Complications in paediatric and adult spinal surgery

Maryem Ismael Aguirre
Athanasios I Tsirikos

Abstract

Spinal surgery procedures are growing rapidly in number and complexity due to an increasingly aging population, high patient expectations and continuous improvements in both surgical techniques and quality of instrumentation. National health services have to finance the rising costs of an increasing number of medico-legal claims against spinal surgeons, often arising from significantly life-changing complications. The most common complications specific to spinal surgery are implant failure, neurological deficit (nerve root, cauda equina or spinal cord injury), and dural tear. General complications include visual impairment, blood loss, thromboembolic events, infection and mortality. Instrumentation failure occurs most commonly due to misplacement, which is more frequent in deformity surgery. Kyphosis correction is associated with the highest risk of neurological injury and visual loss. Thromboembolic events are more frequent in patients undergoing treatment for metastatic spinal disease. Underlying conditions such as neuromuscular scoliosis increase significantly the risk of infection, as well as major systemic morbidity and mortality. Reliable national registries and international databases with accurate recording of information on procedures and corresponding complications help better understand, address, and reduce complications related to spinal surgery with the aim to improve patient care and achieve optimum outcomes.

Keywords adult; complications; database; incidence; morbidity; mortality; paediatric; registries; spinal surgery

Introduction

Spinal procedures are increasing in number and complexity alongside significant improvements in surgical techniques and the quality of available implants. Deformity correction previously required months of bed rest or cast immobilization but newer techniques allow immediate mobilization. Anterior and lateral procedures that were routinely performed through large laparotomy or thoracoabdominal approaches can now be done through minimally invasive incisions thanks to enhanced instruments allowing efficient distraction and better visualization of anatomical structures. Endoscopic approaches are constantly improving and their indications better defined; despite a long learning curve, these allow for certain procedures to be performed as day cases with an almost immediate return to daily activity and work.

However, these continuous advances in surgical techniques along with the ability to treat increasingly more complex spinal conditions result in a rising number of complications related to spinal surgery. National health services are faced with increasing numbers of medico-legal claims following spinal surgeries, often due to the occurrence of severe and life altering complications.

In order to better understand the consequences of our surgery, address complications and improve outcomes, it is essential for such complications to be recorded and analyzed in large databases. Participation in registries like the British Spine Registry (http://www.britishspineregistry.com/) is now required by scientific societies, professional bodies and the government, as well as by insurance companies in many countries. International scientific societies have developed databases requiring their members to report all complications they have had on a yearly basis in order to maintain their membership status. The Scoliosis Research Society Morbidity and Mortality Database (SRS M+M database) has produced the most prolific data so far. Although limitations due to surgeon and technique variability are evident, systematic database queries on the safety of procedures in terms of morbidity and mortality may be the most useful aspect of these registries. In addition, multicenter initiatives for the study of specific conditions, as in the case of the SCOLI-Risk-1 prospective study, can shed light more specifically on complications and indicate the means to improve outcomes and patient satisfaction.

In this review, the most common types of complications in spinal surgery are presented. These include instrumentation failure, neurological deficit (nerve root, cauda equina and spinal cord injury), and dural tear. General complications include visual loss, increased blood loss, thromboembolic events, infection, wrong level surgery and mortality. In addition, complications related to specific pathologies including paediatric and adult deformity correction, spinal tumour surgery and degenerative cervical and lumbar pathology are described.

Instrumentation failure

Spinal surgery has progressed dramatically in the past decades due in part to the development of novel implant materials and advanced technology. The complications related to the use of instrumentation in spinal surgery derived from the SRS M+M database[1] are reported in a total of 167,972 patients. Diagnosis included scoliosis (56%), spondylolisthesis (33%), and kyphosis (9%). Complications occurred in approximately 18.5 per 10,000 patients with the diagnosis of deformity most frequently occurring in kyphosis (0.27%) followed by scoliosis (0.21%), and spondylolisthesis (0.11%). The most frequent implant related complication was malposition (48.6%) followed by migration (28.3%) and failure (23.3%). Instrumentation misplacement occurred most commonly in scoliosis followed by spondylolisthesis. Implant removal due to new onset of intraoperative neurological deficit was necessary in 27% of patients. Infection occurred in 7.1% of patients included in the database.

