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Guidelines

Regional analgesia for lower leg trauma and the risk of acute compartment syndrome

Guideline from the Association of Anaesthetists

M. H. Nathanson,[1] **W. Harrop-Griffiths,**[2] **D. J. Aldington,**[3] **D. Forward,**[4] **S. Mannion,**[5] **R. G. M. Kinnear-Mellor,**[6] **K. L. Miller,**[7] **B. Ratnayake,**[8] **M. D. Wiles**[9] and **M. R. Wolmarans**[10]

1 Consultant, Department of Anaesthesia, Nottingham University Hospitals NHS Trust, Nottingham, UK; President, Association of Anaesthetists (Co-Chair)
2 Professor, Imperial College, London, UK; Vice President, Royal College of Anaesthetists (Co-Chair)
3 Consultant, Hampshire Hospitals NHS Trust, Hampshire, UK; British Pain Society
4 Consultant, Department of Trauma and Orthopaedic Surgery, Nottingham University Hospitals NHS Trust, Nottingham, UK
5 Consultant, Department of Anaesthesiology, South Infirmary Victoria University Hospital, Cork, Ireland; Irish Standing Committee, Association of Anaesthetists
6 Consultant, Department of Anaesthesia, Nottingham University Hospitals NHS Trust, Nottingham, UK and Surgeon Commander, Royal Navy; Chair, Defence Medical Services Military Pain Special Interest Group
7 Consultant, Department of Paediatric Anaesthesia, Birmingham Women's and Children's NHS Foundation Trust, Birmingham, UK; Trainee Committee, Association of Anaesthetists
8 Consultant, Department of Anaesthesia, Kingston Hospital NHS Trust, Kingston-upon-Thames, UK; Immediate Past President, British Society of Orthopaedic Anaesthetists
9 Consultant, Department of Anaesthesia and Operating Services, Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, UK
10 Consultant, Department of Anaesthesia, Norfolk and Norwich University Hospital NHS Trust, Norwich, UK; Past-President, Regional Anaesthesia UK (RA-UK)

Summary

Pain resulting from lower leg injuries and consequent surgery can be severe. There is a range of opinion on the use of regional analgesia and its capacity to obscure the symptoms and signs of acute compartment syndrome. We offer a multi-professional, consensus opinion based on an objective review of case reports and case series. The available literature suggested that the use of neuraxial or peripheral regional techniques that result in dense blocks of long duration that significantly exceed the duration of surgery should be avoided. The literature review also suggested that single-shot or continuous peripheral nerve blocks using lower concentrations of local anaesthetic drugs without adjuncts are not associated with delays in diagnosis provided post-injury and postoperative surveillance is appropriate and effective. Post-injury and postoperative ward observations and surveillance should be able to identify the signs and symptoms of acute compartment syndrome. These observations should be made at set frequencies by healthcare staff trained in the pathology and recognition of acute compartment syndrome. The use of objective scoring charts is recommended by the Working Party. Where possible, patients at risk of acute compartment syndrome should be given a full explanation of the choice of analgesic techniques and should provide verbal consent to their chosen technique, which should be documented. Although the patient has the right to refuse any form of treatment, such as the analgesic technique offered or the surgical procedure proposed, neither the surgeon nor the anaesthetist has the right to veto a treatment recommended by the other.

Correspondence to: M. H. Nathanson
Email: mike.nathanson@nuh.nhs.uk
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Twitter: @Assoc_Anaes; @mikenathanson61; @STHJournalClub
This is a consensus document produced by expert members of a Working Party established by the Association of Anaesthetists of Great Britain and Ireland. It has been seen and approved by the Board of Directors of the Association of Anaesthetists. It has been endorsed by the Royal College of Anaesthetists, the British Pain Society, the British Society of Orthopaedic Anaesthetists and Regional Anaesthesia UK.

Recommendations

1 Patients at risk of acute compartment syndrome (ACS) should be identified on admission to hospital or at the time of surgery, and should be managed within agreed, multidisciplinary protocols.

2 Post-injury and postoperative ward observations and surveillance should be able to identify the signs and symptoms of ACS; these observations should be made at set frequencies by healthcare staff trained in the pathology and recognition of ACS. The use of objective scoring charts is recommended.

3 The equipment necessary to measure intracompartmental pressure should be available on wards caring for patients at risk of ACS. Staff should be trained in its use and there should be standard operating procedures available and implemented that address the performance of such measurements, and the urgent steps to be taken if measurements are abnormal.

