14 Preoperative Assessment

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Core Messages

- ✔ The preoperative patient assessment is the occasion most likely to reduce anxiety and fear
- ✔ More and more elderly patients with comorbidities are scheduled for elective spinal surgery
- ✔ Spinal cord injury can severely affect other organ systems
- ✔ Scoliosis can cause restrictive pulmonary disease. The most common blood-gas abnormality is reduced PaO_2 with normal $PaCO_2$. Restrictive lung disease can progress to irreversible pulmonary hypertension and cor pulmonale
- ✔ Patients with Duchenne muscular dystrophy are a special group deserving special attention and precaution with regard to cardiac and pulmonary problems
- ✔ Surgery for malignant tumors often requires extensive blood transfusions
- ✔ Spinal shock begins immediately after the injury and can last up to 3 weeks
- ✔ Post-traumatic autonomic dysreflexia may be present after 3–6 weeks following the spinal cord injury
- ✔ Preexisting drug therapy needs careful assessment and sometimes adaptation

Aim of Preanesthetic Evaluation

A thorough preoperative assessment of patients with scheduled spinal interventions helps to minimize complications

The preanesthetic evaluation of the patient for spinal surgery is not unique; it follows the general approach used before any patient is given anesthesia. Both adult and pediatric patients present for spinal surgery, which may be elective or urgent. Procedures range from minimally invasive microdiscectomy to prolonged operations involving multiple spinal levels and anterior/posterior surgery. When assessing patients before spinal surgery, particular attention should be given to:

- respiratory function
- cardiovascular system
- metabolic conditions
- neurological function

A clear understanding of the surgical procedure as well as complete knowledge of the patient's status are essential requirements in resolving perioperative problems, particularly in high-risk patients. This helps in the development of an appropriate and optimal anesthetic plan for intraoperative and postoperative management. **Risk factors** for postoperative complications are:

- combined procedures (single or two staged anterior/posterior surgery)
- multiple levels involved
- age over 60 years
- spinal cord injury or preexisting myelopathy
- preexisting comorbidities, ASA physical status classification

Table 1. The American Society of Anesthesiologists (ASA) Score

Class	Physical status
I	Healthy patient
II	Patient with mild systemic disease
III	Patient with severe systemic disease, but not incapacitating
IV	Patient with incapacitating disease that is a constant threat to life
V	Moribund patient who is not expected to live 24 h with or without surgery
E	Emergency case

The ASA score assesses the cardiovascular risk

The **American Society of Anesthesiologists (ASA)** has adopted a six-category physical status classification system to assess the patient preoperatively (Table 14.1). The ASA score makes no adjustments for age, sex, weight and pregnancy, nor does it reflect the nature of the planned surgery. Although this system was not intended as such, it generally correlates with the perioperative mortality [40].

The most frequently cited **comorbidities** [14] include:

- cardiovascular disease
- hypertension
- pulmonary disease
- diabetes mellitus

The general approach should be to characterize those conditions which can be improved by preoperative preparation and to take into account those conditions which will add to the risk of anesthesia and surgery.

Information and Instructions

One aim of the preoperative visit is to explain and describe the anesthetic procedure to the patient and to describe the procedure. This usually reduces the patient's anxiety.

The patient should be **informed about**:

- the possibility of an intraoperative wake-up test
- the importance of following orders to move the extremities at the end of the procedure (if necessary)
- the need for a prolonged intubation and mechanical ventilation
- surveillance on an intensive care unit

Reduce anxiety and give information

The decision to provide a period of postoperative mechanical ventilation should be made before surgery commences. This should be explained to the patient as well as the possibility of unexpected complications leading to prolonged mechanical ventilation. The patient should be reassured that no pain will be felt during the procedure and the wake-up test.

Patient Assessment

History

The preoperative history should clearly establish the presence of medical problems, their severity and any prior or present treatments. Because of potential drug interactions with anesthetics and analgesics, a complete medication history including any herbal therapeutics, the use of tobacco, alcohol and illicit drugs should be elicited. True **drug allergies** must be distinguished from **drug intolerance**. Detailed questioning about previous operations and anesthetics may unco-

ver earlier complications, and a family history of anesthetic problems may indicate whether malignant hyperthermia should be considered.

A general review of the organ systems is important in identifying undiagnosed medical problems. **Questions should emphasize:**

- previous cardiovascular problems
- pulmonary diseases
- endocrine dysbalance
- hepatic dysfunction
- renal insufficiency
- neurological illness

Physical Examination

A physical assessment is mandatory to detect putative intraoperative complications

The physical examination complements the history and helps to detect abnormalities not apparent from the history. Examination of healthy asymptomatic patients should minimally consist of measurement of vital signs (blood pressure, heart rate, respiratory rate, temperature). Using standard techniques of inspection, auscultation, palpation and percussion, the airway, heart and lungs should be examined when the history shows this to be necessary. An abbreviated neurological assessment serves to demonstrate a subtle preexisting neurological deficit. The patient's extremities and joint mobility should be assessed with regard to positioning (e.g., assessment of shoulder mobility for prone positioning).

