

REVISED ILLUSTRATED EDITION | OCTOBER 2026

Philosophy of Major Trauma

Mechanisms, judgement and organised care
from resuscitation to recovery



Mr Peyman Bakhshayesh

MD, PhD, MBA

Consultant Trauma and Orthopaedic Surgeon

Clinical Lead for General Trauma, Leeds Teaching Hospitals NHS Trust

Honorary Clinical Senior Lecturer, University of Leeds

About this edition

PHILOSOPHY OF MAJOR TRAUMA

Mr Peyman Bakhshayesh, MD, PhD, MBA

Revised illustrated edition, 13 October 2026

The purpose of this book is to connect the mechanism of injury with the physiology of the patient, the readiness of the service and the possibility of meaningful recovery. Its central question runs through every chapter: what does this person need now, and what must the team preserve for the next stage of life?

The work brings together the author's supplied manuscript and clinical reflections, relevant material from his doctoral research and trauma literature collection, and the clinical sources cited within each chapter. It follows the injured person from the first assessment through reconstruction, rehabilitation and return to everyday life.

How to read the book

The introduction establishes the philosophy of organised care. Ten chapters develop early care, regional injury and rehabilitation. Reference numbering restarts in each chapter. The contents and PDF bookmarks link to chapter openings; clicking the running book title returns to the contents.

Cartoons introduce the human and team themes. Clinical figures explain selected anatomical relationships and injury mechanisms in simplified form. Diagrams are conceptual schematics, not radiographs or operative maps. Interpret them with their captions, the surrounding discussion and the classification tables.

Clinical scope

This professional educational monograph primarily addresses adult major trauma. It supports clinical judgement alongside current trauma-network protocols, specialist expertise and individual assessment. Children, pregnancy and other specialist populations require adapted pathways. The time of intervention depends on the patient's evolving condition, the injury and the available service.

Publication information

Copyright © 2026 Mr Peyman Bakhshayesh. Author-published. The author's affiliations identify his professional roles and do not imply institutional endorsement. The clinical scenarios are illustrative composites. No patient photographs or identifiable patient histories are included. Conceptual cartoons were created with AI assistance for this edition; clinical schematics and their labels were checked during editorial preparation.

Contents

About this edition	2
The author and the purpose	4
Introduction: A philosophy of coordinated trauma care	5
Chapter 1: Early care in major trauma	12
Chapter 2: Head and neck injuries	22
Chapter 3: Thoracic injuries	31
Chapter 4: Abdominal trauma	42
Chapter 5: Pelvic trauma	53
Chapter 6: Spine and spinal precautions	64
Chapter 7: Plexus injuries	76
Chapter 8: Vascular injuries	86
Chapter 9: Extremity injuries	95
Chapter 10: Rehabilitation and functional return	103

Reading route

Read the introduction and early-care chapter as the common framework. Regional chapters then apply the same questions to different anatomy: what failed, what threatens life or function, what can the patient tolerate, and who owns the next decision? The final chapter returns the focus to the person's own goals.

The author and the purpose

Mr Peyman Bakhshayesh

MD, PhD, MBA

Consultant Trauma and Orthopaedic Surgeon; Clinical Lead for General Trauma, Leeds Teaching Hospitals NHS Trust; Honorary Clinical Senior Lecturer, University of Leeds.

Mr Bakhshayesh graduated from Shiraz Medical School and undertook orthopaedic training in Sweden, followed by further specialist training in Sweden, Germany and the United Kingdom. His clinical interests include major trauma, pelvic and acetabular injury, complex limb reconstruction, and foot and ankle surgery.

His doctoral research at Karolinska Institutet examined clinical and radiological aspects of traumatic pelvic ring injury. It connects the early challenge of preserving life with the later challenges of accurate reconstruction, measurement of stability, avoidable reoperation and meaningful function.

The perspective of this book

A major trauma service is built through preparation, shared language and disciplined judgement. The care of a person with several serious injuries requires technical competence across specialties and an agreed understanding of the whole patient. A decision that is appropriate during initial shock may change after resuscitation; a reconstruction that restores anatomy must also serve the person's future.

The author's Formula One comparison expresses the value of rehearsal, clear roles and coordinated work. His structural descriptions of the thorax, spine and pelvis invite the reader to visualise how energy travels through the body. Throughout the book, those teaching images are brought together with clinical physiology and the individual experience of injury.

Understanding the injury. Understanding the person. Preparing the service.

Professional biography: peymanorthopaedics.world/about/

Author websites: peymanorthopaedics.world and seculardemocraticiran.world

Doctoral thesis: Bakhshayesh P. Clinical and radiological aspects of traumatic pelvic ring injury. Karolinska Institutet, Stockholm; 2020. ISBN 978-91-7831-867-4.

INTRODUCTION

A philosophy of coordinated trauma care

Major trauma is an encounter between a sudden transfer of energy and a human life. In a fraction of a second, tissues are deformed, vessels torn, organs compressed and the continuity of ordinary life interrupted. The injured person may arrive surrounded by noise, equipment and urgency, with little understanding of what has happened. Our task is to give that moment an organised response: to recognise the immediate threat, restore the conditions of survival and preserve the person's capacity to recover.

My philosophy of major trauma begins with understanding. We must understand the mechanism that produced the injury, the physiology that is now sustaining or failing the patient, and the person whose future will be affected by our decisions. We must also understand our service: its capabilities, its limitations, its people and the sequence through which it can deliver effective care. Technical skill becomes most useful when these forms of understanding are brought together.



Figure I.1. The Formula One principle: prepared roles, shared information and parallel work, applied with compassion to the injured person.

The person at the centre of the injury

A patient brings more to the resuscitation room than anatomy. They bring a family, an occupation, previous health, relationships, habits, responsibilities and hopes. An apparently small loss of function may be decisive for a musician, a manual worker, a parent caring for a child or an older person living independently. At the beginning we may know almost nothing about these circumstances. Nevertheless, we can practise in a way that keeps room for them.

I regard the first operation as part of a life that continues beyond the hospital. Preserving a viable muscle, choosing an incision that permits later coverage, documenting nerve function and reducing avoidable immobilisation are immediate surgical acts with long consequences. So are explaining a procedure, protecting privacy and helping a frightened person understand why several people are examining them at once. Physiological rescue and humane care belong to the same professional responsibility.

The word victim describes someone who has suffered harm. The word patient describes the relationship through which we offer care. The person remains larger than either description. As consciousness and physiological stability permit, we should ask what matters to them and include them in decisions. Where they cannot participate, relatives and existing records may help us understand baseline function and previously expressed wishes. These conversations evolve alongside treatment.

Clinical need and urgency guide the order of care. Dignity, confidentiality and compassionate treatment belong to every injured person, whatever their background or the circumstances of injury. This medically impartial approach gives the service a clear ethical foundation. It also supports trust at a moment when the patient may have very little control over what happens around them.

Read the mechanism through the body

The mechanism of injury offers the first account of how energy reached the tissues. Compression, distraction, bending, shear, rotation and penetration each suggest different patterns of damage. The same collision can produce several mechanisms simultaneously. A restrained occupant may sustain chest compression, abdominal loading against the belt, spinal flexion and an extremity fracture during deceleration. A fall may combine axial loading with rotation and a secondary impact to the head.

The equation for kinetic energy, one half of mass multiplied by the square of velocity, gives a useful starting point. Yet clinical interpretation also requires the distance and time over which deceleration occurred, the area over which force was applied, the position of the body and the mechanical properties of the tissues. Bone, blood vessel, bowel, lung and brain respond differently to the same event. An external mark may identify the point of contact while leaving the deeper distribution of injury uncertain.

This is why I ask the team to reconstruct the event without becoming attached to a single predicted diagnosis. What struck the person? What stopped moving first? What continued to move? Which structures were stretched between fixed points? Where could a penetrating track have travelled? These questions guide examination and imaging. The patient's response then refines the initial picture.

Mechanism is particularly valuable when communication is limited. An unconscious person cannot describe abdominal pain or altered sensation. A distracted patient may attend only to the most painful fracture. The history from ambulance clinicians, witnesses and the patient, when available, helps us search deliberately for injuries that might otherwise remain outside our attention.

Prepare the service before the patient arrives

The first treatment provided by a trauma service is readiness. Equipment, blood, imaging, theatre access, critical care capacity and appropriately trained people must be connected before a severely injured person needs them. Readiness is a clinical resource with a practical structure: an activation pathway, a known team, clear responsibilities and reliable access to senior decisions.

Regionalisation brings specialist capability into an organised network. In England, national major trauma networks began in April 2012 following the earlier London development. The national evaluation by Moran and colleagues associated system reorganisation with an improvement in adjusted survival over 2008-2017. The achievement belongs to the linked pathway: prehospital triage, trauma units, specialist centres, retrieval, rehabilitation and continuing care. [1,2]

Centralisation is most effective when it reduces the time between recognising a need and meeting it. The patient who requires haemorrhage control needs a team able to provide that control; the patient with an expanding intracranial lesion needs timely neurosurgical care. Transport arrangements, image transfer and direct consultant communication help the network operate as one service. Local hospitals remain essential to that service, particularly when immediate intervention is required before transfer.

The NICE service framework includes a designated consultant responsible for the hospital trauma service and a named clinical key worker to coordinate care through the pathway. [3] These roles provide continuity across specialties and locations. A complex patient should always have a recognisable overall plan, even when several teams contribute to individual parts of it.

The Formula One principle

I often use the Formula One pit stop to explain trauma preparation. A car entering the pit lane is met by a team that already knows its roles. Equipment is ready, essential information is shared and several tasks occur together under a coordinated plan. The comparison captures the value of rehearsal and disciplined action. In major trauma, these qualities serve a conscious or unconscious human being whose physiology is changing and whose future matters.

The analogy also provides a memorable introduction to the primary survey. Air must enter, exchange must occur, circulation must carry oxygen and the nervous system must maintain communication. The entire body requires examination, and the environment must protect the person during that examination. Catastrophic external bleeding demands immediate control alongside these priorities.

Primary priority	Formula One memory aid	Meaning for the injured person
Catastrophic external haemorrhage	Stop a critical leak	Rapidly identify and control life-threatening visible bleeding.

Primary priority	Formula One memory aid	Meaning for the injured person
Airway	Maintain the air intake	Establish a patent airway while protecting the cervical spine as indicated.
Breathing	Restore air exchange	Assess ventilation and oxygenation and address immediately reversible thoracic threats.
Circulation	Restore delivery through the system	Recognise shock, control haemorrhage and sustain organ perfusion.
Disability	Check central control and connections	Assess consciousness, pupils and neurological function.
Exposure and environment	Inspect, then protect	Examine the body while preserving warmth, dignity and safe handling.

ATLS provides the shared educational structure for this assessment; its eleventh edition explicitly incorporates catastrophic external haemorrhage in the xABCDE sequence. [4] A prepared team can perform connected tasks in parallel while maintaining clear priorities. A nurse may obtain access and warm the patient as the airway clinician assesses ventilation and the trauma leader gathers the mechanism and physiological trends.

The leader's task is to maintain the whole picture. A clear voice, short statements of priority and explicit confirmation of completed actions help turn several simultaneous activities into one coherent treatment. The most useful sentence may be a simple statement of what is now threatening life and where the patient needs to go next.

Physiology determines the next step

An injury is anatomical; its consequences are physiological. A femoral fracture, a ruptured spleen and a haemothorax differ in location, yet all may contribute to shock. Conversely, two patients with similar fracture images may have very different capacities to tolerate surgery. Age, comorbidity, chest injury, brain injury, temperature, coagulation and the response to resuscitation alter the meaning of the radiograph.

I therefore regard physiological assessment as a developing narrative. What was the patient's condition before treatment? What changed after blood, decompression, analgesia or haemorrhage control? Is improvement sustained? What support is required to maintain it? A trend gives meaning to an observation. The team should be able to describe that trend in words as well as numbers.

Imaging belongs within this reasoning. CT can rapidly show the distribution of injury and help organise definitive treatment in a patient who can tolerate it. Persistent instability from uncontrolled bleeding calls for the shortest route to effective haemorrhage control, using only the immediate imaging needed to direct that treatment. NICE links the choice of investigation and intervention to the patient's haemodynamic response. [5]

The same principle applies after a scan. A report is one part of the clinical picture. Examination, physiological change and subsequent specialist review continue to matter. The team must

reconcile new symptoms with the images already obtained and make an explicit plan for any region or injury that remains uncertain.

Surgery as part of resuscitation

Early surgery can restore physiology by stopping haemorrhage, controlling contamination and stabilising damaged structures. These purposes give shape to an operation that might otherwise expand in response to each additional abnormality encountered. Before incision, surgeon and anaesthetist should agree what the operation must accomplish and what the patient can presently tolerate.

Haemorrhage control restores the possibility of effective perfusion. Control of bowel contamination reduces continuing exposure to enteric contents. Temporary skeletal stabilisation can limit painful movement, protect soft tissues and support safe nursing. These interventions may form an abbreviated first operation followed by critical care recovery and later reconstruction.

Early total care, early appropriate care and damage control are different ways of arranging treatment around this objective. A well-resuscitated patient may benefit from early definitive reconstruction. A patient with persistent shock or severe physiological disturbance may benefit from a short stabilising operation. Between these situations, repeated assessment helps the team select and sequence procedures. Chapter 1 develops this decision in detail.

I think of surgical ambition as something that must remain proportionate to physiological reserve. Skill includes the ability to complete a complex reconstruction, and the judgement to stage it when that best serves the patient. It also includes recognising recovery promptly enough to prevent a temporary arrangement from becoming an avoidable barrier to rehabilitation.

Build a team that can think together

The trauma team is a working relationship between people with different expertise. It needs leadership, mutual respect and a common language for uncertainty. Everyone should understand the immediate objective and feel able to report a change that might alter it. A junior clinician who notices a newly unequal pupil or a nurse who identifies increasing drain output may supply the information that redirects the whole plan.

I favour brief, purposeful team pauses at transitions. Before movement to CT, the question is whether the patient can tolerate the journey and who will manage deterioration. Before surgery, the question is what must be achieved, in what order and within what physiological limits. Before leaving theatre, the question is what remains unresolved and who owns the next decision. These pauses organise work and reduce the burden of assumptions.

Team building continues outside the emergency itself. Simulation makes roles familiar and exposes practical weaknesses. Multidisciplinary review allows surgeons, anaesthetists, radiologists, nurses and therapists to understand one another's decisions. A healthy learning culture can examine delay, communication failure and unexpected outcomes with precision and fairness. The purpose is a more reliable service for the next patient.

The physical environment also affects performance. Access to warming, blood sampling, clear displays, functioning suction and correctly arranged equipment can determine how easily good practice is delivered. A fatigued, unsupported workforce will struggle to sustain readiness. Staff

welfare, predictable escalation and protected learning time belong within the architecture of clinical quality.

Establish a rhythm of shared review

In my approach to multidisciplinary trauma review, operative cases, imaging, perioperative decisions, complications and rehabilitation are discussed as connected parts of the patient's course. The meeting should improve today's plan and tomorrow's practice. A registrar or fellow learns most when the reasoning behind prioritisation and staging is made explicit and related to what subsequently happened.

A useful review ends with decisions that can be carried into care: an agreed theatre priority, a clarified restriction, a further examination, a specialist discussion or a change to follow-up. Each action requires an owner and a time for review. The next meeting can then establish whether the action occurred and whether it achieved its purpose.

Complication review creates a further opportunity to learn. We can examine the original injury, the information available at each decision, the treatment delivered and the subsequent functional outcome. Repeated patterns may identify a need for better supervision, equipment, imaging review or coordination. This cycle connects education, quality assurance and daily planning, giving the service a practical method of becoming more reliable.

Look again, and carry the story forward

The primary survey addresses immediate threats. The secondary survey assembles a detailed history and examination once resuscitation permits. The tertiary survey deliberately revisits the injury inventory, imaging, investigations and specialist plans, including examination again when sedation or pain no longer prevents participation. Each stage adds information to a picture that began under pressure.

Hands, wrists, feet and peripheral nerve injuries deserve particular attention in a patient dominated by a major truncal or long-bone injury. A missed injury can become a substantial obstacle when mobilisation begins. Equally, a symptom emerging during recovery may reflect an evolving injury, a complication or a previously concealed functional deficit. The service needs a route through which that concern receives timely reassessment.

Documentation should tell the clinical story. It should identify the injuries, the patient's response, the treatment delivered, unresolved questions and the next planned action. A list of diagnoses becomes useful when each entry has an owner and a plan. Clear records allow the next clinician to continue the same course of care and support later rehabilitation, audit and review.

Survival opens the responsibility for recovery

Major trauma care extends from rescue to participation in ordinary life. Pain, weakness, altered body image, anxiety, fatigue and financial uncertainty may continue long after physiological stabilisation. Early rehabilitation assessment helps connect acute treatment with physical, cognitive and psychological recovery. NICE NG211 places coordinated rehabilitation within the trauma pathway. [6]

In practical terms, this means asking early how the patient will sit, transfer, breathe effectively, communicate and begin to regain independence. Therapists need to understand surgical

restrictions, and surgeons need to understand the functional consequences of those restrictions. Families need a realistic account of what is known and what will become clearer with time.

The philosophy of this book is therefore one of coherent responsibility. Understand the energy and its effects. Recognise the person's vulnerability and strengths. Prepare the service and the team. Match treatment to physiology. Reassess when the situation changes. Preserve continuity until survival has become the possibility of a useful and meaningful life.

Questions for team reflection

1. A patient improves after initial transfusion and then deteriorates during preparation for CT. Which changes would make you redirect the patient towards immediate haemorrhage control, and who should communicate that decision?
2. Before the next trauma activation, can every member of your service describe their role, their escalation route and the destination of a patient requiring emergency surgery?
3. Which injuries are most likely to be overlooked in your pathway, and how will the secondary and tertiary surveys bring them back into view?
4. What information about the patient's ordinary life could change the way you plan reconstruction or rehabilitation?

References

1. NHS England. Independent review of Major Trauma Networks reveals increase in patient survival rates. 2013. <https://www.england.nhs.uk/2013/06/incr-pati-survi-rts/>
2. Moran CG, Lecky F, Bouamra O, et al. Changing the System - Major Trauma Patients and Their Outcomes in the NHS (England) 2008-17. *EClinicalMedicine*. 2018;2-3:13-21. <https://doi.org/10.1016/j.eclinm.2018.07.001>
3. National Institute for Health and Care Excellence. *Major trauma: service delivery*. NG40. <https://www.nice.org.uk/guidance/ng40/chapter/recommendations>
4. American College of Surgeons. *Advanced Trauma Life Support: ATLS 11*. <https://www.facs.org/quality-programs/trauma/education/advanced-trauma-life-support/atls-11/>
5. National Institute for Health and Care Excellence. *Major trauma: assessment and initial management*. NG39. <https://www.nice.org.uk/guidance/ng39/chapter/Recommendations>
6. National Institute for Health and Care Excellence. *Rehabilitation after traumatic injury*. NG211. <https://www.nice.org.uk/guidance/ng211>

CHAPTER 1

Early care in major trauma

The early care of a severely injured person is a sequence of decisions made while the patient is changing. Some decisions are immediate: establish oxygenation, control catastrophic bleeding, decompress a life-threatening pleural problem. Others require a developing understanding of the response to treatment. The team must decide when imaging will help, when surgery becomes part of resuscitation and when the patient has recovered enough reserve to benefit from definitive reconstruction.

My central principle is that the extent and timing of surgery should follow the patient's physiological capacity. The purpose of early care is to move the person from vulnerability towards recovery through actions that are both decisive and proportionate. Early total care, early appropriate care and damage control are complementary strategies within that purpose. A good trauma service can apply each strategy well and move between them as the patient's condition evolves.



Figure 1.1. A coordinated trauma team chooses a route towards definitive reconstruction or staged damage control by following the patient's changing physiological condition.

The development of an organised approach

Modern trauma surgery grew through advances in anaesthesia, transfusion, antimicrobial treatment, infection prevention, transport and operative technique. These developments allowed surgeons to undertake reconstructions that had previously been impractical. Their lasting value came from combining technical progress with reproducible methods, education and the evaluation of results.

The founding of the Arbeitsgemeinschaft für Osteosynthesefragen in Switzerland in 1958 was a major step in the systematic development of fracture fixation. [1] Stable fixation, respect for soft tissues and planned functional recovery became connected elements of orthopaedic practice. Within major trauma, those principles had to be integrated with the physiology of a person carrying injuries in several regions.

This integration explains the continuing development of treatment strategies. Early fixation can relieve the burden of an unstable skeleton. An extensive operation can also impose blood loss, heat loss, inflammatory stress and demands on already injured organs. The clinical task is to recognise which effect will dominate for the individual patient at a particular time.

The prepared centre makes this judgement possible. Rapid laboratory support, senior anaesthesia, radiology, surgical expertise and critical care allow the team to examine the response to treatment and adjust the plan. The value of technology lies partly in the quality of the conversation it enables: surgeon and anaesthetist can discuss the same trajectory using observations obtained close to the time of the decision.

