Complications following spine fusion for adolescent idiopathic scoliosis

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Abstract Complications following spine fusion for adolescent idiopathic scoliosis can be characterized as either intra-operative or post-operative. The most serious and feared complication is neurologic injury, both in the intra- and post-operative period. Other intra-operative complications include dural tears and ophthalmologic or peripheral nerve deficits, which may be related to positioning. Among the most common post-operative complications are surgical site infection, venous thromboembolism, gastrointestinal complications, and implant-related complications. Significant blood loss requiring transfusion, traditionally considered a known sequelae of spine fusion, is now being recognized as a “complication” in large national databases. Pediatric spine surgeons who care for patients with AIS must be thoroughly familiar with all potential complications and their management.

Keywords Adolescent idiopathic scoliosis · Complication · Fusion · Neurologic deficit · Surgical site infection · Blood transfusion

Introduction

Adolescent idiopathic scoliosis (AIS) is a common condition, affecting 1–5 out of 100 children and adolescents [1, 2]. The number of patients with curves over 30° is much lower, around 1–3 per 1000 [3]. Untreated significant scoliotic

deformities may progress after skeletal maturity, leading to back pain, pulmonary dysfunction, and patient concerns regarding body image [4–6]. Surgical intervention is indicated in patients prior to skeletal maturation for progressive curves >45–50°. The purpose of surgery is to prevent future progression by obtaining a solid bony arthrodesis, and to safely correct deformity. Indications for scoliosis surgery in adult patients include significant deformity and pain unresponsive to maximal non-operative intervention.

The rate of complications associated with deformity correction and fusion in adolescent idiopathic scoliosis ranges from 5 to 23% [7, 8, 9, 10, 11]. However, reported rates of complications are dependent on queried databases and the events which are classified as complications. Using surgeon-reported data from the Scoliosis Research Society (SRS) morbidity and mortality database compiled for the years 2001–2003, Coe et al. [7] reported a complication rate of 5.7 % for spinal fusion surgeries performed in 6334 AIS patients, with a disparity between anterior (5.2 %) or posterior (5.1 %) and combined anterior/posterior procedures (10.2 %). More recent data from the SRS database reported in 2011 cited a complication rate of 6.3 % for all cases of idiopathic scoliosis, although this paper did not stratify between infantile, juvenile, or adolescent cases [9]. A prospective, multi-center database using surgeon-reported outcomes found a prevalence of non-neurologic complications of 15.4 % [10]. In this study, risk factors that significantly increased rates of complications included a history of renal disease, increased intra-operative blood loss, and prolonged posterior surgery time and anesthesia time.

These data are in contrast to a recent report which cited a complication rate of 22.3% following fusion for AIS. This article utilized data from the Kids’ Inpatient Database (KID), and the most common complication was found to be transfusion of cells [8]. The large discrepancy and apparent difference in the complication rate between the SRS and KID databases may be

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explained, in large part, by the fact that the SRS does not categorize perioperative blood transfusions as a complication of spinal deformity surgery when compiling their data.

Two recent articles have sought to characterize complications in the acute post-operative period by examining reasons for readmission and reoperation. Using a multicenter registry, Martin et al. [12] determined that the 30 day readmission rate is for idiopathic patients was 2.66 %, and the most frequent reasons for readmission were wound infections or gastrointestinal (GI) disturbances. In a similar article by Jain et al. [13], the 90-day readmission rate was 8 % for all types of scoliosis. These authors did not delineate between adolescent idiopathic and other types of scoliosis when reporting the readmission rate. Wound complications or pulmonary conditions were cited as the most common reasons for readmission.