Laboratory Studies

Requirements for preoperative laboratory studies, chest X-ray and electrocardiogram are determined by the age and health of the patient as well as by the scope of the procedure. There has been a trend toward decreased routine testing in many patients.

In a recent study with elderly surgical patients, the prevalence of abnormal preoperative values for electrolytes, hemoglobin, platelets, creatinine and glucose values was low and was not predictive of postoperative adverse outcomes [12].

Preoperative cardiac testing is indicated when functional status is poor or unclear and the risk of coronary heart disease is increased

Additional **preoperative cardiac testing** is indicated only in those patients at intermediate risk according to the Revised Cardiac Risk Index (Table 2). When the functional status is poor or unclear and the risk of coronary heart disease is increased, additional apparative examinations are indicated, although there is no evidence of improved outcome. In those patients clearly at high risk, the possibility and urgency of an intervention related to their cardiac disease must be weighed against the urgency and invasiveness of planned non-cardiac surgery [27].

Table 2. Revised Cardiac Risk Index [20]

Risk factors	Criteria
high risk surgery	• thoracic, abdominal and vascular surgery
coronary heart disease	• myocardiac infarction, angina pectoris, positive stress testing
congestive heart failure	• history, physical status
cerebrovascular insults	• TIA, apoplexia
diabetes mellitus	• insulin dependency
renal insufficiency	• serum creatinine > 177 (mol/l)

Stable patients undergoing major non-cardiac surgery with at least three of these factors have an increased risk for cardiovascular complications during the subsequent 6 months, even if they do not have major perioperative cardiac complications

Organ-Specific Assessment

Airway Assessment

Difficulties in airway management should always be considered

The potential for difficulties in airway management should always be considered [9, 46], particularly in those patients presenting for surgery of the upper thoracic or cervical spine.

A careful airway assessment should be made with regard to:

- previous difficulty in intubation
- degree of mouth opening
- size of the tongue
- visibility of the pharynx
- the state of dentition
- restriction of neck movement
- stability of the cervical spine

Assessment of cervical stability is mandatory in patients with Down's syndrome and rheumatoid arthritis

In **rheumatoid arthritis** [45] at least 20 % and in **Down's syndrome** [1] up to 20 % of patients suffer from compromised stability of the cervical spine, particularly the atlantoaxial joints. This makes careful manipulations during laryngoscopy, intubation and positioning mandatory to avoid dislocation with subsequent spinal cord compression. In such cases, some authors recommend functional views of the cervical spine to assess the degree of instability.

The cervical spine of traumatized patients is unstable until demonstrated otherwise

Severely traumatized patients or patients with head injury should be assumed to have an unstable cervical spine. It is essential to discuss preoperatively the stability of the spine with the surgeon who is responsible for the clinical and radiological assessment. In patients with an unstable spine, awake intubation is required.

Awake fiberoptic intubation is recommended in patients with an unstable cervical spine

Several methods may be used to **intubate** these patients:

- awake fiberoptic intubation after topical anesthesia
- intubation with manual stabilization of the neck by the surgeon (in selected cases)

Awake fiberoptic intubation of a mildly sedated patient is preferred, because intubation of the unconscious patient predisposes to greater risk of hypoxic injury [2].

In these patients, nasotracheal fiberoptic intubation is usually easier than oral fiberoptic intubation because the nasopharynx, oropharynx and glottis are commonly in the same axis. Fiberoptic guided nasal intubation should be attempted only if there is no evidence of facial trauma or skull fracture to avoid neurological injuries. In an airway emergency, direct laryngoscopy and intubation can be necessary before cervical spine injury is excluded. In this situation, a second person should stabilize the cervical spine during the procedure to avoid as much as possible flexion and extension of the neck. In the presence of minor clinical instability, intubation can be carried out with manual stabilization of the cervical spine, which should preferably be done by the surgeon.

The type of intubation in patients with an unstable spine needs to be determined preoperatively

Some inherited disorders such as Duchenne muscular dystrophy or Down's syndrome may lead to **glossal hypertrophy** [39], which may cause a problem during intubation.

Previous radiotherapy of tumors of the head and neck can cause difficulty in direct laryngoscopy.

Respiratory System

The value of routine preoperative chest radiographs in asymptomatic patients is very limited, since abnormal findings are reported to be few, rarely leading to

changes in clinical management and with an unknown effect on patient outcomes [32]. One of the most important reasons for this investigation may be to resolve medicolegal issues.

Pulmonary complications are frequent in major spinal surgery

Pulmonary complications such as pneumonia, lobar collapse and atelectasis are the most common form of postoperative morbidity experienced by patients who undergo general surgical abdominal procedures and thoracotomy. These surgical procedures cause large reductions in vital capacity and functional residual capacity [15]. The latter has long been identified as the single most important lung volume measurement involved in the etiology of postoperative respiratory complications. Functional residual capacity decreases after upper abdominal operations and thoracotomy by 30 – 35 %.