Before arrival: translate the pre-alert into readiness

A useful pre-alert communicates the mechanism, suspected injuries, physiological observations, treatment already given and estimated arrival time. The receiving team uses that information to anticipate immediate needs while retaining flexibility. A patient reported as stable may deteriorate during transport; a patient with profound initial shock may arrive after effective temporary treatment.

Roles should be assigned before arrival wherever possible. The team needs a leader, an airway clinician, staff responsible for circulation and procedures, nursing coordination, documentation and communication with supporting services. More people are helpful when each additional person contributes a defined capability. The leader should maintain enough distance from individual tasks to integrate information and make decisions about sequence and destination.

A short briefing can identify likely difficulties: a contaminated airway, access to emergency blood, a possible pelvic source of bleeding, an anticipated emergency laparotomy or an operating position that will be difficult with associated injuries. Equipment checks then follow the likely problems. This preparation reduces the number of decisions that must be invented during the first minutes.

The ambulance handover should be heard as a clinical account of change. Initial observations and the response to treatment are often more informative than a single reading at the door. Record what happened before sedation, paralysis or transfusion altered the picture. After receiving the essential history, the team proceeds with its own assessment and compares that assessment with the account already given.

Describe anatomy and assess physiology

Injury scores help describe the anatomical burden of trauma. The Injury Severity Score uses the squares of the highest Abbreviated Injury Scale grades in the three most severely affected body regions. The New Injury Severity Score uses the three most severe injuries regardless of region. Their calculation usually becomes reliable after the injury inventory has been established through examination, imaging, surgery and record review. [2,3]

These scores support research, audit and comparisons between cohorts. At the bedside, immediate action follows the suspected threat and the patient's current condition. A single devastating injury may require the full capability of a major trauma service. Several moderate injuries may together create substantial physiological stress or a difficult rehabilitation problem.

The Glasgow Coma Scale describes observed eye, verbal and motor responses. Recording the components, the time and factors that limit testing preserves more useful information than a total alone. [4] In an intubated patient, the verbal component requires an explicit notation of its limitation. Sedation, intoxication, language, hearing and pre-existing neurological impairment should remain visible in the record.

Anatomical scores, neurological observations and physiological trends answer related questions from different perspectives. The injury inventory tells us what has been damaged. The primary survey tells us which consequences demand action now. Repeated assessment tells us whether the patient is moving towards stability.

The primary survey as active treatment

Catastrophic external bleeding is addressed immediately. Airway assessment considers patency, contamination, protective reflexes and anticipated deterioration. Breathing assessment establishes whether ventilation and oxygenation are effective and looks for reversible chest threats. Circulatory assessment considers haemorrhage, cardiac filling and perfusion. Neurological assessment records consciousness, pupils and limb findings. Exposure identifies additional injury while warmth and dignity are maintained.

The sequence supplies a shared order of priorities. Within that order, a rehearsed team can act simultaneously. The clinician examining the chest communicates an urgent pleural finding to the leader while another team member establishes vascular access and the nurse obtains blood. The action and its purpose should be spoken clearly enough that others can coordinate their work around it.

Each intervention creates a new question. After airway treatment, has oxygenation improved and is ventilation effective? After transfusion, is the improvement sustained? After splintage, is perfusion unchanged and pain reduced? After a chest intervention, have respiratory effort and circulation responded as expected? This repeated loop converts activity into assessed treatment.

Pain relief belongs within resuscitation. Pain increases distress, impairs cooperation and can restrict breathing and movement. Analgesia should be titrated to the injury, physiological state and need for repeated assessment. A patient who becomes quieter after medication still requires reassessment of consciousness, respiratory effort and perfusion.

Haemorrhage: restore delivery and control the source

Bleeding is a loss of circulating volume, oxygen-carrying capacity and haemostatic function. My phrase “blood for blood” expresses the need to recognise these connected losses. The major haemorrhage pathway mobilises blood products and the personnel required to deliver them safely while the team searches for, and controls, the source.

The European bleeding guideline supports rapid source control, early haemostatic resuscitation, prevention of hypothermia, monitoring and treatment of coagulopathy, and attention to ionised calcium. Tranexamic acid is recommended as soon as possible for significant bleeding or its risk and within three hours of injury. Serial lactate or base-deficit measurements help assess tissue hypoperfusion and response. [5]

At the bedside, this means several tasks must proceed together. The source of bleeding is being treated, blood is being delivered, the patient is being warmed and new observations are being compared with earlier ones. The leader needs to know the rate of transfusion as well as the measured pressure. A pressure maintained by escalating support tells a different story from the same pressure maintained after control of bleeding.

The physiological consequences of haemorrhage can reinforce one another. Reduced perfusion promotes acidosis; exposure, blood loss and treatment can contribute to hypothermia; haemostatic impairment permits further bleeding. The team interrupts these processes by dealing with their causes and by maintaining the conditions in which clotting and organ function can recover.

Associated brain or spinal cord injury changes the importance of perfusion targets. A resuscitation strategy must protect vulnerable neural tissue while securing haemostasis. This requires a shared plan between the clinicians managing bleeding and those responsible for neurological care. The patient has one circulation, and its management must serve the whole injury pattern.

Interpret the response as a trajectory

The terms responder, transient responder and non-responder describe useful patterns during early resuscitation. A sustained responder shows improvement that persists with a falling need for support. A transient responder improves and then deteriorates or continues to require substantial replacement. A non-responder shows little meaningful improvement. These descriptions should include the treatment and time interval that produced them.

The response directs attention. Recurrent shock raises concern for continuing haemorrhage, inadequate source control or another cause of circulatory failure. Respiratory deterioration may reveal tension physiology, airway difficulty or increasing lung injury. The team returns to the primary priorities while refining the explanation.

Domain	Evidence to integrate	What it contributes to the decision
Perfusion	Clinical appearance, pulse and pressure trends, peripheral circulation, urine output in context	Whether organ delivery appears to be improving and whether the improvement persists.
Metabolic response	Serial lactate, pH and base excess or deficit	The direction of recovery from physiological stress.

Domain	Evidence to integrate	What it contributes to the decision
Haemostasis	Observed bleeding, transfusion requirement, coagulation results and locally available viscoelastic testing	Whether haemorrhage and clotting impairment remain active.
Temperature	Repeated core temperature and warming requirements	Whether the patient is regaining a physiological environment favourable to recovery.
Respiration	Oxygen requirement, gas exchange, ventilatory support and chest findings	The reserve available for anaesthesia, positioning and further surgery.
Neurology	Examination, imaging and intracranial or spinal concerns	Whether neural injury imposes additional priorities or constraints.
Proposed operation	Expected duration, blood loss, position and likely benefit	The additional burden the patient would be asked to tolerate.

I use this table as a conversation framework. The team should be able to state what has improved, what remains vulnerable and what the next operation will add. Confidence comes from agreement between the observations and the clinical story.

Imaging and destination

The next location is a treatment decision. CT is valuable when the patient can safely undergo it and when the information will help direct care. A patient with persistent haemodynamic instability and a suspected bleeding source may require immediate operative or endovascular control. NICE recommends damage-control surgery for an unstable patient who fails to respond to resuscitation and permits definitive surgery to be considered as haemodynamics and the response improve. [6]

Movement introduces risk unless the team prepares for it. Monitoring, oxygen, ventilation, blood and appropriately skilled accompaniment must continue through transfers. Before leaving the resuscitation room, the team should state the destination, the reason for going there and the action to take if deterioration occurs.

Radiology is part of the clinical team. A clear clinical question helps prioritise urgent interpretation. Initial findings require prompt communication, and the formal report and subsequent amendments need an identified reviewer. This is particularly important when the first scan is followed quickly by surgery or transfer to another unit.

Early total care

Early total care is the strategy of undertaking early definitive fracture treatment in a patient able to tolerate it. Its attraction is practical and biological. Stable fixation can reduce painful movement, facilitate nursing and respiratory care, and establish a secure foundation for mobilisation. It can also reduce the need for a further operation to replace temporary fixation.

The classic randomised study by Bone and colleagues supported early femoral stabilisation, with fewer pulmonary complications and shorter hospital and intensive-care stays among multiply injured patients treated early. [7] This evidence helped establish the importance of timely skeletal treatment within trauma care.

For an individual patient, the benefit depends on the injury pattern and the proposed reconstruction. A definitive femoral procedure may make turning and nursing substantially easier. A lengthy pelvic or acetabular reconstruction may impose a different burden. The team should discuss each component of the intended operation and the recovery it is expected to enable.

Early definitive treatment also requires service readiness. An adequately resuscitated patient can lose the opportunity for timely treatment through unavailable expertise, implants, theatre access or postoperative support. A healthy service identifies these requirements early and resolves them while resuscitation and assessment continue.

Damage control surgery and orthopaedics

Damage control is active, staged treatment. The first intervention achieves the urgent objective with a burden suited to the patient's condition. Subsequent physiological recovery creates the opportunity for planned definitive care. In abdominal trauma, this may involve control of haemorrhage and contamination. In orthopaedics, it may involve realignment, temporary fixation and essential treatment of threatened tissues.

The rationale becomes clear when the total burden is considered. The patient has already sustained a major insult. Shock, tissue injury and associated organ damage may leave little reserve for a prolonged reconstruction. An abbreviated operation can protect life and limb while allowing resuscitation to continue in a controlled environment.

A multicentre randomised study by Pape and colleagues found greater acute lung injury after initial intramedullary nailing in a subgroup of multiply injured patients classified as borderline, compared with initial external fixation. [8] The finding helped refine the selection of patients for staged orthopaedic care.

The first stage must be technically purposeful. Provisional fixation should provide the stability required for care, respect soft tissues and preserve later approaches. Debridement should address the tissue that requires treatment. Vascular compromise and compartment syndrome retain their urgency within an abbreviated plan. Damage control succeeds when it achieves the necessary immediate objective and leaves a clear route to the next stage.

That route needs an owner. The postoperative record should describe the reason for staging, the residual problem, the expected conditions for further surgery and the team responsible for review. Temporary treatment is a commitment to continuing assessment. As the patient improves, the service should actively identify the point at which definitive care becomes beneficial.

Early appropriate care and safe definitive surgery

Early appropriate care makes early definitive fixation conditional on recovery after resuscitation. In Vallier and colleagues' prospective protocol, selected major fractures were considered for fixation within 36 hours when the patient was responding without vasopressor support and met at least one biochemical criterion: lactate below 4.0 mmol/L, pH at least 7.25, or base excess at least -5.5 mmol/L. The early group had fewer complications than patients treated after delay. [9]

These published criteria describe a particular clinical protocol. Their value is in making physiological readiness visible and encouraging timely treatment after improvement. In practice,

the team integrates the metabolic trend with chest and brain injury, temperature, haemostasis and the burden of the proposed procedure.

Base excess requires careful reading. A value of -8 mmol/L describes a greater metabolic deficit than -3 mmol/L. Laboratories may report base deficit using a different sign convention. Recording the actual measure and units avoids ambiguity during a discussion between teams.

Safe definitive surgery extends the same philosophy through repeated assessment and adjustment of the operative plan. [10] The question is revisited before surgery, during surgery and between procedures. A patient may receive definitive treatment for one injury and temporary treatment for another within the same episode. This can be a coherent response to differences in urgency, complexity and physiological burden.

Strategy	Immediate intention	Typical clinical setting	Essential continuing responsibility
Early total care	Deliver early definitive skeletal treatment	Sustained stability and adequate reserve for the intended procedure	Maintain surveillance and an agreed plan for recovery.
Early appropriate care	Proceed early once resuscitation supports definitive treatment	Improving physiology assessed against a structured pathway	Integrate biochemical recovery with the whole injury pattern.
Damage control	Control urgent threats and provide proportionate temporary treatment	Persistent instability, substantial physiological disturbance or excessive anticipated operative burden	Resuscitate, reassess and arrange definitive care as readiness develops.
Safe definitive surgery	Adapt the extent and sequence of reconstruction through repeated assessment	A changing patient whose tolerance requires continuing review	Agree and apply conditions for proceeding, staging or stopping.

The operative agreement

Before starting, I want surgeon and anaesthetist to share an explicit agreement. What is the immediate objective? Which procedure comes first? How much blood loss and time are anticipated? What will count as sufficient progress? Which changes will prompt a shorter operation or a return to critical care?

This agreement helps the whole theatre team. Nursing staff can prepare for the planned stages. Blood-bank communication can reflect likely need. A second surgical team can understand when its contribution will be required. The plan can include a review point after the first procedure, when the patient's actual response replaces the assumptions made before incision.

During surgery, new information may change the balance. Unexpected bleeding, worsening gas exchange or a rising support requirement can favour abbreviation. Rapid progress and sustained improvement may permit completion of the agreed definitive work. The judgement should be stated openly and recorded so that the next team understands the reasoning.

Orthopaedic priorities within early care

The orthopaedic examination identifies threats to perfusion, nerve function, skin and compartments as well as fractures. Neurovascular findings should be recorded before and after reduction, splintage or fixation. Limb position, swelling and the condition of the soft-tissue envelope require repeated review as resuscitation and oedema evolve.

Open fractures require prompt intravenous antibiotic prophylaxis, protection of the wound and coordinated orthoplastic planning. BOAST recommends antibiotics as soon as possible, ideally within one hour of injury, and systematic reassessment of vascular and neurological status. [11] Formal treatment should combine wound assessment, excision of nonviable tissue, stabilisation and a plan for coverage.

The first orthopaedic intervention should support the entire course of care. Pins and incisions need consideration of later reconstruction. A fixation construct must allow the anticipated nursing and rehabilitation. The decision about limb preservation should include the patient's overall condition, tissue viability, reconstructive options and eventual function.

Education that becomes shared capability

Training gives the team a common foundation and prepares individuals for the tasks they may need to perform under pressure. ATLS structures initial assessment and priorities. Definitive Surgical Trauma Care develops operative decision-making for severe injury, while Advanced Surgical Skills for Exposure in Trauma teaches access to anatomical structures requiring urgent control. [12,13]

The European Trauma Course uses scenarios to develop technical and non-technical performance in a team environment. [14] Its abbreviation, ETC, is also used for early total care; the full term makes the intended meaning clear. The educational contribution is complementary: the service needs a shared resuscitation language, sound operative judgement, reliable exposure skills and coordinated team behaviour.

Course learning becomes a clinical resource through supervised practice, simulation and review of real decisions. A team should rehearse unusual but time-critical events as well as familiar routines. At a debrief, the useful questions include whether information reached the right person, whether the plan remained clear and whether the equipment and environment supported the response.

I regard education as part of maintaining readiness. Consultants, registrars, fellows, nurses, ambulance clinicians and therapists each bring observations that improve the pathway. Their learning should return to the daily plan through clear supervision, shared review and practical changes that can be evaluated.

Three clinical teaching scenarios

Sustained recovery after resuscitation

A patient with femoral and pelvic fractures arrives after a high-energy collision. Bleeding is controlled and the metabolic trend improves. Temperature and coagulation recover, respiratory support is modest and circulation remains satisfactory with decreasing treatment requirements. The team agrees that early definitive femoral fixation will improve nursing and permit a more coherent recovery plan. Pelvic reconstruction is discussed separately according to complexity and anticipated operative burden.

The decision uses recovered reserve for a defined benefit. It includes reassessment during treatment and a clear postoperative plan. Early appropriate care is expressed through the relationship between the patient's progress and the proposed procedure.

A changing respiratory problem

A second patient has an improving lactate after resuscitation but requires progressively greater oxygen and ventilatory support for associated chest injury. Turning is difficult and the proposed definitive reconstruction would be lengthy. The team reassesses pleural pathology, analgesia and lung function, then chooses a shorter stabilising procedure while respiratory treatment continues.

The metabolic improvement is valuable information within a wider trajectory. The staged plan preserves the possibility of later reconstruction and gives the chest injury time and treatment appropriate to its course.

Persistent shock with a threatened limb

A third patient has uncontrolled truncal bleeding and a limb with arterial disruption. Haemorrhage control and restoration of limb perfusion require coordinated urgent treatment. The teams agree the sequence that will preserve life and minimise ischaemic injury, using temporary measures when they best serve that sequence. Critical care receives a detailed plan for reassessment and the next operation.

This scenario shows why physiological instability calls for purposeful intervention. The immediate operation is directed towards creating the conditions in which the patient can recover.

Continuity after the first operation

The handover should explain what has been achieved and what remains. It includes airway and respiratory support, bleeding and transfusion, temperature and metabolic trends, known injuries, limb findings, drains, temporary constructs and planned reassessment. Outstanding imaging or specialist decisions should have named ownership.

Recovery begins during this period. Nutrition, pain relief, respiratory care, safe positioning and rehabilitation assessment influence how the patient will emerge from critical illness. Communication with relatives and, when possible, the patient helps them understand the reason for staging and the milestones being sought.

My philosophy of early care is proportionate action sustained by an organised service. We act promptly when a threat requires treatment. We choose the operation that advances recovery

within the patient's present reserve. We reassess actively and proceed with definitive care as soon as the person and the team are ready.

Questions for clinical reflection

1. Which features of the patient's trajectory would lead your team to choose temporary fixation even after an improving blood gas?
2. How would you describe the intended benefit and physiological burden of each procedure in a combined operative plan?
3. Who reviews a patient after damage control, and how does your service ensure that readiness for definitive surgery is recognised promptly?
4. What information must travel with the patient from resuscitation to theatre and from theatre to critical care?

References

1. AO Foundation. *AO archive and history*. <https://www.aofoundation.org/who-we-are/about-ao/ao-archive-and-history>
2. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187-196. <https://pubmed.ncbi.nlm.nih.gov/4814394/>
3. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43:922-925. <https://doi.org/10.1097/00005373-199712000-00009>
4. Glasgow Coma Scale. *Recording the GCS*. <https://www.glasgowcomascale.org/recording-gcs/>
5. Rossaint R, Afshari A, Bouillon B, et al. The European guideline on management of major bleeding and coagulopathy following trauma: sixth edition. *Critical Care*. 2023;27:80. <https://doi.org/10.1186/s13054-023-04327-7>
6. National Institute for Health and Care Excellence. *Major trauma: assessment and initial management*. NG39. <https://www.nice.org.uk/guidance/ng39/chapter/Recommendations>
7. Bone LB, Johnson KD, Weigelt J, Scheinberg R. Early versus delayed stabilization of femoral fractures: a prospective randomized study. *J Bone Joint Surg Am*. 1989;71:336-340. <https://doi.org/10.2106/00004623-198971030-00004>
8. Pape HC, Rixen D, Morley J, et al. Impact of the method of initial stabilization for femoral shaft fractures in patients with multiple injuries at risk for complications (borderline patients). *Ann Surg*. 2007;246:491-499. <https://doi.org/10.1097/SLA.0b013e3181485750>
9. Vallier HA, Moore TA, Como JJ, et al. Complications are reduced with a protocol to standardize timing of fixation based on response to resuscitation. *J Orthop Surg Res*. 2015;10:155. <https://doi.org/10.1186/s13018-015-0298-1>
10. Pape HC, Pfeifer R. Safe definitive orthopaedic surgery (SDS): repeated assessment for tapered application of Early Definitive Care and Damage Control? *Injury*. 2015;46:1-3. <https://doi.org/10.1016/j.injury.2014.12.001>
11. British Orthopaedic Association. *BOAST: Open Fractures*. 2017. <https://www.boa.ac.uk/resource/boast-4-pdf.html>
12. International Association for Trauma Surgery and Intensive Care. *Definitive Surgical Trauma Care: introduction*. <https://iatsic.org/DSTC-Introduction/>
13. American College of Surgeons. *Advanced Surgical Skills for Exposure in Trauma*, second edition. <https://learning.facs.org/content/advanced-surgical-skills-exposure-trauma-asset-2nd-edition>
14. European Trauma Course Organisation. *European Trauma Course*. <https://www.europeantraumacourse.com/course>

CHAPTER 2

Head and neck injuries

The head and neck bring together the airway, the brain, major vessels, the cervical spinal cord and the organs through which we see, hear, speak and express ourselves. Injury in this region can threaten life within minutes and alter independence for years. The initial examination must therefore connect immediate physiology with the functions that make later recovery meaningful.

My approach is to keep head and neck injury within the whole patient. Oxygenation protects the injured brain. Haemorrhage control supports cerebral perfusion. Cervical protection accompanies airway treatment. Facial reconstruction later serves breathing, eating, vision, communication and identity. The trauma consultant's responsibility is to organise these connected needs into an effective sequence.



Figure 2.1. A trauma team protects airway, brain, cervical spine and vision while maintaining a coordinated view of the whole injured person.

Mechanism and the concentration of vulnerable structures

Direct impact deforms the face and skull. Acceleration and deceleration move the brain within its supporting structures. Rotation stretches neural and vascular tissues. Penetration creates a track through a compact region where vessels, nerves, airway and digestive structures lie close together. The visible wound is the beginning of the anatomical question.

The head is a relatively heavy structure carried by a mobile cervical column. Sudden movement can transmit force through the skull base, vertebrae, ligaments and vessels. A severe facial impact should therefore prompt attention to the brain, neck and cervical spine as well as the facial skeleton. The distribution of bruising, the direction of impact and the prehospital neurological history help guide this assessment.