4 All patients who have suffered trauma or who have undergone surgery should be offered effective analgesia.

5 Where possible, patients at risk of ACS should be given a full explanation of the choice of analgesic techniques and should provide verbal consent to their chosen technique, which should be documented.

6 Although the patient has the right to refuse any form of treatment, such as the analgesic technique offered or the surgical procedure proposed, neither the surgeon nor the anaesthetist has the right to veto a treatment recommended by the other. Ideally, consensus should be achieved but, if consensus is not achievable, the role of the anaesthetist as the expert on pain relief should be respected. It is, therefore, the anaesthetist who has the right to offer the patient the range of what they consider to be acceptable analgesic techniques provided they express to the patient the concerns voiced by the surgeon.

7 The available literature suggests that the use of neuraxial or peripheral regional techniques that result in dense blocks of long duration, that is, significantly exceeding the duration of surgery, should be avoided.

8 The available literature suggests that single-shot or continuous peripheral nerve blocks using lower concentrations of local anaesthetic drugs without adjuncts are not associated with delays in diagnosis provided post-injury and postoperative surveillance is appropriate and effective.

9 Given the lack of reliable, published data on the safety and efficacy of analgesia in patients at risk of ACS, the Working Party recommends that studies that address the use of low-dose regional analgesia, spinal opioid analgesia and wound infusion with local anaesthetic drugs for patients undergoing surgery for tibial fractures be conducted as a matter of urgency. The low incidence of ACS means that prospective, randomised trials would need to be large, and the conduct of prospective audit should therefore be encouraged

What other guideline statements are available on this topic?

There are no other guidelines currently available.

Why were these guidelines developed?

Pain resulting from lower leg injuries and consequent surgery can be severe. There is a range of opinion on the use of regional analgesia and its capacity to obscure the symptoms and signs of ACS. However, a systematic review of the available literature is absent. We offer a multi-professional, consensus opinion based on an objective review of case reports and case series. We aimed to provide pragmatic guidance to enable optimal analgesia and to highlight the need for careful observation for ACS in any patient at risk (irrespective of the mode of analgesia).

How and why does this statement differ from existing guidelines?

Opinion on the optimal choice of anaesthesia and analgesia is often based on a single case or a small case series in which the impact of the mode of analgesia was poorly understood. Other evidence is often anecdotal. In the absence of high-quality trials, consensus opinion offers the next best guidance and should supplant personal opinion.

Introduction

Few topics divide orthopaedic surgeons and anaesthetists quite so quickly and reliably as the question of whether regional techniques should be used for analgesia during and after surgery for lower leg trauma. This is in large part because of the well-recognised association between lower limb fracture and acute compartment syndrome (ACS), the potentially life-changing complications of ACS, and the assumption made by many that effective analgesia can mask pain as one of the cardinal symptoms of this syndrome.

This guidance document aims to provide a brief review of ACS and an appraisal of the literature available on the subject. It also aims to present the current consensus view of a group of experts brought together by the Association of Anaesthetists with the purpose of providing pragmatic guidance to those managing these potentially challenging cases.

This document will limit itself to trauma to the lower leg, while accepting that ACS is by no means restricted to this area of the body, in order to provide an exemplar of the management of similar clinical situations for which there is less supporting information.

Pathology and diagnosis

Incidence

Acute compartment syndrome has a reported incidence of 3.1 per 100,000 [1], with a range of 1–7.3 per 100,000 [2]. It has an incidence in men of 10 times that in women, at 7.3 per 100,000 [2], although this difference is accentuated in those who suffer ACS that is associated with fractures, for which the male to female ratio is 13:1 [3]. Fractures account for 69% of all ACS cases [4]. Up to 40% of all ACS episodes involve a tibial shaft fracture, and approximately 4–5% of all tibial fractures result in ACS [5]. There is an increased risk in young men aged < 35 y with tibial fractures [1, 4, 6]. Children are at a theoretically increased risk due to the higher pre-existing compartment pressures. However, the overall incidence in children is lower [1]. Acute compartment syndrome is a recognised side-effect of intra osseous access [1]. Acute compartment syndrome can occur in the absence of a fracture if there is soft tissue damage.

Additional risk-factors in developing ACS after lower limb trauma include: open fracture; intramedullary nailing; anticoagulation; high energy injury; penetrating trauma; vascular injury; burns; the use of tourniquets; and haemophilia [1].

