal pathology, and the rates of complications associated with these procedures are high (33%-86%), especially for cases in which instrumented arthrodesis is necessary.[3,7,8]

A recent review of the literature on postural deformities in PD demonstrated that spinal deformities are very common in this population and include several different types of deformities. The prevalence of sagittal plane deformities such as camptocormia were reportedly from 3% to 30%, and drop head syndrome was reported to be 5.8%.[9-13] Coronal plane deformities such as scoliosis were reported in 9% to 60% and Pisa syndrome was present in 2% of patients with PD.[14] Unfortunately, these postural deformities are often not responsive to Levodopa (L-dopa)-based medical treatment. Postural deformities may have a significant negative impact on patient functional status, even when typical PD symptoms (tremor and rigidity) are well controlled with medical treatment. Corrective

TABLE 1. Parkinson Disease (PD) and Associated Spinal Deformity

Postural Deformity	Definition	Prevalence in PD (%)
Sagittal plane deformity		
Camptocormia	Marked (minimum 45 degrees) flexion in the thoracolumbar spine laterally, almost complete resolution in the supine position	3-18
Antecollis	Marked (minimum 45 degrees) neck flexion, unable to fully extend the neck against gravity	5-6
Coronal plane deformity		
Pisa syndrome	Marked (minimum 15 degrees) lateral flexion that can be alleviated by passive mobilization or supine positioning	2
Scoliosis	Lateral flexion not relieved by voluntary or passive movement and lateral curvature of the spine of at least 10 degrees as measured by the Cobb method	9-91

surgery for these deformities may be an option for many of these patients as a means of improving quality of life.

This review provides an update on the general characteristics of postural deformities encountered in PD and discusses potential indications for surgical treatment, including specific preoperative and postoperative considerations. In addition, reported surgical outcomes are reviewed, and areas that require further study are highlighted.

GENERAL CHARACTERISTICS OF PD AND ASSOCIATED SPINAL DEFORMITY

PD is a progressive neurodegenerative disorder characterized by bradykinesia, resting tremor, cogwheel rigidity, and postural instability.[15,16] PD is a lifelong, incurable, yet nonfatal disease; disease progression leads to reduced quality of life and increasing healthcare burden.

The prevalence of spinal deformity in PD is higher than that of age-matched adults without PD.[17] In addition, the magnitude of spinal deformity in PD is proportional to the severity of PD.[18] The etiology of spinal deformity in PD is likely multifactorial.[10] Contributing factors may include dystonia, rigidity, proprioceptive disintegration, myopathy, enhanced degenerative spinal changes, drugs, and soft tissue changes.[10] Therefore, when managing spinal deformity in the setting of PD, it is important to consider the interplay of the 2 pathologies. Patients with concomitant PD and spinal deformity may have less capacity for compensation than those without PD.[18] The most distinct spinal deformities in PD include camptocormia, antecollis, Pisa syndrome, and scoliosis (Table 1).[10]

Camptocormia

James Parkinson[19] first described the stooped or bent posture of patients with PD. The term camptocormia in PD refers to abnormal flexion of the thoracolumbar spine during standing and walking that abates or disappears in the recumbent position (Figure 1A).[20-22] Camptocormia is also referred to as bent spine syndrome. There is no consensus regarding the criteria for diagnosis of camptocormia. Epidemiological studies have suggested that the prevalence of camptocormia is higher in Asian patients, which could reflect a genetic difference in skeletal shape and other characteristics between different ethnic groups.[23] Patients with camptocormia also tend to be older.[24] On average, camptocormia tends to present 7 to 8 years after the onset of PD.[20,21,24-27]

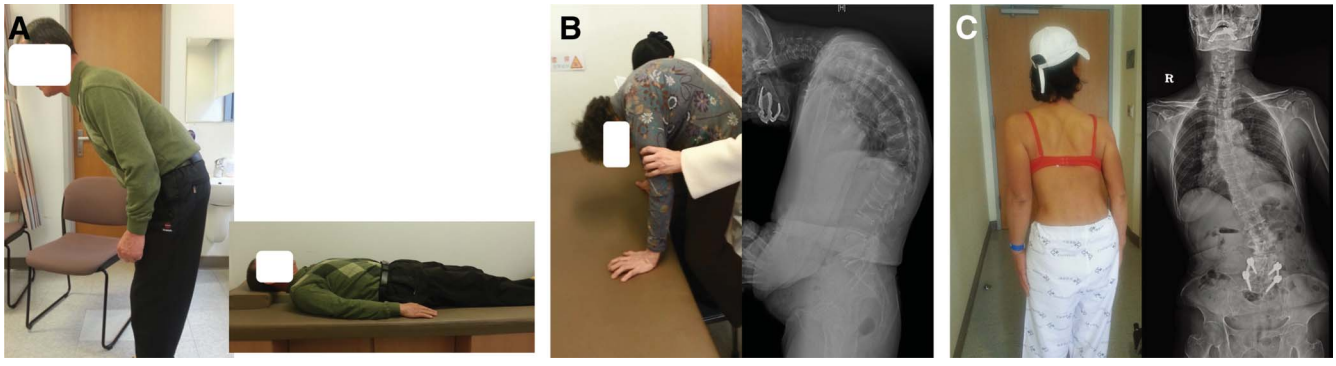

FIGURE 1. *Representative images of patients with Parkinson disease exhibiting sagittal plane deformities (**A**, camptocormia and **B**, antecollis) and coronal plane deformities (**C**, Pisa syndrome).*