According to the extent of the surgical procedure and the preoperative patient condition, the respiratory function should be assessed with **pulmonary function testing** including blood gas analysis in patients with:

- asthma
- chronic obstructive pulmonary disease
- chronic intrinsic restrictive pulmonary diseases such as fibrosis and sarcoidosis
- extrinsic restrictive pulmonary diseases such as kyphoscoliosis and neuromuscular disorders

As a rough guideline, the **risk of postoperative pulmonary complications** can be assumed to be increased when:

- forced vital capacity (FVC)
- forced expiratory volume in 1 s (FEV_1)
- FEV_1/FVC ratio
- peak expiratory flow rate (PEFR)

Respiratory function should be assessed focusing on functional impairment

are lower than 50 % of the predicted value based on patient age, weight and height [4]. In patients with Duchenne muscular dystrophy, the limits for FVC and PEFR will have to be set at lower values [31]. The result of these investigations can influence the decision on the kind of anesthesia (epidural or spinal anesthesia instead of general anesthesia), and in the case of very limited conditions with respiratory global insufficiency, the dimension of the surgical procedure may be discussed and reevaluated with the surgeon.

Respiratory function should be optimized by treating any reversible cause of pulmonary dysfunction, including infection, with physiotherapy and nebulized bronchodilators as indicated. Although a controversial topic in the literature [19, 42], for patients at increased risk for postoperative pulmonary complications, preoperative instruction and training on how to perform postoperative pulmonary rehabilitation can still be recommended.

There is controversy as to whether surgery for idiopathic scoliosis improves or worsens **pulmonary function** [8, 23]. In one study, surgery involving the thorax (anterior or combined approach, rip resection) was associated with an initial decline in forced vital capacity, forced expiratory volume in 1 s and total lung capacity at 3 months, followed by subsequent improvement to preoperative baseline values at 2 years postoperatively. Surgery involving an exclusively posterior approach, however, was associated with an improvement in pulmonary function tests by 3 months (statistically not significant) and after 2 years (statistically significant) [44].

A history of dependence on **continuous nasal positive airway pressure at night** is also a sign of severe functional impairment and of reduced physiological reserve. These findings should prompt serious consideration as to whether surgery represents an appropriate balance between its potential benefits and the high risk of long-term postoperative ventilation in such patients.

Cardiovascular Assessment

Perioperative cardiac risk assessment with the Revised Cardiac Risk Index is recommended

Perioperative cardiac morbidity is one of the major challenges for the anesthetist. The elderly patient population presenting for spinal surgery has substantially increased over the last decade. Consequently, the incidence of spinal surgery in patients with coronary heart disease has increased. Special attention must be paid to those patients at increased risk and where coronary heart disease has not been formally assessed. This patient population represents the vast majority. The use of a **Revised Cardiac Risk Index** [25] (Table 2), which includes patient-related as well as surgery-related risk, is recommended as its predictive value has been confirmed to be very high in elective non-cardiac surgery.

In patients with proven coronary heart disease, poor functional status and/or positive stress testing, a preoperative coronary angioplasty can reduce the risk of suffering from cardiac complications, but only when performed at least 90 days before the non-cardiac surgical intervention [27].

Elective surgery should be postponed for 3–6 months after myocardial infarction

Patients who have had a myocardial infarction should have their operations postponed for at least 3–6 months after the infarct in order to avoid the greatest risk of reinfarction.

An atrial septal defect (ASD) is apparent in 10% of patients with congenital heart disease. There is an accumulating incidence in patients with Marfan, Turner's and Down's syndromes. The ostium secundum form is caused by failure of closure of the foramen ovale and is the most common type (75%) of ASD. Most children with this defect are minimally symptomatic. Often adults in the 4th decade become symptomatic for the first time with congestive heart failure or hypertension. In the absence of heart failure, anesthetic responses to inhalational or intravenous agents are not altered. The presence of shunt flow between the right and left heart, regardless of the direction of blood flow, mandates the exclusion of air bubbles or clots from intravenous fluids to prevent paradoxical embolism into the cerebral or coronary circulation [16].

The anesthetist must be aware of the impaired cardiovascular function in patients with systemic rheumatoid arthritis, since cardiovascular disease (e.g., myocardial infarction secondary to coronary arteritis or pericardial manifestation of cardial disease) is the leading cause of death in the rheumatoid patient [29].