Pathophysiology

Acute compartment syndrome is the result of an increased pressure in a closed, relatively inelastic osteofascial compartment [7]. There is then a spiralling action that results in a rapid increase in pressure requiring early action (Fig. 1) [8]. The increasing pressure reduces the capillary and venous blood flow, and the resulting tissue ischaemia results in more oedema and release of vaso-active mediators, further increasing the pressure in the compartment.

The above describes the arteriovenous gradient hypothesis. However, there is an alternative hypothesis: the ischaemic-reperfusion mechanism [9]. Within both hypotheses, there is increased pressure resulting in decreased capillary blood flow, decreased oxygen delivery to the tissues and a resulting metabolic deficit. However, the latter hypothesis focuses on free radicals, calcium and vasoactive substrates released under ischaemic conditions resulting in the increased vessel permeability and subsequent increase in extravascular fluid and pressure. In both, the pressure cannot be relieved until the inability of the compartment to expand has been resolved.

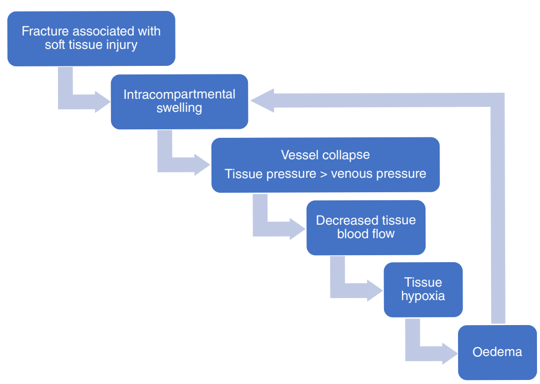

Figure 1 Pathophysiology of acute compartment syndrome (adapted from [8]).

Diagnosis

The diagnosis of ACS remains a controversial area. Historically, it was regarded as a clinical diagnosis, with compartment pressure measurement reserved for cases in which the diagnosis remained unclear after clinical examination. However, several studies have cast doubt on the reliability of diagnosing ACS on clinical signs alone. This uncertainty in diagnostic criteria may lead to a significant variation in rates of fasciotomy between surgeons [10].

Classically, six clinical signs or symptoms are attributed to ACS: pain; cold; paraesthesia; paralysis; pulselessness; and pallor [11]. As perfusion to the affected compartment decreases, the lack of oxygen and the accumulation of metabolic waste products cause nerve and muscle ischaemia and irritation, resulting in pain and decreased peripheral sensation. Pain out of proportion to the injury or clinical situation is often reported as being the earliest sign of developing ACS. Pain on passive stretch of the affected muscle compartment is regarded by some as the most sensitive early sign. The affected compartment may also physically swell and become increasingly firm as intracompartmental pressure rises. The loss of a pulse, paralysis, pallor and decreased temperature are late signs, indicating significant disruption to the vascularity and viability of the affected limb. As diagnosis should be made before the onset of muscle ischaemia, these signs are not useful in the early diagnosis of ACS.

There is a paucity of published evidence to allow the calculation of the sensitivity and specificity of individual clinical signs. The information available from published prospective studies suggests the sensitivity and positive predictive value of clinical signs are low, whereas the specificity and negative predictive value are high [12–15]. Palpation of the suspected compartment has been shown to be unreliable in isolation, with a sensitivity and specificity of 54% and 76% respectively in predicting an increased compartment pressure in children [16]. In isolation, severe pain gave around only a 25% chance of a correct diagnosis of ACS. However, as the number of clinical signs increases, the likelihood of a positive diagnosis of ACS increases [17]. The presence of both severe pain and pain on passive stretch of the affected muscle compartment gives a positive predictive value of 68%. A predictive value of 93% is found if pain, pain on passive stretch and paralysis are present. However, as paralysis is a late clinical sign, it is likely that by this stage the patient would have experienced irreversible muscle ischaemia. The absence of clinical signs is therefore arguably more accurate in excluding ACS than their presence is in making the diagnosis.

The use of scoring charts such as that provided by the UK's Royal College of Nursing [18] is recommended. While clinical signs are not completely reliable, their recording will help maintain a heightened sense of awareness of this condition among the healthcare workers caring for at-risk patients.

