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**EDITORIAL**

- 1 Damage control orthopaedics: State of the art  
*Guerrero E, Bertrand ML, Cano JR, Cerván AM, Galán A*

**ORIGINAL ARTICLE****Observational Study**

- 14 Inter- and intra-rater reliability of vertebral fracture classifications in the Swedish fracture register  
*Morgonsköld D, Warkander V, Savvides P, Wihlborg A, Bouzereau M, Möller H, Gerdhem P*
- 23 Validation of the Danish version of the musculoskeletal tumour society score questionnaire  
*Saebye CKP, Keller J, Baad-Hansen T*

**CASE REPORT**

- 33 Contralateral trapezius transfer to treat scapular winging: A case report and review of literature  
*Gil-Álvarez JJ, García-Parra P, Anaya-Rojas M, Martínez-Fuentes MDP*
- 45 Peroneus longus tendon rupture: A case report  
*Koh D, Liow L, Cheah J, Koo K*

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Editor-in-chief of *World Journal of Orthopedics*, Baogan Peng, MD, PhD, Chief Doctor, Professor, Department of Spinal Surgery, General Hospital of Armed Police Force, Beijing 100039, China

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## Damage control orthopaedics: State of the art

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### Abstract

Damage control orthopaedics (DCO) originally consisted of the provisional immobilisation of long bone - mainly femur - fractures in order to achieve the advantages of early treatment and to minimise the risk of complications, such as major pain, fat embolism, clotting, pathological inflammatory response, severe haemorrhage triggering the lethal triad, and the traumatic effects of major surgery on a patient who is already traumatised (the “second hit” effect). In recent years, new locations have been added to the DCO concept, such as injuries to the pelvis, spine and upper limbs. Nonetheless, this concept has not yet been validated in well-designed prospective studies, and much controversy remains. Indeed, some researchers believe the indiscriminate application of DCO might be harmful and produce substantial and unnecessary expense. In this respect, too, normalised parameters associated with the acid-base system have been proposed, under a concept termed early appropriate care, in the view that this would enable patients to receive major surgical procedures in an approach offering the advantages of early total care together with the apparent safety of DCO. This paper discusses the diagnosis and treatment of severely traumatised patients managed in accordance with DCO and highlights the possible drawbacks of this treatment principle.

**Key words:** Damage control orthopaedics; Early total care; Early appropriate care; Polytrauma; Resuscitation; External fixation; Packing; Embolisation; Compartment syndrome

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**Core tip:** Damage control orthopaedics (DCO) is the treatment of lesions that provoke major bleeding and pathological inflammatory response, whilst avoiding the traumatic effects of major surgery in a patient who is already traumatised (the “second hit” effect). The concept of DCO has not previously been validated and much controversy remains as

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to whether the indiscriminate application of DCO might be clinically and economically harmful. In addition, parameters associated with the acid-base system have been published with the idea that the existence of normalised parameters will enable patients to receive major surgical procedures, under a concept termed early appropriate care. This paper discusses the above concepts.

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## INTRODUCTION

The concept of damage control orthopaedics (DCO)<sup>[1]</sup> originally concerned the provisional immobilisation of long bone fractures - mainly the femur - in the severely traumatised patient (STP) in order to minimise the traumatic effects of non-life saving surgical procedures, termed the "second hit" effect<sup>[2-5]</sup>. In recent years, new locations have been added to the DCO concept, such as pelvis fractures, spine fractures and upper limb injuries<sup>[6]</sup>.

Haemorrhage is a major cause of acute morbidity and mortality in the STP, and it also worsens the evolution of the generalised inflammatory response<sup>[3-5]</sup>. Although haemorrhage complicates the generalised inflammatory reaction, transfusion may also aggravate the general traumatic syndrome, as this therapy can provoke complications in a patient who already presents a pathological inflammatory response. Massive transfusion can also provoke coagulation abnormalities, ion disorders and immunosuppression with subsequent infection as well as proclivity to lung injury and hypothermia<sup>[6,7]</sup>. Therefore, blood transfusion can be a life-saving procedure, but it may also provoke a "second hit" reaction. This ambivalent effect can also arise from surgical procedures. Even interventions aimed at stopping a haemorrhage can provoke the release of molecules that aggravate the coagulation mechanism and heighten the inflammatory response. The fundamental goal of DCO is to do as little as possible in order to avoid further damage, and, therefore, only life-saving procedures should be performed when the patient's condition is acute.

