Clinical Article

Optimising safety in the spine theatre

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With the proliferation of spinal surgery, both in numbers of cases annually and variety of surgery, there has been an increase in complications and associated litigation. Fager reports that up to 40% of cases were non-defensible.
A review of the published literature was performed to highlight some of the more common aspects in an effort to highlight them to the spine surgeon in an attempt to reduce their incidence and optimise safety in theatre.
The following issues are discussed:
- Wrong level surgery
- Patient positioning
- Infection risk and rituals
- Neurophysiological monitoring
- Neuronavigation.

Spinal surgery has evolved from a modest and limited field of practice into a highly specialised and technically challenging specialty. In the developed world there is an increase in degenerative conditions as a result of an increasingly aged population. It is estimated that the number of lumbar fusions in the USA have increased from 9 000 to 36 000 pa from 1996 to 2002,[1] and the trend continues. In the developing world, the prevalence of HIV and tuberculosis has increased the surgical management of infective conditions of the spine.

As spinal surgery has become more widely practised, litigation has also increased. Fager[2] reviewed a study of 275 recent malpractice claims compared with a prior study of 300 cases of liability and potential liability reported in 1985. Twenty years later, the results are surprisingly similar. Spinal surgery continues to dominate neurosurgical malpractice claims. More than 40% of claims were considered either not defensible or had merit for the plaintiff.

The South African scenario brings its own challenges with surgeons forced into independent private practice early due to limited state appointments, high patient volumes necessitated by poor remuneration, and failing infrastructure due to nursing shortages and inadequate resources.

The aim of this review is to highlight potential intra-operative complications in an effort to improve the safety in spinal surgery practice with an emphasis on patient positioning, wrong level surgery, infection rituals, electrophysiological monitoring and computer-assisted navigation.

Patient positioning

Complications during positioning are most commonly associated with prone positioning. Careful, controlled rotation is important to prevent patient injury and dislodgement of anaesthetic lines/tubes. This requires adequate staff, with the anaesthetist usually controlling the head, two rolling and two receiving. This allows log-rolling and simultaneous control of the limbs. Control is even more important in patients with a known traumatic spinal instability, as secondary injury is a concern. In this situation, keeping the cervical collar on and using the Jackson table was found to significantly reduce the cervical motion in all angular planes compared with that of manual transfer.[3] Cervical hyperextension must be avoided as this may precipitate neurological compromise in a stenotic canal.

On final prone positioning, pressure points need to be checked. Although partly caused by intra-operative hypotension, retinal ischaemia and loss of vision can be worsened by pressure on the eyeball. Appropriate padding of the eye socket (*Figure 1*) and use of a horseshoe frame or gel cushion can prevent this. Employment of the Mayfield clamp in cervical procedures allows a firm anchorage of the head which is susceptible to motion during posterior spinal surgery (*Figure 2*). This prevents pressure on the face.

Padding should be placed under vulnerable areas. These include the axilla (brachial plexus), ulna nerve at the elbow and wrist, breasts in female patients, genitalia in male patients, groin for femoral artery compression, lateral femoral cutaneous nerve, knee and foot prominences. The urinary catheter should be secured. It is often left dangling free when light at the beginning of the operation, only found to be hanging later when full.

The abdomen should be allowed to hang free in an effort to reduce venous pressure and bleeding. Prolonged compression on the abdomen has been associated with venous stasis and bowel ischaemia.[4] Intra-abdominal pressure changes and blood loss was studied by Park using a rectal balloon pressure catheter during spinal surgery. Blood loss tended to increase with an increase in intra-abdominal pressure in the narrow pad support width of the Wilson frame.[5]

Dharmavaram[6] assessed haemodynamic and cardiac function after prone positioning using different prone positioners. They found the Jackson spine table had the least effect on cardiac performance. Palmon *et al*[7] compared the effect of prone positioning on a Wilson frame, chest rolls and Jackson table (*Figure 3*) on pulmonary mechanics. They concluded that the dynamic pulmonary compliance and haemodynamic variables were not altered in patients positioned on the Jackson table regardless of body habitus, as opposed to a decrease in these variables with the other positioners.