In contrast, most pediatric cardiac compromise is a direct result of the **underlying pathology**, such as:

- cardiomyopathy in Duchenne muscle dystrophy or Friedrich's ataxia
- aneurysmal dilatation in Marfan syndrome with potential risk for acute dissection
- cardiac dysfunction in severe kyphoscoliosis with distortion of the mediastinum, and secondary cor pulmonale

Assessment of **functional cardiovascular impairment** is difficult in patients who are wheelchair-bound. Minimum investigations should include electrocardiography and echocardiography to assess left ventricular function. Dobutamine stress echocardiography may be used to assess cardiac function in patients with a limited exercise tolerance [36].

The indications for preoperative transthoracic echocardiography are evaluation of ventricular dysfunction and evaluation of valvular function in patients with a murmur. But these investigations add only little information to routine clinical and electrocardiographic data for predicting ischemic outcomes [27].

Angiography should only be performed before spinal surgery in those high-risk patients who warrant revascularization for medical reasons, independent of surgery [27].

Furthermore, there is an increased incidence of cardiac complications during emergency non-cardiac surgery [25]. The reason is simply because there is no (or only limited) time for a proper risk stratification with adequate consecutive diagnostic and therapeutic management.

If the history and physical status taken by the surgeons reveal the presence of pathological conditions of the large vessels such as stenosis of the carotid artery, aortic aneurysm or peripheral vascular disease, it should be discussed whether spinal surgery needs to be postponed. The anesthesiologist can help to evaluate carefully the individual risk-benefit balance for this patient and to define the risk management in this situation (planned operation, necessary anesthetic procedure).

Neurological Assessment

A neurological examination of the patient should be made preoperatively including assessment of gait, motor or sensory deficits and reflexes. This should be documented since the anesthesiologist has a responsibility to avoid further neurological deterioration during maneuvers such as tracheal intubation and patient positioning. Congenital kyphosis and scoliosis, postinfectious scoliosis, neurofibromatosis and patients with skeletal dysplasias carry an increased neurological risk as well as patients with neurological deficits prior to surgery.

Avoid further neurological deterioration during tracheal intubation and patient positioning

Perioperative Drug Therapy

There is a need to assess the present drug therapy and any history of potential drug allergies. Together with the history and physical examination this will help to decide which drugs should be stopped, continued or added to provide the best possible perioperative conditions.

Assess any history of drug allergies

What to Stop, to Continue and to Add?

Even on the day of surgery, treatment of systemic hypertension should be continued with **antihypertensive drug therapy** as usual. It is important that patients under therapy with **beta-blocking agents** continue to receive their medication to avoid complications that accompany a sudden withdrawal. However, it is controversial as to whether **ACE inhibitors** should be administered perioperatively when profound blood loss is expected.

Treatment of systemic hypertension should be continued

Therapy with digoxin should be continued perioperatively, but control of serum concentration is recommended in the elderly patient if the renal function is impaired, if patient compliance is doubtful or comedication with, e.g., amiodarone has been introduced.

Patients with increased cardiac risk can receive a benefit from prophylaxis (for up to 5 – 7 days postoperatively) with **cardioselective beta-blocking agents** such as atenolol, metoprolol and bisoprolol by the blocking of adverse cardiac effects of an activated sympathetic tone. It has been shown that this perioperative medication can prevent perioperative cardiac complications, can reduce the incidence of perioperative ischemic episodes and can improve survival rate up to 2 years postoperatively [26, 47].

Perioperative prophylaxis with beta-blocking agents is advised in patients with increased cardiac risk

Preoperatively, therapy with **inhibitors of the platelet aggregation** (e.g., aspirin, clopidogrel, abciximab or tirofiban) or therapy with coumarin derivates must be replaced 7 – 10 days before the intervention with continuous unfractioned heparin or repetitive bolus of low-molecular weight heparins [30].

Long-acting antihyperglycemic drugs should be stopped preoperatively

Oral antihyperglycemic drugs should be stopped preoperatively because of potential dangerous hypoglycemic episodes (e.g., sulfonylurea) and lactacidosis (e.g., biguanide). Long-acting insulins are preferably changed to intermediate- or short-acting insulins that offer better glucose control in the perioperative setting.

The use of **bronchodilating agents** such as β_2-agonists may be of value in optimizing respiratory function preoperatively in patients with chronic obstructive pulmonary disease. A preoperative therapy with these drugs should be continued.

Chronic neurotrophic medication with:

- tricyclic antidepressants
- selective serotonin reuptake inhibitors
- lithium, neuroleptic agents
- anti-Parkinson drugs

should all be continued perioperatively. However, therapy with first generation inhibitors of monoaminoxidase should be interrupted 2 weeks prior to surgery.

Patients on long-term steroid medication are prone to an acute Addison's crisis

Patients with rheumatoid arthritis are often on long-term **steroid therapy**. Patients who have received potentially adrenal gland suppressive doses of steroids (e.g., the daily equivalent of 5 mg of prednisone) by any route of administration for more than 2 weeks in the previous 12 months should be considered unable to respond appropriately to surgical stress. This medication should be continued perioperatively and these patients require careful observation so as not to miss an acute adrenal insufficiency; sometimes they will require perioperative steroid supplementation. What represents adequate steroid coverage is still controversial. Drugs such as penicillamine, methotrexate and azathioprine have immunosuppressant properties and may retard wound healing.

