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Chapter

The Functional Effects of Adult Spinal Deformity and the Effectiveness of Surgery

David Christopher Kieser and Michael Charles Wyatt

Abstract

The prevalence of adult spinal deformity (ASD) is increasing worldwide, driven by changing patient demographics, as well as an increased capacity to diagnose and treat this condition. ASD carries the worst healthcare burden of all chronic conditions including arthritis, chronic lung disease, congestive heart failure, diabetes and ischaemic heart disease. Recent advances in diagnostic and treatment modalities have resulted in an increase in surgical intervention for this condition. To be successful, however, a comprehensive understanding of the functional deficits caused by ASD must be recognised by those clinicians managing such patients. This chapter provides an overview of the functional deficits caused by ASD and its treatment.

Keywords: spine, function, deformity

1. Introduction

Spinal conditions are some of the most common health conditions affecting adults [1]. Many spinal conditions do not affect spinal alignment, whilst others induce spinal deformity. Adult spinal deformity (ASD) is an umbrella term for a complex spectrum of spinal conditions causing spinal deformity [2]. The most common causes of ASD are degenerative disease and idiopathic (**Figure 1**). Other causes of ASD include oncologic, traumatic, neuromuscular and iatrogenic. Whilst the exact incidence of ASD is unknown, the rate of ASD increases with age with a reported prevalence of 32% of patients aged over 50 years and 68% of patients aged over 70 years [3].

Despite this prevalence, many patients have mild deformities and little or no symptoms. Conversely some patients have marked spinal deformity with global spinal imbalance causing severe disability [4]. The predominant reason for this disability is that spinal imbalance prevents the normal economic resting posture of the spine, whereby the centre of gravity runs in close proximity to the spine and the head is centred over the hips. This therefore requires an increase in the physiological demands of the spine and peri-spinal musculature which subsequently causes pain, fatigue and disability. It is therefore perhaps unsurprising that the extent of spinal imbalance directly relates to the degree of disability [5–8].

It is now recognised that the consequences of an imbalanced spine on a patient's function and quality of life (QoL) can be devastating [3, 5, 6, 8, 9]. In fact, compared to all other common long-term disorders, such as arthritis, chronic lung disease, congestive heart failure, diabetes and ischaemic heart disease, ASD has the worst patient reported QoL [10] (**Figure 2**). Furthermore, because of its increasing
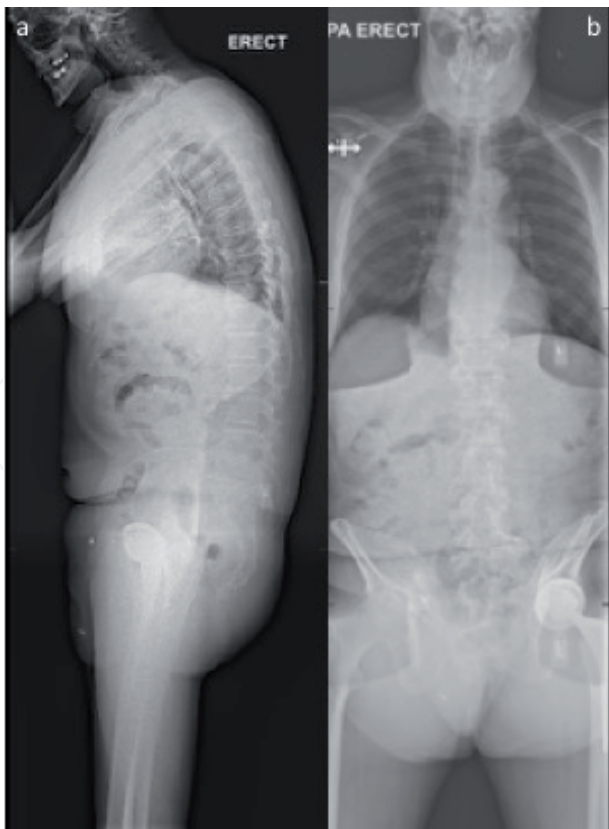
Figure 1.
Lateral (a) and postero-anterior (b) standing X-rays of a 70-year old male with adult spinal deformity predominantly affecting the sagittal plane. Note the compensatory mechanisms for his lack of lumbar lordosis, notably thoracic hypokyphosis and pelvic retroversion, which results in a typical flat-back deformity.

Figure 2.
Lateral (a) and postero-anterior (b) standing X-rays of a 55-year old female previous athlete who is now house-bound due to severe axial pain caused by her degenerative thoraco-lumbar spine, causing severe local kyphosis. Note her attempted spinal compensation for the thoraco-lumbar kyphosis, notably pelvic retroversion, lower lumbar hyperlordosis, thoracic hypokyphosis and cervical hyperlordosis.

incidence, driven by multiple factors, ASD is the highest ranked disorder in estimates of global disease burden [10].

