Anaesthesia in the prone position

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Key points

The prone position is used for a variety of procedures ranging from short day-case procedures to prolonged major surgery.

Changes in cardiovascular physiology depend on the specific prone position used; changes in respiratory physiology are generally advantageous.

Injury can occur to all organ systems (including the eyes), due to direct or indirect pressure effects.

For most cases, a securely fastened tracheal tube is the airway device of choice.

In the event of a cardiac arrest, chest compressions and defibrillation can be commenced in the prone position.

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As surgical techniques evolve, the prone position is being used more frequently (e.g. laparoscopic-assisted oesophagectomy) to facilitate surgical access. It is also adopted to improve oxygenation in patients with acute respiratory distress syndrome (ARDS).

Nevertheless, the practice of prone positioning remains relatively unfamiliar to the majority of anaesthetists. This article will focus on prone positioning within the operating theatre. It will discuss the effects on physiology, the complications that occur, the practicalities of turning and positioning the patient, and the management of emergencies once prone.

Physiology

The changes to respiratory and cardiovascular physiology in the prone position have been extensively discussed elsewhere.[1] We present some of the key features.

Respiratory

In anaesthetized patients, the prone position confers a number of benefits in physiological parameters when compared with the supine position.

As long as abdominal movement is unimpeded, functional residual capacity and arterial partial pressure of oxygen are increased, yet chest wall and lung compliance remain unchanged.[1,2] These changes form part of the reason for the use of prone position in ventilated intensive care unit patients with severe refractory ARDS.

A gravitational theory to explain the improvements has been proposed and widely accepted. It suggests that pulmonary blood flow favours the dependent areas of the lung and better matching of ventilation and perfusion occurs, brought about by the following:

(i) gravity displacing the heart and smaller volumes of the lung being compressed.
(ii) improved diaphragmatic excursion, unhindered by the intra-abdominal contents.

However, single-photon emission computed tomography measurements in healthy ventilated patients have shown no change in the distribution of ventilation, but a more evenly distributed pulmonary blood flow, and improved matching of ventilation and perfusion.[3]

The gravitational theory has been challenged, and a model based on the branching architecture of the airways and pulmonary vessels has recently been proposed[4] that provides an alternative explanation for the improvements in matching of ventilation and perfusion seen in the prone position. This model, based on anatomy, offers some explanation why prone position can worsen respiratory parameters in some patients.

Cardiovascular

The decrease in cardiac output seen on turning prone is considered to be a result of reduced stroke volume. The resulting decrease in arterial pressure is, to some extent, countered by a compensatory sympathetic tachycardia and an increase in peripheral vascular resistance.

A decrease in pre-load is thought to be responsible for the reduced stroke volume that is seen. Many factors contribute to a decrease in pre-load and include:

(i) blood sequestration in dependent body parts;
(ii) caval compression;
(iii) increased intra-thoracic pressure with poor positioning and chest wall compression;
(iv) positive pressure ventilation and PEEP.

The type of prone position adopted can affect the changes observed in cardiovascular physiology. A study using transoesophageal ECHO (that excluded the obese patient or those with cardiovascular disease) measured cardiac index, stroke volume, and cardiac output in patients placed on the differing supports. The least effect on all cardiovascular parameters was seen with the Jackson table, whereas the cardiac index was decreased when prone on the Wilson table and the Andrews support (knee–chest position).[5]

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The jack-knife prone position has been shown to cause a decrease in cardiac index, a bradycardia, and raised mean arterial pressure that returned to supine values when the patients were placed in the Trendelenburg position.[6]

Variabilities in pulse pressure and stroke volume are greater in the prone position, compared with the supine position, and both can be used to predict whether the anaesthetized ventilated prone patient will respond to a fluid challenge. For practical purposes, patients with a pulse pressure variation of >14% are likely to respond to a fluid challenge.[7]

Cerebral blood flow

It is postulated that a rotated head position will reduce cerebral blood flow (CBF) and raise intracranial pressure by partial occlusion of the internal carotid and vertebral arteries, spinal vessels, and by compression of venous drainage. Vessel distortion can also occur from external pressure during positioning (e.g. by pillows), or from flexion or extension of the neck. Transcranial Doppler measurements of flow velocity (as a marker of CBF) across the middle cerebral artery demonstrated a reduction in CBF when the head was rotated to the side in healthy subjects ventilated with positive pressure.[8] The diameter of the internal jugular vein was also reduced indicating a reduction in cerebrovenous drainage.[8]

In patients where even modest reductions in CBF would be deleterious, for example, the elderly with vascular disease or those with raised intracranial pressure, the head and neck should be kept in the neutral position during turning and while in the prone position.