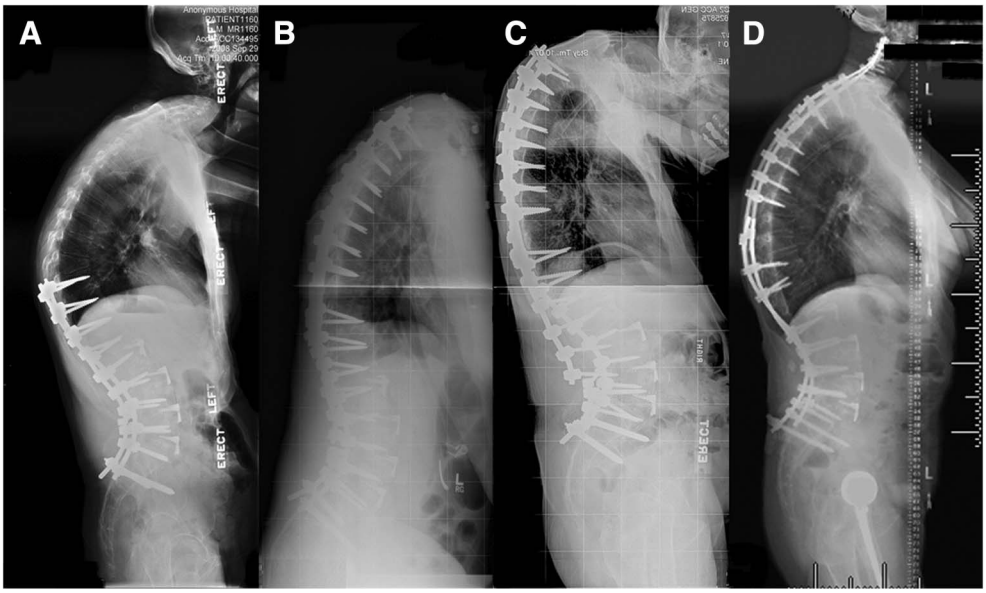

FIGURE 2. *Representative case example of a patient with Parkinson disease with initial failure to restore sagittal balance.* **A**, *failure to restore sagittal alignment after fusion from T-10 to the pelvis.* **B**, *patient underwent a posterior instrumented fusion from upper thoracic to the pelvis.* **C**, *proximal junctional failure after fusion from upper thoracic to the pelvis.* **D**, *successful correction of sagittal alignment after extension to C2.*

Antecollis (Drop Head Syndrome)

Antecollis refers to a forward flexion of the head and neck (Figure 1B). The term dropped head syndrome is sometimes used to describe marked neck flexion, but is more often reserved for neuromuscular disorders such as polymyositis, myasthenia gravis, and motor neuron disease.[28] The prevalence of antecollis in PD has been reported to be approximately 6%.[29,30]

Pisa Syndrome and Scoliosis

Pisa syndrome is characterized by lateral flexion of the trunk when sitting or standing, similar to the Leaning Tower of Pisa (Figure 1C).[10] This postural deformity was first described as a truncal dystonia or pleurothotonus, occurring as a side effect of neuroleptic medications.[31] More recently, Pisa syndrome has been described in PD, and some consider it to be a precursor to the development of scoliosis.[10,32]

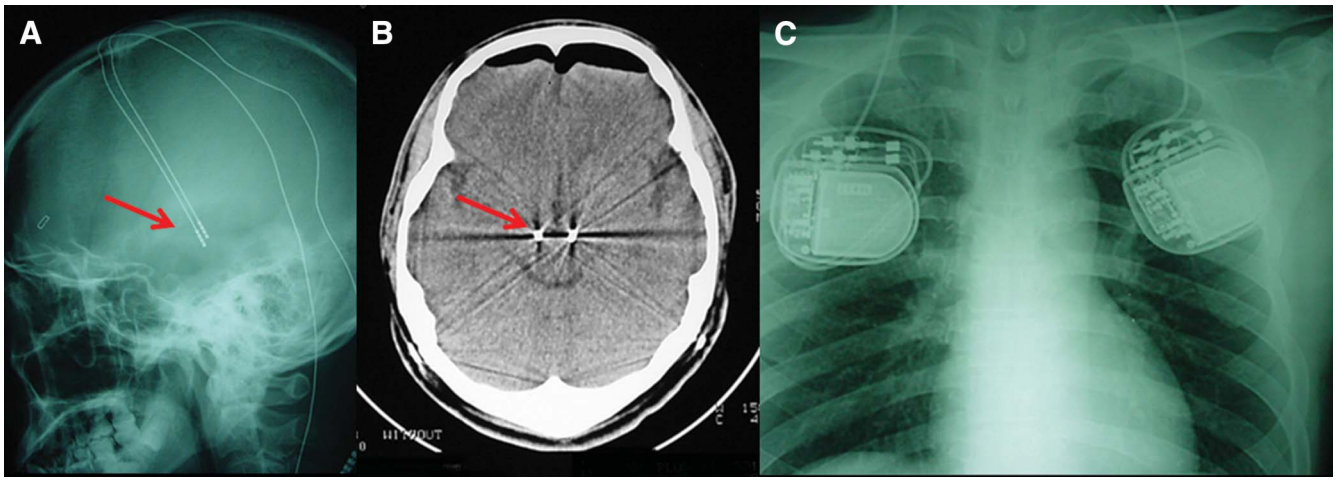

FIGURE 3. *Plain skull radiograph (*A*) and brain computed tomographic scan (*B*) demonstrating deep brain stimulator electrodes (arrow) implanted in both subthalamic nuclei in PD. Chest radiograph (*C*) showing implant pulse generators, which send electrical impulses through the implanted electrodes to specific parts of the brain.*