Maryem Ismael Aguirre *MD Senior Spinal Clinical Fellow, Scottish National Spine Deformity Centre, Royal Hospital for Sick Children, Edinburgh, UK. Conflicts of interest: none declared.*

Athanasios I Tsirikos *MD FRCS PhD Consultant Orthopaedic and Spine Surgeon, Scottish National Spine Deformity Centre, Royal Hospital for Sick Children, Edinburgh, UK. Conflicts of interest: none declared.*

Screw malposition is not necessarily symptomatic and has not routinely resulted in revision surgery. However, screw misplacement was the most common cause of reoperation in a series of 10,350 patients in whom unplanned surgery was reported within a week of the index procedure.[2] This occurred in 0.82% of patients. In this series, the other most frequent complications requiring revision surgery were inadequate neural decompression and symptomatic epidural haematoma. It is of note that 25.93% of patients requiring surgery for epidural haematoma presented persistent symptoms.

New neurological deficit

Neurological damage following spinal surgery can be due to nerve root injury (NRI), cauda equina injury (CEI) or spinal cord injury (SCI). This complication can occur due to direct trauma to the neural elements by spinal manipulation or implant placement, neural compression (bone, haematoma, residual disc material) and oedema. In addition, the spinal cord is susceptible to ischaemic injury due to hypotension, especially during correction maneuvers in deformity surgery.

In 1975, a review of neurological complications following scoliosis treatment reported an incidence of 0.72% (87 patients). Of these, 74 patients were reported to develop a complication affecting the spinal cord and resulting in complete paraplegia in 50% and partial paraplegia in the remaining 50% of patients. Complete recovery occurred in 36%, partial recovery in 32%, and persistent symptoms in 32% of patients.[3]

An SRS M+M database search of 108,419 spinal procedures from 2004 to 2007 found an overall rate of new onset neurological deficits following spinal surgery of 1.0%.[4] This complication was more common in paediatric deformity correction (1.32% versus 0.83%), in revision surgery (1.25% versus 0.89%), and with the use of implants (1.15% versus 0.52%). The highest risk in patients under the age of 21 years was associated with spondylolisthesis reduction and kyphosis correction. In adults, new neurological deficit was most likely to occur in the treatment of a primary tumour and in kyphosis correction. Among degenerative procedures, thoracic decompression for spinal stenosis carried out the highest risk with 3.11% of SCI and 1.86% of CEI. Within the adult patient group, correction of degenerative scoliosis presented the highest risk for neurological deficit (2.49%). In young paediatric patients, post-traumatic scoliosis and congenital scoliosis presented the highest neurological risk (3.33% and 2.0%, respectively). Corroborating results from previous studies, kyphosis was once again related to an increased rate of neurological injury both in the adult and paediatric population (3.38 and 3.54% respectively).

In this database study, intraoperative neuromonitoring (IOM) was reported to be used in 65% of surgeries (87% paediatric and 55% adult). Changes in IOM were recorded in 44% of cases with new neurological deficit varying from 32% in adult revision surgery to 62% in paediatric revision surgery. An IOM event was noted in 11% of NRI, 8% of CEI, and 40% of SCI. No evidence of recovery was documented in 4.7% of NRI, 9.6 of CEI, and 10.6% of SCI.

In the following SRS M+M report presenting data from 2009 to 2012, the overall rate of new onset neurological deficit increased from 0.44% in 2009 to 0.79% in 2012.[5] The two pathologies at greatest risk for this complication were dysplastic spondylolisthesis and congenital kyphosis, which agrees with previous reports.

Dural tear

Incidental dural tear is the most common complication in spinal surgery frequently associated with lumbar decompression. Its incidence can vary between 1 and 17%,[6] and known risk factors include ossified ligamentum flavum, revision same level surgery and presence of synovial cysts. Primary dural repair is the preferred treatment when possible.