In patients with a high spinal cord lesion, or those undergoing fiberoptic intubation, administration of anticholinergic agents such as atropine should be considered.

Many patients will have factors which increase the risk of regurgitation and aspiration of gastric contents such as:

- high spinal cord injury
- recent traumatic injury
- stomach ulcers and gastritis
- gastroesophageal reflux disease
- nasogastric tubes in situ (compromise of the upper esophageal sphincter)

In these circumstances, it may be prudent to premedicate patients with a histamine-2 receptor antagonist, a proton pump inhibitor or even sodium citrate [13].

Premedication

The goal of premedication is to have a mentally relaxed and comfortable patient arriving in the operating room. No single drug or dose will accomplish this satisfactorily and it must be decided for every patient what and how much to use. **Anxiolytic drugs** such as oral benzodiazepines (e.g., midazolam) are effective for this purpose. If the patient is currently receiving appropriate analgesics (e.g., oral opioids), it is logical to continue this medication if there are no contraindications.

Thromboembolic Prophylaxis

The risk of developing a venous thromboembolism increases continuously with aging. Surgery, especially orthopedic surgery, can increase this risk about 20 times and thus also increase the danger of developing a pulmonary embolism

(PE) [5]. While clear schemes do exist for the prevention of venous thromboembolism in orthopedic hip and knee surgery, there is little concordance in spine surgery. The possibility of developing deep vein thrombosis (DVT), PE and serious bleeding is often present in the same patient. Bleeding in spine surgery, such as spinal epidural hematoma (SEH), can result in grave complications, e.g., residual paraplegia. In spine surgery the risk of developing a DVT without prophylaxis is around 5 % (0.3 – 15.5 %) [10, 34], while serious bleeding complications manifest in only 0.1 – 1 % of patients [7, 24]. There are no studies dealing with bleeding complications under thromboembolic prophylaxis, but the risk of a DVT can decrease to 0.05 – 1 % [18]. Another study showed that there was no significant difference between the occurrence of DVT and/or PE with or without thromboembolic prophylaxis in lumbar disc surgery [11]. A clear significance in the efficacy of DVT prevention could be seen in favor of intermittent pneumatic compression (IPS) vs compression stockings [10].

If the decision is made to perform antithrombotic therapy for spine surgery, the question arises about the onset and modality. Options for the latter include mechanical prophylaxis such as compression stockings and intermittent pneumatic compression and medicamentous prophylaxis such as **low molecular weight heparins** (LMWH) and low dose **unfractioned heparins** (LDUH).

The **American College of Chest Physicians** (ACCP) suggest following the procedures for elective spine surgery without giving firm recommendations [17]:

There are no firm recommendations for anti-thromboembolic prophylaxis

- The use of compressive stockings and the best possible early mobilization in every case.
- Patients without or few risk factors should receive standardized LMWH.
- Patients at risk should receive standardized LMWH and IPS, or postoperative LDUH.
- In high risk patients or patients with DVT/PE, a caval umbrella should be considered preoperatively.

The onset of antithrombotic treatment by LMWH, especially in spine surgery, has not yet been standardized. In Europe the initiation of the thromboembolic prophylaxis starts on the preoperative evening with mostly one dose of 0.4 ml (40 mg) enoxaparin subcutaneously (s.c.). The second administration takes place about 8 h postoperatively and then is dispensed once daily. In the United States the first dose of LMWH, mostly 0.3 ml/30 mg of nadroparin s.c., is given about 12 – 24 h postoperatively, then twice daily.

In a literature review, taking the levels of evidence into account, the following schedule is proposed [17, 37]:

The most effective **timing for prophylaxis** onset is 2 h preoperatively, but increases the risk of bleeding tremendously. The administration of LMWH more than 12 h preoperatively is no longer effective. The particular risk of developing a DVT/PE starts about 6 h postoperatively, when no LMWH has been administered previously. A suggested timing for antithrombotic treatment in spine surgery is to administer 0.4 ml enoxaparin s.c. between 12 and 8 h preoperatively and/or 8 h postoperatively.

In our center, we routinely follow the ACCP guidelines for the prevention of venous thromboembolism in spine surgery with LMWH, despite the implantation of caval umbrellas. In a retrospective review of 1 400 patients whose spines were operated on in our institution, 16 (1.1 %) had postoperative spinal epidural hematomas needing surgical revision. Fourteen of those had high risk factors for either DVT or postoperative bleeding (Table 1) and received more than the standard LMWH dosage perioperatively.