TABLE 2. Deep Brain Stimulation for Camptocormia: Literature Review[a]

Reference	Type of Report	Patient, Age, Sex	Etiology of Camptocormia, Procedure	Improvement of Camptocormia, Follow-up Duration (mo)
Nandi et al,[66] *Neurosurg Focus*, 2002	Case report	1 patient, 39, M	Camptocormia in dystonia (tardive)	Marked improvement
			Bilateral GPi DBS	6 mo
Micheli et al,[71] *J Neurosurg*, 2005	Case report	1 patient, 62, M	Camptocormia in PD	90%
			Bilateral GPi DBS	14 mo
Azher and Jankovic,[20] *Neurology*, 2005	Case report	1 patient, n.a.	Camptocormia in PD	No improvement of camptocormia
			Bilateral STN DBS	PD symptoms improved
Hellman et al,[72] *Mov Disord*, 2006	Case report	1 patient, 53, M	Camptocormia in PD	Marked improvement
			Bilateral STN DBS	10 mo
Fukaya et al,[65] *Acta Neurochir Suppl*, 2006	Case report	3 of 36 patients with primary dystonia	Idiopathic camptocormia, camptocormia in dystonia	92.2% (±5.3%)
			Bilateral GPi DBS	14 mo
Yamada et al,[68] *Parkinsonism Relat Disord*, 2006	Case report	1 patient, 71, F	Camptocormia in PD	75%
			Bilateral STN DBS	20 mo
Sako et al,[67] *Mov Disord*, 2009	Case report	6 patients, mean age 60, range 53-71, 2 M 4 F	Camptocormia in PD	78% (±9.1%), Improvement of thoracolumbar angle
			Bilateral STN DBS	17 mo
Umemura et al,[73] *J Neurosurg*, 2010	Analysis	8 patients with camptocormia, 59-79, 2 M 6 F	Camptocormia and Pisa syndrome from PD	Moderate postural abnormality (13 patients)
		10 patients with Pisa syndrome, 58-73, 2 M 8 F	STN DBS for PD	Immediate improvement: 9 patients (1 patient relapsed)
				Gradual improvement: 2 patients
				No improvement: 2 patients
				Severe postural abnormality (5 patients)
				Gradual improvement: 2 patients
				No improvement: 3 patients
Capelle et al,[69] *J Neurol*, 2011	Case report	7 patients, mean age 60, range 39-73, 4 M 2 F	Camptocormia in dystonia (4)	63% (range, 50%-67%)
			Bilateral GPi DBS	14.3 mo
			Camptocormia in PD (3)	19% (range, 0%-33%)
			Bilateral STN DBS (2)	21 mo
			Bilateral GPi DBS (1)	
Sakas et al,[74] *J Neurosurg*, 2010	Case report	2 patients, 26 and 21, 1 M 1 F	Idiopathic dystonic camptocormia	Marked improvement for 44 mo (patient 1) and 42 mo (patient 2) F/U
			Bilateral GPi DBS	
Thani et al,[75] *Neurosurgery*, 2011	Case report	1 patient, 57, F	Camptocormia in PD	Marked improvement in 14 mo F/U
			Bilateral GPi DBS	

(Continues)

TABLE 2. *Continued*

Reference	Type of Report	Patient, Age, Sex	Etiology of Camptocormia, Procedure	Improvement of Camptocormia, Follow-up Duration (mo)
Asahi et al,[76] *Stereotact Funct Neurosurg*, 2011	Case report	4 patients, 60-69, 2 M 2 F	Camptocormia in PD	3 patients: improved
			Bilateral STN DBS	1 patient: no change 18-40 mo
Lyons et al,[77] *Turk Neurosurg*, 2012	Case report	1 patient, 63, F	Camptocormia in PD	Significant and sustained improvement over 5 yr
			Bilateral STN DBS	
Hagenacker et al,[78] *J Neurol*, 2013	Case report	2 patients, 60 and n.a., 1 M 1 F	Camptocormia in generalized dystonia	Marked improvement in patient 1 (2 yr) and patient 2 (1 yr)
			Bilateral GPi DBS	
Reese et al,[79] *Parkinsonism Relat Disord*, 2014	Case report	3 patients, n.a., 1 M 2 F	Camptocormia in primary dystonia	Marked improvement in 3 patients (38-45 mo): mean improvement 82% BFM scale
			Bilateral GPi DBS	
Schulz-Schaeffer et al,[80] *Mov Disord*, 2015	Analysis	25 patients, 54-83 (67.1), 21 M 4 F	Camptocormia in PD	Response: 13 patients
			Bilateral STN DBS	No response: 12 patients

[a]BFM scale, Burke Fahn Marsden Dystonia Rating Scale; DBS, deep brain stimulation; F/U, follow-up; GPi, globuspallidusinternus; n.a., not available; PD, Parkinson disease; STN, subthalamic nucleus.