The above makes a strong argument for the use of the Jackson table. It also allows the surgeon to stand close to the patient, which is both comfortable and provides easy surgical access.

Figure 1: Pre-fabricated cut-out sponge to support face without ocular pressure

Figure 2: The Mayfield clamp provides excellent control of the head for posterior cervical surgery and keeps the face free of all pressure risks

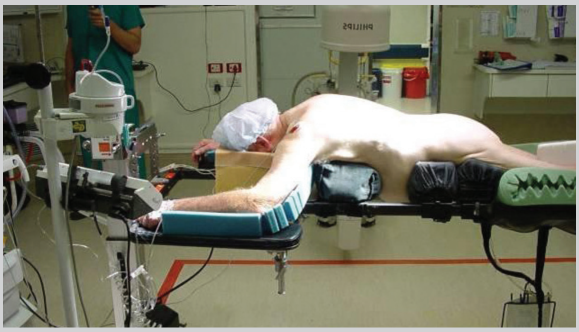

Figure 3: The Jackson table has been shown to minimise intra-abdominal pressure with the least pulmonary, cardiac and haemodynamic effects

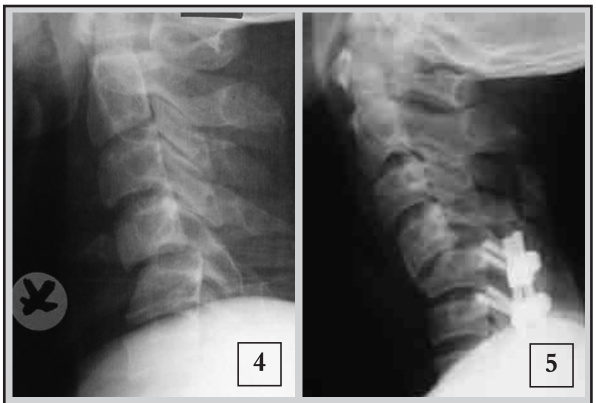

Figure 4 and 5: Even an obvious pathology can result in wrong level surgery. Fifty per cent of surgeons will make such an error in their career

Wrong level surgery

Wrong level surgery is more common than generally expected (*Figures 4 and 5).* Although many reasons are given, it comes down to system failure of checks pre- and intra-operatively. Moody[8] surveyed members of the American Academy of Neurologic Surgeons (n=3 505) by sending an anonymous, 30-question survey with a self-addressed stamped envelope. In typical surgeon style only 415 (12%) responded. Of these, 64 surgeons (15%) reported that, at least once they had prepared the incorrect spine level, but corrected before the incision. Fifty per cent had performed one or more wrong level surgeries during their career with a prevalence of one in 3 110 procedures. One wrong level surgery led to permanent disability, and 17% resulted in legal action or monetary settlement to the patient.

Michaels[9] reviewed programmes initiated in North American facilities to reduce wrong site surgery. He found no scientific evidence available to guide hospitals in evaluating whether they had an effective policy. They concluded that there was limited evidence of behavioural interventions to reduce wrong site, patient, and surgical procedures.

A WHO system has recently been instituted at the authors' institution. This has pre-incision timeout where the full theatre team confirms the procedure, side and level. Haynes reports a decrease in both mortality and morbidity with the implementation of this protocol in eight international hospitals.[10]

Control of infection risk

Infection can be catastrophic and is the bug-bear of surgeons. This has led to some irrational efforts or rituals to minimise the incidence. Redfern[11] confirms that only 12% of practitioners based infection control practice in theatre on evidence.

Woodhead chaired the Hospital Infection Society Working Group aimed to provide clear and practical guidelines for infection control in operating theatres based in the United Kingdom. Many of these rituals were challenged.[12]

A Canadian editorial[13] stated that there was no increase in day case infection in cataract removal surgery when remaining fully dressed including their ordinary shoes. Brown[14] states that underwear removal is the most illogical of rituals and serves only to embarrass patients and serves no useful purpose.

They recommended jewellery be removed but rings simply taped to avoid loss in the drapes. There was consensus that there was no need for removal unless in the operative field.[12] Despite this, there are concerns about swelling of the digits and ischaemic injury with the fluid shifts in spine surgery.