The number of surgical interventions for AIS has risen substantially in the past 15 years (1783 cases in 1997 to 5228 in 2012, an increase of 193 %) [8•], yet the surgeon-reported complication rate has remained fairly constant [7, 9•, 10, 14]. In light of this fact, it is important that those providing surgical care for pediatric spinal deformity patients are well aware of the complications associated with this procedure. The purpose of this review is to assess the recent literature on complications following spinal fusion surgery in patients with adolescent idiopathic scoliosis. Most events that are considered complications can be categorized as occurring in either the intra-operative or post-operative period, and will be discussed in that order. It is important to note that this review will not discuss adverse events associated with the surgical management of neuromuscular, congenital, or syndromic scoliosis, although there is certainly some level of overlap with AIS. This review will also not discuss complications associated with surgical management of early onset scoliosis and the growing spine [15]. Surgery for early onset scoliosis has higher complication rates than that performed for AIS patients, which remains the focus of this chapter.

Intraoperative complications

Neurologic injury

The most feared intraoperative complication of scoliosis surgery is neurologic injury. Manifestations of intraoperative neurologic injury range from transient neuropraxias related to positioning, to complete spinal cord injuries with resultant paralysis. Historically, rates of neurologic injury ranged from 0.3 to 4% [14, 16, 17], depending on type of instrumentation type and surgical approach (anterior, posterior, combined). A large series from the SRS morbidity and mortality database cited new neurologic deficits occurring in 86 of 11,741 pediatric idiopathic cases, a rate of 0.73 %. The deficits were characterized as either spinal cord injuries (50 cases, 0.43 %) or nerve root injuries (36 cases, 0.31 %), but these data did not differentiate adolescent cases from infantile or juvenile cases

[18]. Other data from the SRS morbidity and mortality database cites neurologic injury following spine fusion specifically for adolescent idiopathic scoliosis as 0.26–1.75 %, depending on surgical approach [7]. Other large series support these findings, with reported rates of 0.69 % [19] and 1.06 % [20].

A thorough knowledge of the types of neurologic injury, and their causes, as well as systematic management of any detected intra-operative neurologic change is paramount. Prior to initiation of the procedure, appropriate patient positioning and padding of bony prominences can help avoid common and preventable injuries such as brachial plexopathies and peripheral nerve neuropraxias [21, 22].

Once the procedure has begun, intra-operative spinal cord or nerve root injuries may be due to a variety of mechanisms. Examples include direct trauma to the spinal cord from a surgical instrument or implant, cord ischemia due to diminished perfusion from intraoperative hypotension, or excessive stretch from a deformity correction maneuver. Utilization of somatosensory (SSEP) and transcranial motor evoked potentials (tcMEP) has improved the timely diagnosis of intraoperative neurologic injuries [23], thus affording surgeons the opportunity to reverse or correct potential harm to the spinal cord. In a recent series of 162 spinal deformity patients by Vitale et al. (of which 78 were idiopathic scoliosis) [24], electrophysiology (SSEP and tcMEP) was noted to have a sensitivity of 100 % and a specificity of 88 % for detecting a true neurologic deficit. All patients in their series who had a true electrophysiological event had an identifiable precipitating event to account for the change, and most of these issues could be reversed effectively [24].

A recent collaborative, multi-center consensus statement from a group of experienced pediatric spinal surgeons has produced an intraoperative “checklist” that can be used in surgery to address common reasons for intraoperative neuromonitoring changes, and suggests potential solutions [25•]. Mooney et al. have also provided guidance on how to manage neurologic deficits in the intra-operative setting [26•]. Both of these groups stress the same fact: any intra-operative neuromonitoring change requires a thoughtful, systematic, and controlled investigation of all possible sources of such changes, as well as timely remedy of all potential causes.