In order to quantify the degree of disability and effect on a patient's well-being from ASD, multiple functional scores have been employed [11]. Some scores have been specifically developed to assess spinal conditions, whilst others have been developed for other conditions but offer a proxy for "well-being" in patients with ASD. The most useful parameters available to understand the effect of ASD on a patient's well-being are pain, function and QoL. Thus, scores assessing these factors are commonly used to report outcomes in patients with ASD.

In general, pain scores numerically rate a patient's degree of pain (numeric rating scale (NRS)) in specific anatomical locations through a visual analogue score (VAS). For ASD, pain is usually separated into back and leg pain. In contrast, functional outcome scores attempt to understand what specific functions or activities are inhibited by a condition. In ASD, the most commonly used functional outcome score is the Oswestry Disability Index (ODI) [12]. This score was initially described to evaluate low back pain in a general population rather than evaluate the functional outcome of patients with ASD [12]. However, it is now widely used to evaluate the functional deficits induced by ASD and the response to treatment.

The ODI is a questionnaire that evaluates activities of daily living (ADL) that offers a subjective score of the respondent's level of disability. This index specifically assesses pain, personal care, lifting, walking, sitting, standing, sleeping, sexual life, social life and travelling [12]. For each domain the total achievable score is 5, with zero being no disability and 5 being severe disability. The scores for each domain are then summed and an overall percentage of disability is calculated. Whilst the overall disability value is one of the most commonly reported values in the literature, within each domain of the ODI the degree of disability can be scored and used to determine the effect of ASD treatment on specific ADLs.

QoL scores attempt to quantify the global effect that a condition has on the patient's life. The two most commonly reported QoL scores in ASD are the Scoliosis Research Society 22 (SRS-22) and Short Form 36 (SF36). The SRS-22 is a composite questionnaire of 22 questions developed specifically to determine the pain, function, self-image, mental health, and satisfaction of patients with spinal deformity [13]. In contrast, the SF36, which comprises 36 questions, was not specifically developed for spinal conditions, but does determine a patient's physical function, pain, vitality, social function, emotional effect, mental health and general health [14].

2. Discussion

To date a complete understanding of which factors independently affect patient pain, function and QoL in patients with ASD remains unclear. In the general population affected by back pain a number of factors are reported to affect pain, function and QoL, with most factors contributing a variable amount to the disability. Because of this multi-factorial affect a biopsychosocial approach to understand the interconnected importance of each factor is appropriate. Biologically, the more sinister the cause and the more severe the condition, the more likely the patients are to be symptomatic. Similarly, the greater the spinal load, particularly increased body mass index (BMI), but also physical workload, as well as the more medical conditions affecting the patient the more likely they are to experience back pain [5, 15–17].

Psychologically, the psychological profile and capacity to cope influence the degree of back pain and dysfunction experienced by patients as does the patient's locus of control. A patient with an intrinsic locus of control (a patient who takes

personal responsibility for their own outcome) as opposed to a patient with an extrinsic locus of control (a patient who relies on others for their outcome) is likely to experience less pain and dysfunction. From a social perspective, those with a higher socio-economic status, greater supports, current employment and non-smokers experience less pain and disability. It is also known that other factors including geographic, and genetic factors influence back pain, function and QoL in the general population [18–22].