The idea of doing "as little as possible" but "sufficient" to save the patient's life, the philosophy on which DCO is based, remains ill-defined. Although DCO is currently applied worldwide, the concept has not been validated in well-designed prospective studies, and controversy remains as to whether the indiscriminate application of DCO might be harmful and incur substantial unnecessary expense<sup>[8]</sup>. The Polytrauma Study Group of the German Trauma Society reviewed 63 controlled trials of DCO but found no generalised management strategy<sup>[9]</sup>. Similarly, a study conducted in the United States reported DCO implementation rates in reputed institutions ranging from 12%<sup>[10,11]</sup> to 57%<sup>[12]</sup>. Thus, there is a need to propose a better definition of the general physiopathology of major trauma in response to the need for a universal validation of DCO.

In addition to the above concerns, molecular-mediated mechanisms responsible for trauma-inducing coagulopathy<sup>[13,14]</sup>, susceptibility to infections<sup>[13]</sup> and fracture-healing impairment<sup>[15]</sup> all remain poorly understood<sup>[16]</sup>. In consequence, the relationship between levels of inflammatory biomarkers and the "second-hit" effect is not firmly established. In this respect, only a few small prospective studies have been undertaken.

In a related area, a small non-comparative study was performed to consider the immediate impact of intramedullary femoral nailing, as the second hit, on multiple trauma patients, measuring various indices of haemodynamic stability, coagulation, fibrinolysis, oxygenation and inflammatory cytokines in the blood, using a pulmonary artery catheter before nailing. However, this analysis did not enable firm conclusions to be drawn<sup>[17]</sup>.

Some indices (the thrombin/anti-thrombin complex, tissue plasminogen activator and interleukin-10) present maximum values at the time of admission before surgery (first hit), while others (tissue factor, plasminogen activator inhibitor, tumour necrosis factor- $\alpha$ , interleukin-6 and pulmonary shunting) increase later, at 48-72 h after surgery. None of the remaining indices considered are significantly affected, other than a transient increase in pulmonary vascular resistance at around 2 h after

surgery<sup>[17]</sup>.

Besides the trauma severity itself, genetics is also thought to play an important role in the inflammatory response<sup>[18-20]</sup>, but in this respect, much remains to be determined before any clinical application can be made.

In summary, the concept of DCO is far from being universally accepted and validated, and the cornerstone of major trauma survival continues to be the control of bleeding and the inflammatory response. Although in the case of major bleeding, blood haemoglobin concentration sensitivity may be very low, this is a key variable, together with blood pressure, to be taken into account when rapid treatment decisions must be taken.

Attention should also be paid to other laboratory markers (evidence grade 1B)<sup>[21]</sup>. Serum lactate and base deficit are very sensitive measures for detecting and monitoring the extent of bleeding and shock (evidence grade 1B) in conjunction with repeated combined measurements of prothrombin time, activated partial thromboplastin time, fibrinogen and platelets (evidence grade 1)<sup>[21]</sup>.

The current debate on DCO *vs* early appropriate care (EAC) has led to much discussion regarding the significance of various laboratory markers<sup>[22-32]</sup>. In addition, it has been claimed that definitive early treatment of major fractures can be achieved under an EAC regime and more frequently than *via* DCO<sup>[23-25]</sup>.

Timely resuscitation enhances the initial treatment of fractures, and definitive fixation appears to be associated with a low incidence of complications. Therefore, early fixation usually results in better general and local outcomes, as well as being more cost-effective, and it has long been a major research goal to identify parameters associated with early fracture fixation. Since 2011, the Cleveland group<sup>[23-25]</sup> has highlighted parameters believed to be associated with the acid-base system, based on the idea that if excessive base and lactate values can be normalised, patients will be better able to withstand major surgical procedures. The importance of this approach is that the consideration of any other metabolic parameter in the severely traumatised patient can then be dismissed. Under these circumstances, patients could be treated under a quasi-early total care (ETC) regimen, *i.e.* EAC, in an approach that might provide the advantages of ETC but the safety of DCO.