The face also has an unusually rich blood supply. Soft-tissue injuries may produce considerable visible blood, and blood in the mouth can compromise the airway. Neck bleeding may expand within confined tissues and distort the airway before external loss becomes dramatic. These relationships explain why airway and circulation teams often need to act together.

The head and neck throughout the primary survey

Survey priority	Head and neck concern	Immediate question
Catastrophic haemorrhage	Major scalp, facial or neck bleeding	Can the source be controlled while airway preparation continues?
Airway	Blood, teeth, tissue swelling, displaced bone or loss of protection	Is the airway patent now, and how likely is deterioration?
Breathing	Aspiration, airway disruption, high cervical cord injury or associated chest trauma	Is effective ventilation reaching functioning lung?
Circulation	External bleeding, major vessel injury and cerebral perfusion	What is causing shock and how will brain perfusion be maintained?
Disability	Brain injury, cord injury, vascular injury or seizures	What are the neurological findings and how are they changing?
Exposure	Concealed wounds, eye injury, septal swelling and posterior scalp injury	Which important structures remain to be examined?

The table is a map for coordinated attention. The team returns to it when consciousness changes, swelling increases or bleeding recurs. A change in one region can create a problem elsewhere: aspiration may follow loss of airway protection, while hypotension from abdominal bleeding can worsen the consequences of an intracranial injury.

The threatened airway

An airway assessment begins with the patient's voice, breathing pattern and ability to handle secretions. Blood, vomit, loose teeth and fragments require prompt attention. Facial swelling and displaced structures can narrow the passage; loss of consciousness can remove the muscular support and protective responses that were maintaining it.

Bilateral anterior mandibular injury can displace the tongue-bearing segment backwards. A displaced midface may encroach on the upper airway. These mechanisms help explain why the airway can become progressively more difficult even while the patient is being examined. Early senior anaesthetic involvement allows a planned primary and rescue strategy. AO's

craniomaxillofacial guidance emphasises swelling, bleeding and associated laryngeal injury in this assessment. [1]

Suction, positioning consistent with spinal protection, oxygenation and preparation for a definitive airway need coordinated attention. Suspected skull-base or severe midface injury favours avoidance of blind nasal instrumentation. A distorted airway requires an approach selected by clinicians with the necessary expertise, with surgical airway capability available when indicated.

The airway plan should anticipate the next stage. A patient may need transfer, prolonged imaging, prone surgery or repeated operations. Swelling may increase after resuscitation. The decision to secure the airway therefore considers the present examination, the anticipated course and the ability to rescue deterioration in the environment through which the patient will move.

Le Fort patterns as an anatomical language

Le Fort classifications describe characteristic lines of midface separation. Actual injuries often contain combinations, asymmetry and comminution. Their value is to organise anatomical understanding and communication with maxillofacial colleagues. [2-4]

Pattern	Core anatomical concept	What deserves attention during early care
Le Fort I	Horizontal separation of the tooth-bearing maxilla and palate from the upper midface	Oral bleeding, mobility, occlusion and displaced fragments.
Le Fort II	Pyramidal midface separation involving the nasal bridge, medial orbit and infraorbital region	Airway, orbital injury and associated skull-base or vascular damage.
Le Fort III	Craniofacial disjunction, separating the midface from the cranial base	Complex airway difficulty and extensive orbital, intracranial and vascular associations.

Definitive facial assessment includes occlusion, facial symmetry, eye findings, sensation and tissue loss. The early priority is to establish safe breathing and control bleeding so that reconstruction can be planned in a patient able to tolerate it.

Laryngeal and tracheal injury

Voice change, stridor, haemoptysis, neck tenderness and surgical emphysema raise concern for laryngeal or tracheal damage. The airway may initially remain open while oedema or haematoma evolves. Penetrating wounds can injure the airway directly; blunt compression may disrupt cartilage and supporting tissues.

The challenge is both anatomical and physiological. An injured airway may be difficult to visualise, and instrumentation can further disturb damaged structures. Anaesthesia and ENT should agree the method of securing ventilation, the rescue route and the need for endoscopic or operative assessment. A controlled, communicated plan helps avoid multiple uncoordinated attempts.

Ventilation failure also requires assessment below the neck. Aspiration, pulmonary injury or a high cervical neurological lesion may coexist. Effective management follows the entire pathway from mouth and nose to gas exchange in the lungs.

Haemorrhage and cervical vascular injury

Scalp wounds, facial fractures and neck vessel injuries can contribute substantially to blood loss. Appropriate direct pressure and definitive haemostasis proceed with resuscitation. Deep neck wounds require controlled assessment because major vessels, nerves and aerodigestive structures are closely related.

An expanding haematoma, uncontrolled bleeding or haemodynamic instability demands immediate senior surgical attention. A stable patient may undergo CT angiography to define the injured structure and guide operative or endovascular treatment. The Western Trauma Association algorithm links the urgency of exploration to clinical signs and physiological stability. [5]

Access differs across the neck. Distal carotid injury near the skull base presents a different exposure problem from an injury at the thoracic inlet. The vertebral artery's relationship to the transverse foramina adds further complexity. Early involvement of vascular, maxillofacial, ENT, neurosurgical or cardiothoracic expertise should follow the injury's location and treatment requirements.

Blunt cerebrovascular injury may present through dissection, thrombosis, pseudoaneurysm or embolic stroke. The vessel can retain some flow while an intimal injury creates a developing hazard. Screening pathways bring mechanism, cervical and skull-base injury patterns, and unexplained neurological findings into the decision about CT angiography. EAST recommends screening protocols and antithrombotic therapy for confirmed injury when safely feasible; the treatment plan accounts for associated bleeding. [6]

This is a useful example of forward-looking trauma care. An immediate examination may be satisfactory while the mechanism and imaging identify a threat to later cerebral perfusion. The team acts on that risk through specialist assessment, treatment and follow-up.

Understand traumatic brain injury through mechanism

The brain can be damaged by direct deformation, acceleration, deceleration, rotation and penetration. Contusions reflect focal tissue injury. Haematomas occupy space and may expand. Axonal injury reflects stretching and disruption of neural connections and can be extensive when the initial CT shows relatively limited structural change.

The initial mechanical injury is followed by physiological and cellular responses. Hypoxia, impaired perfusion, oedema, seizures and metabolic disturbance can add to the original damage. Early care seeks to maintain oxygen delivery, identify treatable mass lesions and create the best conditions for neural recovery.

The cranial cavity is a constrained space. Brain tissue, blood and cerebrospinal fluid share that space. As an expanding lesion or swelling consumes compensatory capacity, pressure can rise and perfusion can fall. This relationship helps explain why a patient may deteriorate rapidly after an interval of relative stability and why serial examination is so important.

A change in consciousness should prompt immediate reassessment of oxygenation, ventilation, perfusion, glucose and neurological findings while intracranial causes are investigated. The patient may have several contributors at once. A known brain injury should increase attention to these reversible physiological influences.

Record the neurological story before it is obscured

The eye, verbal and motor components of GCS, pupil findings and limb responses should be documented with time and context. The pre-intubation examination can be particularly valuable. Once sedation and paralysis have been given, the team needs to know which findings were observed beforehand and which remain uncertain.

Lateralising signs, a new pupillary abnormality, post-traumatic seizures or a deteriorating level of consciousness require urgent escalation. An intubated patient's neurological assessment uses the information available from pupils, motor responses when assessable, imaging and monitoring. Repeated observations should be compared using consistent language.

CT is the principal early investigation for clinically important traumatic brain injury. NICE NG232 identifies adult high-risk findings requiring CT within one hour, including marked GCS impairment, focal deficit, post-traumatic seizure and signs of open, depressed or basal skull fracture. [7] Further assessment may include MRI when persistent neurological dysfunction requires clarification after the patient is stable enough for that investigation.

Intracranial haemorrhage and the purpose of surgery

Extradural, subdural and intraparenchymal bleeding differ in anatomical location and associated tissue injury. Each may produce compression, disturbed cerebrospinal fluid circulation and herniation. The neurosurgical decision brings imaging together with examination, change over time and the patient's overall condition.

The Brain Trauma Foundation surgical guidance includes evacuation of an extradural haematoma exceeding 30 cm³ and an acute subdural haematoma thicker than 10 mm or producing more than 5 mm of midline shift. Clinical deterioration, pupillary abnormalities and pressure-related findings can make smaller lesions urgent. [8]

Craniotomy permits evacuation of clot and control of bleeding, with replacement of the bone flap when appropriate. Decompressive craniectomy provides additional space for a swollen brain by leaving the flap off. The choice addresses a particular physiological and anatomical problem and carries implications for subsequent care, disability and later reconstruction.

The trauma team should facilitate the time-critical neurosurgical decision while controlling extracranial threats. Haemorrhage, chest injury and hypotension can influence both the urgency of intervention and its feasibility. A joint plan makes these competing demands explicit and helps arrange the safest sequence.

Protect the brain during the whole course of care

Protection of the injured brain continues during transfers, imaging, anaesthesia and operations in other regions. The 2024 ACS guidance gives initial adult goals including oxygen saturation at least 94%, PaCO₂ 35–45 mmHg in the absence of intracranial hypertension, and systolic pressure at least 110 mmHg, with individualisation to the clinical situation. [9]

These goals are translated into practical work: reliable ventilation, avoidance of desaturation during movement, adequate perfusion and a plan for managing pressure-related deterioration. Positioning should support venous drainage while remaining compatible with spinal and other injuries. Sedation and analgesia must serve both physiological control and the need for neurological assessment.

Raised intracranial pressure may require specialist-directed sedation, hyperosmolar treatment, cerebrospinal fluid drainage or surgery. Brief adjustment of ventilation may be used as a bridge in impending herniation. Prolonged prophylactic hyperventilation and corticosteroid treatment of traumatic cerebral oedema are excluded from evidence-based severe-TBI care. [10]

Seizures require prompt treatment. Anticonvulsant prophylaxis, haemostatic management, nutrition and thromboprophylaxis are selected through the relevant neurotrauma pathway. The shared principle is to prevent additional injury while supporting the body through the period of neurological vulnerability.

Cervical spine and cord

Cervical fractures, dislocations and ligament injuries can accompany head and facial trauma. Spinal motion restriction should be maintained when indicated while essential resuscitation proceeds. The absence of a reliable pain history in an unconscious or distracted patient makes systematic assessment particularly important.

CT defines much of the bony injury. When a neurological abnormality could arise from spinal cord injury, NICE recommends MRI after CT even if CT has not demonstrated the cause. [11] Early spinal advice connects the imaging with stability, cord compression and treatment priorities.

A high cervical cord lesion can impair breathing. Loss of sympathetic tone can contribute to circulatory disturbance, while haemorrhage may also be present. The assessment should account for all plausible causes and the response to treatment. Detailed spinal injury mechanisms and classifications are developed in Chapter 6.

Vision and the confined orbit

Vision deserves deliberate attention during the primary and subsequent surveys. The conscious patient can describe reduced acuity, diplopia or pain. The sedated patient depends on examination for evidence of globe or orbital injury.

Orbital compartment syndrome develops when pressure within the orbit compromises ocular and optic nerve perfusion. Proptosis, a tense orbit, impaired movement, visual deterioration and a relative afferent pupillary defect support the diagnosis. Clinically evident compartment syndrome requires urgent decompression by a trained clinician, usually lateral canthotomy with inferior

cantholysis, with ophthalmic involvement and reassessment. Treatment should proceed without waiting for imaging when the clinical diagnosis is clear. [12]

An open globe requires a different form of protection: a rigid shield without pressure, avoidance of manipulation and urgent ophthalmic care. An embedded foreign body remains in place pending specialist management. Examination and imaging are selected to preserve the injured structure. [13]

Orbital fractures may also entrap extraocular muscles. Restricted movement, diplopia and associated autonomic symptoms need early specialist attention. As with intracranial injury, the useful question is which function is threatened and what action will protect it in time.

Nose, ear, mouth and aerodigestive tract

The nasal septum should be examined after relevant facial trauma. A septal haematoma separates cartilage from its nourishing tissues and requires prompt ENT or maxillofacial treatment. Persistent epistaxis may threaten the airway or circulation and calls for coordinated haemostasis. [14]

Clear fluid from the nose or ear after injury raises concern for a cerebrospinal fluid leak. Hearing loss, vertigo or facial weakness may accompany temporal bone injury. These findings should be recorded early and communicated to the appropriate specialists so that they remain part of the treatment plan after the immediate crisis.

The mouth requires attention to dental injury, occlusion and missing teeth. A missing tooth may have been expelled, swallowed or aspirated. Identifying its likely location prevents a visible dental injury from concealing an airway problem.

Penetrating neck trauma can injure the pharynx or oesophagus. Dysphagia, painful swallowing, haematemesis, emphysema or a suspicious wound trajectory should lead to targeted investigation. CT angiography may need to be supplemented by endoscopic or contrast assessment. Early recognition allows the team to address the defect, contamination and nutritional requirements before deep infection becomes established. [5]

Coordinate reconstruction with recovery

Once immediate threats are controlled, the plan broadens. Facial form, occlusion, swallowing, speech, hearing and vision become connected goals. The timing of reconstruction depends on the tissues, the neurological course, associated injuries and the patient's capacity to tolerate further treatment.

An organised service gives each problem an owner while preserving an overall lead. Anaesthesia and critical care manage physiological support; neurosurgery and spinal surgery address neural and structural threats; maxillofacial, ENT, ophthalmic and vascular colleagues contribute according to the injury. Therapists and rehabilitation clinicians help interpret the functional consequences of the eventual plan.

Families may face uncertainty about consciousness and recovery. Clear, consistent communication is part of care. We can explain what has been treated, what is being observed and which developments will clarify prognosis. The aim is to offer an honest account while continuing to protect every reasonable opportunity for recovery.

A worked clinical reflection

A patient arrives after a severe facial impact with blood in the mouth, falling consciousness and increasing neck swelling. The airway clinician prepares a controlled airway strategy with specialist support while the circulation team addresses bleeding and establishes resuscitation. The leader records the pre-sedation neurological findings and ensures cervical protection accompanies treatment.

Once ventilation and circulation permit, imaging defines the intracranial, facial and cervical injury pattern. Neurosurgery reviews a traumatic mass lesion; vascular imaging identifies a cervical vessel concern. The team agrees the sequence of interventions, protects cerebral perfusion throughout and records the outstanding eye and hearing examinations for repeated assessment.

The strength of this approach lies in its coherence. Several specialists contribute, yet each action supports the same injured person and the same evolving plan.

Questions for clinical reflection

1. Which features in the initial examination would make you anticipate airway deterioration before imaging?
2. How does your team preserve and communicate the neurological examination obtained before sedation?
3. Which visual, dental, nasal or auditory findings could be missed during an urgent neurosurgical pathway?
4. How would ongoing extracranial bleeding alter your discussion of perfusion and the timing of cranial surgery?

References

1. AO Foundation. *AO Surgery Reference: Airway considerations*. <https://surgeryreference.aofoundation.org/cmft/trauma/midface/further-reading/airway-considerations>
2. AO Foundation. *Le Fort I fracture, simple: definition*. <https://surgeryreference.aofoundation.org/cmft/trauma/midface/le-fort-i-simple/definition>
3. AO Foundation. *Le Fort II fracture: definition*. <https://surgeryreference.aofoundation.org/cmft/trauma/midface/le-fort-ii/definition>
4. AO Foundation. *Le Fort III fracture: definition*. <https://surgeryreference.aofoundation.org/cmft/trauma/midface/le-fort-iii/definition>
5. Western Trauma Association. *Penetrating neck trauma: algorithm and explanatory notes*. <https://www.westerntrauma.org/western-trauma-association-algorithms/penetrating-neck-trauma/>
6. Kim DY, Biffl W, Bokhari F, et al. Evaluation and management of blunt cerebrovascular injury: an EAST practice management guideline. *J Trauma Acute Care Surg*. 2020;88:875-887. <https://www.east.org/education-resources/practice-management-guidelines/details/blunt-cerebrovascular-injury-evaluation-and-management-of>
7. National Institute for Health and Care Excellence. *Head injury: assessment and early management*. NG232. <https://www.nice.org.uk/guidance/NG232/chapter/recommendations>
8. Brain Trauma Foundation. *Guidelines for the Surgical Management of TBI*. <https://braintrauma.org/coma/guidelines/surgical>
9. American College of Surgeons. *Best Practices Guidelines: The Management of Traumatic Brain Injury*. 2024. <https://www.facs.org/media/vgfgjpfk/best-practices-guidelines-traumatic-brain-injury.pdf>
10. Brain Trauma Foundation. *Guidelines for the Management of Severe TBI*, fourth edition. <https://braintrauma.org/coma/guidelines/severe-tbi>
11. National Institute for Health and Care Excellence. *Spinal injury: assessment and initial management*. NG41. <https://www.nice.org.uk/guidance/ng41/chapter/Recommendations>

12. American Academy of Ophthalmology. *Orbital Compartment Syndrome*. EyeWiki.
https://eyewiki.aao.org/Orbital_Compartment_Syndrome
13. American Academy of Ophthalmology. *Pre-Ophthalmologist Management of Eye Trauma*. EyeWiki.
https://eyewiki.aao.org/Pre-Ophthalmologist_Management_of_Eye_Trauma
14. Defence Medical Command. *Nasal injuries*. Clinical Guidelines for Operations.
<https://cgo.mod.uk/clinical-guidelines-for-operations/treatment-guidelines/oral-and-maxillofacial-surgery/nasal-injuries/>

CHAPTER 3

Thoracic injuries

The thorax brings breathing and circulation into the same moving structure. Its walls protect the lungs, heart and great vessels while expanding with every breath. An injury may disrupt that movement, separate the lung from the chest wall, fill the pleural cavity with blood or interfere with cardiac filling. Several of these mechanisms can occur together. Understanding their relationship makes the urgency and purpose of treatment clearer.

My approach begins with function. Is air reaching the lungs? Can the lungs exchange gases? Can blood return to the heart and be circulated effectively? Can the person breathe deeply enough to clear secretions and sustain recovery? The answers connect emergency decompression and haemorrhage control with analgesia, reconstruction, physiotherapy and later independence.



Figure 3.1. Chest assessment as coordinated teamwork: breathing and circulation are evaluated together while the team prepares the next intervention.

A protective structure designed to move

The thorax is broadly conical, narrower above and wider below. The sternum forms its anterior support, the ribs and their cartilages its curved sides, and the thoracic vertebrae its posterior foundation. The diaphragm closes the lower aperture and separates the thoracic and abdominal cavities. The shoulder girdle lies around the upper chest and connects upper-limb movement with the trunk.

The ribs combine strength with flexibility. Their posterior articulations and anterior attachments permit the chest to change shape during respiration. Upper rib movement contributes to forward and upward displacement of the sternum; lateral expansion increases the transverse diameter. The familiar pump-handle and bucket-handle descriptions make this movement easier to visualise.

During spontaneous inspiration, the diaphragm contracts and descends while the chest expands. The resulting pressure change draws air into the lungs. Quiet expiration follows relaxation and elastic recoil; more forceful expiration recruits additional muscles. This changing relationship between pressure, volume and muscle action is the starting point for understanding chest injury.

Each lung lies within a pleural compartment. Between the lungs, the mediastinum contains the heart, pericardium, great vessels, central airways and oesophagus. A lower chest wound may cross the diaphragm into the abdomen. A thoracic injury therefore deserves examination of neighbouring regions and interpretation within the mechanism of the entire event.

From energy transfer to physiological failure

Blunt compression can deform the rib cage, fracture ribs and injure the lung underneath. Deceleration places stress on structures at transitions between mobility and fixation. Penetrating trauma follows a track through the chest wall and potentially through several internal structures. A compliant chest, particularly in a child, can transmit substantial energy while leaving fewer obvious skeletal signs.

Age and reserve influence the effect of the same injury. An older patient with reduced lung function may struggle after a relatively limited rib injury. A younger patient may initially compensate for a larger injury and then deteriorate as contusion, pain and fatigue develop. The mechanism provides suspicion; repeated physiological assessment shows its consequences.

I find it useful to consider five interacting problems: loss of an effective pleural environment, blood loss, impaired gas exchange, painful or unstable chest wall movement, and obstructed or damaged cardiac function. The patient may need treatment in several of these domains. A successful chest drain can restore pleural mechanics while substantial pulmonary contusion continues to impair oxygenation.

Examine the patient and the support being provided

Observe respiratory rate, depth, symmetry and effort. Listen to speech where possible and note whether the patient can complete a sentence. Inspect the chest, axillae and accessible posterior surfaces for wounds, bruising, swelling and deformity. Assess tenderness, crepitus and subcutaneous emphysema, compare breath sounds and examine circulation at the same time.

Record oxygen delivery as well as saturation. An unchanged saturation achieved with progressively greater support describes a changing patient. The same applies to ventilation pressures, respiratory effort and the ability to cough. These observations should remain visible when the patient moves between resuscitation, imaging, theatre and critical care.