Renal function

A small study in non-anaesthetized healthy volunteers has shown a slight increase in urine output in the prone position but no difference in renal sodium excretion.[9]

Complications

Complications that occur from poor positioning cause morbidity, and in some cases mortality. Knowledge of the potential problems allows the practitioner to pay particular attention to areas at risk.

Pressure injuries

Pressure injuries are caused either directly by pressure on the affected tissue or indirectly by pressure to the vascular supply and drainage of the injured area (Table 1, Fig. 1).[1]

Table 1 Pressure injuries

Direct pressure injuries	Indirect pressure injuries
Skin necrosis	Macroglossia and orpharyngeal Swelling
Contact dermatitis	Mediastinal compression
Tracheal compression	Visceral ischaemia—liver, pancreas
Salivary gland swelling	Avascular necrosis of femoral head
Breast injury	Peripheral vessel occlusion
Injury to the genitalia	Limb compartment syndrome and rhabdomyolysis
Compression of the pinna	
Compression of the femoral neurovascular bundle	

Ophthalmic complications

Ophthalmic complications range from corneal abrasions to devastating postoperative visual loss. Visual loss has an incidence of 1:60 000–1:125 000 but is more common in spinal surgery (1:30 000).[10]

There are two mechanisms, with differing aetiology. Direct pressure on the eye can lead to central retinal artery occlusion, whereas ischaemic optic neuropathy can occur without any pressure on the globe or orbit.[10]

Of 83 cases of postoperative visual loss reviewed in America,[11] 16 occurred in patients whose face and eyes were free from pressure, with the head in pins and supported by the Mayfield clamp. Lengthy surgery (over 6 h) or blood loss >1000 ml was present in 96% of the reported cases. Risk factors identified included patients with atherosclerosis, diabetes, hypertension, and male gender. More than half of the patients had bilateral visual loss; less than half had recovery of some vision (light/dark perception).

There was no association with pre-existing glaucoma, arterial pressure management intraoperatively (but deliberate hypotensive anaesthesia remains under suspicion), anaemia (*per se*), hypothermia, type of prone support used, or type of anaesthetic administered.[11]

The exact aetiology of ischaemic optic neuropathy has not been elucidated, but may be due to reduced venous drainage and increased interstitial fluid around the optic nerve causing a ‘compartment syndrome’.[11]

Peripheral nervous system

Injuries to the peripheral nervous system are one of the most common complications[12] and all superficial peripheral nerves should be considered at risk. It is widely believed that poor positioning and compression or stretch of the nerve within its narrow boney canal (ulnar nerve at the elbow) or from external compression (common peroneal nerve by straps/pads below the knee) is responsible for the development of a neuropathy. However, a large study found ulnar neuropathy in the absence of general anaesthesia, long procedures, or poor padding—suggesting other factors play a part.[13] Nevertheless, careful positioning can still reduce stretch and pressure injury.[12]

Cases of peripheral neuropathy do not usually present in the recovery room. Symptoms often occur only after 24 h, with over 90% of cases presenting within 7 days; the symptoms can be sensory (47%) or mixed motor/sensory. About 53% of patients will recover within a year, those with sensory loss are more likely to make a full recovery compared with those with mixed motor/sensory deficit, but one-quarter will suffer persistent pain.[13]

Risk factors that have been identified are being male (70%), a prolonged hospital stay, extremes of body habitus, and diabetes. Advanced age increases the risk of motor neuropathy.