Dural tear

Exposure of the dura with concomitant risk of dural tear is uncommon in surgery for adolescent idiopathic scoliosis, as osteotomies and large ligamentous releases that may put the dura at risk usually are necessary only in the setting of rigid or severe deformities. However, as posterior column Ponte osteotomies become more common for deformity correction, this issue may increase in frequency. Dural tear is also a known and well-reported complication of pedicle screw placement [27–29]. The incidence of dural tear associated with

surgery for AIS is reported between 0.12 and 0.26 % [7, 9•]. Once recognized, timely and watertight closure of the tear should be achieved. Repair of the tear can be undertaken by the pediatric spinal surgeon or consulting neurosurgeon, depending upon the experience of those surgeons involved in the procedure. In most cases, repair consists of suture closure of the tear with or without an overlying fibrin glue or supplemental patch to protect the repair. Patient activity level and mobilization may be limited in the immediate postoperative period in the face of a dural repair.

Ophthalmologic and other positioning-related complications

Knowledge of proper positioning of the pediatric spinal fusion patient is important. In most cases of posterior spinal fusion for adolescent idiopathic scoliosis, the patient will be in the prone position for several hours. Therefore, the surgeon, in conjunction with the anesthesiologist and circulating nurse, must make all efforts to ensure that the patient's face/eyes, as well as arms and legs are appropriately positioned to avoid any injuries.

Ophthalmologic injuries in pediatric scoliosis patients are very rare. In the most recent and largest report of all complications in the treatment of pediatric scoliosis, no cases of vision deficits were reported in idiopathic scoliosis patients (one case was reported in a neuromuscular patient) [9•]. A survey of SRS members by Myers et al. [30] reported 37 cases of ophthalmologic injury. Most of these patients were adults (average age 46.5 years), and many of these incidents were accompanied by a period of hypotension. Patil et al. [31] performed a population-based review of visual loss after spinal surgery. They reported an overall incidence of visual disturbance after spinal surgery of 0.094 %. However, they noted that pediatric patients (<18 years) were 5.8 times more likely than patients aged 18 to 44 years to develop two specific, albeit rare, types of post-surgical visual loss (non-ischemic optic neuropathy and non-central retinal artery occlusion).

Other complications related to patient positioning include brachial plexopathies secondary to abduction of the upper extremity, and ulnar nerve and lateral femoral cutaneous nerve palsies associated with direct compression on the arm boards or resting pads of the spinal frame or table. The risk of these complications is approximately 0.5 % for all types of idiopathic scoliosis [9•]. Many do not become apparent until well into the postoperative period. With careful patient positioning and padding, these complications can be minimized [21, 22], and fortunately, many of them resolve over time [32].

Post-operative complications

Delayed neurologic injury

Although the majority of neurologic injuries or deficits in adolescent idiopathic scoliosis surgery occur during the

intraoperative period, spinal cord injury can occur in a delayed fashion. In a survey of members of the SRS, Auerbach et al. [33] reported 92 cases of delayed postoperative neurologic deficit in 82 surgeon practices during the prior 10 years. Extrapolating from the reported surgeons' volume, they concluded that the incidence of delayed neurologic deficit is approximately 0.01 %. Spinal cord monitoring was used in 97 % of the cases and most events (90%) occurred within the first 48 h postoperatively. Other reports detailing delayed neurologic injury following surgery for AIS exist as well [34, 35]. Such evidence speaks to the importance of serial neurologic exams in all inpatient AIS patients the post-operative period, including patients with previously normal post-operative neurologic exams.

Once recognized, management of a delayed-onset postoperative neurologic deficit can be difficult. Little data exists to guide surgeon decision making. Surgeons must balance the need for potential information that could be gleaned from imaging studies with the urgency to return to operating room for decompression or revision of instrumentation. In the survey by Auerbach et al. [33], almost 75 % of patients had an imaging study performed prior to repeat operative intervention. This clinical experience adds weight to the belief that in the case of a delayed neurologic deficit, it may be beneficial to obtain advanced imaging of the spine (such as CT scan or MRI) preoperatively to determine precisely if and where a source of compression (either bone or blood) or aberrant implant (potentially requiring revision) may be located.