Scoliosis is defined as a lateral curvature of the spine, usually associated with vertebral rotation. Doherty et al[10] proposed that a diagnosis of Pisa syndrome requires pronounced (at least 10 degrees) lateral flexion, which can be alleviated completely by passive mobilization or in a supine position. They indicated that the term scoliosis should be reserved for patients whose posture cannot be substantially improved by passive movement or supine positioning, and who have radiological evidence of a structural curve with axial vertebral rotation that persists when the effect of gravity has been eliminated.[10] Notably, scoliosis is more common in patients with PD than in the general elderly population, with a prevalence ranging from 8.5% to 60% in PD.[11,33-36]

PREOPERATIVE ASSESSMENT OF PD PATIENTS WITH SPINAL DEFORMITY

Spinal surgery may be considered for correction of postural deformity in patients with PD, particularly when medical treatments have failed. The general surgical indications for spinal deformity correction in patients with PD are not substantially different from the indications for patients without PD. However, there are special considerations that need to be taken into account in planning deformity surgery in PD patients, which are discussed below. And it is also important to discuss these considerations with movement disorder specialists before spinal surgery planning.

Spinal Alignment

Optimal alignment of bone structures is functionally important in the musculoskeletal system, and the complex interaction of the neuromuscular system is necessary for ergonomic balance and deliberate displacement of the human body.[37] Today, the importance of sagittal alignment for the treatment of spinal disorders is widely recognized and is an important part of spinal surgery planning.[37-53]

Incomplete correction of spinopelvic alignment in PD patients can cause intractable sagittal imbalance due to the disease-related forward "pull" of the trunk and gravity line. The degree of postural instability correlates with increasing severity of neuromuscular disease, which can lead to further exacerbation of insufficiently corrected spinopelvic alignment (Figure 2: Representative case example of PD patient with failed restoration of sagittal balance).[54]

Previous studies have shown that the severity of sagittal and coronal malalignment in PD is correlated with the severity of PD.[12,18] Greater severity of PD is associated with a higher prevalence of sagittal spinopelvic malalignment, even after adjusting for the effects of age, sex, and duration of PD. In addition, the severity of PD is associated with increased magnitude of coronal Cobb angle (scoliosis), suggesting that progression of PD is a risk factor for worsening of coronal and sagittal deformity. These results imply that neuromuscular pathology of PD may interact with the age-associated degenerative cascade to induce deformity.

TABLE 3. Surgical Indications of Corrective Spinal Deformity Surgery in Parkinson Disease (PD)

1. Medically (L-dopa) unresponsive spinal deformity in PD
2. Marked disability associated with spinal deformity, which is not responsive to conservative management
3. Good functional performance

Sway

Sagittal alignment reflects the anatomic shape of the spine during standing, but in assessing sagittal balance, we should also consider a dynamic factor.[55] Patients with PD have characteristically poor postural stability, often presenting with greater oscillations in the standing position and a significantly higher risk of falling.[56] Long spinal fusion in a PD patient who has intrinsic loss of stability could achieve appropriate alignment, but poor balance and instability can still lead to repeated catastrophic falls. Thus, postural instability should be carefully assessed when treating PD patients with sagittal imbalance.[55]

Bone Quality

PD and osteoporosis are both chronic diseases associated with increasing age. Osteoporosis describes a reduction in bone mineral density (BMD), which places those affected at increased risk of fragility fractures, particularly those involving the hips, wrist, and spine. A meta-analysis of 23 studies showed that patients with PD are at significantly higher risk of osteoporosis (OR 2.61; 95% CI 1.69-4.03) compared with healthy controls, and that PD patients are also at significantly increased risk of osteoporosis-related fractures (OR 2.28; 95% CI 1.83-2.83).[57]

Muscular Weakness

PD patients tend to have a weak posterior muscular tension band, resulting in a flexed or stooped posture. This feature makes the biomechanics of a long lever arm at the lumbosacral junction particularly unfavorable. Therefore, for longer spinal instrumentation constructs, it is necessary to use additional sacral fixation points or iliac screw fixation.[58,59] In addition, L5-S1 interbody grafting to enhance fusion rates at the lumbosacral junction should be strongly considered.[58,59]

Levodopa (L-dopa)

L-dopa is used to increase dopamine concentration in the treatment of PD. It is effective against rigidity and tremor, but provides less benefit for bradykinesia, balance, and gait. L-dopa tends to be very effective in the early stages of PD, but it is typically necessary to increase the dose gradually over time to maintain the maximum benefit. Increased doses of L-dopa are associated with greater side effects. It is well known that L-dopa-induced dyskinesia involves hyperkinetic movements, including chorea, dystonia, and athetosis.[60] Although there is no clear explanation for the relationship between L-dopa treatment and the progression of spinal deformity in PD, it is possible that L-dopa-induced neuromuscular changes may negatively impact neuromuscular competency and indirectly affect spinal structural