Treatment is followed by reassessment. Has decompression improved ventilation and circulation? Has drainage reduced the pleural burden? Has analgesia enabled a useful breath? If the expected change has not occurred, the team re-examines the mechanism of failure and the effectiveness of the intervention.

Thoracic problem	Principal physiological effect	Direction of immediate treatment
Tension pneumothorax	Impaired ventilation with pressure-related obstruction to venous return	Urgent pleural decompression when clinically indicated.
Open pneumothorax	Disrupted chest wall and pleural mechanics	Wound management, pleural drainage and close reassessment.
Haemothorax	Blood loss and compression of the lung	Resuscitation, drainage where indicated and assessment for haemorrhage control.
Massive haemothorax	Major blood loss with substantial pleural occupation	Simultaneous haemostatic resuscitation and urgent definitive control.
Cardiac tamponade	Restricted cardiac filling within the pericardium	Rapid recognition and operative relief with control of the injury.
Pulmonary contusion	Impaired gas exchange in injured lung tissue	Oxygenation, analgesia, secretion clearance and appropriate respiratory support.
Unstable or painful chest wall	Ineffective inspiration and cough	Functional analgesia, respiratory support and selected reconstruction.

Imaging in a patient who may need treatment first

Portable chest radiography and eFAST can answer immediate questions during the primary survey. CT provides a more complete assessment of the pleural spaces, lung, chest wall and mediastinum when the patient's condition permits. NICE supports immediate chest radiography and/or eFAST in adults with severe respiratory compromise, and consideration of CT in adults with normal haemodynamics or a response to resuscitation. [1]

The investigation should serve the treatment decision. Clinical tension pneumothorax causing severe respiratory or circulatory compromise requires treatment before diagnostic completion. A patient who can safely undergo CT may benefit from a detailed anatomical map that helps coordinate thoracic, vascular and orthopaedic care.

Imaging and examination should be reconciled. A small radiographic abnormality may have major significance in a patient with little respiratory reserve. A substantial image finding may coexist with a relatively stable examination while the team develops a monitored treatment plan. The condition of the person gives the image its clinical meaning.

Pneumothorax: understand pressure and lung expansion

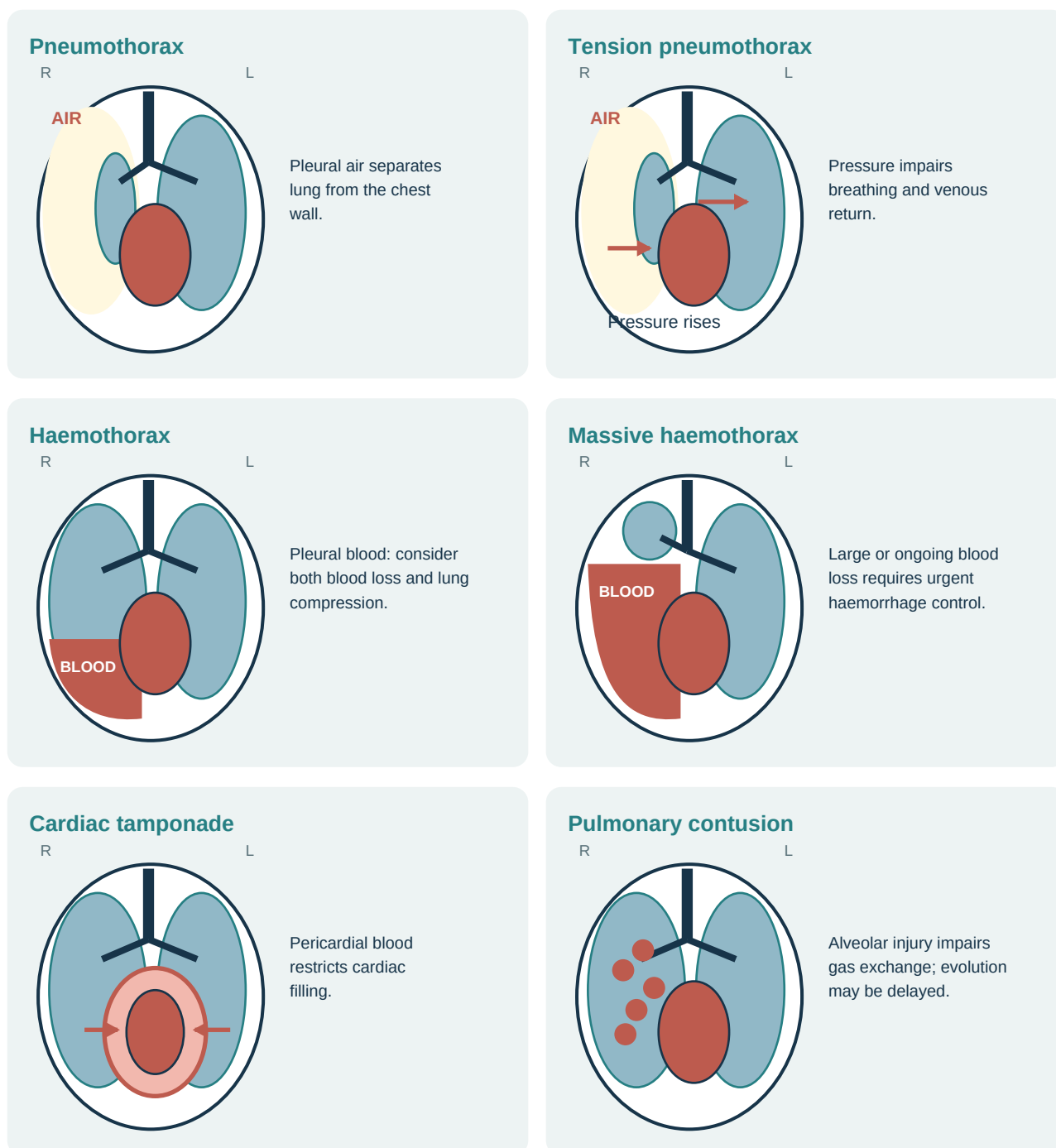


Figure 3.2. Chest injury mechanisms: schematic frontal views distinguish pleural air, pleural blood, pericardial blood and lung injury. R and L mark the patient's sides.

Air entering the pleural space interrupts the relationship through which chest expansion draws the lung outward. The degree of physiological disturbance depends on the size and behaviour of the air collection, associated lung injury, the patient's reserve and whether positive-pressure ventilation is being used.

An uncomplicated traumatic pneumothorax may be treated by drainage or, in selected stable patients, monitored observation with an explicit rescue plan. The decision includes the anticipated course: transfer, ventilation, additional surgery and the ability to reassess promptly. A developing need for greater support changes the balance.

Tension pneumothorax

Tension describes pressure-related physiological compromise. Air accumulates in a way that impairs lung expansion and venous return. Deterioration can be rapid, particularly during positive-pressure ventilation. Severe respiratory compromise or shock with compatible chest findings should trigger urgent clinical action.

NICE favours open thoracostomy over needle decompression when the appropriate expertise is available, followed by a chest drain in a spontaneously breathing patient. [1] The essential endpoint is effective relief of the pressure and reassessment of ventilation and circulation. The team then establishes continuing pleural management and identifies associated injuries.

The diagnosis remains dynamic. A patient can develop tension after initially satisfactory observations, during ventilation or after a drain ceases to function. New deterioration therefore prompts a fresh examination of the pleural spaces and the equipment already in place.

Open pneumothorax

An open chest wound allows air to move through the chest wall defect and alters the mechanics of ventilation. Management combines appropriate wound coverage, surveillance for tension physiology and definitive pleural drainage at a suitable separate site. A cover can change the behaviour of the air leak, so reassessment is essential.

The underlying injury may include lung damage, bleeding or a track through the diaphragm or mediastinum. Once the immediate breathing problem is addressed, the team establishes the full anatomical pattern and plans wound treatment accordingly.

Haemothorax and massive haemothorax

Blood in the pleural cavity creates two connected problems: loss from the circulation and occupation of space needed for ventilation. Bleeding can arise from chest wall vessels, lung, great vessels or the heart, depending on the injury. The patient's perfusion, respiratory state and response to treatment determine the urgency.

A massive haemothorax is a major haemorrhagic event. Drainage and blood resuscitation proceed alongside urgent surgical assessment. The team must also consider bleeding elsewhere, because a multiply injured patient may have several sources contributing to shock.

WSES-AAST identifies haemodynamic instability from thoracic bleeding, chest-tube loss exceeding 1,500 mL in 24 hours, or more than 200 mL/hour for three consecutive hours as indications for operative assessment; deterioration or continuing transfusion need can require earlier intervention. [2]

Drain output is a measurement of what reaches the collection system. Clotted blood, obstruction, malposition or a separate bleeding cavity can make that measurement incomplete. The team should connect it with examination, imaging, transfusion and the patient's trajectory. Persistent shock deserves an active explanation even when recorded output is modest.

Definitive control may require open surgery, thoracoscopy or selected endovascular treatment according to physiology and anatomy. In an exhausted patient, the first operation may be abbreviated to arrest bleeding and permit recovery. Later treatment can address retained blood, tissue repair and reconstruction within a more favourable physiological state.

A chest drain creates an ongoing clinical responsibility

Successful insertion begins a period of observation and decision-making. The record should include indication, side, initial drainage, air leak, blood loss and the response of the patient. The drain and connections must remain secure, the system must function as intended and the responsible team must specify the escalation plan.

Unexpected persistence of pleural air or blood calls for reassessment of both the patient and the drain. Review its position and function, the possibility of clot or kinking, and the likelihood of a continuing air leak or bleeding source. Imaging helps define the problem when the condition allows.

For selected stable patients, EAST conditionally supports pigtail drainage of traumatic haemothorax. For retained haemothorax, its guideline conditionally favours early video-assisted thoracoscopic surgery, within four days when indicated, over delayed intervention or thrombolytic treatment. [3] The choice should fit the patient's condition and the specialist service available.

Drain handover should be specific enough for action. Staff need to know the expected pattern, what constitutes an urgent change and whom to contact. The patient's respiratory recovery, temperature and symptoms then help establish whether the pleural problem is resolving as intended.

Cardiac tamponade: a filling problem requiring source control

Blood accumulating within the pericardium can restrict cardiac filling. The physiological effect depends on the speed of accumulation and the ability of the pericardium to accommodate it. A relatively small, rapidly accumulating collection may produce profound circulatory compromise.

Mechanism, shock and bedside ultrasound guide rapid recognition. The classic collection of clinical signs may be difficult to appreciate in a noisy resuscitation room or in a patient who is also bleeding elsewhere. The leader should integrate the available findings and obtain immediate surgical support when tamponade is suspected.

Definitive treatment generally requires operative relief and control of the cardiac wound. Needle aspiration may provide temporary benefit in selected circumstances, but ongoing bleeding and clot limit its role. The practical priority is to bring the patient to a team and environment capable of definitive treatment. [2]

A penetrating cardiac injury can also bleed into the pleural cavity when the pericardium is disrupted. Mechanism and continuing haemorrhage should therefore remain part of the assessment even when the pericardial ultrasound finding is less striking than expected.

Blunt cardiac injury and aortic injury

Blunt cardiac injury ranges from transient electrical disturbance to structural damage. Suspected injury should prompt ECG and troponin assessment. EAST recommends monitored care for new ECG abnormalities or elevated troponin I, and echocardiography for haemodynamic instability or a persistent new arrhythmia. [4]

The results are interpreted with the mechanism, symptoms and other causes of shock. Repeat testing follows the local assay and pathway. A sternal fracture is an anatomical marker that invites assessment of associated injury; the subsequent monitoring plan follows the cardiac findings and clinical course.

High-energy deceleration can injure the thoracic aorta. CT angiography defines the lesion in a patient who can safely undergo imaging. Early vascular involvement allows morphology, rupture risk and competing injuries to be considered together. Blood-pressure treatment must also protect the brain and other vulnerable organs.

The 2026 Society for Vascular Surgery update recommends definitive nonoperative management for SVS Grade I and II blunt thoracic aortic injuries. Higher-grade injuries may require thoracic endovascular aortic repair, with urgency determined by the lesion and physiology. [5] A named grading system and specialist follow-up plan make the decision understandable across the service.

Pulmonary contusion: injury within the gas-exchanging tissue

Pulmonary contusion produces haemorrhage and oedema in the lung. Air may enter the chest effectively while injured regions exchange oxygen poorly. The respiratory picture can evolve after arrival, making serial assessment important even when the initial examination appears relatively reassuring.

Treatment is supportive and directed towards useful gas exchange: oxygen, effective analgesia, secretion clearance and appropriate respiratory assistance. Selected cooperative patients may benefit from non-invasive support in an environment capable of recognising failure promptly. Invasive ventilation is used when required by oxygenation, ventilation, airway protection or the wider injury pattern. EAST emphasises analgesia and respiratory care in contusion and flail injury. [6]

After urgent circulatory needs are addressed, fluid treatment should maintain perfusion while avoiding unnecessary loading of an injured lung. Mechanical ventilation should protect against additional lung injury. Corticosteroids have no role as treatment for the contusion itself. [6]

Increasing respiratory support should trigger renewed assessment of the airway, pleural spaces, secretions, pain and associated injuries. A familiar diagnosis can explain part of the course while another treatable problem develops alongside it. The team's task is to maintain a complete explanation for the patient's change.

Rib fractures, flail segments and functional breathing

The significance of a rib fracture lies in pain, stability, associated internal injury and the patient's respiratory reserve. The number and displacement of fractures help describe severity, but bedside function shows the consequence. Can the patient take a deep breath, cough, clear secretions and move with adequate comfort?

A radiological flail segment consists of at least three consecutive ribs fractured in at least two places. Clinical flail chest describes paradoxical movement during respiration. Chest wall instability, pain and pulmonary contusion can contribute in different proportions to the resulting respiratory impairment. [7]

I view analgesia as part of respiratory treatment. Its success is demonstrated when the patient can breathe, cough and participate in care. Assessment at rest should be accompanied by assessment during a useful activity. The prescription is then adjusted to function, alertness, renal status, bleeding risk and the rest of the injury pattern.

A multimodal approach can reduce reliance on any single agent. Early acute-pain or anaesthetic review allows regional techniques to be considered when systemic treatment provides insufficient function. Epidural, paravertebral and fascial-plane approaches have different practical advantages and constraints. EAST conditionally supports multimodal and epidural analgesia, with technique selection guided by the individual patient. [8]

Older patients deserve early attention to baseline lung disease, frailty, cognitive state and the support needed to cooperate with respiratory exercises. The service should identify who is at risk of fatigue and deterioration and provide a level of observation suited to that risk.

Surgical stabilisation of rib fractures

Rib fixation can restore chest wall mechanics in selected patients. The decision should identify the functional problem that reconstruction is intended to solve: flail instability, severe displacement, deformity, persistent pain with respiratory impairment or difficulty progressing from ventilatory support.

The WSES/CWIS position paper supports consideration of fixation for flail chest and selected non-flail patterns, with early surgery generally within 48-72 hours when feasible. Physiological stability, associated injuries and the likely benefit of restoring mechanics inform selection. [7]

The operation should fit the whole trauma plan. Chest wall reconstruction may be coordinated with evacuation of retained haemothorax or another indicated thoracic procedure. Conversely, severe ongoing shock or an overriding intracranial priority may determine a different sequence. The discussion should explain the expected improvement and the limitations imposed by lung or neurological injury.

Plan the exposure around the fracture and the person

CT mapping identifies fracture distribution and helps plan positioning and exposure. Posterior injuries under the scapula differ from lateral or anterior patterns. Muscle-sparing approaches and careful protection of the long thoracic nerve, serratus anterior and intercostal structures help preserve function. Taylor and colleagues describe approaches adapted to these anatomical relationships. [9]

Marasco and Saxena emphasise planning from CT, selecting position according to fracture location and respecting periosteal and soft-tissue attachments. [10] These principles connect rib surgery with the broader orthopaedic responsibility to restore mechanics while preserving biology.

The patient should understand that recovery may still require respiratory rehabilitation and pain treatment after fixation. The operation provides a mechanical contribution to a course of recovery involving lung healing, strength, confidence and the resolution of other injuries.

Airway, diaphragmatic and oesophageal injuries

Persistent major air leakage, failure of lung expansion despite a functioning drain, or unexplained difficulty with ventilation should prompt consideration of tracheobronchial injury. Bronchoscopy provides direct assessment when indicated. Airway, anaesthetic and thoracic teams should coordinate management so that ventilation and definitive repair serve the same plan.

Diaphragmatic injury links chest and abdomen. Blunt rupture may allow abdominal organs to herniate into the thorax; penetrating injury can create a smaller defect that becomes significant later. The wound location, trajectory and associated injuries determine the level of suspicion. EAST conditionally favours laparoscopy over CT alone to exclude injury in stable patients with left thoracoabdominal stab wounds and no peritonitis. [11]

Oesophageal injury can produce mediastinal or pleural contamination. Suspicious penetration, unexplained mediastinal findings, pleural contamination or evolving sepsis require timely investigation. WSES supports contrast-enhanced CT and CT oesophagography in stable suspected traumatic injury, with endoscopy as an adjunct when needed. [12]

Treatment connects control of the defect with drainage, decontamination and nutrition. The philosophical lesson is that an injury can become more dangerous through its continuing biological consequences even after the initial mechanical event has ended. Early recognition limits that additional burden.

Traumatic cardiac arrest and resuscitative thoracotomy

Traumatic arrest calls for immediate treatment of reversible causes, including haemorrhage, hypoxia, tension pneumothorax and tamponade. The 2025 Resuscitation Council UK pathway prioritises correction of these causes, with interventions such as chest decompression and blood-product resuscitation delivered by appropriately trained teams. [13]

Resuscitative thoracotomy is considered in selected circumstances where a reversible intrathoracic cause can be treated in time. EAST gives its strongest recommendation to patients arriving pulseless after penetrating thoracic injury who retain signs of life; selection after blunt injury is more restrictive. [14]

The decision involves mechanism, observed signs of life, elapsed time, likely pathology and immediate team capability. A prepared service rehearses both the technical response and the communication required around it. The team also needs a clear process for family communication, documentation and support after the event.

Integrate chest injury with surgery elsewhere

Chest injury influences tolerance of prolonged anaesthesia, operative positioning and blood loss. Before major limb, pelvic or spinal reconstruction, the team should review oxygen requirement, ventilatory support, pleural drainage, chest wall function and the direction of physiological change.

The same CT appearances can accompany different operative decisions at different times. One patient may be improving after effective analgesia and pleural treatment; another may be

developing respiratory fatigue and increasing support requirements. Early appropriate care depends on recognising that difference.

The operative discussion should state what skeletal stabilisation will enable and what burden it will impose. A short procedure may improve nursing and respiratory care during a vulnerable period. Definitive treatment may become appropriate once the patient's progress and the anticipated burden support it. Chest and orthopaedic teams should share this reasoning with anaesthesia and critical care.

Recovery, discharge and continuing responsibility

Respiratory recovery requires repeated attention to pain during movement, cough, sleep, confidence and activity. Physiotherapy, supported mobilisation and a clear analgesic plan connect healing with daily function. Associated shoulder girdle or spinal injury may affect that progress and should be included in the rehabilitation plan.

Before discharge, the patient should understand medication use, expected follow-up and the need to seek reassessment for worsening breathlessness, fever, haemoptysis or increasing chest pain. Continuing limitation deserves a clinical explanation, including assessment for unresolved pleural disease, infection, persistent instability or another injury.

A technically successful emergency intervention has served its purpose when it creates the opportunity for this longer recovery. Restoring air entry, circulation and chest wall stability helps the person regain useful breathing, movement and participation in ordinary life.

A worked clinical reflection

A patient with displaced rib fractures, a pulmonary contusion and a femoral fracture remains unable to cough effectively after initial resuscitation. Circulation has improved, but oxygen requirements are increasing. The team reassesses pleural pathology and drain function, improves analgesia and provides respiratory support. The response to these measures becomes part of the operative decision.

If physiology improves and the anticipated procedure is proportionate, definitive femoral fixation may advance nursing and mobilisation. If respiratory support continues to rise, temporary stabilisation may better fit the patient's reserve. Chest wall fixation is considered for a defined mechanical problem within the same coordinated plan.

The treatment strategy develops from an understanding of failure and recovery. Each intervention is chosen because it addresses a problem that matters to this person at this time.

Questions for clinical reflection

1. How would you distinguish a problem of pleural pressure, blood loss, gas exchange and chest wall pain in a deteriorating patient?
2. What would make modest chest-drain output an incomplete account of the patient's haemorrhage?
3. Which functional observations would show that the analgesic plan is helping respiratory recovery?

4. How would increasing respiratory support alter the sequence of definitive fracture surgery?
5. Which findings would prompt deliberate investigation of the diaphragm, major airway or oesophagus?