Spinal epidural hematoma (SHE) remains a rare postoperative incident also in patients receiving thromboembolic prophylaxis with LMWH. It mainly occurs in

patients who are at risk of bleeding complications, as well as DVT and/or PE. Optimized patient management with the awareness of present risk factors may not prevent the development of a SHE, but will allow the recognition of this problem at an early stage and result in a rapid operative intervention. Revision surgery should take place a maximum of 12 h after the first appearance of symptoms, which will be mostly severe radiculopathic pain followed by spinal compression symptoms. With early decompression, the sequelae will remain distinctive and transient. In decompression surgery with laminectomy over more than one level, or anterior approaches, the higher risk of DVT/PE can be minimized by perioperative application of mechanical and medicamentous prophylaxis.

Special Conditions Requiring Spinal Surgery

Spinal Deformity

Scoliosis can cause restrictive pulmonary disease

It is mandatory to evaluate pulmonary and cardiac function before scoliosis correction. The heart and lungs may be directly affected (such as by mechanical pulmonary compromise) or they may be affected as part of a syndrome.

Pulmonary Assessment

The most common blood-gas abnormality is reduced PaO_2 with normal $PaCO_2$

Scoliosis causes restrictive pulmonary deficit and the severity of functional impairment is related to the angle of the scoliosis, the number of vertebrae involved, a cephalad location of the curve, and a loss of the normal thoracic kyphosis [28] (**Table 3**). The extent of functional impairment cannot, therefore, be directly inferred from the angle of scoliosis alone. The most common blood-gas abnormality is a reduced arterial oxygen tension with a normal arterial carbon dioxide tension (normal range of PaO_2 9.5 – 14.5 kPa, normal range of $PaCO_2$ 4.5 – 6 kPa), as a result of the mismatch between ventilation and perfusion in hypoventilated lung units.

Table 3. Influence on pulmonary impairment in patients with scoliosis

- angle of scoliosis
- number of vertebra bodies involved
- cephalad location of the curve
- loss of normal thoracic kyphosis
- neuromuscular disease

Restrictive lung disease can progress to irreversible pulmonary hypertension and cor pulmonale

An important clinical determinant is assessment of the patient's exercise tolerance, which is a clinical indicator of pulmonary reserve. As the disease progresses, hypercapnia may be seen, which is an indicator of severe pulmonary compromise. Pulmonary disease can progress to the point of irreversible pulmonary hypertension and cor pulmonale [29]. In patients with idiopathic scoliosis, a curvature of less than 65° is usually not associated with pulmonary compromise. However, patients with neuromuscular disease, paralysis or congenital scoliosis may show significant pulmonary compromise with lesser degrees of curvature. Scoliosis associated with neuromuscular disease has also been shown to be accompanied by abnormalities in central respiratory control. Routine preoperative testing should therefore include chest X-ray, spirometry, arterial blood gas analysis and an echocardiogram.

Cardiac Assessment

Cardiovascular abnormalities are most commonly caused by **pulmonary hypertension** (secondary to chronic hypoxia and hypercapnia). Right ventricular hypertrophy and cor pulmonale may develop as a result of the elevated pulmonary resistance. ECG changes associated with pulmonary hypertension and right atrial enlargement (P wave greater than 2.5 mm, R greater than S in V_1 and V_2) may be seen but are usually not evident until late in the disease process.

Scoliosis is also associated with congenital heart abnormalities [30]. Mitral valve prolapse is common in patients with idiopathic scoliosis with a prevalence of about 25 %. If a murmur is heard on physical examination, an echocardiogram is recommended.

Mitral valve prolapse can be associated with idiopathic scoliosis

Marfan syndrome may be associated with mitral valve prolapse, dilatation of the aortic root and aortic insufficiency. Prophylaxis against infective endocarditis should be administered to patients who have mitral valve prolapse or other lesions resulting in disturbances of flow.

Echocardiogram is recommended to assess pulmonary hypertension and congenital heart abnormalities

Neuromuscular Disease

The most common neuromuscular disease is **Duchenne muscular dystrophy**, with an incidence of one in 3 300 male births. It is inherited as a sex-linked recessive condition affecting skeletal, cardiac and smooth muscle. Over 90 % of these patients develop a progressive scoliosis when they become wheelchair bound. Patients lack the membrane cytoskeletal protein dystrophin and typically present between the ages of 2 and 6 years with progressive weakness of proximal muscle groups. Up to one-third of patients have intellectual impairment. Duchenne muscular dystrophy patients have a high incidence of deteriorating lung function and cardiac abnormalities (50 ± 70 %). In the later stages of the disease, a dilated cardiomyopathy may occur associated with mitral valve incompetence. Dysrhythmias occur and up to 50 % of patients have cardiac conduction defects [31]. Cardiac arrest in patients with Duchenne muscular dystrophy has been reported during spinal surgery [32].