Long-term recovery from neurologic deficits following scoliosis surgery can be unpredictable. In the series of adolescent idiopathic patients from Coe et al. [7], 18 spinal cord injuries were reported, but the chronicity of the injury (intraoperative versus delayed) is not clear. In those cases, complete recovery was noted in 11 (61 %), and incomplete recovery was noted in six (33 %). Auerbach et al. [33] reported that partial or complete neurologic recovery occurred in only 67 % of patients, however, their patient population was heterogeneous, and comprised kyphosis, spondylolisthesis, and cervical cases. In that series, almost 75 % of patients had achieved their final neurologic status by 6 months. Patients with compression-related (e.g., hematoma or instrumentation) delayed neurologic deficits had a significantly higher likelihood of some level of neurological recovery compared with patients in whom the deficit appeared to be related to ischemia (e.g., spinal cord swelling or spasm secondary to distraction from correction) [33].

Surgical site infection

In pediatric spine surgery, it is important to differentiate surgical site infection (SSI) in patients with adolescent idiopathic scoliosis from that which occurs in patients with neuromuscular disease. It is well-known that neuromuscular patients are at

higher risk of SSI than AIS patients, as evidenced by several recent multi-center studies [36, 37], as well as two recent systematic reviews [38, 39].

In AIS, rates of SSI range from 0.17 to 9 % depending on the studied patient population [37, 40, 41, 42]. In an SRS database series, Coe et al. [7] reported a wound infection rate of 0.17 to 1.37 %, depending on the approach used. Updated data in 2011 from Reames et al. [9] reported a similar rate in all idiopathic cases (0.5 % superficial wound infection, 0.8 % deep wound infection), but did not differentiate adolescent cases from juvenile or infantile. In a single surgeon, single institution review of 236 patients over an 18-year period, seven cases were noted to have a post-operative infection (3 %) [43]. A large multi-center prospective study by Carreon et al. found an infection rate of 0.71 % [10].

In most studies the majority of infections in patients with AIS occur in a delayed fashion (>6 months after the index fusion procedure) [43–45], and acute postoperative deep infections are rare, unlike the relatively higher acute infection rate in neuromuscular scoliosis patients. Furthermore, most delayed infections are caused by low virulence skin flora organisms (such as *Propionibacterium acnes* or *Staphylococcus epidermidis*), in contrast to highly virulent gram negative bacteria which more commonly affect neuromuscular patients [38].

In 1995, Richards and Emara [45] reported a 6.7 % incidence of delayed infection in 149 AIS patients managed with Texas Scottish Rite Hospital instrumentation. Richards et al. [44] followed this with a larger series in 2001 that reported a 4.7 % incidence of late infection. Ho et al. [46] investigated potential risk factors for delayed infection, and found that, while most likely multifactorial, a significant past medical history and perioperative blood transfusions were associated with an increased risk of developing a delayed infection. A previous study by that lead author, while reviewing patients from another institution, assessed the management of infection after AIS surgery. They found a nearly 50 % incidence of persistent infection if the implants were not removed [42].

Treatment strategies for managing postoperative infections in adolescent idiopathic scoliosis patients stem from retrospective reviews of large series of patients or from single surgeon practices [42, 43–45, 47, 48]. Early infections (<6 months post index procedure), while rare, do occur. Management of early infections should include attempts at irrigation and debridement with retention of implants if at all possible, in conjunction with infectious disease consultation and long term antibiotics. There is no data that supports a definitive length of antibiotic treatment. In light of this, the duration of antibiotic therapy, as well as oral versus intravenous route, is highly subjective, and open to interpretation.