As far as the surgeons' rings are concerned, the work group highlighted the higher incidence of glove breakage at the base of the ring finger and suggest pre-operative removal to avoid this. On a personal note, having lost one wedding band in theatre already and never having witnessed a glove breakage at the ring site, the author finds the balance of risk favouring wearing the ring!

Much has been made about surgical site shaving with the belief that hair increases infection risk. Traditionally this was done the night before. Cruse and Foord[15] reported that infection with shaving was 2.3% and clipping 1.7%, yet neither shaved nor clipped was 0.9%. De Koos and McComas[16] noted no difference between shaving and chemical depilation in 253 patients and commented that cream was easier. Alexander[17] compared hair clipping or shaving the night before versus on the morning of surgery and found that the lowest infection rate was with clipping the morning of surgery. The work group report made the recommendation that only the incision site should be shaved. This was either done by cream the day before or shaved immediately pre-op using clippers rather than razor.

Pre-operative showering has been shown to reduce bacterial loads and intuitively thought to reduce infection. Garibaldi[18] found 4% chlorhexidine showers reduced pre-op and intra-op skin contamination. Kaiser[19] confirmed that chlorhexidine was more effective than povidine iodine in reducing staphylococcus skin count. However this does not necessarily translate to lower infection risk. Byrne[20] studied 3 482 patients and found no difference in wound infection irrespective of showers and concluded that showers are not cost-effective.

As regards pre-operative hand-scrubbing, Dineen[21] found no difference between a five- and ten-minute scrub. Rehork and Ruden[22] found that an initial five-minute wash was adequate and that if an operation was less than one hour in duration, only a one-minute re-wash was required. The work group conclusion was that there was no evidence that a hand wash longer than two minutes with aqueous disinfectants is required and that alcoholic rubs are acceptable for repeated washing.

Patient skin preparation followed the hand studies of Lilly and Lowbury[23] in 1960 where they showed that 1% iodine in 70% alcohol and 0.5% chlorhexidine in 70% alcohol were effective for hand cleansing and thus used for patient skin preparation. However, alcohol brings the risk of intra-operative fires from flammable vapour and electrocautery ignition. This is extremely difficult to recognise, with the author (RD) having personal experience of an intra-operative incident when the clear flames were only recognised by the 'browning swab' before the heat was detected. Twenty to 30 such incidents occur in the USA annually.[24] The recommendation is that alcoholic preparations be used but be allowed to dry before initiating surgery.

Neurophysiological spinal cord monitoring

Neurological deterioration is an infrequent but ever-present complication of spinal surgery and on the forefront of deformity surgeons' minds when operating. Motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) can be utilised intra-operatively to detect early neurological injury and possibly allow timeous action to reverse it.

Kelleher[25] sought to define the incidence of significant intra-operative electrophysiological changes and new post-operative neurological deficits in a cohort of patients undergoing cervical surgery. This included SSEP recording in 1 055 patients, MEP recording in 26, and electromyography (EMG) in 427. SSEP had a sensitivity of 52%, a specificity of 100%, a positive predictive value (PPV) of 100%, and a negative predictive value (NPV) of 97%. MEP had a sensitivity of 100%, specificity of 96%, PPV of 96%, and NPV of 100%. EMG had a sensitivity of 46%, specificity of 73%, PPV of 3%, and an NPV of 97%.

Schwartz[26] looked at the value in deformity surgery by monitoring the spinal cord motor tracts directly by recording transcranial electric (Tc) MEPs in addition to SSEPs. They reviewed intra-operative neurophysiological monitoring records of 1 121 consecutive patients with adolescent idiopathic scoliosis. Tc MEPs were found to be exquisitely sensitive to altered spinal cord blood flow due to either hypotension or a vascular insult. Moreover, changes in Tc MEPs were detected earlier than changes in SSEPs, thereby facilitating more rapid identification of impending spinal cord injury. Pelosi[27] found that by combining SSEP/MEP methods one may enhance the impact of neuromonitoring on the intra-operative management of the patient and favourably influence neurological outcome.