Visual loss

An SRS M+M database search of 167,972 spinal deformity procedures from 2009 to 2012 found an overall rate of visual loss following spinal surgery of 0.01% with more than half of these events occurring during the first 24 h after surgery. The risk was five times higher in patients with kyphosis compared to those with scoliosis and spondylolisthesis. The mean age of patients with visual loss was 34.8 $\pm$ 24.3 years. Hypertension was reported in 23.8% of cases. The extent of visual loss was: partial bilateral in 19%, total bilateral in 23.8%, partial unilateral in 38.1% and total unilateral in 14.3% of patients. Diagnosis was of anterior ischaemic optic neuropathy in 19%, posterior ischemic optic neuropathy in 19%, central retinal artery occlusion in 23.8%, and cortical blindness in 23.8% of patients. Half of these incidents resolved completely.[7]

Blood loss

In posterior thoracic/lumbar approaches where muscle layers are stripped off the posterior elements of the spine both bone and muscle surfaces are prone to bleeding, especially in adults due to the thinner periosteum, larger vascular channels, and osteoporotic bone. Any further removal of bone, either to access the vertebral canal or to increase mobility of the spine in order to correct a deformity can increase bony bleeding. It is particularly in tumour resections and 3-column osteotomies to correct complex deformities that bleeding is most significant. Associated complications when these techniques are employed include segmental and large abdominal vessel bleeding due to the invasiveness of the surgical approach.

Anterior lumbar procedures avoid muscle damage of posterior approaches and allow restoration of lumbar lordosis. However, proximity to the great vessels is inherent to the approach, which usually requires mobilization of the left common iliac vessels at the L4-L5 and L5-S1 levels. The left common iliac vein is the most frequently injured vascular structure, resulting in either bleeding by direct injury or thrombosis following prolonged retraction. Any previous surgery or retroperitoneal infection/discitis can increase the likelihood of adhesions and complicate exposure of the spine. Fantini et al. recorded a 2–4% (1.4–3.7%) rate of venous and 1% (0–2.4%) rate of arterial injuries in anterior approaches.[8] A prospective study on 212 anterior lumbar interbody fusions (ALIFs) reported 13 vascular injuries (6.1%) of which five were major.[9] Increased risk of bleeding was found when ALIF was performed in patients with higher BMI and when more than one disc was accessed.

In lateral approaches to the spine there is an inherently lower vascular injury risk. However, changes in rotation of the vertebral body and corresponding difference in the position of the vessels relative to the vertebral body may occur, especially in the presence of deformity. A vascular injury occurring during this approach can be particularly difficult to address given the minimally invasive nature of the exposure and may require performing an urgent laparotomy. Careful preoperative planning is warranted and immediate access to a vascular surgical team is mandatory.

In the cervical spine, anterior approaches are more anatomical and less aggressive than posterior procedures, which inherently cause more bleeding, postoperative pain and have an increased risk of wound infection. Vertebral artery bleeding is rare and more often caused by direct injury in partial anterior vertebral resection, especially with the use of an air drill.[10]

Intraoperative blood loss (IBL) and the need for blood transfusion are significantly related to postoperative outcomes following spinal surgery. In addition, the risks associated with transfusion include altered fluid shift, which affects the cardiac, pulmonary and renal systems. Growing awareness of these complications warrants specific measures to prevent IBL. Intraoperative measures such as patient positioning, maintenance of body temperature, controlled hypotension and use of cell salvage can markedly reduce the need for allogeneic blood transfusion. In addition, use of tranexamic acid can effectively and safely reduce IBL and the need for transfusion with no significant increase in thromboembolic events. Transfusion of a single unit of RBC following spinal surgery has been shown to increase both length of hospital stay and postoperative morbidity.[11]

Antiplatelet therapy continuation during spinal surgery is controversial and protocols differ from discontinuation several days before the procedure to no discontinuation at all. Surgeons are particularly worried about the risk of precipitating epidural haematomas (associated with a high neurological risk) and increasing perioperative blood loss. Seven studies were included in a systematic review on the effect of discontinuing aspirin on blood loss and other complications in spinal surgery. A total of 1173 patients were identified as belonging to three groups: 587 had never been prescribed aspirin, 416 patients stopped aspirin treatment 3–10 days before surgery and 170 patients continued aspirin treatment until surgery. Of the seven studies, six did not find any statistical difference between the three groups although operative time was significantly longer in the group that discontinued aspirin compared to the group that had continued treatment. Although the risk of developing a postoperative haematoma was 1.2% in the continued treatment group compared to 0.2% in the non-aspirin and discontinued treatment groups this difference was not statistically significant. The authors concluded that there is no strong evidence in favour of either discontinuing or continuing aspirin before spinal surgery.[12]