In cases of deep infection and wound dehiscence, serially applied closed negative pressure dressing systems may be useful to develop healthy granulation tissue to cover exposed implants and assist in wound closure [49]. Most delayed infections can be

treated successfully with debridement and irrigation, implant removal and short term parenteral antibiotics. In a series of 15 patients with delayed infection following fusion for adolescent idiopathic scoliosis, Di Silvestre et al. [48] reported that removal of all implants was needed to completely eradicate an infection. Furthermore, higher rates of infections were found in stainless steel implants versus titanium implants. Hedequist et al. [47] also reported on a series of 26 patients with delayed infection, of which 10 (38 %) had adolescent idiopathic scoliosis. They found that infection could not be eradicated without implant removal, and they recommended implant removal at the first debridement surgery following diagnosis of an infection, so as to save time and resources.

Deformity progression after implant removal is modest [48], and any further deformity progression can be successfully treated once the infection is cleared [47]. The presence of a pseudarthrosis following a treated delayed infection is rare, but even when detected radiographically or confirmed with advanced imaging, does not appear to affect outcomes [43].

Despite the relative infrequency of infectious complications in AIS patients, prevention of both early and delayed infections, which can have high morbidity for the patient and significant utilization of hospital resources, should be the goal. In an effort to further minimize the risk, Best Practice Guidelines have been proposed to determine optimal strategies for preventing SSI in this patient population [50].

Venous thromboembolism

Venous thromboembolism (VTE) is defined as deep venous thrombosis or pulmonary embolism. Although a well-known complication of adult spine surgery [51, 52], venous thromboembolism is a relatively infrequently reported complication in pediatric scoliosis surgery.

The only large series on this topic queried a large nationwide database (the National Inpatient Sample) on in-hospital VTE following spine fusion surgery in patients under the age of 18 [53]. The incidence of VTE was found to be approximately 21 events per 10,000 spine fusion surgeries. Risk factors included syndromic or congenital scoliosis, as well as increasing age and spine fusion surgery for fracture. However, this series likely underestimates the true incidence of VTE, as it only examined in-hospital events, and VTE may develop in the weeks and months following spine surgery. At this time, there are no formal recommendations regarding perioperative prevention or treatment of VTE in AIS patients, which is not considered indicated in children without known hematological risk factors.

Pulmonary

Pulmonary and respiratory complications not associated with embolus are among the most commonly reported

complications following spine surgery for adolescent idiopathic scoliosis, with a reported incidence of 0.6–3.5 % [7, 9, 10]. However, these complications are poorly characterized in many studies, and there are conflicting reports as to whether the risk of postoperative pulmonary complications correlates with preoperative pulmonary function test results or curve magnitude [10, 54–56]. Carreon et al. [10] specified respiratory issues as pleural effusion and respiratory distress, and noted that each was associated with prolonged posterior surgery time and prolonged anesthesia time. Further research may be beneficial in better defining and characterizing these complications and any effect on patient outcomes.

Blood transfusion

Blood loss, and its accompanied risks of blood transfusion, are sequelae well-known to pediatric spine surgeons. As stated previously, perioperative blood transfusion is now considered a postoperative complication in many pediatric databases, such as KID. In a recent review of 9538 hospitalizations for pediatric spinal fusions in the 2009 KID database, 25.1 % of all patients received an allogeneic or autologous blood transfusion. Risk factors included female sex, longer segment fusions, and fusions involving the lumbar spine [57]. The literature regarding potential negative effects of blood transfusion in AIS patients remains unclear at this time. Ho et al. [46] reported that blood transfusion and receiving a greater number of units of transfused blood were significant risk factors for development of postoperative infection in AIS patients. However, this is in contrast to findings in other studies demonstrating that transfusion requirements and volume of blood products transfused are not significant risk factors for infection [58]. Carreon et al. [10] determined that an estimated blood loss of 775 ml in AIS patients undergoing posterior spinal surgery was a statistically significant point of discrimination between those with and without a postoperative non-neurological complication. Overall, it seems that minimizing the need for any type of blood transfusion, be it autogenic or allogeneic, is an appropriate goal.

