Spinal fusion for scoliosis, clinical decision-making and choice of approach and devices

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Scoliosis is a three-dimensional deformity of the spine, characterized by a curve in the coronal plane of 10° or more. The size, stiffness and cosmetic consequences of the curve change over time, the fourth dimension. The causes of scoliosis include congenital anomalies, neuromuscular disorders, connective tissue diseases, infection, tumour or dysplasia. However, the majority of spinal curves are idiopathic and most of these are of late-onset (appearing at the age of six or older) [1].

We will focus our discussion on late-onset idiopathic scoliosis (LOIS). For these patients, the problem is largely one of cosmesis. The effect of the curve on their organic health is relatively benign. The surgeon's role is to counsel the patient on the likely long-term outcome of their scoliosis and to give them information regarding the potential risks and rewards of surgical treatment. The surgeon should elicit the views of the patient on their cosmetic appearance, being very specific about which aspect of their shape makes them unhappy. The final decision to operate is made jointly, by the patient (with their family) and the surgeon. The surgeon should have a very clear understanding of why the patient wishes to undergo surgical treatment. Failing to match patient expectations against the likely result of surgery will result in mutual unhappiness.

It is now almost 50 years since Paul Harrington's spinal instrumentation system gained widespread use and acceptance [2]. He developed his system to aid treatment of paralytic scoliosis (post-poliomyelitis) but it was soon adopted for other aetiological types of curve. Prior to the Harrington era it was said that the surgical treatment for scoliosis was worse than the condition itself, both for the patients and their families. Harrington's rods changed that perception, but did not resolve all the difficulties of securing a stable deformity correction and fusion.

Since Harrington, there has been an evolution in our understanding of the aetiology, natural history [3] and pathomechanics of scoliosis. Advancements have occurred in medical imaging and computing which give us a clearer picture of the development and progression of scoliosis in three dimensions. Pre-operative MR imaging readily reveals any associated conditions which may require pre-emptive treatment or pose a contra-indication to surgery, such as a Chiari malformation, syringomyelia or congenital cord anomalies. This has been coupled with developments in material technology and engineering, leading to a step-wise improvement in the quality and power of spinal instrumentation available to the surgeon. We have a deeper understanding of the biology of spinal fusion. Surgical and anesthetic techniques have also improved in terms of safety and scope for correction, allowing us to perform more complex and challenging procedures.

Despite these advances, the aims of scoliosis surgery remain unchanged: prevent progression and leave a stable and well-balanced spine with the maximum safe cosmetic correction, preserving as many motion segments as possible. Cosmetic correction equates to level shoulders, centralization of the trunk with balanced waist creases and correction of spinal axial rotation to reduce the rib or loin prominence.

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The struggle to find an accurate, meaningful and reproducible descriptor or classification for the curves that we treat continues and this also applies to the outcome of such treatment. Unhappiness with body shape is what drives most patients with LOIS to seek surgical treatment. Cosmesis is a personal and subjective variable; it is unlikely that we will ever be able to measure this directly. Our everyday working measure of scoliosis is the Cobb angle. We know that this is a non-linear measure and that it correlates poorly with cosmesis. The Cobb angle is the one measure for which we have long-term data. Despite its limitations it has meaning and relevance to every spinal deformity surgeon. Standard radiographic views (PA and lateral) will underestimate the angular deformity of large curves as recorded by the Cobb angle, as the inherent axial rotation of the scoliotic curve takes the deformity away from the coronal plane. Taking additional views or computer modeling from the standard views allows us to appreciate the full extent of the deformity.

Classification schemes [4, 5] give us a framework on which we can discuss and study scoliosis. The Lenke classification [6] is comprehensive and is based on static erect and supine bending radiographs; it allows us to describe all curve types in terms of the radiological appearances, with a high degree of reproducibility, and to use this information to determine fusion level at surgery. The simple rule, followed in the majority of cases, is to identify the end vertebrae, i.e. the vertebrae with endplates that are most tilted from the horizontal plane, and fuse all structural curves from upper end-vertebra to lower end vertebra. The highest level should be chosen to ensure that the shoulders are level and there is a normal sagittal profile at the junction from fused to unfused. The lowest level should be selected based on the neutral and stable vertebra on the standing film, as well as examining the correction achieved across the disc spaces on the bending films. Choices regarding the precise levels of fusion will be determined by the choice of approach and the philosophy of correction.

Philosophy of correction

The aims of scoliosis surgery are relatively simple and clear, but how do we achieve them? Can we simply reverse the deforming process and fuse the spine in the ‘normal’ position? The mechanism of reduction of scoliosis has been a topic of debate. Are we reducing the spine with simple translation or are we de-rotating the spine with the translational correction occurring as a consequence? The truth probably lies between these two extreme views [7, 8]. The final coronal and sagittal profile can be fine-tuned by

sequential compression and distraction along with in-situ bending although distraction of the spine is limited by the tolerance of the neural structures.

Dickson described lordosis at the thoracic apex [9], developing with the coronal and rotational deformities. If we translate and de-rotate the spine what will happen to this thoracic ‘lordosis’ or hypo-kyphosis as it is now termed? What will be the effect of this thoracic hypokyphosis on the overall sagittal balance? Failure to restore a normal thoracic kyphosis results in lumbar hypo-lordosis while improvements in thoracic kyphosis have been shown to improve lung function.