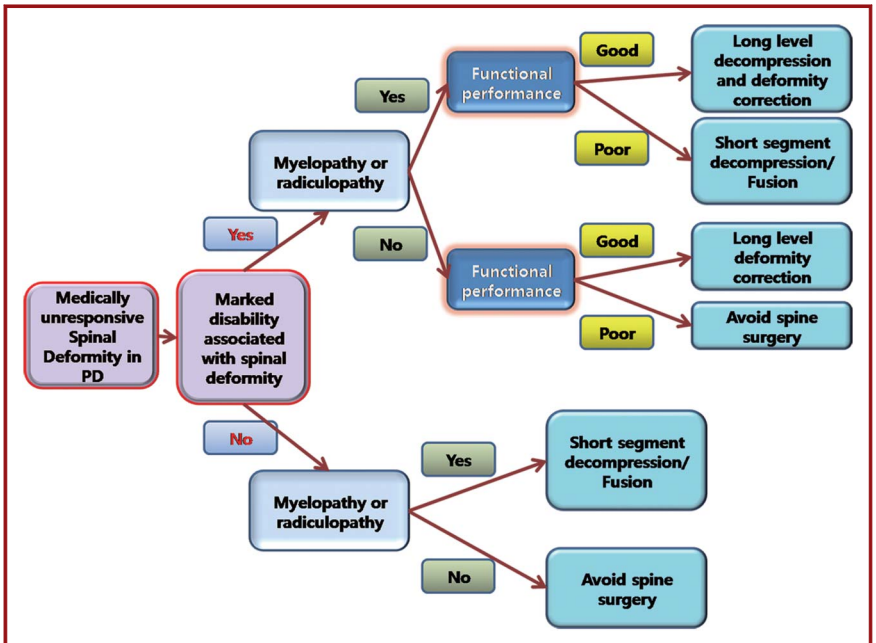

FIGURE 4. *Suggested surgical decision algorithm for spinal deformities in patients with Parkinson disease (PD).*

TABLE 4. Spine Surgery for Patients With Parkinson Disease (PD): Literature Review

Reference	Type of Report	No. of Cases	Age/Sex	Type of Disease	Type of Surgical Procedures
Babat et al,[3] *Spine (Phila Pa 1976)*, 2004	Analysis	14	71.3 (51-79)/3 M, 11 F	Stenosis to deformity	Decompression
					Limited fusion
					Deformity correction
Peek et al,[81] *J Neurol Neurosurg Psychiatry*, 2009	Case report	1	55/M	Camptocormia	Deformity correction
Wadia et al,[82] *J Neurol Neurosurg Psychiatry*, 2011	Case report	2	69/M	Camptocormia	Deformity correction
			77/M		
Koller et al,[54] *Eur Spine J*, 2010	Analysis	23	66.3 (57-76)/8 M, 15 F	Global sagittal imbalance: 18 patients, 78.3%	Deformity correction
				Scoliosis: 10 patients, 43.5%	
Moon et al,[6] *J Spinal Disord Tech*, 2012	Analysis	20	65.2 (48-81)/8 M, 12 F	Lumbar spinal stenosis: 8 patients, 40%	Decompression and fusion
				Degenerative listhesis: 6 patients, 30%	
				Herniation of lumbar disc: 4 patients, 20%	
				Degenerative lumbar scoliosis: 2 patients, 10%	
Bourghli et al,[8] *J Spinal Disord Tech*, 2012	Analysis	12	68/2 M, 10 F	Spinal deformity	Deformity correction
Sato et al,[83] *Case Rep Orthop*, 2013	Case report	2	70/F, 70/F	Kyphoscoliosis, camptocormia	Deformity correction

Reference	Level of Surgery	Follow-up (mo)	Outcome (Satisfaction Rate)	No. Revision Surgery	Complications
Babat et al,[3] *Spine (Phila Pa 1976)*, 2004	—	66.8	—	12	Instrumentation failure (4)
					Infection (2)
					Additional surgery (for instability, decompression) (11)
Peek et al,[81] *J Neurol Neurosurg Psychiatry*, 2009	T7-ilium	29	Good	2	Rod fracture, screw loosening
Wadia et al,[82] *J Neurol Neurosurg Psychiatry*, 2011	T3-pelvis	>5 yr	Good	2	Instrument failure (2)
		>3 yr		1	Rod fracture (1)
Koller et al,[54] *Eur Spine J*, 2010	18 patients: mean of 6.1 ± 4.3 levels (range, 1-16)	14.5 (1-59)	Satisfaction rate (78%)	6 patients (33%)	Medical complication (7, 30.4%)
	19 patients: 82.6%): fusion to the sacrum			3 patients: 1 revision	Surgical complication (12, 52.2%)
	4 patients (17.4%): S2 screws			3 patients: 2 revision	
	3 patients (16%): iliac fixation				
Moon et al,[6] *J Spinal Disord Tech*, 2012	1 level: 14	56.7 (26-118)	Good: 1 patient 5%	1	Screw pull out (1)
	2 level: 5		Fair: 5 patients 25%		
	3 level: 1		Poor: 14 patients 70%		

(Continues)

TABLE 4. *Continued*

Reference	Level of Surgery	Follow-up (mo)	Outcome (Satisfaction Rate)	No. Revision Surgery	Complications
Bourghli et al,[8] *J Spinal Disord Tech*, 2012	T2-pelvis	32.8 (26-45)	Satisfaction rate (92%)	6	Instrumentation failure (3) Proximal junctional kyphosis at T1-T2 (2) Epidural hematoma (1)
Sato et al,[83] *Case Rep Orthop*, 2013	T4-pelvis	12	Good	0	None

integrity.[18] In addition, after spinal fusion, patients with dyskinesia have higher rates of compression fracture, pseudarthrosis, and rod fracture. Therefore, both surgeons and movement disorder specialists should closely follow these patients in order to monitor and optimize postoperative control of dyskinesia.