Implant-related complications

Implant-related complications comprise 0.64–1.37 % of all surgeon-reported complications in spinal fusion surgery for AIS [7, 9]. These include complications associated with hooks, screws, or rods. Although placement of pedicle screws has been found to be safe and effective in pediatric scoliosis patients [27, 59], a variety of reports exist on complications associated with pedicle screw placement, including neurologic complications, screw loosening, dural tears, pneumothorax, pleural effusion, and wound complications [27–29]. Reports of implant associated loosening and wear debris exist as well [60].

Until recently, the metallurgy of spinal implants had been consistent, with the vast majority of all implants manufactured from stainless steel. There has been data in the last decade that has drawn attention to potential complications associated with stainless steel implants. Di Silvestre et al. [48] and others reported an increased rate of postoperative infection in patients managed with stainless steel implants versus those receiving titanium alloy instrumentation systems [61, 62]. This may be a result of greater bacterial biofilm adherence to stainless steel over titanium [63]. In light of these potential issues, and the compatibility of titanium implants with any future MRI examinations, many surgeons have converted from stainless steel to titanium instrumentation systems.

Gastrointestinal

Gastrointestinal (GI) issues associated with AIS surgery are common in the postoperative period. Just over a decade ago, Crawford et al. [64] reviewed 253 spinal procedures and found a 77.9 % incidence of postoperative gastrointestinal morbidity, with emesis and paralytic ileus being the most common diagnoses. In their study, significant risk factors associated with GI morbidity were fusion procedures, medical comorbidities, and prolonged opioid use. These issues were associated with a significant increase in length of hospital stay [64]. Multiple interventions are increasingly utilized in attempts to minimize these risks, including postoperative epidural pain catheters, multimodal non-narcotic pain protocols, and early post-operative mobilization. One randomized study assessed the effect of preoperative bowel preparation on morbidity and length of stay in scoliosis patients showed a modest, but non-statistically significant, effect on post-operative GI morbidity and length of stay [65].

Other, more rare GI diagnoses that have been reported after spinal deformity surgery include Ogilvie's Syndrome and Superior Mesenteric Artery Syndrome (SMA). Ogilvie's Syndrome is acute colonic dilation without the presence of a true mechanical obstruction. Hooten et al. [66] reported on an adolescent patient with Ogilvie's Syndrome after deformity correction and tethered cord release. This patient was treated with bowel rest and intravenous neostigmine with excellent results. SMA is a rare, but well-documented, post-operative complication of AIS surgery. Carreon et al. [10] reported two cases in their review of 702 non-neurological complications. The typical SMA patient is tall and thin, and usually undergoes successful correction of a relatively large coronal and/or sagittal plane deformity. Low BMI has been identified as a risk factor for SMA syndrome [67]. The patient with SMA typically presents with nausea and persistent vomiting a number of days after surgery. Details of the pathophysiology and management of SMA are beyond the scope of this article. However, this diagnosis should be kept in mind and should be part of the differential diagnosis in any post-operative AIS

patient with persistent nausea and vomiting, and an upper GI contrast study with small bowel follow-through is the diagnostic study of choice [68]. If suspected, general surgical consultation should be obtained urgently. The majority of patients respond appropriately to non-operative treatment, including bowel rest, nasogastric decompression, and supplemental enteral or parenteral nutrition.

Conclusions

Spinal fusion surgery for deformity correction and arthrodesis is a relatively safe and effective procedure for patients with adolescent idiopathic scoliosis. Surgeon-reported rates of complications are between 5 and 15 %. However, the expanding definition of complications by national databases to include various post-operative occurrences (such as blood transfusion) has expanded complication rates to almost 25 % in some studies. Pediatric spine surgeons who care for pediatric patients with AIS must be thoroughly familiar with all potential complications and their management. In addition, it is important that the patient and family are made aware of all potential risks prior to consenting to surgical intervention.

Compliance with ethics guidelines

Conflict of interest Robert F. Murphy and James F. Mooney III declare that they have no conflicts of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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