Authors who have supported the DCO concept<sup>[22,30]</sup> in preference to that of EAC<sup>[23-25]</sup> accept that the use of blood lactate levels is the main parameter to be considered in the management of patients with sepsis and/or septic shock<sup>[31]</sup>. However, a normal acid-base situation does not necessarily mean that the patient's clinical condition is satisfactory or even that a surgical procedure can be performed<sup>[25]</sup>. In this respect, other concepts such as the "triad of death", taking into account other indicators, can also be useful<sup>[30]</sup>.

In any case, the concept of EAC, as such, does not require the application of one or more specific surgical techniques, as is the case with ETC (*e.g.*, regarding intramedullary nailing versus ExFix under DCO). EAC is more a concept of metabolic permissiveness for the performance of ETC. Furthermore, the concept of DCO, which at present seems to be internationally accepted, is currently under review because of the belief that use of this technique is being abused. What EAC actually does more frequently approaches ETC. Some researchers have called for the validity of the above concepts and that of DCO in particular to be re-examined<sup>[27-33]</sup>.

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## RESUSCITATION

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The number one priority in resuscitation is to stop the bleeding, while that of any treatment in the acute phase of the STP is to avoid hypovolaemic shock and the "lethal triad"<sup>[34]</sup>, and then to establish DCO. The time elapsed between injury and surgical intervention to control the bleeding should be minimised. Sustained systolic blood pressure of less than 80-90 mm Hg after treatment with vasoactive drugs is considered a sign of active bleeding, making the basis of resuscitation the prompt initiation of surgical treatment to stop the bleeding, together with the use of colloids to avoid the need for blood transfusion, if possible. Hypotonic solutions such as Ringer's lactate should not be administered to patients with significant brain injury<sup>[21]</sup>. Therefore, surgical treatment is the baseline approach to resuscitation, and attention should be focused on the possible sources of severe bleeding: extensive skin lesions, injuries to the chest, abdomen, pelvis or lower limbs and long-bone fractures, particularly the femur. Fractures in the skeleton, especially the pelvis or the femur, are major causes of bleeding and can provoke highly dangerous or even fatal haemorrhages.

Pelvic fractures may be accompanied by ruptures to major vessels or injuries to vascular plexuses. When the STP is still haemodynamically stable, a contrast

computed tomography (CT)-scan should be performed before any X-ray projection, as pelvic and spinal fractures can be missed by conventional radiological studies<sup>[35,36]</sup>. A fracture or dislocation of the pelvis due to an anteroposterior trauma provokes a broadening of the pelvic cavity and can be associated with vertical instability. These fracture patterns are the most severe and require prompt attention to close and stabilise the pelvic ring diameter to normal dimensions<sup>[37]</sup>.

The use of pelvic binders, a technique that dramatically reduces mortality rates<sup>[38]</sup>, is currently considered the gold standard for pelvic ring closure. Whenever possible, therefore, this approach should be taken in acute situations, whenever the pelvic ring is enlarged. Moreover, binders can be applied rapidly and simply, allowing transfer to the CT-scan with the pelvic ring closed<sup>[39]</sup>. Either a commercially-manufactured device or a conventional sheet can be used as a binder<sup>[40-43]</sup>, although they can incite skin sores<sup>[44]</sup> if maintained for more than 2-3 d<sup>[45]</sup>.

ExFix provides more stability than binders, avoiding anterior abdominal cavity compression and also the risk of skin necrosis<sup>[45]</sup>. When properly applied, ExFix facilitates laparotomy, stabilising the pelvic bones<sup>[6,7]</sup>. However, the ExFix technique is much more time-consuming and aggressive. It requires anaesthesia and an operating room and is more upsetting for patients. Moreover, the use of ExFix can lead to the development of pin track infection, and the use of subcutaneous fixation is not yet fully understood<sup>[46]</sup>. The experience of other complications, too, has led ExFix, whether conventional or subcutaneous, to fall out of favour, and for the binder approach to be preferred<sup>[47,48]</sup>. In any case, the conversion of ExFix to internal fixation should be performed as soon as possible<sup>[49]</sup>.