Deep Brain Stimulation (DBS)

DBS of the posteroventral lateral globuspallidus internus and the subthalamic nucleus has been established as a powerful tool in the treatment of refractory primary dystonia and advanced PD (Figure 3).[61-64] However, the use of DBS for camptocormia remains controversial.[65-69] Some articles suggest that spinal surgery should only be offered to PD patients with coexisting spinal stenosis causing radiculopathy or myelopathy. In contrast, patients with PD and camptocormia without spinal stenosis may be better treated with DBS.[70] Although favorable effects of DBS on postural deformity have been reported in previous case reports, the surgical outcomes of DBS have not been predictable (Table 2).[10,66,69,70,80] Therefore, it is difficult to recommend DBS as a first-line surgical option ahead of spinal deformity surgery. Perhaps DBS for the treatment of postural deformities would be best considered for the limited cases in which postural deformities demonstrate responsiveness to L-dopa or camptocormia-associated dystonia.

SPINAL DEFORMITY SURGERY

From the spine surgeon's perspective, PD patients with postural deformities are considerably more challenging than other adult patients with deformity. PD patients usually present with radiographic positive sagittal imbalance, similar to nonPD patients. However, because of associated postural abnormalities and increased flexor tone, they often require more extensive procedures often involving fusion from the upper thoracic spine to the ilium. Decompression alone or decompression with limited fusion are generally only indicated in patients with radiculopathy or myelopathy resulting from focal compression and without significant postural deformities.

In addition to assessing spinal alignment, surgeons should carefully consider the functional status of PD patients. The clinical features of PD are very heterogenous and some symptoms (autonomic dysfunction, dementia, etc.) are poorly responsive to L-dopa treatment. Therefore, the best indication for spinal realignment surgery is good functional status with nonspinal PD symptoms that are highly responsive to L-dopa therapy (Table 3). In patients with poor functional status, the role of spinal deformity surgery is limited, and it is not usually recommended. Importantly, the decision to perform surgery for adult spinal deformity is often driven by patient pain, disability, and loss of independence. However, these parameters are often worse in patients with more advanced PD and likely reflect a higher risk of surgical complications. The majority of PD patients with deformity have some combination of sagittal and coronal plane spinal deformity; therefore, when

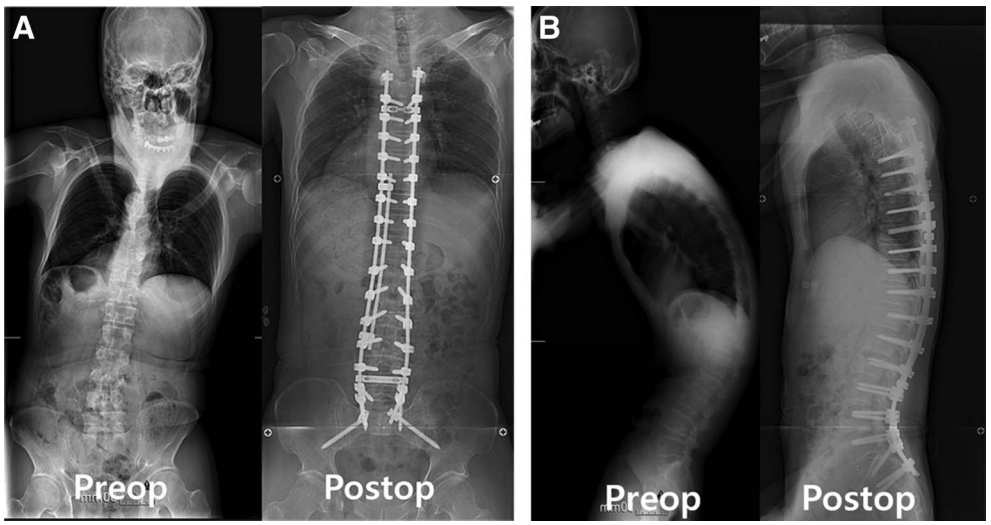

FIGURE 5. *Case illustration of camptocormia. A representative case example of idiopathic camptocormia (**A**, preoperative and postoperative whole spine AP; **B**, preoperative and postoperative whole spine lateral). A 51-year-old male patient presented with intractable back pain, inability to maintain horizontal gaze, and progressive thoracolumbar kyphosis. The patient had a history of L2 compression fracture 2 years prior that healed completely. Back pain and progressive thoracolumbar kyphosis developed 2 years after L2 compression fracture. He was diagnosed with idiopathic camptocormia by a neurologist specializing in movement disorders. He underwent corrective spinal deformity surgery includingT3 to ilium instrumented arthrodesis. Radiographic parameters included pelvic incidence 63 degrees, sacral slope 20 degrees, pelvic tilt 43 degrees, lumbar lordosis 17 degrees, and thoracic kyphosis (T5-T12) 64 degrees.*

surgery is considered, surgeons should carefully assess the causal relationship between spinal deformity and functional disability (Figure 4). Literature on spine surgery in PD patients is summarized in Table 4.