Cheh[28] performed a retrospective review of paediatric kyphosis patients undergoing a spinal cord-level osteotomy for correction. Of the 42 patients, nine demonstrated a complete loss of MEP data sometime during surgery while concomitant SSEP data remained within acceptable limits of baseline values. All nine patients had intra-operative intervention. In all cases, SSEPs were unchanged and MEPs returned within eight to 20 minutes after loss, with all patients having a normal wake-up test intra-operatively and a normal neurologic examination after surgery. They concluded that intra-operative multimodality monitoring with some form of motor tract assessment is a fundamental component of kyphosis correction surgery in the spinal cord region in order to create a safer, optimal environment and to minimise neurologic deficit.

Monitoring in degenerative conditions has been investigated. Taunt[29] in a retrospective multicentre study of 163 patients who underwent anterior cervical decompression and fusion (ACDF) surgery, concluded that in no instance were positive SSEP findings clinically useful in alerting the surgeon to potential intra-operative complications and thus SSEP is not helpful to the surgeon when performing routine ACDF. Patrick[30] reviewed 1 039 non-myelopathic patients undergoing single or multilevel ACDF surgery: the control group (462 patients) were not monitored, whereas the monitored group (577 patients) had continuous intra-operative SSEP. None of the patients in the control group had any new post-operative neurological deficits, yet in the monitored group there were six instances of transient SSEP changes. One was due to suspected carotid artery compression and five were thought to be due to transient hypotension which resolved with the appropriate intra-operative intervention such as re-positioning of retractors or raising the arterial blood pressure. Upon waking up from anaesthesia, one patient in the monitored group had a new neurological deficit (despite normal intra-operative SSEP signals).

It would therefore appear that neurophysiological monitoring (*Figure 6*) does not add value in degenerative spinal surgery, but is increasingly useful in aggressive correction of deformities. It must however be recognised that it is not simply the technology that is required, but also the human resources to interpret the data that will ultimately be the key to safer surgery.

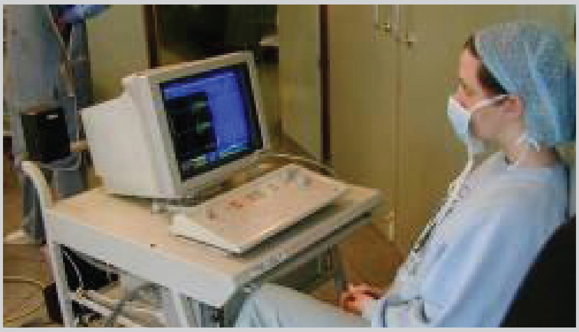

Figure 6: Neurophysiological monitoring may provide an early warning system. However it is not just the technology, but adequately trained personnel, that are vital to make it useful

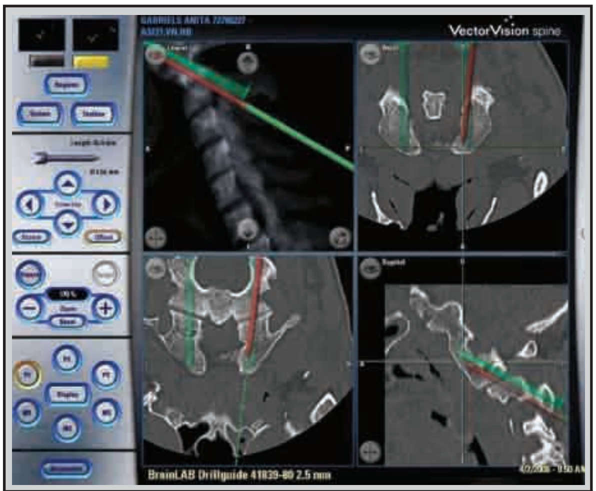

Figure 7: Computer-based neurovavigation may assist in complex deformity or revision surgery where anatomical landmarks are distorted

Neuronavigation

Neuronavigational systems (*Figure 7*) can be broadly classified into computer tomography (CT)-based and fluoroscopy-based systems, depending on the way the image is acquired.