Similar to that of the general population, it is likely that multiple factors affect the pain, function and QoL of patients with ASD. However, only relatively few of these factors have been analysed in depth. The most well recognised correlation is that of sagittal imbalance. Sagittal balance can be described clinically as one's sagittal position of the skull relative to the hips, however, it is most accurately defined
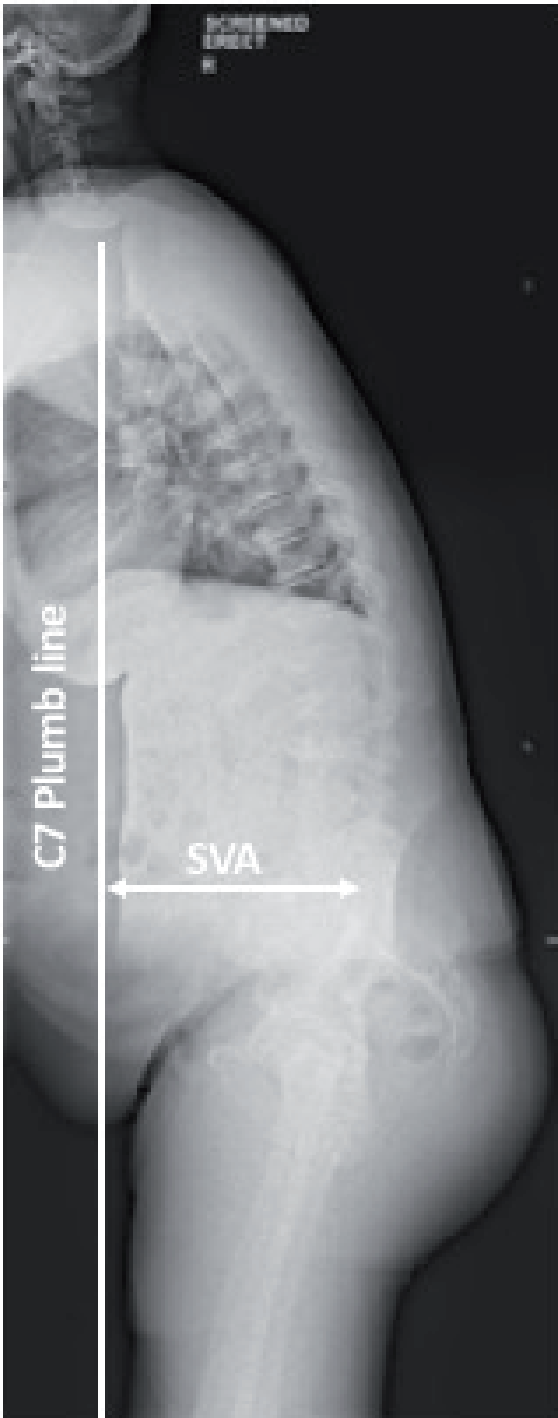
Figure 3.
Representative standing lateral X-ray demonstrating the measurement of the sagittal vertical axis (SVA).

radiologically as the sagittal vertical axis (SVA) which is the distance from the posterior superior aspect of the first sacral vertebral body to a line drawn perpendicular to the floor that runs through the middle of the C7 vertebra (C7 plumb line) in a standing patient (**Figure 3**).

Glassman and colleagues were the first to study this parameter and its effect on functional outcomes and found that an increase in sagittal balance directly affects functional outcomes in patients with ASD [5]. This finding has been confirmed in a number of subsequent publications [6–8].

Obesity has also been studied and shown to affect pain, function and QoL in patients with ASD. Intuitively an increased load on a compromised spine would affect a patient's well-being, however, the exact mechanism by which obesity affects these patients remains unproven. Furthermore, the effect of weight loss on the improvement of symptoms is yet to be determined. That said, the fact that obesity negatively affects the pain, function and QoL in these patients is of significant concern considering the rate of obesity is increasing internationally [23, 24].

Despite the paucity of data on other factors affecting the disability profile of patients with ASD, it is likely that there are multifactorial contributors that are yet to be studied. These include the patient's baseline requirements and ADLs, often driven by age, occupation and social activities; the patient's locus of control; the location and cause of the spinal deformity as well as the severity and number of levels affected; the degree of stiffness of the spine and hips and capacity to compensate for the deformity, the degree of coronal imbalance and global tilt. The contribution that each plays towards the patient's disability is likely varied, but on-going research into this area is warranted.

Similarly, the specific functional limitations induced by ASD have a likely multifactorial basis, which makes specific treatments for specific functional deficits limited. However, it is recognised that severe ASD can affect all ADL and severely affect QoL [3, 6, 8]. Since Glassman's correlation between the ODI and SVA, the use of health-related quality of life scores (HRQLs) to assess the success of treatments in ASD has become routine [5, 25]. Unfortunately, there is a lack of published material on the specific disabilities induced by ASD. In contrast, some information is available on the specific functional benefits of the treatment of ASD.

The treatment of ASD is challenging. To date, non-operative treatment, although used extensively, has not been shown to improve long term outcomes for these patients, especially when significant anatomical abnormality and spinal imbalance is present [26, 27]. However, core strengthening, aerobic exercise and weight loss strategies are useful in the treatment of LBP in the general population and are relatively cheap, easy, safe with patients gaining a degree of self-control over their condition and gaining multiple other health benefits of such lifestyle modifications. Pain management offers symptom control to alleviate pain which may improve function, but often at the effect of sedation. Furthermore, long-term symptom control is required with the development of medication tolerance and reliance, with the associated expense and complications of long-term medical treatment. Injection therapy with epidurals, nerve blocks and facet injections may offer some temporary benefit. Bracing may offer short term benefit but defunctions the paraspinal musculature which often worsens symptoms when the brace is removed. Glassman and colleagues analysed the non-operative resource utilisation and cost benefit of non-operative treatment in ASD. They identified a large resource utilisation and cost for patients with ASD, particularly those with severe symptoms, but no improvement in the health status at 2-year follow-ups with non-operative treatment [26, 27].