Duchenne muscular dystrophy warrants thorough cardiac assessment

Cerebral Palsy

Cerebral palsy is a non-progressive disorder of motion and posture and is the result of an injury to the developing brain. Clinical manifestations relate to the area affected and these children require special consideration because of their various disabilities. Visual and hearing deficits are common and will make communication difficult. This often leads to anxiety, but premedication has to be balanced with the unpredictable response. These patients should be accompanied by their carers at induction and in the recovery room, as they usually know how to communicate with the patient. Their understanding may be greater than seems apparent on first meeting. About one-third of these patients suffer from epilepsy and the anticonvulsive therapy should be continued. Respiratory problems can include pulmonary aspiration from reflux, recurrent respiratory infections and reduced ability to cough. The airway should be assessed for difficult laryngoscopy because of loose teeth and temporomandibular joint dysfunction. Other problems during the perioperative period that require caution may include hypothermia, nausea and vomiting and pain induced muscle spasm [33].

Anticonvulsive therapy should be continued perioperatively

Malignancy

Patients with primary or secondary malignant disease of the vertebral column and spinal cord are increasingly being considered for surgery. Metastatic tumors occur three to four times more frequently than primary neoplasms within the vertebral column, and solitary vertebral lesions are often metastatic in the elderly. The vast majority of neoplastic cord compressions derive from metastatic tumors of the breast, lung, prostate or hematopoietic system. The thoracic spine is the most commonly affected [35].

Cancer patients are prone to complications

These patients have commonly lost a large amount of weight and have reduced physiological reserve. Respiratory complications of malignancy are common in such patients. **Further risks** include [36]:

- wound healing disturbance (protein loss)
- infection
- pleural effusion
- pulmonary toxicity (secondary to chemotherapy)
- increased risk for myocardial infarction (secondary to chemotherapy)
- metabolic derangements (e.g., hypercalcemia, SIADH)
- risk of coagulopathies (prostate cancer, hypernephroma)

The syndrome of inappropriate secretion of antidiuretic hormone (SIADH) is associated with small cell lung tumors, carcinoma of the prostate, pancreas and bladder, and central nervous system neoplasms [37].

Surgery for malignant tumors often requires extensive blood transfusions

Prior to surgery enough units of packed red blood cells should be available since spinal decompressive surgery for malignant processes often leads to a large blood loss.

Spinal Cord Injury

Spinal shock begins immediately after the insult and lasts up to 3 weeks

Patients with traumatic spinal injury frequently present for surgical spinal stabilization during the period of spinal shock, which is the result of a **traumatic sympathectomy**. It begins almost immediately after the insult and may last for up to 3 weeks [38]. The clinical effects depend on the level of the lesion to the spinal cord and may involve several organ systems.

A traumatic sympathectomy occurs below the level of the spinal cord lesion with the risk of hypotension secondary to arteriolar and venular vasodilatation. Injuries at or above T6 are particularly associated with hypotension, as the sympathetic outflow to splanchnic vascular beds is lost. Bradycardia will occur if the lesion is higher than the sympathetic cardioaccelerator fibers (T1–T4), with the parasympathetic cranial outflow being preserved. A complete cervical cord injury produces a total sympathectomy and therefore hypotension will be more marked. Above the level of the lesion, sympathetic outflow is preserved. Vasoconstriction in the upper body vascular beds and tachycardia may be observed in response to the hypotension resulting from reduced systemic vascular resistance in the lower part of the body. Hypotension associated with spinal cord injury responds poorly to i.v. fluid loading, which may cause **pulmonary edema**. Vasopressors are the treatment of choice. Hypoxia or manipulation of the larynx or trachea during intubation may cause profound **bradycardia** or asystolia in these patients because of the unopposed vagal tone. In these situations atropine may be administered to attenuate the vagal effects. Other causes of hypotension should be excluded such as blood loss associated with other injuries, since a hemorrhagic shock will not be accompanied by a compensatory tachycardia. Positive pressure ventilation causes marked arterial hypotension as the systemic vascular resistance cannot be raised to offset the changes in intrathoracic pressure caused by positive pressure ventilation [38, 39].

Ventilatory impairment increases with higher levels of spinal injury. A high cervical lesion that includes the diaphragmatic segments (C3–C5) will result in **respiratory failure** and death unless artificial pulmonary ventilation is instituted. Mid to low cervical spine injuries (C5–C8) spare the diaphragm but the intercostal and abdominal muscles may be paralyzed. Further complications [39] of the paralysis due to a cervical spinal cord injury include:

Perioperative management of spinal cord injured patients is demanding

- an inadequate cough mechanism
- ineffective secretion clearing
- paradoxical rib movement on spontaneous ventilation
- decreased vital capacity (20 – 50 %)
- decrease in functional residual capacity (10 – 20 %)
- loss of active expiration
- paralytic ileus
- gastric distension
- thromboembolism

The paralytic ileus and the gastric distension increase abdominal pressure, further compromising diaphragmatic excursion. This gastric distension can be reduced by placement of a nasogastric tube and attaching it to suction.