Which structure resists or prevents a satisfactory reduction? Is it translation or rotation that gives us the problems? Finally, how much reduction is enough? Many others have asked this question, but still we have no answer. Our aim is cosmetic improvement, but our measure is an angle or percentage correction. Maximal correction in angular terms does not give optimum cosmesis. It is often better to leave a series of small but balanced curves than try but fail to deliver a ‘perfect’ reduction in all three planes: coronal, sagittal and rotational.

Choice of approach

There are three choices when dealing with spinal deformity: all posterior, all anterior or a combined anterior and posterior approach.

In the days of Harrington rods, and even with the advent of segmental wiring techniques, it was common practice to consider an anterior release followed by a posterior fixation, either on the same day or after a short interval. Removal of the intervertebral discs has several theoretical advantages. Approximately 90% of the rotational stiffness of the spine is due to the intervertebral discs. Removal of the discs across multiple levels improves the rotational correction that may be achieved and also shortens the anterior spinal column, correcting the thoracic apical lordosis. A circumferential fusion also results, reducing the likelihood of late loss of correction.

This anterior surgery comes with a price. Thoracotomy has been shown to cause a statistically significant reduction in lung function (approximately 10%), the clinical significance of this is less clear. There is no evidence to show that anterior surgery or combined surgery gives better correction although many surgeons believe that anterior thoracic surgery still has a role in large (>100°) and very stiff thoracic curves.

A large number of surgeons practice a thoracoscopic technique, arguing that this gives a more cosmetic scar, when compared to posterior surgery. However a recent

presentation suggests that there is no difference in acceptability of anterior or posterior scars for scoliosis surgery [10]. Today, using modern pedicle screw systems, the majority of scoliosis surgery for late-onset idiopathic curves is done posteriorly.

For thoracolumbar curves, good arguments can be made for anterior or posterior surgery. The overall correction is no different. The overall complication rate is the same—although we accept that the specific complications may be different. The hospital stay is shorter with all posterior surgery, but 1 to 1.5 motion segments may be preserved with anterior compared to posterior surgery [11]. The thoraco-abdominal approach has been shown to have no long-term effect on lung function [12].

Choice of device

Spinal instrumentation has developed from the solid foundation laid down by Harrington. Modern pedicle screw systems are now very different from what was available in Harrington's time. Today's implants allow gradual reduction and sequential correction with direct derotation of the spine.

Spinal fusion originally required a long (6 month) period in cast or other brace. The devices available today can all provide primary spinal stability, obviating the need for spinal immobilization.

Thoracic pedicle screws have been shown to be relatively safe and all pedicle screw constructs are now widely used. Some advocate very high implant densities, with pedicle screws bilaterally at every level. This may improve the radiological correction but there is no evidence to date that this improves the cosmetic correction. There is still a misplacement rate with pedicle screw insertion, even in the most experienced hands. There is a significant cost associated with pedicle screws, which obviously rises in direct proportion to the implant density used. Advocates would argue that the cost of an increased number of implants is small when looked at against the cost of scoliosis surgery as a whole and that when amortized over the lifetime of the patient, the cost of these screws is small. Nevertheless the cost of high implant densities is something that has to be borne by the healthcare economy today for little proven benefit.

Problems with all pedicle screw constructs have led some surgeons to look for alternatives. Some continue to use hybrid constructs of pedicle screws and hooks. Ilharreborde and Mazda report a development from Luque wiring. They have used a polyester band passed under the lamina or under the laminar and passed around the transverse process. This is then anchored to the rod with a titanium clamp. We have used this device in our institution as part of a hybrid construct with success.

Interbody fusions may be desirable, particularly with a long fusion down to the lower lumbar spine. This may be achieved with bone graft or interbody cages that may be PEEK or titanium. Interbody fusions can be achieved as part of an anterior procedure or extreme lateral approach but may be achieved from a direct posterior or transforaminal approach.

There are currently three main options for the rod material. Titanium is the most flexible of the three (which may or may not be a disadvantage) and results in moderate image degradation on any subsequent MRI scans. This has traditionally been the first choice for the majority of cases in the UK. Stainless steel is stiffer but gives poor images should an MRI scan be required. It does not have the problems of notch-sensitivity and subsequent increased risk of breakage that titanium suffers from; this allows it to be bent in-situ, with confidence. Stainless steel has traditionally been popular in the USA. Cobalt-chrome rods have now been introduced. These are the stiffest and strongest rods and may be useful in high-load situations and enable overall rod (and therefore screw-head) diameter to be reduced, reducing implant profile. The counter-argument is that using a very stiff rod will result in failure of fusion as applied stresses are taken by the implants rather than the spine, inhibiting active bone formation and remodelling.

Costoplasty

The final decision regarding the need for costoplasty can only be truly made once the final curve correction has been achieved. Clearly, a large and prominent rib hump preoperatively would suggest that costoplasty may be required, especially if this is the main cause of the patient's dissatisfaction with their shape. Costoplasty is not a benign procedure. It results in increased postoperative pain and a small long-term reduction in lung function tests. Fortunately it is only required in a small proportion of our patients.

Conclusion

Spinal surgery in general, and scoliosis surgery in particular, have benefited from many technological advances that have been made over the last 50 years. The corrective power of a modern pedicle screw system gives the potential for great change.

The balance of risk versus outcome has swung in favour of posterior-only surgery for a large proportion of the curves encountered by the surgeon.

The goals of surgery remain simple, spinal balance and cosmesis.

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