Thromboembolic events

A previous report looked into the rate of pulmonary embolism (PE) and deep venous thrombosis (DVT) among 9692 cases of lumbar microdiscectomy, 6735 cases of anterior cervical discectomy and fusion and 10,329 cases of lumbar decompression reported to the SRS M+M database from 2004 to 2007.[13] PE and DVT rates were highest in patients undergoing surgery for metastatic tumours (1.24% and 0.826% respectively), adult kyphosis (0.746% and 0.596% respectively), and adult scoliosis (0.431% for both PE and DVT). Death rates due to PE were greater in patients with a diagnosis of metastatic tumour (0.413%), followed by patients with thoracic degenerative disease (0.181%), and patients with spinal fractures (0.166%).

Thromboembolic events in paediatric patients are rare with a reported rate of 0.43% for PE, 0.39% for DVT and 0.08% for death due to PE among 1000 patients. Thromboembolic events were significantly more common in adults, patients with diagnosis of spinal tumours, and patients who underwent surgery with the use of implants without suggesting a causative link.

Infection

An SRS M+M database search of 108,419 procedures from 2004 to 2007 found an overall infection rate of 2.1%, with a lower rate (2.0%) in the adult compared to the paediatric population (2.7%).[14] Spinal deformity correction presented a significantly higher risk for infection compared to procedures for degenerative pathology. Revision surgery, as well as use of instrumentation, significantly increased the risk of infection, whereas this risk was decreased with the use of minimally invasive techniques for lumbar discectomy and transforaminal lumbar interbody fusion.

A subsequent analysis of the 2009–2012 SRS M+M database found that the overall infection rate was lower at 1.14% with patients undergoing neuromuscular scoliosis correction having a significantly higher infection rate of 2.97%.[5]

Wrong level surgery

Wrong level surgery is considered a 'never event' with every effort applied to avoid it. Despite protocols and checklists being implemented the rate of this complication ranges from 0.09 to 4.5 in 10,000 procedures.[15] Most of these cases end in lawsuits and high compensation payouts. Intraoperative imaging with marking of an anatomical structure, as well as comparison to preoperative imaging with clearly defined levels, is highly recommended.

Mortality

An SRS M+M database search of 108,419 spinal procedures from 2004 to 2007 reported an overall 60-day mortality rate of 1.8 deaths per 1000 surgeries. In adults the death rate was increased to 2.0 when compared to 1.3 per 1000 paediatric patients. The diagnosis related to the highest risk of mortality was spinal fracture (5.7 deaths per 1000) followed by kyphosis (4.4 deaths per 1000), scoliosis (1.8 deaths per 1000), and degenerative pathology and spondylolisthesis (both 0.9 deaths per 1000).[16] The cause of death was respiratory in 83, cardiac in 41, sepsis in 35, stroke in 15 and intraoperative blood loss in eight patients. Mortality increased with higher ASA scores, in spinal fusion procedures and with the use of implants but did not depend on patient gender and did not increase in the case of revision surgery.

Coe et al.[17] reported an overall 5.7% complication rate among 6334 patients undergoing anterior, posterior or combined spinal fusion with instrumentation for correction of adolescent

idiopathic scoliosis from 2001 to 2003 when reviewing the SRS M+M database. When stratified by approach, 5.2% of patients undergoing anterior surgery were reported to have complications, compared to 5.1% in the posterior instrumentation and fusion group, and 10.2% in the combined anterior and posterior approach group. Two patients (0.03%) died due to their complications.