Camptocormia

Camptocormia is typically not considered an L-dopa-responsive phenomenon. If medical treatment and physical therapy do not improve functional abilities, spinal surgery to correct malalignment may be indicated (Figure 5). Because the thoracolumbar junction is affected and treatment requires correction of (often marked) positive sagittal malalignment, the upper-most instrumented vertebra is usually between T2 and T4. In order to help reduce the risk of proximal junctional kyphosis, authors suggest using transverse process hooks at the upper-most instrumented vertebra in camptocormia patients. For patients with marked loss of lumbar lordosis, osteotomies (eg, pedicle subtraction osteotomy, Smith-Petersen-type osteotomy) are often required to restore lumbar lordosis. Inclusion of iliac screw fixation and L5-S1 interbody fusion is very important in order to help reduce the risk of instrumentation failure at the lumbosacral junction. In order to help prevent pseudarthrosis or rod fracture, osteoinductive materials such as bone morphogenetic protein and dual-rod fixation may be helpful. For patients with osteoporosis, perioperative synthetic parathyroid hormone replacement therapy may be beneficial.

Antecollis

Antecollis is a more common feature of multiple system atrophy than PD (prevalence in multiple system atrophy is 42% vs PD is 5.8%).[11,28-30] The prognosis of multiple system atrophy is extremely poor; therefore, when we consider surgical treatment for antecollis, it is critical to have the correct neurological diagnosis and to explain the general prognosis to patients and family.

It has been reported that some patients with PD and dropped head syndrome have improved head position after treatment with L-dopa. However, these results have not been consistent.[29,84,85] Other medical treatments, such as muscle relaxants and botulinum toxin, may be considered for patients with dystonic features. If medical treatment and vigorous physical therapy fail to restore head balance, surgical treatment maybe considered. Surgical treatment may be required for patients with respiratory difficulties or poor oral intake due to compromised mouth opening.

Surgical correction of dropped head syndrome is particularly challenging, even more so than correction of other cervical kyphotic deformities. Progressive weakness of residual neck extensor muscles and upper back muscles leads to compromised biomechanical support and may result in instrumentation failure at the lower instrumented vertebra. Therefore, when considering surgical options for dropped head syndrome, full length standing radiographs should be examined, and the neutral vertebra should be selected as the lower instrumented vertebra.

Pisa Syndrome and Scoliosis

Pisa syndrome may result from adverse effects of L-dopa treatment. Therefore, for patients with Pisa syndrome, modification of medications should be considered first. Other medical treatments, including muscle relaxants or botulinum toxin injection of paraspinal muscles, often improve and may even resolve symptoms. Spinal orthroses usually fail to correct this postural abnormality. Patients with Pisa syndrome who have very mobile and dyskinetic movement are at increased risk of compression fracture in the lower lumbar spine. Due to the mobile nature of Pisa syndrome, compression fractures associated with Pisa syndrome often do not have a benign course. Osteonecrosis and intractable radicular and back pain may require surgical intervention. In cases of compression fracture or marked sagittal imbalance associated with Pisa syndrome, spinal surgery should be cautiously considered (Figure 6). As in other deformity surgeries in PD patients, fusion extending from the upper thoracic spine to the ilium is usually required.

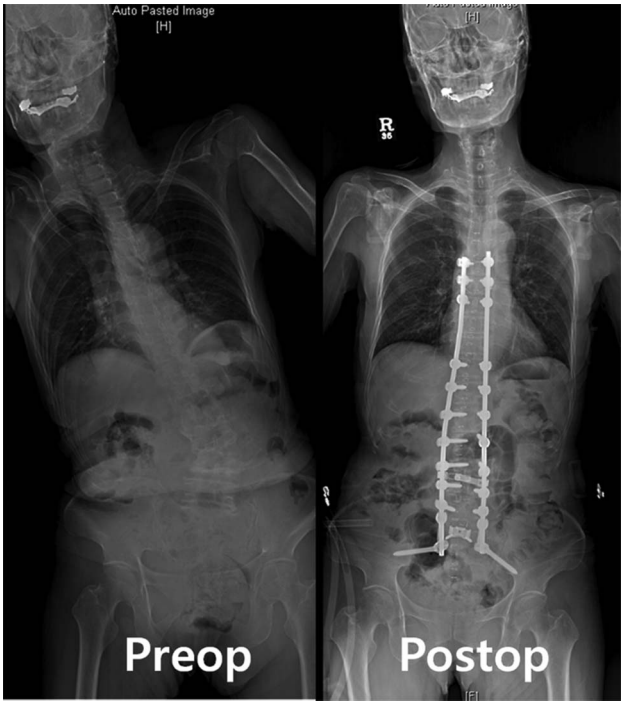

FIGURE 6. *Case illustration of Pisa syndrome. Representative case of a 65-year-old female patient with Parkinson disease and severe coronal imbalance (138 mm to the right) with high C7 SVA (264 mm).* **A**, *preoperative full length PA radiograph.* **B**, *postoperative full length PA radiograph. This patient had an 8-year history of Parkinson disease (Hoehn and Yahr stage 3, Unified Parkinson Disease Rating Scale score of 35), a 5-year history of L-dopa treatment, and no history of spine surgery. She developed Pisa syndrome and trunk dyskinesia 4 years after initiation of L-dopa. The patient had intractable low back pain and left leg radicular pain due to L4 compression fracture with marked coronal imbalance. Radiographic parameters included C7 SVA 264 mm, pelvic tilt 48.4 degrees, sacral slope 24 degrees, pelvic incidence 72.4 degrees, lumbar lordosis −17 degrees, thoracolumbar kyphosis 15 degrees, thoracic kyphosis 5.7 degrees, and Cobb angle (L1-L4) 33 degrees. PA, posterioranterior; SVA, Sagital Vertical Axis.*

Scoliosis is very common in PD patients. Surgical correction of scoliosis may be indicated when associated with severe coronal imbalance or radiculomyelopathy; otherwise, close observation with physical therapy is generally preferable. The risk of curve progression in PD patients is generally high and increases with greater PD severity.[12] Decompression alone is not usually recommended due to the high risk of curve progression after surgery. Short segment fusion may be considered in the setting of small coronal curves (Cobb angle $<$ 20 degrees), minimal rotational deformity, and absence of significant coronal and/or sagittal imbalance. Long fusion with correction of scoliosis is indicated in the presence of large, progressive coronal curve(s) and/or significant coronal or sagittal imbalance.