Measurement of compartment pressure

The diagnosis of ACS can be especially challenging in obtunded, confused or unco-operative patients, in whom clinical signs may be impossible to elicit. Direct measurement of intracompartmental pressure is indicated in those cases in which the diagnosis remains in doubt. Direct compartment pressures can be obtained using a variety of equipment and techniques. Described methods include traditional needle manometry, multiparameter monitors usually used to monitor arterial blood pressure and dedicated transducer-tipped intracompartmental pressure monitors [19]. The obtained compartment pressure may be affected by the technique and equipment used. The use of an 18-G needle may lead to an overestimation of compartment pressure by up to 18 mmHg when compared with a slit catheter or side-ported needle [20]. Whatever equipment is used, pressure should be measured in the relevant compartments in the affected limb.

Single or continuous pressure monitoring may be performed. Continuous compartment pressure monitoring has been suggested in high-risk, obtunded patients. There is little evidence that continuous monitoring reduces the risk of missed ACS compared with serial examination in the alert and co-operative patient [21].

Pressure threshold for fasciotomy

Traditionally, an absolute compartment pressure of $\geq$ 30 mmHg has been regarded as a diagnostic cut-off for ACS requiring fasciotomy [14, 22]. When taken in isolation without other clinical suggestions of ACS, this may lead to a rate of fasciotomy of up to 29% after tibial surgery [23]. Higher thresholds of up to 45 mmHg have been suggested [24], although these too may over-diagnose ACS when taken in isolation [13]. The differential pressure threshold is the most recognised cut-off for intervention in current use [25]. Tissue perfusion is affected both by the patient's diastolic blood pressure and intracompartmental pressure. Patients with an increased diastolic blood pressure can tolerate a greater increase in compartment pressure without muscle or nerve ischaemia from hypoperfusion when compared with patients who are hypotensive. Fasciotomy should usually be performed when the tissue pressure increases to within 10–30 mmHg of the diastolic pressure in a patient with any of the other signs or symptoms of ACS. When combined with the differential pressure threshold, continuous pressure monitoring in patients after tibial shaft fracture has been reported to have a sensitivity of up to 94%, with an estimated specificity of 98% [26]. Unfortunately, by definition, even this approach may miss some cases of ACS.

There is insufficient prospective evidence for any single sign or investigation that is guaranteed to diagnose or exclude ACS. Despite clinical signs frequently being relied on in clinical practice, the literature suggests that the predictive value of these signs is relatively low. Based on limited prospective evidence, measurement of intracompartmental pressures can be regarded as the gold standard diagnostic investigation but only when other clinical features suggesting ACS are present. When the diagnosis is in doubt or a patient is considered high-risk, and serial examination is not reliable, continuous pressure monitoring may be the safest diagnostic investigation to avoid a missed case of ACS.

Publications on analgesia and acute compartment syndrome

The available literature on ACS is marked by the complete absence of reports of the results of prospective, randomised, controlled studies and, therefore, of informative meta-analyses. There exist a large number of case reports and case series that are often interpreted in accordance with their authors' inherent bias. We have highlighted selected publications that shed some light on the occurrence of ACS and on the interpretation of how analgesic techniques may affect diagnosis in online Supporting Information (Appendix S1).

Our summary of the available, and admittedly not high quality, literature is as follows: dense neuraxial or peripheral nerve blockade may be associated with a delay in the diagnosis of ACS if extended into the postoperative period; there is no convincing evidence of the potential for the use of single-shot or continuous peripheral nerve blocks with low concentrations of local anaesthetic to mask the symptoms of ACS or delay the diagnosis of ACS; and some surgeons continue to be concerned about the use of regional analgesia in patients undergoing surgery associated with a significant incidence of ACS.

Special circumstances: children

Children present unique challenges in the diagnosis and management of ACS. They constitute a heterogeneous group, ranging from a neonate to a 17-year-old with adult physiology. Younger children may have difficulty articulating symptoms such as pain and paraesthesia, which are the common symptoms alerting one to possible ACS. One group has suggested the use of 'three As' to diagnose ACS in children: anxiety; agitation; analgesic requirement [27].

A recent study found an incidence of ACS after paediatric trauma of 0.02% [28]. This study included 18-year-olds and found 24 cases of ACS in > 144,000 trauma admissions (21 male patients). The mean (range) age was 13 (2–18) years. Over the age of 14 y, all cases were men with long bone fractures but with similarly increased compartment pressures at diagnosis (25–90 mmHg vs. 30–75 mmHg in those aged ≤ 14 years); the cut-off of 14 years was chosen because the epiphyseal plates close at around that age. Age is an important predictor for the development of ACS; children aged 12–19 years have a high prevalence of ACS after tibial fracture [29]. As in adults, most cases of ACS in children occur after tibial or forearm fractures [30]. In a study of 978 children with upper limb fractures, the incidence of ACS was 0.6% for humeral and 0.7% for forearm fractures [31].