Autonomic dysreflexia is a syndrome associated with chronic spinal cord injury and may be present after 3 – 6 weeks following the spinal cord injury. This condition is characterized by extreme autonomic responses such as:

- severe paroxysmal hypertension associated with bradycardia
- ventricular ectopy
- various degrees of heart block

Autonomic dysreflexia may be present after 3 – 6 weeks following the spinal cord injury

The initiation of these events can be stimulation of nerves below the level of the spinal cord lesion (for example, cutaneous, rectal, urological, peritoneal stimulation). Injuries higher than T7 have an 85 % chance of producing serious cardiovascular derangement [40]. Treatment involves removal of the noxious stimulus (e.g., bladder distension), increasing the level of analgesia and/or anesthesia and the administration of direct-acting vasodilators. If left untreated, the syndrome can provoke a hypertensive crisis causing seizures, myocardial ischemia or cerebral hemorrhage. Avoidance of this phenomenon in scheduled patients with chronic spinal injury necessitates either regional or general anesthesia despite a lack of motor or sensory function in the area of the surgery.

Recapitulation

Patient assessment. The **preanesthetic evaluation** of patients for spinal surgery follows the general approach used before any patient is given anesthesia. Particular care should be given to the respiratory, cardiovascular, and neurological systems that can all be affected by the spinal pathology. The aim of the preoperative visit is to explain the anesthetic procedure and reduce the patient's anxiety. The need for **preoperative testings** is determined by the patient's age and health and by the scope of the procedure.

Organ-specific assessment. When assessing the **airway**, difficulties should always be considered. Traumatized patients or those with head injury are assumed to have an unstable cervical spine until this has been ruled out; the stability of the spine should be discussed preoperatively with the surgeon. These patients may be managed with awake fiberoptic intubation after topical anesthesia. **Respiratory function** should be assessed by a thorough history, focusing on functional impairment, and reversible causes of pulmonary dysfunction should be optimized. Because of the increased prevalence of coronary heart disease, **cardiac assessment** is a challenge to the anesthesiologist. Special attention should be paid to patients bear-

ing an increased risk where coronary heart disease has not been proven. Most pediatric cardiac compromise is a result of the underlying pathology, e.g., in patients with Duchenne muscle dystrophy, Marfan syndrome or scoliosis. Preoperative **neurological examination** should be documented since the anesthesiologist is responsible for avoiding further neurological deterioration during tracheal intubation and patient positioning. In **scoliosis** the thoracic deformity causes restrictive lung disease that can progress to irreversible pulmonary hypertension and cor pulmonale. Duchenne muscle dystrophy is a **neuromuscular disease** with a high incidence of lung function and cardiac abnormalities. Patients with **malignancy** have impaired physiological reserves, and metabolic derangements and surgery for malignant processes often lead to large blood loss. Spinal injury patients frequently present during **spinal shock**, a traumatic sympathectomy below the lesion which begins almost immediately after the insult and which may last up to 3 weeks. Vasopressors are the treatment of choice for the resulting hypotension. **Autonomic dysreflexia** may be present after 3–6 weeks following the spinal cord injury and is characterized by extreme autonomic responses such as severe paroxysmal hypertension. Avoidance of this phenomenon necessitates regional or general anesthesia for patients with chronic spinal cord damage scheduled for surgery.

Perioperative drug therapy. It is important to decide which **drugs** to stop, continue or add. Perioperative prophylaxis with beta-blocking agents in patients with increased cardiac risk can improve postoperative survival rate.

Key Articles

Mangano DT (1999) Assessment of the patient with cardiac disease: an anesthesiologist's paradigm. Anesthesiology 91:1521–6
Systematically presented suggestions for selection of preoperative tests and therapy, based on the presence of coronary artery disease (or risk factors) and the patient's functional capacity.

Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, Cook EF, Sugarbaker DJ, Donaldson MC, Poss R, Ho KK, Ludwig LE, Pedan A, Goldman L (1999) Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 100:1043–9
Useful and clinically applicable index for cardiac risk stratification in the context of elective major non-cardiac surgery. The authors outlined six risk factors for cardiac complications such as high risk type of surgery, ischemic heart disease, congestive heart failure, history of cerebrovascular insult, insulin dependent diabetes mellitus and increased preoperative serum creatinine.

Hambly PR, Martin B (1998) Anaesthesia for chronic spinal cord lesions. Anaesthesia 53:273–89
An excellent review of this topic.

Mangano DT, Layug EL, Wallace A, Tateo I (1996) Effect of atenolol on mortality and cardiovascular morbidity after noncardiac surgery. Multicenter Study of Perioperative Ischemia Research Group. N Engl J Med 335:1713–20
In patients who have or are at risk for coronary artery disease and who are undergoing non-cardiac surgery, it has been shown by these authors that the administration of atenolol throughout hospitalization can substantially reduce mortality and cardiovascular events after discharge from the hospital, particularly during the first 6–8 months after surgery, and the effects on survival persist for at least 2 years.

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