The role of routine magnetic resonance imaging in the preoperative evaluation of adolescent idiopathic scoliosis

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Abstract The routine use of magnetic resonance imaging (MRI) in adolescent idiopathic scoliosis remains controversial, and current indications for MRI in idiopathic scoliosis vary from study to study. The purpose of this study was to demonstrate the prevalence of neural axis malformations and the clinical relevance of routine MRI studies in the evaluation of patients with adolescent idiopathic scoliosis undergoing surgical intervention without any neurological findings. A total of 249 patients with a diagnosis of idiopathic scoliosis were treated surgically between the years 2002 and 2007. A routine whole spine MRI analysis was performed in all patients. On the preoperative clinical examination, all patients were neurologically intact. There were 20 (8%) patients (3 males and 17 females) who had neural axis abnormalities on MRI. Three of those 20 patients needed additional neurosurgical procedures before corrective surgery; the remaining underwent corrective spinal surgery without any neurosurgical operations. Magnetic resonance imaging may be beneficial for patients with presumed idiopathic scoliosis even in the absence of neurological findings and it is ideally performed from the level of the brainstem to the sacrum.

Introduction

Idiopathic scoliosis is diagnosed when no other underlying aetiological factors can be identified, such as neurovascular or musculoskeletal congenital anomalies, or inflammatory

or demyelinating processes leading to primary or secondary motor neuron damage (myotony, myopathy, etc.) [8, 9, 12].

Although treatment of idiopathic scoliosis has improved, the aetiology of idiopathic scoliosis is still unsolved. Previous studies have focussed on neurological factors in the aetiology of this disorder, and the association between idiopathic scoliosis and craniovertebral abnormalities has been well established [7]. With the development of magnetic resonance imaging (MRI), neural axis abnormalities such as syringomyelia or Chiari malformations are increasingly being found in patients with presumed idiopathic scoliosis in the absence of neurological findings. Even when syringomyelia or Chiari malformations without neurological deficit appear on preoperative MRI, the clinical significance of these malformations is not fully understood.

The intraspinal anomalies that can be associated with idiopathic scoliosis can be summarised as Arnold-Chiari malformation, tethering of the cord (fibrous adhesion of cauda equina), diastematomyelia, syringomyelia, lipoma and lipomeningocele, teratomas, neurenteric cyst, dermoid cyst, and epidermoid cyst. The presence of intraspinal anomalies in the absence of neurological findings in idiopathic scoliosis varies from region to region and has been estimated between 4% and 26% [1, 4, 5, 10, 11, 17].

The relevance of these lesions with respect to the natural history of scoliosis and the risk of treatment with spinal arthrodesis in the face of unrecognised or subclinical abnormality of the central nervous system has not been clearly established [5, 6, 13, 16, 19]. As a result, there is substantial controversy about the indications for imaging of the central nervous system in the evaluation of patients with presumed adolescent idiopathic scoliosis.

The risk of neurological complications during correction of scoliosis without prior decompression surgery for syringomyelia has been documented. Syringomyelia may

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be a risk factor for neurological complication during correction of scoliosis, especially after distraction [14]. It is important to investigate neural axis abnormalities using routine MRI before corrective surgery for scoliosis.

The routine use of MRI remains controversial, and current indications for MRI in idiopathic scoliosis vary from study to study. The current established indications for routine use of MRI may be summarised as follows: presence of pain (back, neck, radicular, headache), presence of neurological findings (clonus, abnormal abdominal reflexes, weakness, urinary dysfunction, hyper-reflexia, asymmetric deep tendon reflexes, paresthesia, diminished rectal tone, cavus foot deformity, skin lesions), atypical curve pattern (left thoracic, short segment, decreased rotation, absence of thoracic apical segmental lordosis, rapid progression, thoracic kyphosis angle >30 degrees), early onset scoliosis, male gender and presence of associated organ anomalies [2].

The purpose of this study was to demonstrate the prevalence of neural axis malformations and the clinical relevance of routine MRI studies in the evaluation of patients with idiopathic scoliosis undergoing surgical intervention without any neurological findings.