Normal leg compartment pressures in children are higher than those found in adults (13–16 mmHg vs. 0–10 mmHg) [32]. This difference has been postulated to be the result of muscle hypertrophy related to growth. Some authors have suggested that these higher compartment pressures combined with lower normal diastolic blood pressure predispose children to ACS [32]. The threshold intracompartmental pressure used clinically is usually the same as for adults at 30 mmHg by direct measurement, or a difference between diastolic blood pressure and intracompartmental pressure of ≤ 30 mmHg. Higher baseline intracompartmental pressures and communication difficulties have led some to recommend the measurement of compartment pressures in all children [33, 34]. Others have argued against this for children aged < 12 y with minimally displaced tibial fractures [35]. There were no cases of ACS in 159 children with these fractures whose pain was well controlled and who mobilised in a back slab, with early follow-up following Emergency Department discharge [35]. Near infra-red spectroscopy has also been used successfully in young children to diagnose ACS [36]. However, there is currently no agreement on what method of monitoring is best: clinical; intracompartmental pressure measurement; near infra-red spectroscopy; or a combination of these. Complications after ACS in children are rare. One study found a complication rate of 4.2%, with 87.5% of children who underwent fasciotomy having a secondary closure of skin and only 12.5% requiring split skin grafting. Mean time from admission to fasciotomy was just under 28 h and ranged from 2.5 h to 99 h [28].

Debate continues regarding the use of regional anaesthesia and patient/nurse-controlled analgesia in children at risk of ACS. Paediatric regional anaesthetists' desire to prove the safety of low-dose peripheral nerve blockade and the absence of convincing case reports linking regional analgesia in children to diagnosis delays led the European Society of Regional Anaesthesia and Pain Therapy (ESRA) and the American Society of Regional Anesthesia and Pain Medicine (ASRA) to conclude in guidance published in 2015 [37] that: "*there is no current evidence that the use of regional anaesthetics increases the risk for ACS or delays its diagnosis in children*" and to recommend that after discussion with the child, parents and surgical team, low concentrations of local anaesthetic (bupivacaine or ropivacaine 0.1–0.25% for single shot and 0.1% for continuous nerve blocks) can be used safely for single-shot and continuous nerve blocks for surgery associated with an increased risk of ACS. The guidelines recommended cautious use of adjuncts to local anaesthetics, as these can increase the density and duration of blocks. An acute pain service should also be in place and rapid provision of intracompartmental pressure monitoring should be available.

Since the ESRA/ASRA guidelines were published in 2015, there have been no cases reported of ACS in children associated with regional analgesia or anaesthesia. There are increasing numbers of case reports and series of successful diagnosis of ACS in children receiving regional anaesthesia, including continuous upper and lower limb blocks [38–40]. Definitive studies have not been performed, with no randomised trials or cohort studies investigating a possible association. Proper systems should be in place to recognise ACS occurring in children after trauma and allow clinicians to react promptly and provide appropriate management [41].

Special circumstances: military injuries

The management of an ACS in a military environment may come with additional layers of complexity due to variable access to surgical services in the area of operations and prolonged repatriation times. While military casualties from recent conflicts in Iraq and Afghanistan often underwent repatriation soon after their injury and initial surgery, the repatriation journey itself can take many hours. A compartment syndrome developing during this repatriation process would have been catastrophic without urgent fasciotomy [42]. These factors have influenced the UK Defence Medical Services approach to injuries at risk of ACS. As such, military surgeons perform early fasciotomies as part of the initial management of those casualties with either clinical suspicion or at high risk of developing ACS [43]. It is accepted that limb fasciotomies are not a benign surgical intervention, with risks including haemorrhage, nerve damage, infection, difficult wound closure and poor cosmetic result. However, these risks should be balanced against the risk of not performing fasciotomy, namely development of ACS and subsequent potential limb loss. It is worth noting that during operations in Afghanistan, those casualties at high risk of ACS underwent fasciotomies irrespective of whether or not they were going to receive regional nerve blockade [44].