Fig 1 Patient A positioned on Wilson frame with DisposaView^{TM} headrest. The headrest is applied with the patient still supine. Note the final position of the neck. The mirror permits easy confirmation of face support without pressure to the orbit or globe. All pressure areas are padded and protected.

Placing the arms by the side provides the greatest protection for the ulnar nerve and brachial plexus. If the arms are to be abducted, they should have no greater than a 90° bend at the elbow or shoulder. Direct pressure in the axilla should be avoided to protect nerves and vessels, and the elbows should be well padded. The rotator cuff can also be damaged during positioning of the arms.

In the lower limbs, the lateral cutaneous nerve of the thigh is at risk from compression in the prone position.

Central nervous system

Some complications to the central nervous system have been discussed earlier. While rotation of the head has been considered, it is also important to take care not to over-extend or flex the cervical spine. Those patients with an unstable spine should be log rolled and it is our practice (once the airway has been secured) to transfer care of the head and neck during positioning to the surgeon in this group.

Cases of hypotension and arterial hypoperfusion leading to ischaemic stroke of the brain and spinal cord have been reported.[1]

Practicalities

Six members of staff are needed to position a patient prone: one person (usually the anaesthetist, except in cases of unstable spine injury) at the head, one moving the feet, and two either side of the patient. Additional members of staff may be required for obese patients or patients with unstable spines requiring 'log-rolling'. Alternatively, specialized equipment such as the Jackson table can be used to turn the patient, see the in-line video that can be viewed online from Figure 2. It is our practice to disconnect monitoring, infusions, and the breathing system while turning the patient to decrease the risk of accidentally dislodging lines or the tracheal tube (TT). As soon as the patient is prone all lines, monitoring and the breathing circuit are reconnected.

In practice, the table supports used (e.g. the Wilson frame, especially in obese patients) do not allow completely free movement of the abdomen and chest wall and thus turning the patient prone will lead to reduced dynamic lung compliance and increased peak airway pressure. It is worth making a note of the supine airway pressures, as in our practice, sustained or significant increases (>5 cm H_2O) once prone position trigger a check for causes such as bronchospasm or inadvertent endobronchial intubation.

The advantages and disadvantages of commonly used operating tables and head supports are summarized in Table 2. For photographs of commonly used equipment, see Figure 2A and B.

Airway management

A securely fastened reinforced cuffed TT is considered the airway of choice for patients in the prone position and is the authors' preference.

However, there is a small yet increasing trend towards the use of a supraglottic airway device. Articles reporting successful use of these devices for elective surgery, and as an airway rescue

Table 2 Commonly used body supports and head supports. See Figures 2A body supports and Figure 2B head rests, along with the in-line video showing the building and turning of the Jackson sandwich that can be viewed online from Figure 2, and Supplementary Allen Table S1.