Materials and methods

The patients were evaluated for idiopathic scoliosis by clinical examination including the forward bending test and roentgenograms. Children with a family history of muscular dystrophy or connective tissue disorders, such as Marfan syndrome, osteogenesis imperfecta, and Ehlers-Danlos syndrome were excluded. Furthermore, children affected with spinal dysraphisms, including myelomeningoceles, diastematomyelia, and tethered cord syndrome, were also excluded.

A total of 249 patients with a diagnosis of idiopathic scoliosis were treated surgically between the years 2002 and 2007. Plain radiographs of the spine were analysed preoperatively. Curve magnitudes in the coronal plane were measured by the Cobb method. Coronal plane curve patterns were classified as thoracic, thoracolumbar, lumbar, or double curves on the basis of the location of the apices and the magnitudes of the curves.

A routine whole spine MRI analysis was performed in all patients. A spin echo technique with T1 and T2-weighted sagittal and axial images of the occipitocervical junction, cervical, thoracic, and lumbosacral spine were examined using a 1.5 Tesla MR Scanner (Sonata; Siemens, Erlangen, Germany).

The appearance of the cord, the level of the conus medullaris, and the presence or absence of syringomyelia, diastematomyelia, or Chiari malformations were evaluated on the magnetic resonance images by two independent radiologists.

The orthopaedic examination consisted of a complete examination of the back, including plumb-line assessment for decompensation of the trunk and identification of apical trunk rotation and rib prominence. Motor strength and sensation in the upper and lower extremities as well as deep tendon and abdominal reflexes were assessed. The examination was performed first by an orthopaedic surgeon than also by a neurologist independently.

The indication for surgical correction of scoliosis was a magnitude of curvature of more than 45°, if the patient and family wished to undergo radical surgery. A total of 241 of 249 patients received an isolated posterior spinal fusion and eight patients received an isolated anterior spinal fusion.

To identify intraoperative neurological complications, intraoperative somatosensory evoked potential (SSEP) spinal cord monitoring was routinely used for all patients. When compared with the baseline response before correction of scoliosis, a 50% decrease in SSEP response amplitude was considered significant.

Results

The female to male ratio of the patients was 212 to 37. Their mean age at first visit was 14.3 (range 12–18) years. If the age at the first visit was considered to be the age of onset, all patients had adolescent scoliosis. According to the Lenke classification, 112 of the patients were Lenke type I, 14 were type II, 18 were type III, three were type IV, 95 were type V and seven were type VI.

On the preoperative clinical examination, all patients were neurologically intact. There were 20 (8%) patients (3 males and 17 females) who had neural axis abnormalities on MRI. MRI revealed isolated hydrosyringomyelia in 15 patients, syringomyelia with Arnold-Chiari malformation type I in three patients, and isolated Arnold-Chiari malformation type I in two patients. Isolated syringomyelia was thoracic in 12 patients, cervicothoracic in two and cervical in one patient. Ten of 15 syrinx cavities were less than 3 mm in diameter and long segment and the rest were between 3 mm and 8 mm in diameter and short segment (less than 3 cm). None of those patients had any sub-clinical abnormality. Three of those 20 patients needed additional neurosurgical procedures before corrective surgery (Fig. 1); the remainder underwent corrective spinal surgery without any neurosurgical operations. The neurosurgical procedures were performed in three patients having syringomyelia with Arnold-Chiari malformation type I. Suboccipital craniectomy (decompression) was done in two patients and decompression with syringopleural shunt placement was performed in one patient.

Intraoperative somatosensory evoked potential monitoring was performed on all patients from the beginning of the

Fig. 1 Fourteen-year-old boy with thoracolumbar scoliosis. His neurological examination was normal. Routine magnetic resonance imaging showed Arnold-Chiari malformation and cervical syrinx. He first

underwent neurosurgical decompression surgery, then, three months later, corrective scoliosis surgery was performed

operation to its conclusion, with no changes noted. The intraoperative average SEP values for neural axis abnormality patients were 23 ± 4 ms of latency and 8 ± 5 microvolts of amplitude for N₂₂ (tibia), 31 ± 3 ms of latency and 0.3 ± 3 microvolts of amplitude for P₃₀ (lumbosacral region) and 42 ± 5 ms of latency and 1.2 ± 5 microvolts of amplitude for P₄₀ (cortex). Those values were 24 ± 3 ms of latency and 9 ± 3 microvolts of amplitude for N₂₂ (tibia), 32 ± 4 ms of latency and 0.3 ± 4 microvolts of amplitude for P₃₀ (lumbosacral region) and 44 ± 3 ms of latency and 1.3 ± 5 microvolts of amplitude for P₄₀ (cortex) for patients without any neural axis abnormalities. Motor evoked potentials were not routinely monitored. The Stagnara wake-up test was performed after the instrumentation was applied in all patients; there was no detectable neurological deficit. There were no complications in the immediate perioperative period.

