No disputes when there is a simple solution

Editorial

No disputes when there is a simple solution: monitoring in acute compartment syndrome (ACS)

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Acute compartment syndrome (ACS) occurs when there is a critical pressure rise to a point that reduces the perfusion pressure to the soft tissues within a confined compartment and is commonly seen in association with orthopaedic trauma, most frequently after a fracture of the tibial shaft [1]. Prompt treatment with timely fasciotomy is the treatment of choice to preserve muscle function and provide an acceptable functional outcome for the patient. A delay in diagnosis is invariably associated with muscle necrosis and late outcome is poor with ischaemic contractures that result in permanent disability of the affected limb [1, 2].

Unfortunately, late diagnosis is a well-recognised problem and is a potent source of litigation [3, 4]. In most cases, these claims are difficult to defend if the patient has presented in a timely fashion, before the onset of the complication. However, despite the known limitations of clinical diagnosis, most centres in the UK still utilise clinical symptoms and signs alone in the diagnosis of ACS. As the guideline document published in the current issue of this journal correctly points out [5], the symptoms and signs that clinicians rely on to make the diagnosis are neither sufficiently sensitive nor specific (Table 1) [6]. A systematic review documented that clinical assessment in isolation has a sensitivity of 13-19% and a specificity of 97% [6]. Diagnostic performance characteristics do improve somewhat when these symptoms and signs are combined but it has been shown that this is often when late signs of ACS have developed and is associated with muscle necrosis that will result in irreversible disability.

The authors of the guideline [5] go on to list the clinical symptoms and signs of the condition which were classically described as being "*pain; cold; paraesthesia; paralysis; pulselessness; and pallor*"**.** In fact, only pain out of proportion to the injury and pain on passive stretch are in any way helpful in the diagnosis and neither are specific or sensitive enough to be reliable in diagnosis [6]. Temperature and pallor have no relationship to development of compartment syndrome. Paraesthesia [7] and paralysis [8] are late signs associated with muscle necrosis, whilst pulselessness is associated with a vascular injury or an established ACS that will likely require amputation [1].

Compartment pressure monitoring is the most objective method of establishing the diagnosis of ACS in the absence of a gold standard test. There is an abundance of evidence reporting that continuous compartment pressure monitoring is the most reliable technique in at-risk patients [1, 9-11], with continuous compartment pressure monitoring shown to have a sensitivity of 94% and a specificity of 98% for the diagnosis of ACS when utilising a slit catheter

technique, with a differential pressure threshold (diastolic blood pressure – compartment pressure) < 30mmHg for > 2 h (Table 1) [11]. Although there is conflicting evidence regarding the strength of these diagnostic performance characteristics [12], it is the only objective method that aids in the diagnosis of the condition, particularly in scenarios where clinical evaluation is not possible e.g. patients with impaired consciousness, patients sedated on intensive care or following the use of regional anaesthesia.

We would disagree with the pessimistic appraisal of compartment pressure monitoring in this guideline document. The authors acknowledge the sound diagnostic performance characteristics of compartment pressure monitoring but then state that "*unfortunately, by definition, even this approach may miss some cases of ACS*" [5]. This may be true, but no investigation used in any field of clinical medicine has an accuracy of 100%. However, the evidence is quite clear that compartment pressure monitoring is currently far superior to any other method of diagnosis (Table 1). Their subsequent comment that "*continuous pressure monitoring may be the safest diagnostic investigation to avoid a missed case of ACS*" is an understatement [5] – it is the most reliable and indeed the only diagnostic investigation currently available.

The authors' statement in the same section of their article [5] that "*measurement of intracompartmental pressures can be regarded as the gold standard diagnostic investigation but only when other clinical features suggesting ACS are present*" is incorrect. Studies have found that compartment pressure monitoring can establish the diagnosis in many cases before the patient becomes symptomatic, leading to an earlier time to fasciotomy when compared to clinical signs alone [9, 13]. There are also limited data to suggest that this earlier time to fasciotomy confers a higher rate of primary wound closure due to a prompt intervention in the natural history of ACS that means swelling and ischaemia is reduced [13]. These are the key goals in management of the condition: early recognition and timely fasciotomy preserve muscle and limb function. In our own experience and from data reported in the literature, clinical evaluation alone is not a safe method of achieving these aims. In addition, it must be borne in mind that the complication is relatively uncommon and the fact that assessment of patients with suspected ACS is often undertaken out of hours by inexperienced doctors in training who are poorly equipped to establish to diagnosis and implement the rapid clinical actions required.

Compartment pressure monitoring is a safe technique that requires simple and readily available equipment found in all acute centres. Some of the other arguments often raised against monitoring are the potential for complications associated with the use of the monitor, as well as the perception of 'over-diagnosis' or a high false-positive rate that could lead to unnecessary fasciotomies being carried out [14]. There are currently no data to support a complication rate associated with the use of compartment pressure monitoring. Furthermore, the literature would suggest that there is no increase in fasciotomy rates when monitoring is employed and rates reported from our centre are certainly consistent with the published literature [15,16]. It would also seem logical that given the devastating sequelae associated with a missed or delayed diagnosis of ACS a degree of 'over-treatment' would likely be preferable, particularly given the comparable long-term outcomes of patients that do and do not have fasciotomies for ACS following a fracture of the tibial shaft [16].

The authors of the guideline [5] have reviewed the literature regarding the risk factors associated with ACS and we would take issue with their interpretation of this evidence. Unfortunately, the list includes intramedullary nailing as a factor. It was a common misconception after intramedullary nailing became popular in the 1990s that the procedure would increase the risk of ACS. This has been shown not to be the case [17] with large data using multivariable regression suggesting youth is the most important risk factor [18]. We consider there is no reason to choose an alternative method of fixation if intramedullary nailing is considered the best method of fracture treatment.