References

1. National Institute for Health and Care Excellence. *Major trauma: assessment and initial management*. NG39. <https://www.nice.org.uk/guidance/ng39/chapter/Recommendations>
2. Coccolini F, Cremonini C, Moore EE, et al. Thoracic trauma WSES-AAST guidelines. *World J Emerg Surg*. 2025;20:78. <https://doi.org/10.1186/s13017-025-00651-1>
3. Patel NJ, Dultz L, Ladhani HA, et al. Management of simple and retained hemothorax: an EAST practice management guideline. *Am J Surg*. 2021;221:873-884. <https://pubmed.ncbi.nlm.nih.gov/33487403/>
4. Clancy K, Velopulos C, Bilaniuk JW, et al. Screening for blunt cardiac injury: an EAST practice management guideline. *J Trauma Acute Care Surg*. 2012;73:S301-S306. <https://www.east.org/education-resources/practice-management-guidelines/details/blunt-cardiac-injury%2C-screening-for>
5. DuBose JJ, et al. The Society for Vascular Surgery clinical practice guideline on the management of blunt thoracic aortic injury: focused update. *J Vasc Surg*. 2026;83:1281-1290.e8. <https://doi.org/10.1016/j.jvs.2026.02.013>
6. Simon B, Ebert J, Bokhari F, et al. Management of pulmonary contusion and flail chest: an EAST practice management guideline. *J Trauma Acute Care Surg*. 2012;73:S351-S361. <https://www.east.org/education-resources/practice-management-guidelines/details/pulmonary-contusion-and-flail-chest%2C-management-of>
7. Sermonesi G, Bertelli R, Pieracci FM, et al. Surgical stabilization of rib fractures: the WSES and CWIS position paper. *World J Emerg Surg*. 2024;19:33. <https://doi.org/10.1186/s13017-024-00559-2>
8. Galvagno SM Jr, Smith CE, Varon AJ, et al. Pain management for blunt thoracic trauma: EAST and Trauma Anesthesiology Society guideline. *J Trauma Acute Care Surg*. 2016;81:936-951. <https://www.east.org/education-resources/practice-management-guidelines/details/thoracic-trauma-blunt-pain-management-of>
9. Taylor BC, French BG, Fowler TT. Surgical approaches for rib fracture fixation. *J Orthop Trauma*. 2013;27:e168-e173. <https://pubmed.ncbi.nlm.nih.gov/23287754/>
10. Marasco S, Saxena P. Surgical rib fixation - technical aspects. *Injury*. 2015;46:929-932. <https://doi.org/10.1016/j.injury.2014.12.021>
11. Eastern Association for the Surgery of Trauma. *Diaphragmatic injury: evaluation and management*. 2018. <https://www.east.org/education-resources/practice-management-guidelines/details/diaphragmatic-injury-evaluation-and-management-of>
12. Chirica M, Kelly MD, Siboni S, et al. Esophageal emergencies: WSES guidelines. *World J Emerg Surg*. 2019;14:26. <https://doi.org/10.1186/s13017-019-0245-2>
13. Resuscitation Council UK. *Special circumstances guidelines*. Resuscitation Guidelines 2025. <https://www.resus.org.uk/professional-library/2025-resuscitation-guidelines/special-circumstances-guidelines>
14. Seamon MJ, Haut ER, Van Arendonk K, et al. An evidence-based approach to patient selection for emergency department thoracotomy: EAST practice management guideline. 2015. <https://www.east.org/education-resources/practice-management-guidelines/details/emergency-department-thoracotomy>

CHAPTER 4

Abdominal trauma

The abdomen teaches the trauma team to reason beyond what is immediately visible. Its compliant wall may return almost to its original shape after impact while an organ beneath it continues to bleed. An injured mesentery may initially support bowel that looks viable, yet its circulation can deteriorate over the following hours. A patient with several obvious fractures may therefore have a relatively quiet abdomen containing the most urgent threat to life. Understanding this possibility should produce attentive, organised care rather than indiscriminate investigation.

My approach is to connect three accounts of the same event: the mechanical account of how the injury occurred, the anatomical account of what has been damaged, and the physiological account of how the person is responding. Each account is incomplete on its own. Together they help us choose a useful investigation, recognise when intervention cannot wait, and determine how much treatment the patient can tolerate. The operation becomes part of resuscitation, and resuscitation prepares the conditions in which the operation can succeed.

This chapter follows adult abdominal trauma from the initial assessment to recovery. Its central question is practical: what must be controlled now, what can safely be preserved, and what requires planned reassessment? The same philosophy links definitive abdominal repair with early appropriate fracture care and, when physiological reserve is threatened, with damage-control treatment across specialties.



Figure 4.1. Seeing the concealed injury: the trauma team combines the mechanism, the patient's physiological trajectory and the anatomical map before choosing the next intervention. Conceptual illustration.

The abdomen as a connected anatomical space

The abdomen extends from the diaphragm to the pelvis. Anteriorly and laterally, its muscular wall supplies protection, movement and pressure control; posteriorly, the spine and surrounding muscles provide a firm boundary against which organs may be compressed. The external oblique, internal oblique, transversus abdominis and rectus muscles participate in this flexible enclosure. Flexibility is essential for breathing and ordinary activity, but it also permits considerable deformation during a collision or crush injury.

The peritoneum creates a useful anatomical map. Its parietal layer lines the abdominal cavity, while its visceral layer covers much of the surface of the intraperitoneal organs. Mesenteries support mobile viscera and convey their blood vessels, nerves and lymphatics. Relatively mobile structures can move differently from the fixed structures beside them during rapid deceleration. The point at which mobility meets fixation is therefore important when reconstructing a mechanism of injury.

The digestive tract passes from the abdominal oesophagus through the stomach, duodenum, small bowel and colon to the rectum. The duodenojejunal junction is supported near the ligament of Treitz; the terminal ileum enters the caecum at the ileocaecal junction. The liver and biliary system, pancreas and spleen have different functions and different vulnerabilities. Their position, vascular supply and attachments explain why an apparently similar external impact can produce very different clinical problems.

Anatomical region	Important structures	Consequence for trauma assessment
Intraperitoneal space	Stomach, spleen, most of the liver surface, jejunum, ileum, transverse and sigmoid colon	Blood and contamination may spread within a shared space.
Retroperitoneum	Kidneys, ureters, great vessels, most duodenum and pancreas, ascending and descending colon	Significant haemorrhage or leakage may remain concealed from early examination and FAST.
Pelvic extraperitoneal space	Bladder, pelvic vessels and structures around the lower rectum	Abdominal, pelvic-ring and urinary injuries frequently require a combined plan.
Thoracoabdominal boundary	Diaphragm, lower chest and adjacent upper abdominal organs	A single trajectory can involve both cavities and impair both breathing and circulation.

This map also explains the consequences of leakage. Blood threatens circulating volume; enteric contents introduce contamination; bile, urine and pancreatic secretions produce their own patterns of tissue injury and inflammation. Several processes can coexist. An adequate exploration or radiological review therefore follows anatomical continuity rather than stopping after the first recognisable lesion.

Reconstructing the transfer of force

Blunt abdominal injury commonly combines compression, shear and deceleration. A solid organ can be compressed against the spine or lower ribs. A vascular pedicle can be stretched as its organ continues moving after the torso has stopped. Bowel and mesentery can be crushed between an external restraint and the vertebral column. Sudden changes in pressure can disrupt hollow viscera or the diaphragm. The energy pathway matters because it directs attention to structures that may initially look normal.

A transverse seat-belt mark, for example, gives a visible clue to loading through the abdominal wall. Its significance increases when there is abdominal pain, a flexion-distraction spinal injury or suspicious bowel and mesenteric findings. A direct upper abdominal blow raises a different set of questions, including possible duodenal or pancreatic compression. Flank impact directs attention towards the kidney and retroperitoneum. These are working hypotheses to be tested by examination, physiology and imaging.

Penetrating injury requires an equally three-dimensional interpretation. The skin wound describes the point of entry more reliably than the internal trajectory. Lower chest, back, flank, buttock and perineal wounds can reach abdominal structures. Tissue movement and changes in body position complicate reconstruction of the track. A retained object may be contributing to temporary haemostasis; its removal belongs within a controlled surgical plan. Ballistic wounds require assessment of energy transfer and the tissues traversed as well as the visible entry and exit sites.

Mechanism also connects the abdomen with the rest of the patient. An occupant compressed against a restraint may have chest injury, spinal injury and lower-limb fractures. A person crushed at work may have prolonged entrapment, muscle injury and hypothermia. This broader account helps the team prepare a sequence of care that addresses interacting injuries rather than treating each compartment as an isolated consultation.

Reading physiology while looking for the source

Abdominal assessment begins within the primary survey. Under breathing, consider whether pain, distension, diaphragmatic disruption or associated chest injury is limiting ventilation. Under circulation, investigate concealed blood loss while recognising that several sites may be bleeding. Under disability, establish whether consciousness, intoxication, sedation or neurological injury makes abdominal examination unreliable. Exposure permits inspection of the abdomen, flanks, back and perineum while maintaining warmth and dignity.

The patient's trajectory is more informative than an isolated observation. Blood pressure, pulse, skin perfusion, mental state, urine output, lactate or base deficit, temperature and the amount of support required should be interpreted together. A patient whose pressure remains acceptable only during continuing transfusion has a different physiological state from one who maintains perfusion after resuscitation has been reduced. The team needs language that makes this distinction explicit.

Resuscitation supports haemostasis and oxygen delivery while the source is being controlled. Major-haemorrhage activation, warmed blood components, coagulation assessment, calcium monitoring and prevention of hypothermia should be coordinated. Tranexamic acid is given promptly for significant actual or suspected traumatic bleeding within the relevant three-hour

window and local protocol. Resuscitation targets account for associated brain injury and other threats to perfusion. These principles are developed in Chapter 1 and supported by the European bleeding guideline. [1]

I find it useful for the trauma leader to state the current hypothesis aloud: where the team believes the bleeding is, how confident it is, and which observation would change the destination. This makes uncertainty usable. It also allows the radiologist, anaesthetist or surgeon to add information before a diagnostic commitment becomes a delay. Closed-loop communication is particularly valuable when the patient improves briefly and then deteriorates again.

Investigation as a decision about physiological safety

The immediate question is whether investigation can be completed safely before haemorrhage control. NICE recommends limiting imaging to what is necessary to direct intervention when a haemodynamically unstable patient is not responding to resuscitation. Immediate CT can be considered when haemodynamics are normal or the response is sufficient; a preceding FAST should not delay indicated immediate CT. [2]

FAST can rapidly show free fluid and support a time-critical decision. It offers a focused answer, not a complete abdominal assessment. Retroperitoneal bleeding, bowel injury and early organ injury may remain undetected. Contrast-enhanced CT provides a fuller anatomical account in a patient able to tolerate the scan, including active bleeding, organ disruption, vascular injury, free gas and associated pelvic or spinal lesions. The value of either investigation depends on the clinical question and the time required to act on the result.

A transient responder deserves particular attention. The team should consider the sustainability of the improvement, current transfusion requirement, scanner location, monitoring arrangements and access to theatre or interventional radiology. The phrase “stable for CT” should represent a shared, current judgement, not a status assigned once and carried forward regardless of change.

Examination continues after imaging. A reliable, repeated abdominal assessment can reveal a developing problem that was not apparent initially. Observation must specify the reviewing team, frequency of assessment, laboratory and imaging plan, and escalation criteria. Increasing pain, peritonism, recurrent shock or an unexplained physiological deterioration needs senior reassessment without waiting for the next scheduled review.

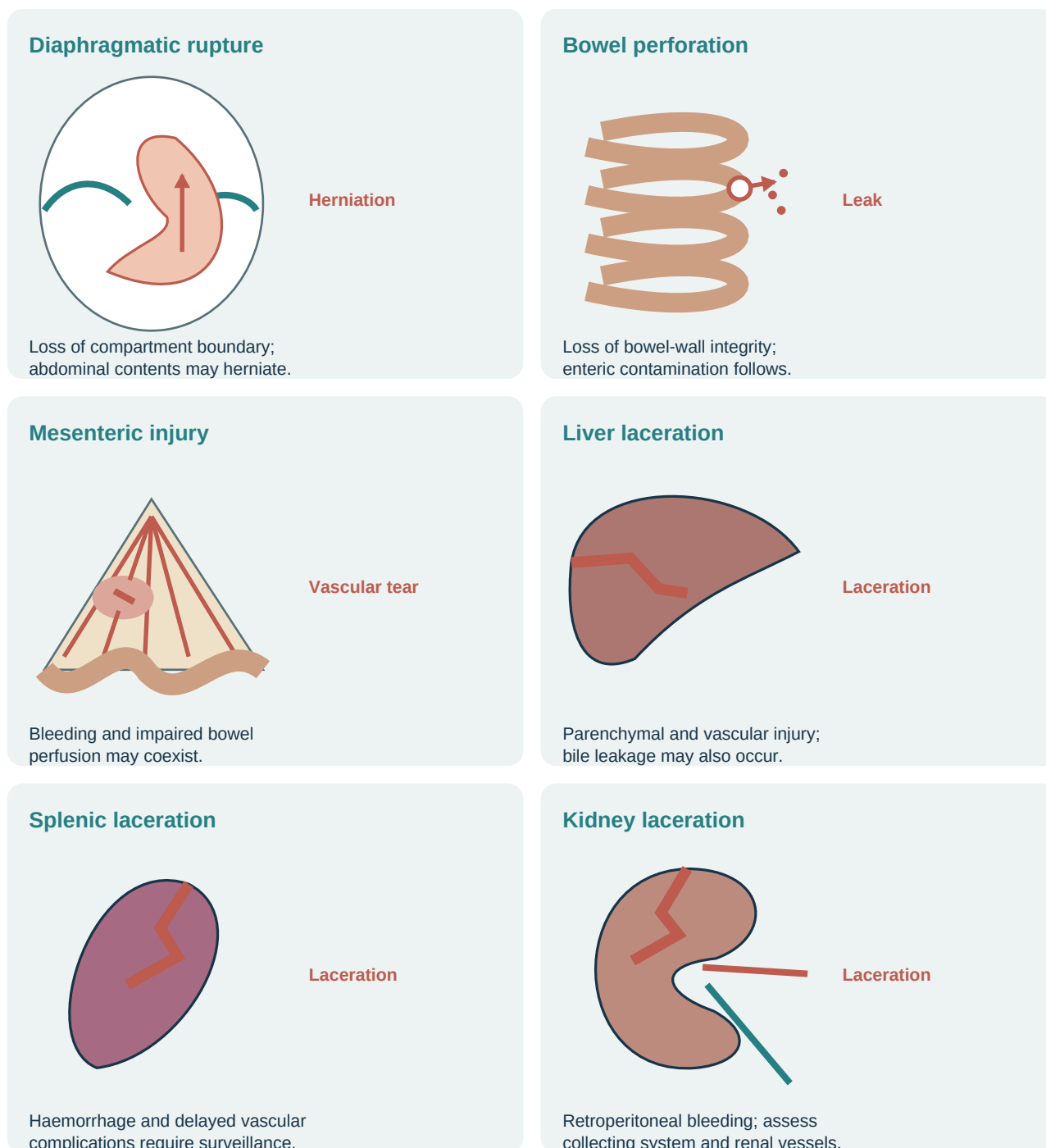


Figure 4.2. Principal abdominal injury patterns: diaphragmatic rupture with herniation, bowel perforation, mesenteric vascular injury, and liver, splenic and renal laceration. Schematic anatomy supports the clinical descriptions; it does not determine treatment without physiological assessment.

Diaphragmatic rupture: an injury across two compartments

The diaphragm contributes both to separation of the cavities and to the mechanics of breathing. Blunt rupture can follow marked deformation of the lower chest or a sudden pressure gradient across the diaphragm. Penetrating wounds may create a much smaller defect. Abdominal viscera can herniate into the chest through either, producing altered ventilation, obstruction or later strangulation. Associated haemorrhage and injuries to adjacent organs often determine the immediate priority.

Assessment should connect the lower chest with the upper abdomen. On CT, discontinuity, abnormal visceral position and the configuration of a herniated organ may help identify the injury. Persistent suspicion deserves further evaluation even when the defect is difficult to demonstrate. EAST conditionally favours laparoscopy over CT to exclude diaphragmatic injury in selected stable patients with left thoracoabdominal stab wounds. The recommendation addresses that specific scenario and reflects limited-quality evidence. [3]

Repair requires recognition of the defect and assessment of the organs passing through or lying beside it. The operative route depends on the acute injuries, physiological state, timing of presentation and available expertise. The thoracic and abdominal teams should agree which cavity needs priority access and whether there are associated injuries requiring treatment during the same procedure. The educational lesson is that a boundary organ creates a shared responsibility: neither specialty should assume that the other has assessed it simply because the patient has undergone chest and abdominal imaging.

Liver injury: controlling bleeding while preserving functioning tissue

The liver is a substantial, vascular organ anchored beneath the diaphragm and connected to major inflow and outflow vessels. Compression and shear can produce capsular tears, parenchymal lacerations, vascular disruption and biliary leakage. The anatomical grade records the extent of injury; the clinical decision also depends on circulation, associated injuries and the resources available for rescue.

In haemodynamically stable patients without another indication for surgery, nonoperative treatment is appropriate for many liver injuries across anatomical grades. Contrast CT and serial assessment support this strategy. Arterial extravasation may be addressed by angiography and embolisation. Persistent instability requires prompt operative haemorrhage control, with an abbreviated approach when the physiological burden makes extended reconstruction unsafe. [4]

The philosophy of liver care is selective intervention within active surveillance. Preserving tissue has value, but preservation requires an organised environment that can recognise failure quickly. After initial haemostasis, an unexplained fall in haemoglobin, recurrent pain, jaundice, fever or deterioration prompts consideration of recurrent bleeding, bile leakage, collection or another missed injury. The resuscitation team, abdominal surgeon and interventional radiologist need a shared understanding of what has been controlled and what remains under observation.

Splenic injury: haemostasis, preservation and continuing responsibility

The spleen lies beneath the left hemidiaphragm, related to the lower ribs and attached by ligamentous folds containing important vascular structures. A laceration may bleed freely or produce an initially contained haematoma. Vascular complications can become apparent after the first assessment, which makes the follow-up plan part of the original treatment decision.

Stable adults may undergo nonoperative treatment, with splenic artery embolisation selected according to vascular findings, injury grade and local expertise. The 2022 WSES consensus supports follow-up contrast-enhanced ultrasound or CT at 48-72 hours for adults with AAST grade

III or higher injury managed nonoperatively. Patients with continuing haemorrhage or physiological deterioration require prompt reassessment for intervention. [5]

Organ preservation and emergency surgery belong within the same patient-centred objective: survival with the best achievable subsequent health. When splenectomy is necessary, the responsibility continues through an appropriate vaccination and infection-prevention pathway, patient education and a clear record for future clinicians. After successful nonoperative care, the patient still needs understandable advice about activity, follow-up and the symptoms that require urgent review. A technically successful initial treatment is incomplete if the patient leaves without knowing how recovery should proceed.

Bowel perforation and mesenteric injury: time changes the findings

Bowel injury may arise from direct perforation, a crush lesion, a penetrating track or interruption of blood supply. Mesenteric injury deserves particular attention because it can produce two threats: haemorrhage and ischaemia of the bowel it supports. A segment may remain in continuity while losing adequate perfusion. The resulting injury therefore has a temporal dimension; its clinical expression can evolve after the initial scan.

CT findings with high specificity, such as a convincing bowel-wall defect or extraluminal enteric contrast, support exploration. Less specific changes - including mesenteric stranding, free fluid and altered enhancement - need interpretation with the mechanism and clinical course. WSES recommends close observation after equivocal findings and selected repeat CT at approximately six hours; deterioration or peritonitis requires earlier operative reassessment. [6]

At operation, the surgeon evaluates the entire relevant bowel and mesentery, seeking additional injuries and judging viability. The reconstructive choice reflects perfusion, contamination, tissue quality and the patient's physiological reserve. Primary repair, resection with anastomosis, diversion and deferred reconstruction are different ways of achieving source control in different circumstances. During damage-control surgery, bowel continuity may deliberately be left for a subsequent operation after resuscitation.

This is a useful example of purposeful restraint. A rapid first operation can establish control without imposing a reconstruction that poorly perfused tissue is unlikely to tolerate. Equally, when the patient and tissues are suitable, definitive treatment avoids the burden of unnecessary further surgery. The skilled decision concerns suitability at that moment, supported by anaesthesia, critical care and a realistic plan for the next stage.

Duodenum, pancreas and biliary tract

The deep position of the duodenum and pancreas can conceal injury. Compression against the spine may damage them while the abdominal wall shows relatively little change. Persistent upper abdominal pain, an unexplained clinical course or concerning radiology should bring these structures back into the discussion. Pancreatic duct integrity is particularly important because disruption changes the likelihood of ongoing leakage and influences treatment.

For stable patients with continuing clinical suspicion after a negative or nonspecific initial study, WSES-AAST guidance supports considering repeat CT within 12-24 hours. MRCP or ERCP may

answer selected ductal questions and contribute to treatment. The investigation must fit the patient's physiology and the specialist resources available. [7]

These injuries benefit from early hepatopancreatobiliary expertise, yet consultation must occur alongside urgent source control when the patient is deteriorating. A staged combination of surgery, drainage, endoscopy and radiological intervention may be more suitable than a single extensive reconstruction. The handover should distinguish haemorrhage already controlled from a duct injury, collection or leak that still needs a defined plan.