A subsequent analysis using the SRS M+M database from 2009 to 2012 recorded a total mortality rate of 0.12%, with the most common associated diagnosis being dysplastic spondylolisthesis, neuromuscular scoliosis, congenital kyphosis and idiopathic scoliosis above the age of 18 years.[5]

Paediatric deformity correction

Scoliosis

A review of 19,360 patients with paediatric scoliosis from the SRS M+M database between 2004 and 2007[18] found that 10.2% patients had a complication, although significant differences were found between groups depending on diagnosis. Complications occurred in 17.9% of patients with neuromuscular scoliosis, including neurological deficit which occurred in 1.1%. Complications also occurred in 10.6% of patients with congenital scoliosis, with neurological injury (2.0%) being the most common. The complication rate was 6.3% in idiopathic scoliosis of which neurological damage occurred in 0.8% of patients. In the idiopathic scoliosis group, the most common complication was instrumentation-related (1.1%). The most frequent complication in patients with neuromuscular scoliosis was deep wound infection (3.8%). Higher rates of neurological deficits were associated with revision surgery and 3-column osteotomies. In relation to the type of instrumentation, sublaminar wire only and anterior screw only procedures caused significantly more neurological injury than posterior pedicle screw only and hook only constructs. Mortality in this study was 0.34% in the neuromuscular, 0.3% in the congenital, and 0.02% in the idiopathic group (Table 1).

In patients with early onset scoliosis, rapid progression of the deformity often occurs at a young age and traditional growing rods (TGR) have been used if brace treatment fails to control the curve in order to preserve growth of the spine and postpone the need for spinal fusion. Given the increased risk related to multiple anaesthesics and serial admissions with TGR in patients who commonly have complex co-morbidities,[19] magnetically controlled growing rods (MGR) that do not require surgical lengthenings have been developed with promising early results.[20] Data reported from the multicentre Growing Spine Study Group on 140 patients who had a total of 897 growing rod procedures included a 58% complication rate. Implant failure leading to unplanned surgery was more common when using a single-rod as opposed to a dual-rod construct (27% versus 10%). Wound complications were more frequent when the rod was placed subcutaneously when compared to submuscularly (26% versus 10%). Each additional year of treatment with the growing rod increased the risk of complications by 13% and each additional procedure increased the risk of complications by 24%.[19]

A systematic review including 336 patients treated with MGR found a procedure-related complication rate of 44.5%, with one third of patients requiring revision surgery. The most common complications included implant pull-out (11.8%), implant failure (11.7%) and rod breakage (10.6%).[21]

Complication rates in paediatric and adult scoliosis surgery (*excluding neurological complications)[18,23]

Scoliosis Surgery	Paediatric			Adult
	Idiopathic	Neuromuscular	Congenital	
Deep Wound Infection	0.8%	3.8%	0.9%	1.5%
Neurological injury	0.8%	1.1%	2.0%	1.5%
Implant Failure	1.1%	2.1%	1.5%	1.6%
Death	0.02%	0.34%	0.3%	0.27%
Total	6.3%	17.9%	10.6%	13.4 −67.7%*

Table 1

Kyphosis

The frequency of complications is higher in Scheuermann's kyphosis compared to scoliosis in the SRS M+M database, with a reported rate of 14% among 683 procedures from 2001 to 2004. Complications included 3.8% wound infections and 1.9% acute neurological injury (0.6% SCIs). Mortality rate was reported as 0.6%. Complications occurred more commonly in adult patients but no differences in complication rates were identified between the different surgical techniques (posterior versus anterior versus combined anterior/posterior correction).[22]

Adult deformity correction

Adult deformity surgery is increasingly performed with the use of less invasive techniques, which are producing improved health-related quality of life outcome scores. In order to optimize the results of such major procedures in medically frail patients, treatment-oriented classifications have been developed. Severe complications have been reported with significant variability and patient selection, as well as cost effectiveness must be addressed by meticulous preoperative planning and close monitoring of outcomes.

Sansur et al.[23] used the SRS M+M database to report on 4980 patients who underwent adult scoliosis surgery from 2004 to 2007. Of these, 521 patients (10.5%) had a total of 669 complications (13.4%). Dural tears were the most common complication (2.9%) followed by implant-related complications (1.6%), deep wound infections (1.5%), acute neurological injury (1.0%), superficial wound infections (0.9%), and delayed neurological deficits (0.5%).