ExFix presents other problems, too, in relation to biomechanics. Although many attempts have been made<sup>[50]</sup>, posterior pelvic lesions are poorly stabilised by anterior frames<sup>[49]</sup>. However, C-clamp devices<sup>[50-53]</sup> applied to posterior lesions can achieve good bone fracture reduction<sup>[54]</sup>. Nevertheless, due to the wide range of patient types and results that can be encountered, universal conclusions cannot be drawn, even from systematic reviews<sup>[55]</sup>. C-clamping can be a dangerous technique, and iatrogenic lesions may occur as a result, even when the method is applied by an experienced surgeon. The main complications reported in this respect are migration into the pelvic cavity, which can provoke intestinal piercing or further bone fractures<sup>[51,56]</sup>.

Even in an emergency, a less invasive method, such as iliosacral screw internal fixation, an X-ray-guided technique, can often be used, if the surgeon is familiar with this procedure<sup>[53,56-59]</sup>. Iliosacral screws usually produce better outcomes than the C-clamp, although pelvic dysmorphism can make this method technically demanding even for experienced surgeons<sup>[52,56,57]</sup>, particularly in an emergency setting<sup>[58]</sup>. Moreover, both C-clamps and iliosacral screws require full integrity of the iliac bone, in the case of a pure iliosacral dislocation or sacral fractures<sup>[53,57-60]</sup>.

When there is major retroperitoneal bleeding that remains uncontained after pelvic ring closure, the indicated approach could be packing or embolisation<sup>[6,7]</sup>. However, since pelvic ring closure produces a tamponade effect, stabilises the pelvis and occludes fractures, thus enhancing cessation of the haemorrhage, pelvic stabilisation is advised before any attempts are made at packing or embolisation<sup>[6,7,37]</sup>, although if necessary the latter could be performed even in the case of an unfixed, unstable pelvic fracture<sup>[61]</sup>.

Extraperitoneal packing is a safe and useful technique that facilitates the repair of any abdominal or pelvic cavity bleeding. Injuries to major vessels can also be treated by the extraperitoneal approach<sup>[62]</sup>. It is especially useful for “in extremis” patients when a CT-scan is not advisable or when ring closure is impractical and also if further bleeding takes place following pelvic ring closure. Training in this technique is necessary, as it is not yet widely known<sup>[63]</sup>, although it is straightforward for a trauma surgeon and can be performed more rapidly than angiography plus embolisation<sup>[64]</sup>. Moreover, the latter methods require the presence of a specialised radiology team, a resource that is not always available. Even when such a team is in full-time attendance, any embolisation during the night or weekend can make treatment schedules more complex and result in higher mortality<sup>[65]</sup>. In addition, embolisation may only address arterial bleeding, and not that provoked by major vessels, and is very time consuming<sup>[61,66]</sup>. Finally, this technique is associated with an increase of up to 10% in overall complications, including gluteal muscle necrosis, surgical wound breakdown, deep or superficial infections, impotence and bladder necrosis<sup>[67]</sup>.

In view of these considerations, the complementation of packing with angiography and embolisation appears to be a reasonable strategy<sup>[68]</sup>. A systematic review in this respect concluded that pelvic packing, as part of a DCO protocol, provides crucial time for a more selective management of haemorrhage<sup>[69]</sup>. Other technologies such as temporary partial intra-iliac balloon occlusion during internal pelvic fixation are also in use but to our knowledge have not yet been validated<sup>[70]</sup>.

Open pelvic injuries require special attention. A study of 29 battlefield trauma

patients reported mean blood requirements of 60.3 units during the first 24 h. Ring closure in these patients is often not possible, and other circumstances such as vascular, bowel, genital and bladder injuries are often coexistent<sup>[71]</sup>. In this context, haemorrhage control, concurrent regional lesions and soft tissue lesion with infection prevention are the main issues to be addressed<sup>[72-75]</sup>. Apart from clinical inspection, including consideration of possible injuries to the bowel and urinary systems, a contrast CT-scan is mandatory when the patient is haemodynamically stable. When there is a bowel lesion, early diverting colostomy is usually necessary<sup>[72-75]</sup>. Experience with battlefield pelvic wounds is often valuable in the subsequent treatment of civilian patients, particularly in relation to open blast injuries to the pelvis<sup>[71]</sup>.