Kidney, urinary tract and the retroperitoneum

The kidneys are protected by the posterior abdominal wall, ribs and surrounding tissue, but rapid deceleration and direct flank compression can cause laceration, collecting-system injury or vascular disruption. Haematuria is useful when present; its absence cannot exclude important renal or ureteric injury. Contrast CT, with appropriate delayed phases where indicated, evaluates perfusion, bleeding and urinary leakage.

Stable patients can often receive kidney-preserving treatment, including selective embolisation or urinary drainage when appropriate. Persistent shock, a major vascular lesion or another indication for laparotomy changes the pathway. The WSES-AAST kidney guideline integrates haemodynamics with anatomical severity, allowing treatment to reflect the whole patient. [8]

Bladder and urethral assessment links this chapter with pelvic trauma. When bladder rupture is suspected, active retrograde filling for CT or conventional cystography is required; passive accumulation of excreted intravenous contrast is insufficient. Intraperitoneal traumatic rupture usually requires repair, whereas uncomplicated extraperitoneal rupture can often be managed with drainage. Suspected urethral disruption requires a urological plan before repeated catheter attempts. [9]

Retroperitoneal haematoma should be understood in relation to mechanism and anatomical zone. A contained blunt pelvic haematoma has different implications from active central vascular bleeding or a penetrating retroperitoneal injury. Exploration must therefore have a defined purpose and appropriate vascular capability. The aim is to preserve useful tamponade where appropriate while obtaining control of injuries that need direct treatment.

Penetrating injury and selective management

Haemodynamic instability, peritonitis or another clear operative indication after penetrating abdominal injury requires urgent surgery. Selected stable patients can be managed without immediate laparotomy when the examination is reliable, the injury pattern is suitable and experienced reassessment with rapid access to theatre is available. CT can clarify trajectory and associated injury. Stab wounds and gunshot wounds require their own risk assessment within an established specialist pathway. [11]

The quality of selection includes the quality of the service. A nonoperative plan depends on the ability to recognise change and act promptly, with a named surgeon responsible for review. The patient should understand why observation is active treatment and why a later operation may still become necessary. New peritoneal signs or physiological deterioration changes the plan immediately.

Antimicrobial treatment accompanies the management of penetrating injury and enteric contamination. Timely aerobic and anaerobic cover is selected according to the local protocol, with duration determined by whether the purpose is prophylaxis or treatment of established infection. Source control and antimicrobial stewardship are planned together. [12]

Choosing the scope of the first operation

The first abdominal operation should have objectives understood by the entire theatre team. These usually begin with control of haemorrhage and contamination, followed by a decision about definitive repair. Physiological reserve, ongoing transfusion, temperature, coagulation, perfusion and the burden of associated injuries all influence that decision. The likely length and complexity of reconstruction matter as much as the current monitor readings.

A patient who has recovered sufficiently may benefit from definitive repair at the first operation. A patient with worsening shock, coagulopathy, hypothermia or acidosis may benefit from abbreviated surgery, temporary closure and planned return. NICE supports damage-control surgery in haemodynamically unstable patients who do not respond to resuscitation. [2] The decision is strongest when made early enough to prevent a long operation from consuming the reserve required for recovery.

Abdominal treatment must be coordinated with the orthopaedic plan. After effective haemostasis and physiological recovery, early definitive fracture fixation may support nursing and mobilisation. When abdominal bleeding, contamination or organ dysfunction remains active, temporary skeletal stabilisation may be the appropriate contribution. In both settings, the treatment burden is matched to the patient's capacity. This is the shared reasoning behind early appropriate care and damage control.

The open abdomen and the return to theatre

Temporary abdominal closure may be necessary when resuscitation continues, bowel viability remains uncertain, continuity has been deferred, contamination needs further control or closure would create harmful pressure. It is a stage in treatment with explicit obligations. The team must record retained packs, the state of the bowel, drains, unresolved injuries and the intended purpose of re-exploration.

WSES recommends re-exploration within 24-48 hours after the index operation, with earlier return when the patient's course demands it, and fascial closure as soon as physiological and operative conditions permit. [10] The open abdomen requires attention to visceral protection, fluid and protein losses, nutrition, infection and the risk of fistula. These needs should be anticipated before the patient leaves theatre.

Abdominal compartment syndrome represents pathological pressure associated with new organ dysfunction. Increasing ventilatory difficulty, oliguria and circulatory deterioration in the appropriate setting warrant assessment, including reliable pressure measurement. Management addresses reversible contributors and proceeds to decompression when indicated. The interaction is systemic: abdominal pressure can compromise the lungs, venous return and renal perfusion simultaneously, so apparently separate organ problems may share one cause.

A service prepared for the next decision

Good abdominal trauma care depends on continuity of reasoning. After nonoperative treatment, the next team needs the organ injury, vascular findings, examination reliability and rescue criteria. After damage-control surgery, it needs the exact temporary state of the abdomen and a booked, purposeful next step. After definitive repair, it needs the expected recovery and the complications that should trigger review.

Preparation includes an available theatre team, blood bank, radiology, critical care and a surgeon who can take responsibility for the evolving picture. Specialist assistance should be invited early enough to be useful. The system should also protect basic care: analgesia, warmth, communication, respiratory support, nutrition and mobilisation when appropriate. These are parts of recovery, not additions made after the important treatment is finished.

Consider three hypothetical teaching situations. A patient with persistent shock and findings supporting intraperitoneal bleeding needs a rapid route to haemorrhage control; the useful investigation is the one that directs that route without unsafe delay. A stable patient with a seat-belt mark and equivocal CT needs planned reassessment capable of recognising evolving bowel injury. A patient with both a disrupted pelvis and haemoperitoneum needs a joint decision about the bleeding sources and the fastest sequence of control. Each scenario asks the same question: what intervention changes this person's prospects now?

For me, the philosophy of abdominal trauma lies in recognising the concealed injury and giving each stage a purpose. We investigate to guide action, operate to restore survivable physiology, preserve organs when the conditions allow, and reassess because injury continues to declare itself over time. The successful operation belongs within a successful service, and both are judged by the patient's opportunity to recover.

References

1. Rossaint R, Afshari A, Bouillon B, et al. The European guideline on management of major bleeding and coagulopathy following trauma: sixth edition. *Critical Care*. 2023;27:80. <https://doi.org/10.1186/s13054-023-04327-7>
2. National Institute for Health and Care Excellence. *Major trauma: assessment and initial management*. NG39. Recommendations. <https://www.nice.org.uk/guidance/ng39/chapter/Recommendations>
3. McDonald AA, Robinson BRH, Alarcon L, et al. Evaluation and management of traumatic diaphragmatic injuries: an EAST practice management guideline. *Journal of Trauma and Acute Care Surgery*. 2018;85:198-207. <https://www.east.org/education-resources/practice-management-guidelines/details/diaphragmatic-injury-evaluation-and-management-of>
4. Coccolini F, Coimbra R, Ordonez C, et al. Liver trauma: WSES 2020 guidelines. *World Journal of Emergency Surgery*. 2020;15:24. <https://doi.org/10.1186/s13017-020-00302-7>
5. Podda M, De Simone B, Ceresoli M, et al. Follow-up strategies for patients with splenic trauma managed non-operatively: the 2022 WSES consensus document. *World Journal of Emergency Surgery*. 2022;17:52. <https://doi.org/10.1186/s13017-022-00457-5>
6. Smyth L, Bendinelli C, Lee N, et al. WSES guidelines on blunt and penetrating bowel injury: diagnosis, investigations, and treatment. *World Journal of Emergency Surgery*. 2022;17:13. <https://doi.org/10.1186/s13017-022-00418-y>
7. Coccolini F, Kobayashi L, Kluger Y, et al. Duodeno-pancreatic and extrahepatic biliary tree trauma: WSES-AAST guidelines. *World Journal of Emergency Surgery*. 2019;14:56. <https://doi.org/10.1186/s13017-019-0278-6>
8. Coccolini F, Moore EE, Kluger Y, et al. Kidney and uro-trauma: WSES-AAST guidelines. *World Journal of Emergency Surgery*. 2019;14:54. <https://doi.org/10.1186/s13017-019-0274-x>
9. European Association of Urology. *EAU Guidelines on Urological Trauma*. 2026 edition, urogenital trauma recommendations. <https://uroweb.org/guidelines/urological-trauma/chapter/urogenital-trauma-guidelines>
10. Coccolini F, Roberts D, Ansaloni L, et al. The open abdomen in trauma and non-trauma patients: WSES guidelines. *World Journal of Emergency Surgery*. 2018;13:7. <https://doi.org/10.1186/s13017-018-0167-4>
11. Eastern Association for the Surgery of Trauma. *Penetrating Abdominal Trauma, Selective Non-Operative Management of*. Practice management guideline. 2010. <https://www.east.org/mobile/practice-management-guideline/78>

12. Goldberg SR, Anand RJ, Como JJ, et al. Prophylactic antibiotic use in penetrating abdominal trauma: an EAST practice management guideline. *Journal of Trauma and Acute Care Surgery*. 2012;73:S321-S325.
<https://www.east.org/mobile/practice-management-guideline/trauma/99>

CHAPTER 5

Pelvic trauma

A disrupted pelvis asks the trauma team to think in three dimensions and across several specialties. The visible fracture records where force has passed through the body. Around it lie blood vessels, neural structures, the urinary tract, bowel and a substantial soft-tissue envelope. Within the same patient may be brain, chest, abdominal and limb injuries that influence both survival and the timing of reconstruction. The first responsibility is to understand this whole injury while controlling the threats that cannot wait.

The pelvis also connects the phases of trauma care unusually clearly. A correctly applied binder can support early resuscitation. A purposeful temporary construct can make haemorrhage control and nursing possible. Accurate definitive reconstruction can restore the pathway by which the spine transfers load to the legs. Rehabilitation then determines how this structural restoration becomes walking, sitting, independence and return to ordinary life. Each phase prepares the next.

My clinical and research interest in pelvic injury has followed this same progression: from the immediate problem of haemorrhage, through the significance of associated injuries and reoperation, to the quality of reconstruction and its measurement. The underlying philosophy is consistent. We must read the physiology, understand the mechanics, prepare the service and preserve the patient's future function.



Figure 5.1. Restoring the load-bearing ring: coordinated resuscitation creates the opportunity for reconstruction, and reconstruction prepares the patient for rehabilitation. Conceptual illustration.

The pelvis as the structural outlet of the trunk

The two innominate bones, sacrum, sacroiliac joints and pubic symphysis form the pelvic ring. Strong posterior ligaments provide essential restraint, while the pelvic floor and surrounding muscles contribute to the integrity of the whole structure. The sacrum receives load from the spine; the acetabula transfer that load to the femoral heads. The ring therefore needs sufficient strength to bear weight and enough controlled movement to accommodate ordinary activity.

As a teaching image, I compare the pelvic girdle around the lower trunk with the shoulder girdle around the upper thorax. Broad iliac wings invite comparison with the scapulae, the anterior connection with the sternoclavicular region, and the central posterior connection with the cervicothoracic foundation. The image helps learners orient themselves spatially. The pelvis then becomes distinctive through its load-bearing role, its powerful posterior restraint and its close relationship to pelvic viscera.

The anterior ring is often easiest to recognise on the first radiograph, but the posterior lesion commonly determines the mechanical problem. A pubic-ramus fracture should prompt assessment of the sacrum and sacroiliac region. An apparently reduced anterior gap should be interpreted in the context of binder use, recoil and posterior ligament integrity. The soft tissues and organs require the same disciplined attention as the bones.

Blood may be lost from cancellous fracture surfaces, disrupted venous plexuses, arterial branches or larger vessels. The retroperitoneal space can conceal substantial haemorrhage. Open communication through a perineal, rectal or vaginal injury adds contamination and may reduce the effectiveness of local containment. The resulting patient may need simultaneous skeletal, vascular, abdominal, urological and soft-tissue decisions.

The fracture as part of the whole injury burden

In our work examining pelvic fracture and mortality, the clinical question was whether the fracture itself explained the outcome or whether it identified patients with a greater burden of trauma. The observational study by Holtenius, Bakhshayesh and Enocson showed the importance of interpreting pelvic fracture alongside injury severity and physiological factors. [1] This perspective encourages a complete primary survey and a continuing search for associated injury while pelvic haemorrhage is treated promptly when present.

In our separate series of 385 adults with high-energy pelvic and/or acetabular injuries, 30 patients died within 30 days and 36 within one year. Traumatic brain injury was a prominent cause of death, and age and depressed consciousness contributed to risk. [2] These historical cohort observations are a reminder that the most striking radiograph is only one part of a person's condition. Their practical contribution is to strengthen whole-patient judgement.

The same reasoning applies to recovery. A satisfactory pelvic reconstruction may coexist with neurological injury, chronic pain or the consequences of major chest or brain trauma. Conversely, an injury that looks modest on an anteroposterior image may substantially restrict mobilisation in a frail patient. The team should therefore distinguish the severity of the anatomical lesion, the physiological threat and the effect on the person's function.

Mechanism, displacement and the language of classification

Young-Burgess describes dominant loading patterns: lateral compression, anteroposterior compression, vertical shear and combined mechanisms. [3] The purpose is to make the deformity intelligible. It directs attention to where the ring has opened, impacted, rotated or translated. Actual collisions frequently combine forces, so the final description should include the observed posterior lesion and displacement as well as the category.

Young-Burgess pattern	Typical anatomical pattern	Mechanical meaning
LC I	Pubic-ramus fractures with ipsilateral sacral compression or fracture	Variable stability; assess posterior fracture completeness and displacement.
LC II	Anterior injury with posterior iliac fracture or fracture-dislocation, often a crescent fragment	Internal rotation with important posterior involvement.
LC III	Lateral compression on one side and opening on the opposite side	Windswept deformity with substantial ring instability.
APC I	Limited anterior opening with posterior restraint preserved	Usually stable when the presumed ligament integrity is confirmed.
APC II	Anterior opening with anterior sacroiliac ligament disruption; posterior sacroiliac restraint remains	Rotationally unstable, generally vertically stable.
APC III	Anterior injury with complete posterior sacroiliac disruption	Rotational and vertical instability.
Vertical shear	Vertical translation through anterior and posterior ring disruption	Major loss of vertical restraint.
Combined mechanism	Features of more than one loading pattern	Describe each displacement and the residual posterior stability.

Table 5.1. Young-Burgess patterns: a clinical orientation to the mechanisms and resulting ring injuries. [3]

Lateral compression deserves careful interpretation. The category includes relatively limited sacral impaction as well as complete posterior fractures with potential instability. Its label therefore initiates a stability assessment. Anteroposterior injuries require equally careful review of posterior restraint. The traditional 2.5 cm symphyseal measurement is a descriptive guide; recoil, applied compression and individual anatomy mean that a single distance cannot represent all ligament injury.

Tile provides a complementary language focused on residual stability. Type A injuries are mechanically stable, type B injuries have rotational instability while retaining vertical stability, and type C injuries have both rotational and vertical instability. The two classification systems answer related questions: Young-Burgess helps explain the force pattern, while Tile helps describe what load-bearing restraint remains. Modern AO/OTA categories add further anatomical detail and should be reported using the applicable edition.

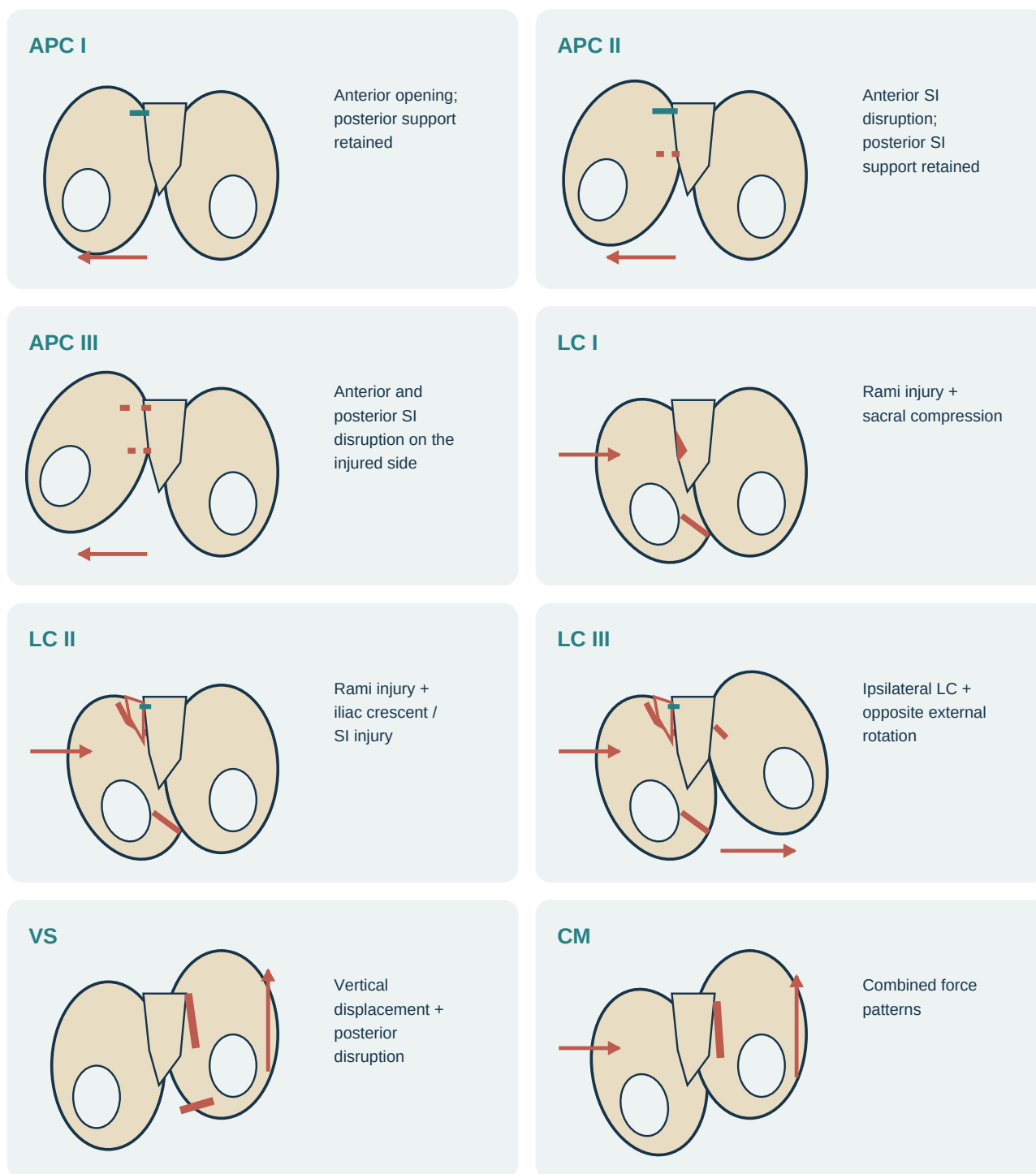


Figure 5.2. Pelvic ring injury patterns: lateral compression, anteroposterior compression and vertical shear, with the posterior lesion shown alongside anterior displacement. The figure complements the Young-Burgess and stability tables. Red marks indicate injury; teal bars indicate retained ligament support; arrows show force or displacement concepts. Patterns are simplified, not radiographs.

Mechanical stability and haemodynamic stability

A patient can have a mechanically unstable pelvis and adequate circulation after resuscitation. Another can have limited displacement but important arterial bleeding or haemorrhage elsewhere. These two meanings of stability must be stated separately. The WSES pelvic framework explicitly brings anatomical and haemodynamic information together. [4]

Mechanical state	Physiological state	Immediate clinical direction
Stable or incompletely characterised	Sustained adequate perfusion	Complete assessment, define associated injuries and plan mobilisation or further investigation.
Unstable	Sustained response after resuscitation	Protect alignment and organise timely specialist reconstruction.
Any pattern	Persistent shock or recurrent deterioration	Continue resuscitation and urgently identify and control bleeding.

A useful referral therefore says more than “LC injury” or “unstable pelvis”. It describes the mechanism, physiological trajectory, blood-product requirement, binder position and time, posterior lesion, open wounds, neurological findings and associated injuries. It identifies the decision required from the receiving team. This enables preparation for haemorrhage control, temporary fixation, reconstruction or specialist transfer before the patient arrives.

Initial care: parallel work around a common plan

Pelvic management belongs within the repeated primary survey. Airway obstruction, tension pneumothorax, chest haemorrhage and intra-abdominal bleeding retain their urgency. The trauma leader ensures that pelvic stabilisation occurs alongside oxygenation, blood replacement, thermal protection and the search for other bleeding sources.

Assessment combines physiology with purposeful examination. Inspect the abdomen, groins, perineum and accessible buttocks for wounds, bruising, swelling and degloving. Record limb position, distal perfusion and neurological findings when participation allows. Minimise unnecessary movement of the injured ring and avoid repeated springing. Examination limitations caused by shock, sedation or brain injury should be recorded so that a later clinician knows what remains to be established.