Using the same database but identifying 5470 patients who underwent adult scoliosis surgery a second report found an overall complication rate of 13.5% including 0.3% mortality. In this study, a direct correlation between age and complication rates was identified possibly due to the presence of major medical and surgical risks with increasing patient age. Complications were also more frequent when the patient had an osteotomy to achieve deformity correction. Patients above 50 years of age had 15.4% risk of complications whereas the risk in patients younger

than 50 years was 10.5%. The most common complication in patients older than 50 years was a dural tear while implant-related complications were more frequent in patients below the age of 50 years.[24] Eleven of 15 mortalities in this group occurred in patients over the age of 65 years.

Scoli-RISK-1 is a prospective multicenter collaborative initiative between the AO Spine and the SRS for the study of complications and outcomes in adult spinal deformity (ASD). Patients were prospectively enrolled from September 2011 to October 2012. Using this dataset, a report on neurological outcomes of ASD surgery found 22.18% among 272 patients had worse and 12.78% had improved neurological function after treatment.[56] At 6 months, 10–82% of patients had persisting worsening of lower limb motor function while 20.52% demonstrated improved function. Among 265 of these patients, 61 (23%) demonstrated worse lower limb function at discharge.[25] Key factors associated with neurological deterioration after ASD correction included older age, lumbar level osteotomy, 3-column osteotomy and larger intraoperative blood loss. The three main predictive factors of neurological injury included older age, larger coronal deformity and lumbar osteotomy.

The non-neurological complications in patients undergoing ASD surgery after 2-year follow-up were recently reported to be 67.6%,[26] which is strikingly higher than previous reports. The most common complications were surgery-related including implant failure and dural tear. The incidence of non-neurological complications was higher in revision surgery.

Spinal tumours

Primary and metastatic spinal tumour surgery is related to a high complication and mortality rate. Spinal cord tumours have a reported hospital mortality rate of 0.55% and a total complication rate of 17.5%.[27] Surgical treatment of spinal metastases is also associated with increased complication rates ranging from 10 to 52%. These include haematoma formation, wound dehiscence, infection and need for revision surgery. Rates of complications are affected by the patients' baseline condition and adjuvant treatment. Techniques such as preoperative embolization in vascular tumours can help reduce surgical blood loss. In addition, new techniques including spine stereotactic radiosurgery are revolutionizing treatment of metastatic tumours.

Compared to the rest of patients who undergo spinal surgery, patients with spinal tumours are at significant risk for developing thromboembolic complications. The risk of PE is 12.4%, of death due to PE is 4.13% and of DVT is 8.26%.[13] Both mechanical and chemical thromboprophylaxis should be considered in this population.

Degenerative spine

The aging population is giving rise to an increasing number of patients seeking treatment for back pain, radiculopathy and myelopathy secondary to degenerative changes in the spine. There has been marked increase of related procedures including spinal decompression, fusion, and vertebral disc replacement.

Cervical

The overall complication rate for anterior cervical discectomy and fusion among 6735 patients was 2.4% (159 patients) with a significant increase in risk among patients above 50 years of age (3.1% versus 2.9%).[13] These included four deaths (1 PE; three cardiac failures). Neurological deficits were reported in 22 patients with three being delayed onset. The most common deficit was due to NRI (13 patients) of which nine recovered completely.

In a review of 13,191 cervical procedures a reoperation rate within 3 months of 1.03% was recorded with increased risk of revision surgery related to the presence of diabetes mellitus, female gender and presence of other comorbidities.[28] A study of 303 patients undergoing surgery for cervical spondylotic myelopathy between January 2005 and December 2013 identified that the most common cause for revision surgery was deep wound infection followed by acute deep haematoma after anterior procedures with the rate of unplanned revision surgery being 2.6%. Patients who needed unplanned surgery were 9 years older, although this was not statistically significant. The presence of diabetes mellitus increased significantly the risk of requiring unplanned surgery. Interestingly, requiring a reoperation did not affect patient satisfaction after surgery.[29]