The CT systems can be further classified into pre-op and intra-op acquisition. When acquiring a CT pre-operatively the surgeon risks inaccuracies in navigation in cases of underlying instability. When a patient is turned prone for surgery but the CT was performed with the patient in a supine position, there is a change in the spatial relationships assumed by the computer software. Image acquisition by intra-operative CT can overcome this.

Fluoroscopy performed intra-operatively, and images loaded into the navigational system, do not provide axial images and still have a measure of radiation exposure. There may be difficulty with image interpretation in osteopaenic and obese patients. More recent 3-D fluoroscopy guidance systems allow more accurate imaging.

The principle use of neuronavigation is during instrumentation of the vertebral column. Complications related to pedicle screw placement can vary from none to catastrophic and may only present post-operatively giving an early false sense of security. Frameless neuronavigation allows utilisation of the once-off acquired image and thus lower radiation exposure.

An experienced spinal surgeon may argue that neuronavigation adds little value as it can be more time-consuming to set up the system, and the low incidence of misplacement of a pedicle screw in experienced hands does not warrant the additional costs. Ebmeier[31] used intra-operative CT imaging to assess accuracy of thoracic pedicle screw placement using neuronavigation. There was a 6.3% incidence of misplacement. In 11.5% of cases they observed a minimal lateral perforation (<2 mm) of the pedicle. Several laboratory and clinical studies have shown that lumbar pedicle screw insertion using standard techniques yields misplacement rates that range from 20% to 30%. Weinstein[32] placed T11-S1 pedicle screws in eight cadaver specimens using anatomic landmarks and fluoroscopy. They determined that 21% of the pedicles manifested evidence of cortical violation. Schulze[33] reviewed post-operative CT scans in a large series of patients who underwent lumbar fusion procedures by experienced surgeons and determined that 20% of the screws perforated the pedicle wall. In comparison, Foley and Smith[34] performed a cadaver study based on Weinstein's methodology using image guidance instead of fluoroscopy for navigation. Post-operative CT scans and visual inspection revealed no evidence of pedicle wall violation. Kalfas[35] placed 150 lumbar pedicle screws in 30 patients using image guidance and determined that 149 of the screws were placed satisfactorily.

Pedicle screw misplacement rates using image guidance range from 0% to 4%. Sasso[36] performed a retrospective database analysis of 105 patients undergoing posterior L5-S1 spine fusion with pedicle screw instrumentation for isthmic spondylolisthesis with and without the use of fluoroscopy-based image guidance. Computer-assisted image-guided spine surgery has, overall, demonstrated shorter mean operative times when compared with intra-operative serial radiography technique with an average of 40 minutes less per case.

The literature widely supports the use of neuronavigation to aid placement of thoracic pedicle screws as well as cervical pedicle screws. Liljenqvist *et al*[37] placed 120 thoracic pedicle screws in 32 patients with scoliosis and found that 25% of the screws were misplaced. Vaccaro[38] placed 90 screws in T4–T12 pedicles and determined that 41% violated the pedicle wall. In contrast, Youkilis[39] reported a series of 266 thoracic pedicle screws placed in 65 patients over a 4-year period using image guidance. They determined that the pedicle perforation rate was 8.5%, significantly lower than that reported with conventional techniques. Foley[40] performed cervical spine CT scans on a number of patients and then determined the entry points and trajectories for C1–C2 transarticular screw placement using an image guidance system. They found wide variations of optimal screw entry points between patients and concluded that following a preset path, rather than one dictated by the individual anatomy, may result in screw misplacement and patient injury.

From the authors' perspective, the routine use of neuronavigation is not justifiable in the South African context due to the costs. It may however be useful in revision surgery when there is loss of the normal anatomical landmarks.

The principle use of neuronavigation is during instrumentation of the vertebral column

Conclusion

The surgeon brings the patient to theatre and is ultimately responsible for minimising the risk he or she exposes the patient to. The surgeon therefore needs to minimise this as much as possible. The high cost technology is frequently discussed but simple attention to detail will reduce risk without cost. Many of these issues are common sense and previously assumed to occur but in our challenging local environment, the surgeon needs to see that these measures are in place.

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