Major-haemorrhage resuscitation follows the network protocol, with warmed blood components, coagulation-guided treatment, calcium and temperature monitoring, and prompt tranexamic acid where indicated. The response is judged by perfusion and the amount of continuing support, not by a reassuring blood pressure alone. Associated brain injury influences acceptable resuscitation targets. The same principles apply whether the next intervention is packing, embolisation or surgery elsewhere in the body. [5]

Teams should be called according to the anticipated need. Anaesthesia, emergency medicine, pelvic surgery, general or vascular surgery, radiology and critical care form the core. Urology, colorectal surgery, gynaecology, spinal surgery and plastic surgery contribute when the anatomy requires them. The patient benefits when this is one coordinated plan with clear ownership rather than a series of disconnected requests.

Pelvic binders: a simple device requiring skilled application

A purpose-made binder provides rapid circumferential support when active pelvic bleeding is suspected after high-energy blunt trauma. Its centre should lie over the greater trochanters. The application time, position and patient's response must be documented. The ring may be reduced substantially by the device, particularly when the injury has opened into external rotation. [6]

Mechanical support brings injured surfaces closer and limits repeated movement that can disturb early clot. In an externally rotated injury, reduction also changes pelvic geometry. These effects should be understood together; the binder supplies temporary support while definitive haemorrhage control and stabilisation are organised.

Our three-dimensional assessment of applied binders found correct placement and alignment according to the study criteria in 43 of 73 patients. [7] That observation makes a practical educational point: the record “binder present” should be followed by a check that it lies at the intended level and functions as intended. Training should include body habitus, clothing, transfers, imaging appearances and reassessment, so that application quality remains reliable in a busy resuscitation room.

Leg positioning is selected with the whole limb in mind. Gentle adduction and internal rotation may help an externally rotated hemipelvis when the hip, femur and knee injuries permit it. Forced positioning or routine compression of an already internally rotated injury can create a different mechanical problem. After imaging, device adjustment should reflect the actual deformity and the pelvic team's plan.

A binder needs an exit strategy. Skin, pressure areas and access for care require continuing review. NICE recommends removal of all binders within 24 hours; for an unstable fracture, the alternative stabilisation plan should be agreed with the pelvic surgeon before release. [6] A controlled removal process combines physiological monitoring with reassessment of alignment. A pelvis that appears reduced while bound still needs its unbound stability established.

Imaging that directs treatment

Contrast-enhanced CT is central for a patient with sufficient physiological reserve to undergo it safely. The review should include the sacrum, sacroiliac joints, iliac wings, anterior ring, symphysis and acetabula, followed by vessels, haematoma, viscera and soft tissues. Multiplanar images reveal displacement that can be difficult to appreciate on a single projection. Three-dimensional reconstructions support spatial understanding, while the source images provide essential detail.

For a deteriorating patient, imaging is limited to what will direct immediate intervention. A portable pelvic image may identify gross disruption. FAST may identify intraperitoneal fluid, but retroperitoneal blood remains outside its reliable assessment. Persistent shock requires consideration of several compartments, including chest, abdomen, pelvis, limbs and external bleeding. [5]

An arterial blush can identify a target for embolisation. Continued transfusion dependence or recurrent deterioration may justify angiographic investigation even when extravasation is not visible. The treatment decision includes the speed with which the relevant service can act, not simply the availability of a theoretical option. [8]

The binder's effect must be communicated to radiology and the receiving team. BOAST recommends a pelvic radiograph after binder removal in polytrauma, including when CT appears negative, because reduction may mask a ligamentous ring injury. [9] This is best organised as a controlled clinical event with a responsible team, rather than an incidental action during a ward transfer.

Haemorrhage control: complementary routes to the same objective

Arterial embolisation, pelvic packing and skeletal support address different components of the bleeding problem. Their sequence depends on the source, physiological condition, associated injuries and local capability. A service should have an agreed pathway that makes these treatments timely and permits rapid movement from one to another when the response is incomplete.

Angiography allows identification and treatment of arterial bleeding. Selective or more extensive embolisation is chosen according to the injury and urgency. Persistent haemorrhage may require repeat angiography or another intervention. Major iliac vascular injury with impaired limb perfusion introduces a reconstructive vascular problem and requires specialist planning alongside haemostasis. Distal perfusion is reviewed before and after treatment. [8]

Extraperitoneal pelvic packing provides pressure around bleeding pelvic surfaces, ideally against a supported ring. It can be particularly useful when rapid operative control is needed or angiography cannot be delivered promptly. Packing and embolisation may be used together. The operative record should specify the packs, the state of haemostasis and the plan for removal or revision; AO describes a second look at 24-48 hours, adjusted to the clinical course. [10]

The relationship with laparotomy must be considered deliberately. An associated abdominal injury may need surgery in the same sitting, while the pelvic haematoma is managed through an extraperitoneal approach. Preserving useful containment is part of the strategy. An open abdomen, if required after damage-control laparotomy, has its own indication, temporary-closure requirements and return-to-theatre plan.

Resuscitative aortic balloon occlusion belongs to specialised, highly selected pathways. The UK-REBOA randomised trial did not demonstrate survival benefit and raised concern about harm. [11] It should therefore not be treated as a routine intermediate step or a reason to delay established routes to haemorrhage control. The essential service capability remains rapid definitive haemostasis with effective resuscitation.

Temporary skeletal support and the posterior ring

Temporary fixation should be selected for the displacement it needs to control. An anterior frame can support the ring and facilitate care, but a completely disrupted posterior ring requires consideration of posterior stability. Traction can assist selected cranially displaced vertical-shear injuries while definitive treatment is organised. A posterior emergency device is a specialist option whose safety depends on the fracture anatomy and the operator's experience.

Method	Intended contribution	Planning requirement
Pelvic binder	Rapid circumferential support	Correct trochanteric level, skin surveillance and planned replacement or release.
Anterior external fixation	Temporary rotational control and support during haemorrhage treatment	Frame and pin placement compatible with abdominal access, soft tissues and later reconstruction.
Skeletal traction	Selected reduction of cranial hemipelvic displacement	Suitable limb, prescribed direction and force, imaging and repeated neurovascular review.
Posterior emergency stabilisation	Selected severe posterior instability	Fracture-specific indications, safe placement and experienced pelvic team.

Traction is a clinical prescription. The injured limb, knee stability, wounds and ipsilateral fractures influence where force can safely be applied. Its direction and magnitude are adjusted to the displacement and response. The team documents the intended reduction, monitoring and endpoint, ensuring that a temporary measure contributes to the definitive plan.

Sacral injury brings pelvic and spinal expertise together. Neurological assessment includes lower-limb function and, when appropriate, perineal sensation and sacral function. U-shaped and related sacral patterns may disconnect the spinal column from the pelvic ring. New weakness, saddle sensory change or bladder and bowel dysfunction requires urgent joint assessment. Reduction, stabilisation and any decompression are planned from the actual displacement and neural findings.

Open pelvic injury and the organs within the ring

An open fracture may communicate through a perineal, rectal or vaginal wound. Inspection and intimate examination should be purposeful, sensitive and coordinated, with appropriate analgesia and a chaperone. The objective is to identify contamination and damaged structures while avoiding repeated distressing examinations by separate teams.

Open injuries need prompt antimicrobial treatment under the local protocol, tetanus assessment, haemorrhage control and operative debridement. Rectal injury or substantial perineal contamination may require diversion, with stoma location planned in relation to later fixation and nursing. Tissue viability and the route of contamination matter as much as the bony pattern. Urological and colorectal source control should be integrated with skeletal treatment. [9]

Meatal blood, inability to void, perineal swelling or difficulty with catheter passage should prompt a deliberate urethral assessment. Repeated forceful attempts are avoided. Urology should establish investigation and drainage, using urethrography or endoscopic assessment as appropriate. Bladder injury is evaluated with active retrograde cystography when indicated. Intraperitoneal rupture generally requires repair; uncomplicated extraperitoneal rupture can often be drained, whereas bladder-neck involvement, intravesical bone or associated rectal or vaginal injury usually requires repair. [12]

The soft-tissue envelope can also be injured without a surface wound. Closed degloving, including a Morel-Lavallée lesion, may initially present as bruising, fluctuance or altered skin sensation. Its

location and condition can change incision placement and the safety of implant surgery. Pelvic reconstruction begins with an assessment of the tissue through which the reconstruction must be performed.

The acetabulum and restoration of the hip

Acetabular injury is a related but distinct reconstructive problem. The socket requires articular congruity and stability to support the femoral head and preserve useful hip function. Ring disruption primarily concerns the stability and alignment of the load-bearing pelvis. These injuries can coexist, and the operative strategy should explain how treatment of one influences the other.

Traumatic hip dislocation requires urgent assessment and reduction by an appropriate team, with attention to associated femoral-neck injury and documented neurovascular status. Subsequent imaging defines the articular lesion, wall and column involvement, fragments and marginal impaction. The Letournel-Judet classification provides a common language for these patterns.

Treatment selection considers the weight-bearing surface, joint congruity, bone quality, physiological reserve and the patient's functional aims. Nonoperative care, reduction and fixation, or selected arthroplasty-based reconstruction each require a clear rationale. Specialist concentration of pelvic and acetabular work brings technical skill together with imaging, theatre preparation, anaesthesia and rehabilitation.

Timing definitive reconstruction

Readiness for definitive surgery is a physiological judgement. Review perfusion trends, temperature, coagulation, continuing transfusion, respiratory status, associated brain or abdominal injury and the anticipated surgical burden. The ability to maintain blood pressure with substantial support should be distinguished from recovery of reserve. The decision is strengthened when surgeon, anaesthetist and trauma team share explicit operative goals and stopping points.

BOAST recommends pelvic-ring reconstruction within 72 hours of physiological stabilisation when associated injuries allow. [9] This supports timely definitive treatment after recovery, with damage-control options maintained for patients who need them. Early appropriate care is the continuing process of reassessing when the expected benefit of reconstruction outweighs its physiological burden.

The construct must restore the necessary posterior and anterior restraint. Options may include anterior plating or screws, iliosacral or transsacral fixation, and lumbopelvic constructs for selected sacral injuries. Safe corridors, reduction, soft tissue and contamination influence the choice. A good anterior image becomes meaningful only within a sound reconstruction of the ring as a whole.

From stabilisation to accurate reconstruction

My doctoral work, *Clinical and radiological aspects of traumatic pelvic ring injury*, connected early survival with the quality of later reconstruction. [13] Reoperations in the clinical cohort raised an important question: how can planning, intraoperative imaging and follow-up make the first reconstruction more reliable? The response was to examine not only which implants were used, but how accurately anatomy and subsequent movement could be understood.

In our experimental pelvic model, CT-based volume registration using bone anatomy offered a method of measuring translation and rotation without relying on implanted markers. The work demonstrated a promising measurement approach under controlled conditions and identified the need for clinical evaluation. [14] Its significance for this book is the discipline behind the method: if we wish to improve reconstruction, we need to describe its three-dimensional result and recognise change with sufficient reliability.

A separate study using ten adult CT datasets explored the symmetry of the two hemipelves through mirroring and volume comparison. The findings supported the uninjured side as a useful planning reference, acknowledging anatomical variation. [15] Contralateral templating can help the surgeon visualise the intended reduction and prepare implants. It also makes the target of reconstruction more explicit to the team before the operation begins.

The wider research programme points towards a connected process: plan the reconstruction in three dimensions, guide the operation with appropriate imaging, assess what has been achieved, and relate the result to the patient's recovery. This is a direction for clinical learning, not an assumption that one imaging method guarantees a superior outcome. Radiation exposure, practical workflow, cost and the information that will change treatment remain part of the decision.

Registries complete this connection. They allow patterns of injury, treatment, complications and recovery to be studied across many patients. A useful registry depends on accurate clinical data and meaningful outcomes. Complication review should return its findings to training, operative planning and service design. In this sense, a well-organised trauma unit is also a learning unit: each phase of care generates information that can improve the next patient's treatment.

Recovery as the final test of the plan

The early ward and critical-care plan should state how the pelvis is supported, what movements are permitted, the weight-bearing prescription for each limb, the urinary and wound plan, and which team owns the next review. Pain control, skin protection, nutrition, respiratory care and thrombosis prevention are repeatedly reassessed as bleeding risk and mobility change. Restrictions should have a reason and a review point.

Recovery extends to sitting, transfers, walking, endurance, bladder and bowel function, sexual health and confidence outside hospital. These subjects deserve direct, respectful questions because patients may be reluctant to introduce them. Work, housing, family support and transport can be decisive for independence. Rehabilitation turns the technical reconstruction into an achievable set of activities.

A hypothetical patient with an APC injury and persistent shock needs coordinated blood replacement, correct temporary support and rapid haemorrhage control. A second patient with the same radiological category but sustained physiological recovery may be ready for early definitive reconstruction. A third, with limited initial displacement but inability to mobilise and posterior pain, needs renewed assessment of stability and the whole injury. Classification begins the conversation; the person determines its direction.

For me, the pelvis illustrates the full responsibility of trauma surgery. We understand the force, control the bleeding, restore the ring and support recovery, while measuring how well the service has performed. The patient needs all of these contributions to belong to one coherent pathway.

References

1. Holtenius J, Bakhshayesh P, Enocson A. The pelvic fracture - indicator of injury severity or lethal fracture? *Injury*. 2018;49:1568-1571. <https://doi.org/10.1016/j.injury.2018.06.016>
2. Bakhshayesh P, Weidenhielm L, Enocson A. Factors affecting mortality and reoperations in high-energy pelvic fractures. *European Journal of Orthopaedic Surgery & Traumatology*. 2018;28:1273-1282. <https://doi.org/10.1007/s00590-018-2203-1>
3. Burgess AR, Eastridge BJ, Young JW, et al. Pelvic ring disruptions: effective classification system and treatment protocols. *Journal of Trauma*. 1990;30:848-856. <https://doi.org/10.1097/00005373-199007000-00015>
4. Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma: WSES classification and guidelines. *World Journal of Emergency Surgery*. 2017;12:5. <https://doi.org/10.1186/s13017-017-0117-6>
5. National Institute for Health and Care Excellence. *Major trauma: assessment and initial management*. NG39. <https://www.nice.org.uk/guidance/ng39/chapter/Recommendations>
6. National Institute for Health and Care Excellence. *Fractures (complex): assessment and management*. NG37. Pelvic fracture recommendations. <https://www.nice.org.uk/guidance/ng37/chapter/recommendations>
7. Bakhshayesh P, Hullberg Risling D, Enocson A. Three dimensional quality assessments of applied pelvic binders. *Bulletin of Emergency & Trauma*. 2019;7:156-161. <https://doi.org/10.29252/beat-070211>
8. Eastern Association for the Surgery of Trauma. *Pelvic fracture hemorrhage: update and systematic review*. Practice management guideline. 2011. <https://www.east.org/education-resources/practice-management-guidelines/details/pelvic-fracture-hemorrhage-update-and-systematic-review-update-in-process>
9. British Orthopaedic Association. *BOAST: The Management of Patients with Pelvic Fractures*. 2018. <https://www.boa.ac.uk/resource/boast-3-pdf.html>
10. AO Foundation. *Extraperitoneal pelvic packing for acute pelvic treatment*. AO Surgery Reference. <https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/pelvic-ring/acute-pelvic-treatment/extraperitoneal-pelvic-packing>
11. Jansen JO, Hudson J, Cochran C, et al. Emergency department resuscitative endovascular balloon occlusion of the aorta in trauma patients with exsanguinating hemorrhage: the UK-REBOA randomized clinical trial. *JAMA*. 2023;330:1862-1871. <https://doi.org/10.1001/jama.2023.20850>
12. European Association of Urology. *EAU Guidelines on Urological Trauma*. 2026 edition. <https://uroweb.org/guidelines/urological-trauma/chapter/urogenital-trauma-guidelines>
13. Bakhshayesh P. *Clinical and radiological aspects of traumatic pelvic ring injury*. Doctoral thesis. Karolinska Institutet, Stockholm; 2020. ISBN 978-91-7831-867-4. Author-supplied final thesis, consulted from the research archive.
14. Bakhshayesh P, Olivecrona H, Weidenhielm L, Enocson A. A new CT based method for post-operative motion analysis of pelvic fractures. *3D Research*. 2019;10:7. <https://doi.org/10.1007/s13319-019-0217-z>
15. Bakhshayesh P, Zaghloul A, Sephton BM, Enocson A. A novel 3D technique to assess symmetry of hemi pelvises. *Scientific Reports*. 2020;10:18789. <https://doi.org/10.1038/s41598-020-75884-y>

CHAPTER 6

Spine and spinal precautions

The spine is the central foundation of the body, yet it is a foundation designed to move. It carries the head, organises the thorax, supports the trunk and transfers load to the pelvis. Through it we turn towards another person, sit, stand and maintain balance. Within its canal lies the nervous system through which movement, sensation and much autonomic function are coordinated. Spinal trauma therefore threatens both the architecture of the body and the person's ability to act within it.

I approach these injuries through two connected questions: can the spinal column bear load and maintain alignment safely, and what has happened to the neural structures it protects? Mechanical instability can exist with preserved neurological function. Neurological injury can exist with little visible bony disruption. The clinical examination and imaging need to be understood together, within the physiology and priorities of the whole injured patient.

Spinal care begins at first contact and continues through rescue, resuscitation, transfers, investigation, surgery and rehabilitation. Every stage can either preserve the conditions for recovery or introduce a preventable additional burden. A prepared service therefore treats spinal protection as a coordinated practice carried by all teams, rather than as the presence of a collar or the completion of a scan.



Figure 6.1. Protecting the body's foundation: the team supports alignment, oxygen delivery and neural function while planning safe movement and recovery. Conceptual illustration.

Anatomy as a guide to vulnerability

The cervical spine supports a mobile, relatively heavy head. Flexion, extension, lateral bending and rotation are distributed across joints with different anatomical roles; the upper cervical region contributes substantially to rotation. The thoracic spine is integrated with the rib cage, while the lumbar spine carries considerable load through larger vertebral bodies and discs. At the base, the sacrum forms the connection with the pelvic ring. These regional differences influence both the injury pattern and the treatment required.

A motion segment includes the vertebral bodies and intervening disc, facet joints, ligaments and supporting muscles. Stability depends on their combined integrity. The vertebral body and disc resist compression, while tension-band structures restrain excessive separation and bending. Facet orientation influences how a segment responds to rotation and translation. Bone quality, degenerative change and pre-existing deformity alter these relationships.

The spinal cord continues from the medulla and usually terminates as the conus medullaris around the L1-L2 level in adults, with variation. Below this, descending roots form the cauda equina before leaving the canal. The neurological level of an injury and the vertebral level therefore describe related but different anatomy. A thoracolumbar injury may affect cord, conus and roots in varying combinations; a lower canal injury primarily threatens roots.

The spine also relates to the other compartments of trauma. Rib injury and thoracic spine injury may reflect the same force. A flexion-distraction injury around the thoracolumbar junction may accompany bowel or mesenteric injury. A sacral fracture may disturb both neural function and the connection between spine and pelvis. These relationships make spinal interpretation part of the whole-body assessment.

Understanding how a motion segment fails

The forces involved in spinal trauma include compression, bending, tension, translation and rotation. They commonly act together. A useful description identifies what has failed, in which direction displacement has occurred, and what remains capable of resisting load. The mechanism suggests where to look; the observed injury and neurological findings establish its clinical significance.

Compression can produce an anterior wedge or a burst pattern. In a burst fracture, the posterior vertebral-body wall is involved and fragments may move towards the canal. The posterior ligamentous complex must be assessed separately. A relatively preserved external alignment can coexist with an important vertebral-body lesion, just as a modest body fracture can accompany substantial tension-band failure.

Flexion loads the anterior structures in compression while placing posterior structures under tension. When the posterior restraint fails, the injury may include distraction or displacement. Extension can open the anterior tension band, particularly in a stiff or ankylosed spine. Rotation and translation can disrupt the alignment of the entire segment, producing a complex injury to bone, discs, ligaments and neural structures. These combinations explain why the anatomical result is more useful than ranking mechanisms by a single adjective such as severe or mild.

Dominant loading feature	Structural pattern to consider	Additional question
Compression	Wedge or burst fracture	Is the posterior wall involved, and is the tension band intact?
Flexion	Anterior compression with possible posterior tension-band failure	Has the injury opened posteriorly or translated?
Extension	Anterior opening or tension-band failure	Is there ankylosis, disc disruption or neural compression?
Distraction	Separation across bone, ligaments or a disc	Which tension band and motion segment have failed?
Rotation or translation	Loss of normal relation between adjacent segments	What instability and neural injury remain after recoil or positioning?

The ankylosed and otherwise vulnerable spine

A rigid spine transmits force across longer segments. In ankylosing conditions, a relatively modest fall may therefore create a highly unstable fracture. The patient's usual curvature should be supported during handling; pre-existing kyphosis forms part of the safe alignment. Imaging and specialist review must account for the possibility of more than one injured level and for lesions that are difficult to appreciate on initial studies. [1]

Frailty, osteoporosis, previous surgery and degenerative narrowing also change the clinical problem. Neurological injury may follow deformation in a canal that had limited reserve before the accident. A fracture in poor-quality bone may influence fixation options and the tolerance of a brace. Understanding the patient before injury helps the team interpret what has changed and plan what recovery might reasonably require.