Battlefield injuries are high-energy penetrating injuries involving bone and soft tissue and may involve traumatic amputation. Such high-energy injuries are at high risk of ACS. Similar high-energy injuries are also seen during peacetime in civilians as a result of gunshot wounds or terror-related bombings. The anaesthetic care of patients with these injuries no longer remains the preserve of military anaesthetists. However, their experience of successfully using regional anaesthesia in these patient groups has an increased civilian relevance. The UK Defence Medical Services have successfully used continuous peripheral nerve analgesia using low-dose local anaesthetic solutions in those with high-energy injuries at risk of ACS. This provides analgesia with some preservation of sensory and motor function, thereby allowing identification of breakthrough pain, which is considered a cardinal feature of ACS, although it should be noted that this may not always be a feature of the syndrome [8, 45, 46].

One factor that may have contributed to the low incidences of ACS during recent conflicts is the format of a consultant-led and delivered service within deployed secondary care coupled with a familiarity among nursing staff on the wards with dealing with high-energy injuries at risk of ACS. UK military experience from combat operations suggests that the majority of cases of ACS have been recognised and managed during initial management at in-country surgical centres. An unpublished review of > 100 UK casualties with significant limb injuries identified only two casualties who required fasciotomies after evacuation from theatre, that is, country of wounding. Both cases were late presentations of ACS rather than a 'missed' event during initial management [43].

Education of medical teams on the pattern of injuries likely to be encountered on military operations and their subsequent management may play a part in the UK Defence Medical Services' experiences regarding the use of regional anaesthesia in those with high-energy injuries. The military surgical teams train together on the Military Operational Surgical Team Training (MOSTT) course and again before deployment on a 'whole-hospital' simulation exercise. This education and training support teamworking assists situational clinical decision-making with the aim of reducing adverse events such as ACS [47].

Pain relief after lower leg trauma

The Declaration of Montreal underscores the widespread view that pain relief is a fundamental human right, and the provision of effective analgesia for patients suffering any form of trauma should therefore be a priority [48]. If the injury suffered is one that is associated with a significant incidence of ACS, this human right is not affected, and the provision of pain relief should remain central to the medical management of the patient.

Regional analgesia is not the only form of pain relief available to patients who suffer lower limb trauma, and multimodal analgesia that includes paracetamol, non-steroidal anti-inflammatory drugs (if not contraindicated), opioids and other adjuncts can be effective. Regional analgesia without the use of local anaesthetic drugs has been used in the past (discussed earlier) and there is now anecdotal interest in the use of high-dose spinal diamorphine in the management of postoperative pain after tibial nailing. However, publications of randomised, controlled studies of this latter technique do not exist and its use should, therefore, be considered developmental or experimental. Many anaesthetists hold firmly to the view that regional analgesia with local anaesthetic drugs, and in particular single-shot and continuous peripheral nerve blocks, is the most effective form of analgesia available for tibial fractures and surgery to reduce them.

As noted above, most of those anaesthetists who provide regional analgesia for patients undergoing surgery associated with ACS currently choose to use low concentrations of local anaesthetic drugs without adjuncts, thereby preserving some sensation and movement, and allowing the potential for breakthrough pain. It should be noted that severe pain is not always a feature of ACS [8, 45, 46].

It is easy to believe that the choice of analgesia is the surgeon's alone, the anaesthetist's alone or is a consensus between the two when, in reality, it is none of these. As clearly outlined in the UK General Medical Council's guidance on consent [49], the choice belongs by right to the patient with capacity. Patients should be given treatment options and should base their choice on an open discussion of the risks and benefits of any treatment. Many patients who suffer trauma lack capacity and, only in the setting in which it is not possible to seek consent from a parent or other adult with the legal right to take decisions on behalf of the patient, is it reasonable for the anaesthetist and surgeon to take on the responsibility of determining which form of analgesia will be used.

Conclusion

There is anecdotal evidence of poor analgesia in patients with lower leg injuries that may, in part, be the result of concerns about the risk of ACS. Good analgesia is, however, a basic human right. The Working Party members believe that the use of single-shot or continuous peripheral nerve blocks using lower concentrations of local anaesthetic drugs without adjuncts are not associated with delays in diagnosis, provided appropriate post-injury and postoperative surveillance is used. The use of such techniques, including their risks and benefits, should be discussed with the patient as part of shared decision-making.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1 Selected summary of the available literature relating to acute compartment syndrome.