Outcome of Spine Surgery in PD

Patients with PD undergoing spine surgery are usually considered to have less favorable outcomes than age- and sex-matched controls without PD.[6] Nevertheless, in a study from Koller et al,[54] 78% of PD patients treated surgically for spinal deformities were satisfied or very satisfied with their clinical outcomes, while 22% were either not satisfied or uncertain regarding their outcomes. A previous report of 2 patients with PD who had good surgical outcomes after spinal deformity may provide some limited insight into patient selection.[82] Specifically, patients with good long-term surgical outcomes had a shorter duration of symptoms prior to the onset of camptocormia (less than 5 years from the onset of PD). In addition, these patients did not exhibit motor fluctuations at the time of camptocormia symptom onset, in contrast to many other patients who have been reported to develop this abnormal posture in more advanced stages of PD. Radiologic signs of spondyloarthritic changes were present in these patients, and they did not report any postural benefit from L-dopa treatment, although their PD was L-dopa responsive.

Most unfavorable outcomes of deformity surgery in PD patients relate to mechanical complications that may result in progression of postural deformity, worsening of symptoms, and need for revision surgery.[3,54,82] Therefore, when performing the index surgery, surgeons should be mindful of the importance of patient selection and strive to achieve strong mechanical stability with satisfactory global spinopelvic alignment.

SURGICAL COMPLICATIONS AND REVISION SURGERY

In 2004, Babat et al[3] reported surgical complications in their case series of patients with PD undergoing spine surgeries. They noted a very high need (86%) for revision surgeries after the index procedure. Of 14 patients, 12 required additional surgery, undergoing a total of 31 reoperations. Eleven patients (79%) underwent 22 additional procedures at the same or adjacent levels for instability, including 4 patients (29%) who had

instrumentation failure or pullout, requiring 10 reoperations. The primary mechanisms of failure in their series were progressive kyphosis or segmental instability at the level of operation or at an adjacent segment.

Wadia et al[82] reported on 2 cases in PD patients with good long-term surgical outcomes (more than 5 years) after spinal deformity surgery. Interestingly, both of these patients, despite ultimately having good outcomes, had mechanical complications. One patient required 2 revision surgeries to address instrumentation failure and loosening, and the other patient experienced rod fracture.

Koller et al[54] reported a case series of 23 PD patients who underwent surgical treatment for spinal deformity. They noted medical complications in 7 patients (30.4%) and surgical complications in 12 patients (52.2%); 17% of patients had infection-related and 35% of patients had construct- or fusion-related complications. Revision surgery was performed in 6 of 18 patients (33.3%). A single revision was performed in 3 patients and 2 revisions were performed in 3 patients. They emphasized the necessity for restoring good sagittal alignment to reduce the risk of surgical failure and the need for revision surgery. Mechanical complications were mainly due to peudarthrosis and proximal junctional kyphosis. The primary cause of poor results seemed to be persistent sagittal or coronal plane imbalance, whereas correction of spinal balance was associated with better clinical outcomes. Hence, appropriate restoration of global alignment at the time of the index surgery should be a primary goal. Pedicle subtraction osteotomy may be necessary for restoring sagittal alignment. Three-column osteotomies, such as pedicle subtraction osteotomy, tend to be associated with higher rates of complications, including pseudarthrodesis and rod fracture.[86,87] Therefore, supplementary fixation at the osteotomy site, meticulous preparation of the bone fusion bed surface, and use of osteoinductive materials are often required.

CONCLUSION

Patients with movement disorders, especially PD, have a high prevalence of spinal deformity that warrants consideration of spinal realignment surgery. High rates of mechanical complications can necessitate revision surgery. The success of spinal surgery in patients with movement disorders depends on an interdisciplinary approach, including both surgeons and movement disorder specialists, to achieve appropriate correction of sagittal alignment with strong biomechanical instrumentation and sufficient bone fusion. In order to attain good long-term outcomes, surgeons should keep in mind that patient selection, surgical techniques, patient relationships, and a team approach are all key determinants of satisfactory results.

Disclosures

Dr Shaffrey is a consultant for Biomet, Medtronic, Nuvasive, Stryker, and K2M and receives patents and royalties from Biomet and Nuvasive. Dr Ames is a consultant for DePuy, Medtronic, and Stryker; receives royalties from Stryker and Biomet; receives stock/stock options from Doctors Research Group; has a patent in Fish & Richardson, P.C.; and is employed at University of California San Francisco. Dr Smith is a consultant and receives honorarium and royalties from Biomet; is a consultant and receives honorarium from Nuvasive; is a consultant for Cerapedics; receives honorarium from K2M; has a research grant with DePuy Synthes and AOSNA; and receives research support from AOSNA. The other authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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