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## FEMUR FRACTURES

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Femur bone fractures can also provoke acute life-threatening bleeding. Therefore, high-energy femur fractures must be promptly recognised and immobilised<sup>[76]</sup>. Since these fractures can provoke major limb deformity, diagnosis is usually immediate by simple inspection, and treatment under a DCO regime advises speedy immobilisation by ExFix<sup>[76,77]</sup> in order to avoid poorer outcome, further surgical interventions, more blood transfusion and a longer hospital stay<sup>[78,79]</sup>. Nonetheless, for “in extremis” patients, a non-compressive garment or skeletal traction can be appropriate<sup>[80]</sup>, as a fracture fixation method would not produce a useful effect on the incidence of systemic complications in severely traumatised patients<sup>[12]</sup>. Moreover, some authors have found that early intramedullary nailing can reduce the need for mechanical ventilation, and decrease treatment costs<sup>[81]</sup>. The presence of concurrent lesions, particularly abdominal injuries<sup>[77,82]</sup> or a bilateral femur fracture is, in any case, a very important variable for worsening the outcome, particularly with respect to abdominal injuries<sup>[77,82]</sup>. In these cases, at least, management with ExFix is advisable.

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## SPINAL FRACTURES

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Multiply-injured patients frequently present spinal trauma<sup>[83]</sup>. Thus, 93% of victims of fatal traffic accidents present a cervical fracture, while among survivors of such accidents, up to 40% have cervical fractures, and 10%-30% have thoracolumbar fractures, which can provoke a permanent neurological deficit. In order to prevent these complications, it is important to apply the ATLS®-protocol<sup>[84]</sup>, bearing in mind possible vertebral lesions and how to prevent the aggravation of neurological injuries. Correct performance of the log-roll manoeuvre and maintaining sufficient blood perfusion, especially for patients with injuries to the central nervous system, is mandatory. In the case of spinal shock, hypotension must be treated rapidly with vasoactive drugs<sup>[85]</sup>.

Spinal injuries can frequently be overlooked in severely traumatised patients, and so a full body CT-scan should be performed, as an appropriate diagnostic test to detect possible spinal fractures<sup>[85,86,88]</sup>.

The prompt diagnosis and proper management of spinal lesions are aspects of overriding importance. However, questions may arise as to what type of treatment is most appropriate for severely traumatised patients with associated spinal column fractures. According to most studies, early fixation is preferred; this approach is safe, decreases the incidence of pulmonary complications and neurological damage, reduces the duration of intensive care, lowers morbidity and enhances survival and neurological recovery<sup>[89-92]</sup>. Hence, spinal DC is a staged procedure of immediate posterior fracture reduction and instrumentation within 24 h<sup>[93,94]</sup>. Although immediate reduction and posterior stabilisation of spinal fractures is desirable, if necessary an interbody completion fusion can be performed, together with a large anterior decompression. Nevertheless, if possible, this should be carried out at a later stage, as further blood loss and a “second hit” with extensive soft tissue exposure can aggravate the patient’s general economy. Depending on the fracture type, additional anterior instrumentation may also be added<sup>[95]</sup>.

When sufficient closed reduction is feasible, posterior, less-invasive stabilisation systems (LISS) are to be preferred. When there is neurological damage, speedy open decompression may be required<sup>[96,97]</sup>. LISS techniques provide various benefits, such as decreased blood loss, surgical time, patient morbidity, postoperative pain and infection rates, and improved outcomes<sup>[98-100]</sup>. Studies comparing percutaneous fixation without fusion to traditional techniques have demonstrated similar outcomes in long-term follow-up and according to radiological parameters<sup>[91,92,101,102]</sup>. In summary, whenever possible, LISS is a highly recommended option within algorithms for spinal

decompression.