The current literature would suggest a delay in diagnosis is associated with not only regional or general anaesthesia, but also clinical inexperience, polytrauma cases, soft tissue injuries, along with using clinical symptoms and signs in isolation [6,19-24]. The authors of the guideline also note that there is a range of opinion on the use of regional analgesia and the issues with obscuring the symptoms and signs of ACS [5]. This is described in the guideline [5] and accompanying editorial [25] as a potent source of conflict between orthopaedic surgeons and anaesthetists. In their review of the literature on ACS in relation to regional anaesthetic techniques the authors note the "*complete absence*" of what they refer to as "*randomised controlled studies*". In the accompanying editorial [25], the authors tell us "*the science rather lets us down, as there are no prospective, randomised, controlled studies*". This is not surprising for several reasons. Although a very well-recognised clinical complication, ACS

remains relatively uncommon in clinical practice as the authors have pointed out and there is not gold standard test to confirm or refute the diagnosis. Even with tibial diaphyseal fractures, which is the injury most associated with the complication, the rate is likely anything from 4-11% [15,16]. Conditions that occur with this level of frequency cannot easily be subjected to investigation in randomised trials and assessment of diagnostic performance characteristics is limited. Consequently, it is highly unlikely that any trial evaluating the appropriateness of regional anaesthesia in patients at risk for ACS will take place, as there would be economic and ethical reasons that would render any such trial as unfeasible. A further issue with performing randomised controlled trials in this area is associated with the Hawthorn effect. Any trials of clinical signs versus continuous compartment pressure monitoring would be subject to this due to this bias of inevitably modifying routine day-to-day clinical practices that would result in an increase in the frequency and robustness of clinical assessment. The authors do comment on the lack of reports of ACS being diagnosed late because of regional anaesthesia. There are also plausible explanations for this too: first, the literature is very limited in terms of sample size and study design; and second, clinicians involved in management of missed compartment syndromes who are subject to litigation do not tend to rush to publication to highlight their failings.

The authors of the guideline [5] indicate in their 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*"; we would not agree. In our centre there has been no disagreement between anaesthetist and surgeon on this matter for over three decades. The reason we feel is quite simple – we have used routine continuous compartment pressure monitoring in all patients judged to be at risk of developing ACS since the late 1980s. This takes more of the 'guesswork' out of the diagnosis and the anaesthetist has complete autonomy in deciding what is the best form of analgesia for the patient. In cases where there may be doubt about the risk, the anaesthetist discusses the regional anaesthetic technique to be used with the surgeon who then has the discretion to decide if as a precaution compartment monitoring is advisable.

In relation to the position of the British Orthopaedic Association (BOA) there appears to have been some misunderstanding. The BOA Trauma Committee had the opportunity of reviewing the text agreed with some of the points in this guideline document. However, as the main

body of text is in excess of 5000 words it was considered to be too long for a concise 'guideline' document. The current policy of the BOA is producing regular guidelines under the banner BOASTs (British Orthopaedic Association Standards in Trauma). These documents are produced on a single page with a clear logical sequence of auditable statements regarding management and diagnosis in relation to specific conditions or aspects of service provision. They have proved very popular with consultants and trainees as they are easily used in clinical practice and in a recent survey of the BOA membership the BOASTs were rated as the most useful contribution of the organisation to its membership. It was the view of the trauma committee that the document published in this edition of the journal was a comprehensive literature review on the use of regional anaesthesia and its relationship to compartment syndrome rather than a concise guideline document that would be used in clinical practice. This was the main reason the document was not considered suitable for endorsement. There is an existing BOAST on the diagnosis and management of compartment syndrome. It will be due for review soon, and it is anticipated that it will be co-badged with the relevant specialist associations. It will incorporate the key points made in relation to use of regional anaesthesia in patients at risk of developing compartment syndrome.

The somewhat adversarial language of the guideline document and the accompanying editorial by Bogod and McCombe [25] are pertinent to clinical practice in the late 20th century, but we feel strongly should not be relevant now. The technology to perform continuous compartment pressure monitoring to reliably establish the diagnosis and management of ACS has been available for over three decades. Both articles highlight the importance of patient rights and their entitlement to the best options for analgesia according to the circumstances. We would wholeheartedly agree with these sentiments. In our centre patients at risk of ACS have had access to a holistic team-based approach with the most appropriate analgesia for decades, thanks to continuous compartment pressure monitoring. Surgeons and anaesthetists who work in hospitals where there are inter-disciplinary disputes about patient analgesia and the risk of ACS are delivering a level of care that was unsatisfactory even back in the 1980s, but which is simply unacceptable in the 21st century. It is time for clinicians who are involved in management of patients at risk of ACS to embrace a widely available technology that facilitates access of our patients to the best possible

analgesia and is manifestly more reliable than clinical diagnosis in early recognition and management of this uncommon but potentially devastating complication.

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TABLES

Table 1: The diagnostic performance characteristics of clinical assessment and compartment pressure monitoring for the diagnosis of acute compartment syndrome. Adapted from [1].

	Sensitivity (%)	**Specificity (%)**	**PPV (%)**	**NPV (%)**
Pain	19	97	14	98
Pain on passive stretch	19	97	14	98
Paralysis or motor signs	13	97	11	98
Paraesthesia or sensory signs	13	98	15	98
Swelling	54	76	70	63
Compartment pressure monitoring	94	98	93	99

PPV, positive predictive value; NPV, negative predictive value.

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