Body support	Use	Advantages	Disadvantages
Pillows	Quick cases	Quick to set up	Only limited chest support and difficult to ensure a free abdomen as they are compressible The pillows can move during the procedure or positioning
Chest roll		Easy to ensure a free abdomen	Direct and indirect pressure injury Has been associated with cases of hepatic failure when poorly positioned
Pelvic roll	To elevate the anus and rectum		Direct and indirect pressure injury
Thoracic support/ Montreal mattress	Cervical and thoracic spinal surgery Oesophageal surgery Urology	Different sizes. Easy to store and place on the table. Allows free abdominal movement. Easy to place arms by the sides or flexed and abducted	Direct pressure to groin if incorrectly sized
Allen table/Jackson table	Spinal surgery, especially with instrumentation requiring radiology access	Abdomen and chest free. Some have specific arm supports and a mirror to permit easy view of the face and TT. Excellent for the use of C-arm image intensifier. Permit wide range of rotation of the patient. Movable supports so the frame can be adjusted to the individual patient. Minimal change in cardiovascular physiology. The table can be used to turn the patient prone	Large piece of equipment Patient's head distant from the anaesthetist and difficult to access the airway Cumbersome control mechanism for height and rotation (Allen) Dual control to operate both theatre and operating tables. The torso is on the operating table, the legs on the theatre table (Allen)
Wilson frame/reverse saddle support	Lumbar spinal surgery	Permits loss of lumbar lordosis Pressure distributed across patients sides so the pelvis and chest supported while the abdomen remains free	Can only adjust width of supports so may be too long for some patients. Difficult to position arms by the sides
'Cambridge Frame'/ Relton–Hall frame	Scoliosis surgery	Can be adjusted for each patient Allows good X-ray access	Patient rests on four pressure points only, can cause skin necrosis in prolonged surgery
Andrew's frame (knee/chest position)	Occipital, cervical, lumbar, perineal/perianal surgery	Permits loss of lumbar lordosis. Excellent surgical access to spine and perineal structures.	Decreases in cardiac index and stroke volume due to venous pooling in the legs. Pressure areas on knees and risk of lower limb nerve injury. Requires chest roll, and chest can be unstable. Requires multiple people to position
Head support			
Mayfield clamp and pins	Craniotomies, cervical spinal surgery	No direct pressure on eyes (damage can still occur) Easy to access TT	Risk of scalp lacerations No TT support
Preformed foam, e.g. Disposaview™	All cases, newer pre-formed foam masks are marketed as being suitable for up to 8 h use	Easy view of the eyes Preformed and easy to check positioning	One size does not always fit all Pressure areas if used in prolonged surgery Difficult to access the TT Expensive and not reusable Too low in profile for double-lumen tube
Gel support	All cases	Different types with different height profiles. The higher profile support permits the use of the double-lumen tube Reusable	Shape is distortable so head can move. Difficult to check for pressure on eyes
Horseshoe	Quick procedures	Usually easily available	Can change position when the patient moved. If used as a table extension, it ensures the face is free and easy access to airway and TT
Gel ring	Quick procedures	Easily available	Must have head turned, risk of vessel, nerve, or bony injury
Pillows	Quick procedures	Easily available	Must have head turned, risk of vessel, nerve, or bony injury

Fig 2 (A) Commonly used 'table top' prone body supports. Top, Montreal mattress; middle, thoracic support; bottom, Wilson frame. (B) Head rests for the prone position. The choice of rest chosen will depend in part on the height profile of the head rest and the body position of the patient. The yellow support has a lower height profile and can be used when the patient is positioned on pillows or a Montreal mattress; the turquoise support has a higher profile and is suitable when the patient is supported on the Wilson frame. Some head rests come as part of the prone table, for example, the white supports on the left of the image are compatible with the Jackson table; the lower support has a mirror to allow easy confirmation that the orbit is free from pressure. If reading the PDF online, please click on the image to view the video. The video demonstrates how to build the 'sandwich' and use the turning function of the Jackson table.

technique, are becoming more frequent. The LMA Supreme™ and the Proseal LMA™ were studied in audits of more than 200 patients.[14] Anaesthesia was induced in the prone position with the head rotated to one side. It was claimed the drainage tube allowed easier detection of displacement during positive pressure ventilation and the shape of the LMA Supreme™ made accidental rotational displacement less likely. In the study involving the LMA Supreme™, four cases of regurgitation with no clinical signs of aspiration were reported, but the number of cases was small.

The DAS guidelines for difficult extubation do not address extubation after prone surgery. In our institution, we perform a 'leak test' after prolonged procedures and for cases performed in the prone Trendelenburg position before extubation.

Management of emergencies

Accidental extubation

Anticipation and planning prepares the anaesthetist for timely management of accidental extubation (AE) in the prone position.

The security and patency of the airway must be checked immediately after turning the patient, and the bed not permitted to leave theatre until the correct TT position has been confirmed. If it has become dislodged, the patient can be turned supine on to the bed and reintubated without delay. The TT should be rechecked after any re-positioning of the patient or their head. Once the patient is positioned, and the head and tube supported AE is unlikely. If the head is secured in pins and the Mayfield clamp, AE may still occur during surgery if the TT is 'free hanging'.