Radiologically, the preoperative mean Cobb angle of the major curve was 55.6° (range $45\text{--}80^\circ$) and it was 10.7° (range $4\text{--}14^\circ$) after surgery (correction rate of 80%; correction ratio of 75% for neural axis abnormalities and 81% for the rest; $p > 0.05$).

Discussion

A higher risk of neurological complications has been reported during surgery of scoliosis associated with syringomyelia. To prevent potential neurological complications, neural axis malformations need to be addressed before the treatment of scoliosis. The clinical significance of syringomyelia or Chiari malformations without accompanying neurological deficits is not fully understood.

Several studies suggest that routine preoperative MRI is not indicated in idiopathic scoliosis unless the patient has neurological deficits or complains of pain [3, 11, 15, 18, 20]. However, in our study, 20 (8%) adolescent and neurologically asymptomatic patients had abnormal findings on MRI, and three of the 20 patients required a neurosurgical procedure.

At this point, the question that has to be answered is whether the routine MRI assessment is necessary for idiopathic scoliosis. Nordeen et al. [14] reported that spinal distraction and instrumentation carry a risk of neurological damage in patients with scoliosis and associated syringomyelia. Scoliosis may be the only sign at initial examination.

Samuelson et al. [17] stated that scoliosis associated with syringomyelia may be more common than previously thought, and may be wrongly classified as idiopathic. MRI should be mandatory before bracing or operative correction of scoliosis.

On the other hand, there are several studies in the literature indicating that MRI study is not necessary for a neurologically intact patient with adolescent idiopathic scoliosis [3, 11, 15, 18, 20]. The largest series in the literature is the study of Do et al. [3]. This study strongly suggests that MRI is not indicated prior to arthrodesis of the spine in patients with an adolescent idiopathic scoliosis curve pattern and a normal physical and neurological examination. A total of 327 consecutive patients with adolescent idiopathic scoliosis were enrolled in the study. Magnetic resonance imaging of the brain and the spinal cord were performed as part of their preoperative work-up. A spinal cord syrinx in two patients (0.6%) and an Arnold-Chiari type-I malformation in four (1.2%) were detected. No patient required neurosurgical intervention or additional work-up. All patients who underwent spinal arthrodesis with segmental instrumentation had tolerated the surgery without any immediate or delayed neurological sequela.

However, in our opinion, knowing that there is an intraspinal anomaly, even though no additional neurosurgical procedures are performed, surgeons will modify their surgical plan and be more careful even in small details to prevent any neurological complications. There are some surgical pitfalls in treating such patients with occult intraspinal anomaly. All patients having neural axis abnormality on MRI should have spinal cord monitoring during surgery. Since the spinal cord is compressed due to the syrinx cavity, the removal of facet joints during the corrective surgery should be done with burr instead of hammer to prevent iatrogenic trauma to the spinal cord. Since the subarachnoid space is narrowed due to enlargement of the spinal cord with syringomyelia, extracanal instrumentation such as pedicle screws should be chosen rather than intracanal instrumentation like sublaminar or pedicle hooks and sublaminar wires. To prevent spinal canal violation, the use of the in-out-in (costovertebral placement) pedicle screw technique should be considered. To avoid the creation of iatrogenic trauma to the spinal cord, the compressive manoeuvres on the convex side of deformity should be performed rather than distractive manoeuvres on the concave side of the deformity for correction.

In conclusion, magnetic resonance imaging may be beneficial for patients with presumed idiopathic scoliosis even in the absence of neurological findings to determine any neural axis abnormality. In our opinion, it may be helpful in decision making in the surgical treatment of adolescent idiopathic scoliosis.

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