In contrast to non-operative care, operative intervention has shown long-term improvements in pain, function and QoL in symptomatic patients, and this has

fuelled the increased number of complex ASD surgeries being performed worldwide [2, 28–31]. In the last decade the number of complex operations being performed for ASD has doubled in many countries, including the USA and UK, which contrasts with the 20% increase in all other spinal surgeries [2, 29].

The surgery for this condition can vary from a single level neural decompression to global deformity correction. However, there is growing evidence that most patients with symptomatic ASD benefit from a restoration of their spinal balance [7, 32, 33]. But, procedures to restore spinal balance are far more complex than simple decompressive procedures. Furthermore, spinal realignment surgery is expensive with the demands of a single case and impact on health services being disproportionately greater than those of other elective procedures, such as total hip joint replacement [28, 30, 31]. The average total hospital cost for a primary procedure is estimated at US$103,143, and therefore the improvement in pain, function and QoL needs to be justified [34].

Furthermore, despite the evidence that spino-pelvic fusion is associated with excellent patient satisfaction and improvements in overall function, patients increasingly require information on the specific functional benefits and limitations induced by ASD treatment in order to make informed decisions and avoid inaccurate patient expectations [14]. Kieser and colleagues reviewed the effect of primary spino-pelvic fusion on the specific functional outcomes of ASD in a retrospective review of 45 consecutive patients enrolled in the European Spine Study Group database with a minimum 2-year follow-up [35]. Their study confirms that spino-pelvic fusion significantly improves the overall ODI score at a 2-year follow-up for patients with ASD. They identified a mean 13.5% overall improvement in disability, with a reduction in pain and improvement in function and QoL.

When assessing the effect of ASD surgery on specific ADLs, Kieser and colleagues reported a variable degree of benefit for each ODI domain. Large improvements were found for pain and sexual function, moderate improvements for walking, sitting, standing, social life and travelling and minimal improvements for sleeping, personal care and lifting [35]. No domains were found to worsen after surgery at a 2-year follow-up. These results suggest that the pain relief, spinal stability and balance offered by these procedures improve ADLs such as walking, sitting, standing, travelling, social life and sexual function. However, the rigidity imparted by the fusion limits the improvement in personal care and lifting, which often relies on spinal mobility.

Conceptually, long-segment fusions should worsen certain ADLs such as personal care. Yet the study by Kieser and colleagues revealed an improvement in these functions but commented that this improvement was not statistically or clinically significant [35]. They suggested that the pre-operative spinal mobility of patients with ASD is usually poor, either from stiffness or pain, and therefore fusion carries a less significant functional effect in this condition than in conditions with normal spinal mobility. In addition, the minimal improvement in sleep has been postulated to be due to the effect of gravity driving disability in the upright position being non-influential when lying down [35]. However, the study was limited by only assessing the ODI without including other outcome scores and by the variance in underlying cause, curve type, extent of deformity and preoperative symptoms of included patients.

Recognising that spino-pelvic fusion reduces the overall level of disability in patients with ASD allows the surgeon to advocate for such procedures, but understanding the large improvement in pain and sexual function, moderate improvement in walking, sitting, standing, social life and travelling and limited improvement in sleeping, personal care and lifting allows patients to make informed decisions with clear expectations, that empowers them to make the right personal decision.

Although the only study assessing the effect of ASD surgery on specific ADLs, the study by Kieser and colleagues only assessed primary procedures [35]. To date, no comparable study has been undertaken on revision procedures. However, Scheer and colleagues previously identified that patients requiring revision deformity correction have a worse longer-term outcome than those who do not require revision [36]. This is important to recognise because ASD surgery carries a high complication rate, with a reported major complication rate of 20% and 30-day mortality of 2.4% [25, 37]. Therefore, when contemplating the first procedure, despite the potential increased initial expense and risk involved in a comprehensive deformity correction, it is in a patient's and institution's best interests to optimise the first procedure, to optimise outcome and reduce the longer-term costs associated with revision surgery. An approach to "getting it right first time" is therefore warranted [38].

3. Conclusion

Within the current literature there remain significant deficits in our understanding of the functional effects of ASD and its treatments. It is clear that this condition causes severe disability with significant pain, functional limitations with most ADLs and poor QoL. Non-operative management options do not resolve the spinal imbalance which appears to be the biggest determinant of improved patient outcome and therefore little evidence exists for its efficacy. In contrast, operative intervention has improved patient outcomes, but with high expense and complication rates. Future treatment strategies should therefore focus on enhancing functional outcomes, whilst limiting risk and expense. Furthermore, a holistic biopsychosocial approach should be provided if all factors influencing outcome are to be addressed.

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