Case reports have highlighted the use of supraglottic devices for airway rescue. Placement of the LMA provided a patent airway in the majority of cases at first attempt (87.5%), and 100% at second attempt.[15] The decision to continue surgery with the LMA or whether to re-secure a TT has to be made on a case-by-case basis, taking account of the nature and duration of surgery. The LMA can be used as a conduit for the passage of a fibreoptic scope and TT in the prone position.

An alternative is the use of fibreoptic re-intubation in the prone position to secure the airway. The anatomy for oral intubation is favourable—the tongue falls forward, negating the need for jaw thrust or 'tongue pull'. This is only a solution if the fibreoptic scope is immediately available and the face is easily accessible, for example, when the head is secured in pins and the Mayfield clamp.

Cardiac arrest

Cardiac arrest in the prone position is a rare event. The UK resuscitation council is preparing specific guidance for the management of

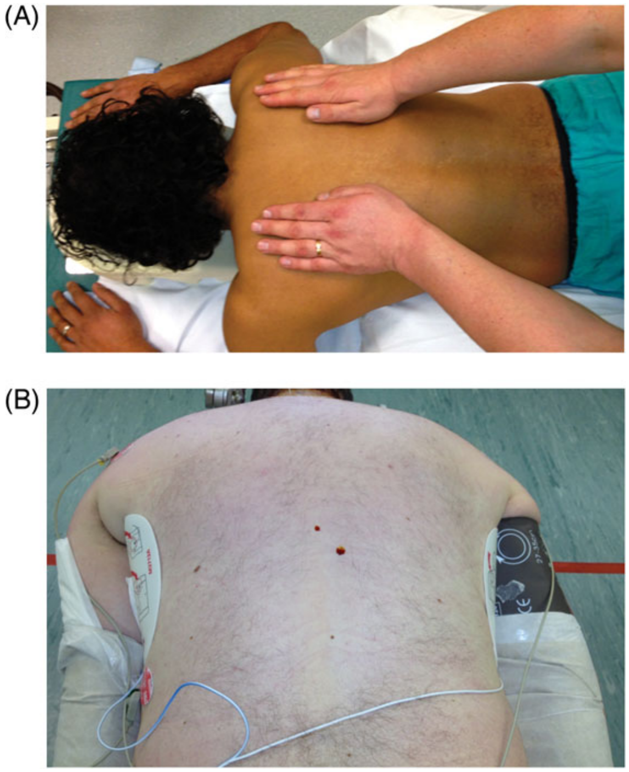

Fig 3 (A) Hand position for chest compressions in the prone position assuming midline surgery. Note the hands should be placed over both scapulae. (B) Defibrillator pads are demonstrated in the postero-lateral position.

cardiac arrest in neurosurgical patients including those in the prone position, and we await its publication. In the meantime, case reports have described successful resuscitation and defibrillation in the prone position. This has allowed immediate commencement of cardiopulmonary resuscitation while preparing to turn supine. Chest compressions have been performed using several methods including placing a hand over each scapula (Fig. 3A), compressions over the thoracic spine with or without counter-pressure on the sternum, or open cardiac compressions if surgery already involves a thoracotomy.[16]

Successful defibrillation has been described with the following pad positions:

(i) antero-posterior,
(ii) right axilla and cardiac apex,
(iii) postero-lateral (Fig. 3B).[16]

If the anaesthetist considers the patient to be at risk for intraoperative cardiac arrest (or in potential need of pacing/synchronized DC cardioversion), defibrillation pads should be placed before turning prone, and checked before commencing surgery. High-risk patients would be identified in the same way as for a patient undergoing surgery in the supine position. The resuscitation council considers it safe for the gloved surgeon to support the head to protect the cervical spine from movement injury when a biphasic shock is applied to the patient.

Conclusion

An understanding of physiology, the practicalities, and complications for prone positioning can make this position less stressful for the anaesthetist who practices it infrequently. Departments developing a prone service can include the correct equipment and staffing levels at the planning stages. In addition, risks can be fully explained to the patient.

Supplementary material

Supplementary material is available at *Continuing Education in Anaesthesia, Critical Care & Pain* online.

Declaration of interest

None declared.

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Please see multiple choice questions 29–32.