An analysis of 12,000 cervical procedures noted that 2.5% of patients required readmission. Posterior cervical fusion was associated with higher hospital costs, whereas anterior approaches had a lower risk of reoperation.[30] While anterior approaches are anatomical and less traumatic, posterior cervical procedures can cause more soft tissue damage and are prone to infection. A retrospective cohort of 5441 patients recorded a 2.94% rate of posterior cervical wound infections following decompression, fusion or laminoplasty with no difference in incidence within these three groups. Of these, 36.9% required readmission. Infection was more likely to occur in patients with a high body mass index (BMI), chronic steroid use, low preoperative albumin level or when surgery lasted more than 3 h[31]

Lumbar

The overall complication rate for lumbar decompression among 10,329 patients was 7.0% including mortality of 0.13%.[13] 6609 patients (64%) underwent decompression and the remaining 3720 patients (36%) underwent decompression and fusion.[32] No difference in complication rates was found depending on patient age or use of instrumentation. In contrast, minimally invasive procedures had less associated complications.

The overall complication rate for lumbar discectomy among 9692 patients was 3.6%. Dural tears were significantly more common in patients over 50 years of age (2.1% versus 1.4%). Neurological deficits were reported in 28 patients (0.29%). Of these one SCI and one CEI were identified; both patients recovered partially. The 26 remaining patients had NRIs of which five were delayed presentations. Two of these patients did not recover function. Wound infections were significantly more common in traditional open techniques compared to minimally invasive procedures (1.1% versus 0.4%).[22]

Predicting postoperative complications

Predicting postoperative complications is paramount for the purpose of patient selection, provision of accurate information to the patient during decision making and consent, prevention which will improve surgical outcomes, as well as cost prediction/effectiveness. Numerous models are available to help predict

postoperative complications in spinal surgery. Models like SpineSage™[33] take into account patient characteristics (age, gender, BMI), presence of comorbidities, ASA, history of previous spinal surgery, surgical invasiveness.[34] Other models have been designed to define the conditions necessary to achieve minimum clinically important difference in Oswestry Disability Index after adult spinal deformity correction.[35]

Although many factors that influence the risk of complications, surgical morbidity and treatment satisfaction are the product of unique patient factors, their medical condition and the type of deformity being addressed, therefore not under direct influence of surgeons. It is critical that the patients are medically optimized prior to complex spinal surgery.

Conclusion

Complications in spinal surgery are becoming more common due to the greater number of procedures performed. In order to increase the safety of spinal procedures it is necessary to optimize patient selection and preparation, positioning and techniques, neuromonitoring and imaging. It is fundamental to understand preoperative risk factors including medical co-morbidities. It is also essential to select surgical techniques and spinal instrumentation based on the individual needs of the patient, their underlying condition and deformity characteristics. Intraoperative neuro-monitoring is mandatory in spinal deformity surgery and is increasingly used in other spinal procedures. It is necessary to standardize a multimodal protocol for neuromonitoring in order to increase sensitivity and specificity of the applied techniques. There is a growing interest in robotics and navigation which can improve accuracy of implant placement and increase patient safety, although not enough conclusive data has been reported in this field.

Implant failure is most commonly related to misplacement often occurring during the index procedure in deformity surgery. Surgical correction of kyphosis remains a high-risk procedure with a combined increased risk of mortality, infection, visual loss and neurological deficit. Thromboembolic events are most frequently encountered in patients undergoing treatment for metastatic spinal disease. Underlying conditions, such as neuromuscular disease increase significantly the risk of infection and major medical morbidity that can result in perioperative mortality.

Randomized control studies are very useful to provide specific information, although these are particularly costly and limited in their follow-up time. Databases and registries encourage reporting of prospectively collected patient information and can allow analysis of results on a population wide basis. There are clear limitations to this type of study including the variability of technique, lack of consensus and under-reporting of events, which may explain the diverse results being reported in journals and at meetings. Continued training and audits to improve quality of data collection may be useful to provide conclusive messages. Despite their limitations, these national and international databases will provide information on the general trends of risks and rates of complications for individual spinal pathologies and surgical techniques, which can in turn define treatment indications and allow clinicians to produce optimum and consistent surgical outcomes. ◆

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