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## UPPER LIMB FRACTURES

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The presence of complex trauma in the upper limb is a challenge for the surgeon because it requires outstanding knowledge of the anatomy at risk<sup>[103]</sup>. Soft tissue cleansing, the extraction of foreign bodies and radical debridement are needed to provide an appropriate base on which to stabilise the fractures<sup>[104]</sup>. For forearm bone fractures, either ExFix or plates can be used as osteosynthesis methods. It is essential to preserve longitudinal vascular, nerve and tendon functioning and viable structures<sup>[105]</sup> by using venous grafts to preserve circulation and by direct suture tension in peripheral nerves<sup>[106]</sup>. Definitive coverage by means of skin and muscle flaps must be undertaken when the patient's general state allows<sup>[107]</sup>. Currently, the development of negative pressure therapy systems facilitates delaying the repair of soft tissues and decreases the complexity of the reconstruction by diminishing the size of the wound<sup>[108]</sup>. Avoiding postoperative rigidity is an important objective for patients who require that attention be paid to other, more urgent areas<sup>[109]</sup>.

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## PHARMACOLOGICAL MANAGEMENT

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### *Tranexamic acid*

Severe haemorrhage is one of the most important causes of death in the STP. To address this condition, tranexamic acid (TXA), an antifibrinolytic product, has recently been added to the pharmacological resources available and is now the only specific pharmacological treatment currently recommended<sup>[110]</sup>. Nevertheless, doubts remain about its management, such as the appropriate dose and the characteristics of the patients who would most benefit from this treatment. Although most guidelines recommend a 1 g bolus, there is great variability of opinion regarding subsequent doses. Moreover, the mechanism of action responsible for its effects was not determined in the Clinical Randomisation of an Antifibrinolytic in Significant Haemorrhage-2<sup>[111]</sup> or the Military Application of Tranexamic Acid in Trauma Emergency Resuscitation studies<sup>[112,113]</sup> and remains unknown.

Researchers have concluded that in patients with more severe injuries the use of TXA is associated with a higher mortality rate regardless of the time of administration<sup>[114]</sup>. Nonetheless, the latter was a retrospective study with a sample of 300 patients, and prospective studies are needed in order to identify the threshold of the beneficial effects of TXA.

While the prompt use of TXA is recommended, a much-debated topic is that of the time and site of its administration. Some recent studies have advocated the prehospital use of the drug, proposing that when in a given site it is not available for prehospital use, the patient should be transferred to another nearby hospital in order to receive this treatment even if it does not have sufficient infrastructure for trauma patients<sup>[115,116]</sup>.

A randomised clinical trial, conducted to evaluate the efficacy and safety of recombinant active factor VII rFVIIa as a complement for direct haemostasis in polytraumatised patients, concluded that the use of rFVIIa reduced the use of blood products but did not affect mortality compared to placebo treatment<sup>[117]</sup>. Ongoing research studies seek to analyse the use of other agents for the control of trauma-induced coagulopathy. Thus, an experimental study in a porcine model was recently published regarding the effects of factor-based resuscitation on shock and trauma-induced coagulopathy and of prothrombin complex concentrate, TXA and fresh frozen plasma - both individually and in combination - on acute trauma-induced coagulopathy. The authors concluded that no benefit was obtained from the use of prothrombin complex concentrate or TXA, either as single agents or in combination, for resuscitation from haemorrhagic shock. However, the concurrent administration of plasma with these agents seems to provide good results in the treatment of haemorrhagic shock, by alleviating hypotension, decreasing lactic acidosis, improving coagulopathy and enhancing clot formation and quality<sup>[118]</sup>. In conclusion, although controversies persist, the early use of TXA, within 3 h of the trauma, and even in the prehospital phase, is currently included in the initial management guidelines for severely traumatised patients.

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## THROMBOEMBOLIC PROPHYLAXIS

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For years, it has been known that STPs are at high risk of suffering deep vein thrombosis (DVT) and pulmonary thromboembolism (PE), both of which are frequent causes of death. In each case, the incidence varies greatly from one study population to another, according to the diagnostic criteria used. Diagnoses of DVT and PE are becoming more frequent<sup>[119]</sup>, and pharmacological antithrombotic prophylaxis (AP) is needed, together with mechanical therapies. The questions of when AP should be initiated and which patients are at most risks remain highly controversial. Studies have suggested that risk factors include age older than 40 years, pelvic and lower extremity fractures, spinal cord injury with paralysis, cranial trauma, more than 3 d of mechanical ventilation, vascular injuries and shock at the time of patient admission and major interventions<sup>[120]</sup>.

The clinical variability observed means that it is currently impossible to protocolise AP. While the concurrent presence or risk of major haemorrhage is a major challenge, the start of AP is often delayed. Nevertheless, as DVT develops within the first days after trauma, AP should be set up as soon as possible<sup>[119]</sup>. It has been demonstrated that in severely traumatised patients, initial hypocoagulability lasts for some 24 h. Accordingly, AP must be started after that time<sup>[121]</sup>. On the other hand, in patients with cranial trauma presenting haemorrhage or with massive visceral lesions, spinal cord injuries or uncorrected coagulopathy, AP should be delayed. By starting AP 72 h after the traumatism, the incidence of DVT seems to decrease without progression of the haemorrhage<sup>[122,123]</sup>. However, this outcome is not evidence-supported, and so it is advisable not to delay AP for the above-mentioned patients<sup>[121]</sup>.

Low molecular weight heparin (LMWH) seems to be the drug of choice for AP<sup>[124]</sup>, although the evidence in this respect remains insufficient. In a study carried out with 743 high-risk polytraumatised patients, in whom the AP was carried out with LMWH, the treatment was started once the patients were haemodynamically stable and the bleeding was under control. For patients with intracranial haemorrhage or spinal trauma, the AP was started when, according to the CT study, the intracranial haemorrhage was inactive. In patients with epidural analgesia, the AP with LMWH was started after removal of the epidural catheter. These patients were given a dose of 5000 units, once daily, administered by subcutaneous injection, and the AP was continued until the patient could walk independently. This treatment was maintained under the same regimen, even when the patient required further surgical treatment. The study concluded that this daily regimen with LMWH provided similar levels of safety and efficacy to those reported in previous studies when LMWH was given twice a day. In addition, the once-daily regimen, regardless of the need for further invasive procedures, obtained better results in terms of compliance<sup>[125]</sup>. Although recent attempts have been made to improve these results by dosing LMWH adjusted for thromboelastography, conclusive data have not yet been obtained<sup>[126]</sup>.

Other preventive measures to avoid DVT and PE events involve the use of mechanical compression. These systems, as well as being of unproven efficacy, may be impossible to use in certain patients with trauma or who require surgery of the lower limbs, particularly if ExFix has been applied. Even so, they are in common use and are usually associated with pharmacological AP<sup>[120]</sup>. Vena cava filters (VCF) have also been evaluated in this regard. This type of prophylaxis is proposed for extremely high risk patients in whom it is not feasible to perform AP by mechanical or pharmacological methods. In these patients, the use of VCF is aimed at achieving the prophylaxis of PE, as it does not prevent DVT<sup>[127]</sup>; however, its use remains hotly debated<sup>[128]</sup>. In summary, most current guidelines for AP advice the use of chemoprophylaxis with LMWH as soon as possible, associated with mechanical methods whenever feasible; the use of VCF is not yet recommended as routine prophylaxis.

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## ANTIBIOTIC PROPHYLAXIS

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Infection is a frequent problem in polytraumatised cases, and sepsis is the second leading cause of death in these patients after haemorrhage. The prevention of infection is a complex matter. It is very difficult to establish protocols or guidelines in this regard, as patients often develop a disturbance of immunity secondary to trauma and their injury patterns vary greatly. Infection also depends on the type and severity of injuries presented, and many doubts arise concerning its treatment, in areas such as the time of administration, antibiotic selection and the duration of administration.

Nevertheless, it is generally accepted that the guidelines for antibiotic use do not change according to whether the patient being treated is severely traumatised. In patients with one or more open fractures, antibiotics should be administered at an early stage, and if possible within 3 h of the trauma<sup>[129]</sup>. Strict measures to prevent

infections should be taken, with aseptic, rigorous management and care of wounds.

There is a consensus that the presence of multiple traumas does not justify changing the autologous blood-derived product regimen or prolonging it from that used in open fractures<sup>[130,131]</sup>. Nonetheless, antibiotic doses in these patients should be individualised in accordance with the general organic function, since renal function impairment varies from one patient to another<sup>[132]</sup>.

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