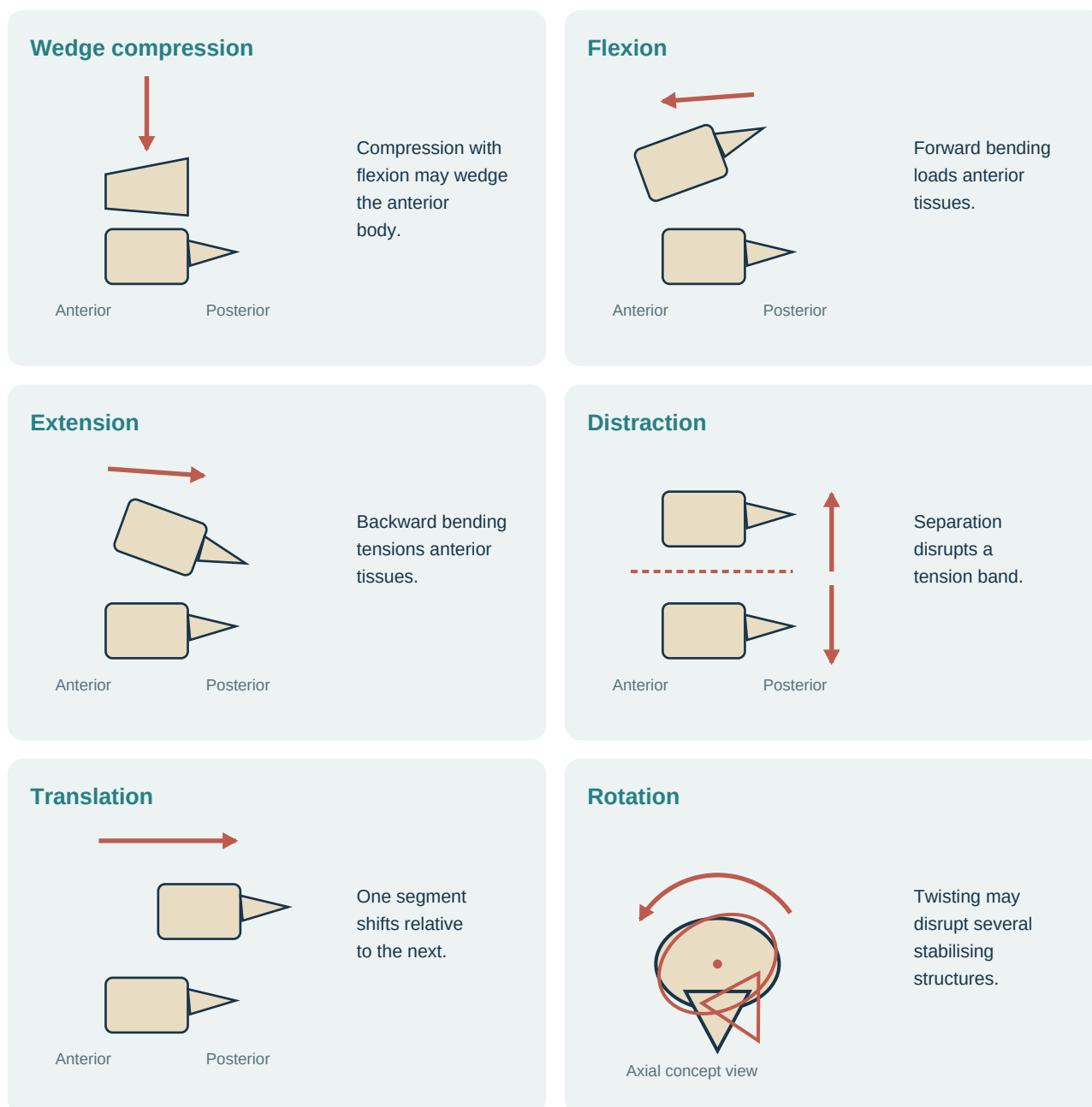


Figure 6.2. Patterns of spinal loading and injury: compression, flexion, extension, distraction and rotation/translation. The schematic shows the force and structural response; definitive classification also requires ligament and neurological assessment.

Protection from rescue to definitive assessment

Spinal protection has a purpose: to limit avoidable displacement while preserving airway, breathing, circulation and timely access to treatment. NICE places airway safety and appropriate manual stabilisation within the initial assessment. A collar should be reviewed for fit and effect on the airway, and a longboard should not be used as the continuing transport surface. Abnormal neurology attributable to the cord requires MRI after CT, even when CT does not demonstrate a bony explanation. [2]

I regard each transfer as a clinical intervention. Before movement, the team identifies who will lead, the alignment to maintain, the equipment required and the position of lines, drains and

injured limbs. An awake patient should hear what is about to happen. Analgesia and reassurance assist cooperation. A coordinated transfer also protects unstable pelvic and limb injuries and reduces the number of occasions on which the patient is moved.

Log rolling and alternative handling techniques require a defined purpose and the locally agreed method. Positioning should be reconsidered when there is severe chest injury, an unstable pelvis, a threatened airway or physiological deterioration. The safe approach is the one that integrates these needs with spinal protection. Unnecessary repeated movements add burden without improving understanding.

Protection continues while imaging is arranged and interpreted. The handover should state which regions remain under precautions, what assessment has been completed and which decision is outstanding. Once clearance or a treatment plan has been established, the patient should benefit promptly from the appropriate change in restrictions. Continuing a device without a reason and removing it without a decision are both failures of continuity.

Examination that can detect change

The first neurological assessment should establish as much as resuscitation permits about limb movement, sensation and symptoms. Ask about new weakness, paraesthesia, altered balance or a change in bladder and bowel function when the patient can respond. Record the time and any limitation due to pain, sedation, intoxication, brain injury or associated limb damage. A finding that cannot be tested is recorded as untestable rather than assumed normal.

The International Standards for Neurological Classification of Spinal Cord Injury, developed through ASIA and ISCoS, provide the structured examination commonly called the ASIA chart. The current official worksheet should be used by appropriately trained examiners. It records bilateral key muscle and sensory findings and the sacral assessment required for classification. Sacral sparing is central to the distinction between complete and incomplete cord injury. [3]

The value of a neurological record lies in its capacity to demonstrate a difference. A summary grade is useful, but the underlying findings, confounding factors and examination conditions remain essential. Repeat assessment after significant interventions and when the patient becomes more able to participate. New weakness or altered sensation is communicated directly to the responsible team and prompts reassessment of oxygenation, perfusion, alignment and possible compression.

BOAST sets expectations for early formal neurological documentation, repeated review and specialist spinal-cord involvement. It also emphasises the nursing and therapy arrangements required while a patient awaits transfer to a spinal cord injury centre. [4] This joins the examination to an actual care pathway: a deficit should lead to a named clinical responsibility and an actionable plan.

Imaging, interpretation and clearance

CT is the principal initial investigation for suspected adult bony spinal injury in major trauma. Multiplanar reconstructions show fracture morphology, alignment and signs suggesting tension-band damage. Imaging should be reviewed for the entire relevant spinal region; the label “whole-body CT” does not replace confirmation that adequate coverage and reconstructions are available.

MRI answers questions about cord, discs, ligaments, neural compression and epidural collections. The need and urgency depend on the neurological findings, CT appearances and the decision the scan will inform. Transfers for MRI must preserve monitoring and physiological support. In a patient with a potentially reversible compressive lesion, access should be actively prioritised rather than left as a routine request.

Clearance is a documented clinical decision using an agreed pathway. Selected alert patients may meet validated criteria for clinical clearance. Patients with unreliable examination, abnormal neurology, concerning symptoms or inadequate imaging require the appropriate further assessment. For obtunded adults after a negative high-quality cervical CT, EAST conditionally supports collar removal on CT alone, under a suitable institutional protocol; clinical-radiological discrepancy still requires attention. [5]

The completed decision should be visible to everyone caring for the patient. State which regions are cleared, which remain injured, whether a device is needed, what positioning is permitted and who will review any remaining uncertainty. This prevents both inadvertent movement through an unrecognised lesion and avoidable prolonged immobilisation after the question has been resolved.

AO Spine: describing the structural injury

AO Spine classifications organise morphology, neurology and modifying factors. In the thoracolumbar system, type A describes compression, type B tension-band failure and type C displacement or dislocation. The following table gives the principal morphological groups; neurological status and relevant modifiers are recorded separately. [6]

Thoracolumbar category	Principal morphology
A0	Minor nonstructural fracture.
A1	Wedge compression, without posterior-wall involvement.
A2	Split fracture, without posterior-wall involvement.
A3	Incomplete burst: posterior wall and one endplate involved.
A4	Complete burst: posterior wall and both endplates involved.
B1	Transosseous posterior tension-band failure.
B2	Posterior tension-band disruption through ligamentous and/or bony structures.
B3	Hyperextension injury with anterior tension-band failure.
C	Displacement or dislocation.

The subaxial cervical AO system additionally describes facet injury, while the upper cervical region has its own anatomical framework. [7] These distinctions matter because the occiput, atlas and axis have relationships different from the more uniform subaxial motion segments. The fracture name should make the anatomy clearer, not obscure it behind a code.

For the sacrum, AO type A injuries preserve pelvic and spinopelvic stability, type B injuries affect posterior pelvic stability, and type C injuries affect spinopelvic stability. [8] A U-shaped fracture can disconnect the spine from the pelvic ring. This is an interface injury requiring a shared spinal and pelvic plan, with particular attention to neural function, reduction and the load-bearing reconstruction.

SLIC: the subaxial cervical injury score

The Subaxial Injury Classification and Severity Scale, abbreviated SLIC or SLICS, combines morphology, the disco-ligamentous complex and neurological status for subaxial cervical trauma. It supports discussion of operative and nonoperative treatment. The score belongs beside the images and examination, with the level, specific injuries and patient factors described explicitly. [9,10]

SLIC component	Finding	Points
Morphology	No abnormality	0
Morphology	Compression	1
Morphology	Burst	2 total
Morphology	Distraction	3
Morphology	Rotation/translation	4
Disco-ligamentous complex	Intact	0
Disco-ligamentous complex	Indeterminate	1
Disco-ligamentous complex	Disrupted	2
Neurology	Intact	0
Neurology	Root injury	1
Neurology	Complete cord injury	2
Neurology	Incomplete cord injury	3
Neurological modifier	Ongoing cord compression with neurological deficit	Add 1

Table 6.3. SLIC scoring. Select the most severe applicable morphology rather than adding competing morphology categories. Burst represents compression plus one additional point, giving two morphology points in total. [9,10]

Totals of **3 or less** generally support nonoperative treatment; **4** permits either strategy according to the clinical context; **5 or more** generally supports surgery. These are decision-support thresholds. They do not replace assessment of the patient's physiology, ankylosis, bone quality, associated injuries or a changing neurological examination. An unknown finding should remain an explicit uncertainty rather than acquiring a reassuring zero.

TLICS: the thoracolumbar injury score

The Thoracolumbar Injury Classification and Severity Score combines injury morphology, posterior ligamentous complex integrity and neurological status. It addresses the thoracolumbar region and uses different component weights from SLIC. The score clarifies why two apparently similar vertebral-body fractures may require different treatment. [11,12]

TLICS component	Finding	Points
Morphology	Compression	1
Morphology	Burst	2 total
Morphology	Translation/rotation	3
Morphology	Distraction	4
Posterior ligamentous complex	Intact	0
Posterior ligamentous complex	Suspected injury or indeterminate	2
Posterior ligamentous complex	Disrupted	3
Neurology	Intact	0
Neurology	Nerve-root injury	2
Neurology	Complete cord or conus injury	2
Neurology	Incomplete cord or conus injury	3
Neurology	Cauda equina injury	3

Table 6.4. TLICS scoring. Use the highest applicable morphology for the injured segment; burst gives two morphology points in total. Distinct injured levels are assessed separately. [11,12]

Totals of **3 or less** generally support nonoperative care; **4** leaves a choice between approaches; **5 or more** generally supports operative treatment. For example, a burst fracture with intact posterior ligaments and normal neurology scores $2 + 0 + 0 = 2$. The same burst with confirmed posterior ligament disruption scores $2 + 3 + 0 = 5$. The ligament assessment changes the mechanical interpretation.

Turning a classification into a clinical decision

Classification is most useful when it exposes the reason for a decision. If surgeons differ about a score, they should identify the component in dispute: a tension-band injury, an uncertain disc lesion, a neurological finding or the exact morphology. The next step can then address that uncertainty through image review, examination or further investigation.

The score also has to be placed within the patient's capacity to undergo treatment. A recommendation for stabilisation does not specify the anaesthetic plan, timing, operative extent or rehabilitation programme. Those decisions require the spinal surgeon, anaesthetist and trauma team to consider associated haemorrhage, respiratory function, positioning and the burdens of other necessary operations.

A nonoperative plan is equally active. It should specify permitted movement, mobilisation, any brace or collar, skin care, review arrangements and the findings that would trigger reconsideration. The patient and ward team need a usable prescription. "Conservative management" becomes meaningful only when it describes what care will actually be delivered.

Cord perfusion and the physiology of spinal injury

The mechanical insult may be followed by secondary neural injury. Hypoxaemia, inadequate perfusion and continuing compression are therefore part of the spinal treatment problem. Airway care, effective ventilation and circulation support preserve the conditions in which neural tissue can recover. The resuscitation room and critical-care unit participate in neurological treatment as directly as the operating theatre.

Neurogenic shock describes circulatory dysfunction after loss of sympathetic control, commonly associated with higher cord injury. Hypotension, vasodilatation and relative bradycardia may occur. Spinal shock describes depression of neurological activity and reflexes below the lesion, often with early flaccidity and areflexia. The two phenomena can coexist, but they refer to different aspects of the injury.

Haemorrhage must remain in the differential diagnosis of hypotension, including when a cord injury is established. A patient may have both blood loss and autonomic dysfunction. Blood replacement and source control are coordinated with the perfusion strategy; an apparently unremarkable pulse rate cannot settle the diagnosis.

The 2024 AO Spine/Praxis guideline suggests augmenting mean arterial pressure to a lower limit of 75-80 mmHg without active augmentation beyond 90-95 mmHg, for 3-7 days after acute traumatic SCI. These are weak recommendations based on very-low-quality evidence. The upper limit concerns active augmentation, not treatment to reduce an otherwise tolerated spontaneously higher pressure. Individual critical-care judgement is required, especially with associated haemorrhage or cardiovascular disease. [13]

The physiological plan should state its target, rationale, monitoring and review. This matters when different injuries create competing priorities. A shared discussion makes those priorities visible and allows the team to revise treatment as haemostasis, cardiac function and neurological assessment evolve.

Decompression, stabilisation and timing

Operative treatment may restore alignment, relieve neural compression, provide stability or achieve several of these objectives together. The operation should be selected for the actual lesion. Anterior compression, posterior tension-band failure and a dislocated segment create different reconstructive questions. The planned approach needs to explain which problem it solves and what function it seeks to protect.

The 2024 AO Spine/Praxis guideline recommends offering decompressive surgery within 24 hours of injury for adults with acute SCI when medically feasible, supported by moderate-quality evidence. It does not establish one universal ultra-early threshold below 12 hours. A deteriorating neurological examination requires urgent specialist action rather than waiting for an interval to elapse. [14]

In polytrauma, timing and operative extent are part of the same decision. Ongoing abdominal haemorrhage, severe chest injury or the physiological consequences of prone positioning may require a revised sequence. The team should state what prevents immediate treatment, what protection and resuscitation continue, and when readiness will be reassessed. Once the necessary conditions are present, organisational delay should be actively reduced.

This is where early appropriate care becomes a practical discipline. A sufficiently resuscitated patient may benefit from timely definitive stabilisation that supports respiratory care and mobilisation. A patient with limited reserve may need a staged strategy. The measure of success is the benefit to the whole person, including the ability to tolerate subsequent treatment and rehabilitation.

Conus, cauda equina and sacral dysfunction

Injuries near the thoracolumbar junction may affect both cord and roots, while lower spinal and sacral injuries can compromise the cauda equina or exiting sacral nerves. The neurological assessment therefore includes more than lower-limb power. Bladder, bowel, perineal and sexual function provide important information about the involved structures and the patient's needs.

New difficulty initiating urination, altered awareness of bladder filling or flow, retention, saddle sensory change or bowel disturbance requires prompt investigation in the appropriate setting. A suspected compressive cauda equina lesion requires urgent MRI and spinal review. A bladder scan is an adjunct to assessment; a low post-void residual does not safely exclude the syndrome. GIRFT provides a national pathway linking recognition, imaging and specialist care. [15]

In a patient with pelvic injury, urinary retention may have neurological, urological, pharmacological and pain-related contributors. The team should keep those possibilities connected while protecting the bladder from overdistension. Possible urethral injury influences how drainage is achieved. A catheter manages a consequence; it does not complete the investigation of the neurological cause.

Sacral displacement can injure roots through compression, stretching or direct trauma. Joint spinal and pelvic review determines whether reduction, stabilisation and direct decompression are indicated. The decision depends on the neurological trajectory and the demonstrated anatomy. The patient needs one explanation of that plan, even when its delivery requires several specialties.

Rehabilitation begins while the spine is being treated

The early care plan should anticipate breathing, pressure protection, joint movement, pain, nutrition, thrombosis risk, bowel and bladder function and psychological adjustment. These needs begin before a patient can participate fully in rehabilitation. A protected but poorly supported patient may accumulate preventable problems while waiting for definitive surgery or transfer.

The objectives are personal as well as neurological. Hand function may determine feeding, communication or wheelchair use. Sitting balance may determine transfers and independence. Continence, pain and sexual function may influence quality of life as deeply as walking. The patient's own priorities should help organise the rehabilitation programme as soon as participation is possible.

NICE rehabilitation guidance supports coordinated multidisciplinary care, assessment of changing needs and attention to the practical consequences of injury. [16] Specialist spinal-cord services contribute expertise in autonomic dysfunction, skin protection, respiratory support and long-term self-management. Patients without cord injury also need a clear recovery pathway for pain, mobilisation, return to work and surveillance of alignment or healing.

Communication should preserve realistic hope. Early findings can inform treatment without determining every aspect of the final outcome. The team can explain what is known, what remains uncertain and what the next stage aims to achieve. This helps the patient and family participate in decisions while avoiding promises that no examination or operation can guarantee.

The handover as protection of the next stage

A complete handover states the injured levels, neurological findings and trend, mechanical assessment, positioning instructions, devices, outstanding imaging, perfusion and respiratory needs, and the named team responsible for review. It includes bladder, bowel, skin and rehabilitation requirements. The quality of this transfer of responsibility can be as consequential as the quality of the physical transfer.

Consider three hypothetical situations. A patient with a burst fracture, intact posterior restraint and normal neurology needs a deliberate stability and mobilisation plan. A patient with a translation injury and preserved neurology needs protection and specialist stabilisation planning while that function remains intact. A patient with new weakness after a collision needs urgent evaluation of the cord even when initial CT does not explain the deficit. Each situation demonstrates why morphology, neurology and physiology must be read together.

For me, spinal trauma care returns to the image of a living foundation. We preserve the structure through which the person moves and the neural function through which the person acts, senses and maintains bodily control. Technical treatment, careful nursing, rehabilitation and honest communication all contribute to that task. The objective is a safe route from injury towards the fullest achievable life.

References

1. British Orthopaedic Association. *BOAST: Assessment of the Spine in the Trauma Patient*. April 2025. <https://www.boa.ac.uk/resource/boast-assessment-of-the-spine-in-the-trauma-patient.html>
2. National Institute for Health and Care Excellence. *Spinal injury: assessment and initial management*. NG41. <https://www.nice.org.uk/guidance/ng41/chapter/recommendations>
3. American Spinal Injury Association and International Spinal Cord Society. *International Standards for Neurological Classification of Spinal Cord Injury: official worksheet and resources*. Revised 2026. <https://asia-spinalinjury.org/international-standards-neurological-classification-sci-isncsci-worksheet/>
4. British Orthopaedic Association. *BOAST: The Management of Traumatic Spinal Cord Injury*. November 2022. <https://www.boa.ac.uk/resource/boast-the-management-of-traumatic-spinal-cord-injury.html>
5. Patel MB, Humble SS, Cullinane DC, et al. Cervical spine collar clearance in the obtunded adult blunt trauma patient: an EAST systematic review and practice management guideline. *Journal of Trauma and Acute Care Surgery*. 2015;78:430-441. <https://doi.org/10.1097/TA.0000000000000503>
6. AO Foundation. *AO Spine Thoracolumbar Injury Classification System*. Official classification toolkit. <https://www.aofoundation.org/spine/clinical-library-and-tools/aospine-classification-systems>
7. AO Foundation. *AO Spine subaxial cervical spine injury classification system*. AO Surgery Reference. <https://surgeryreference.aofoundation.org/spine/trauma/subaxial-cervical/further-reading/classification>
8. AO Foundation. *AO Spine sacral injury classification system*. AO Surgery Reference. <https://surgeryreference.aofoundation.org/spine/trauma/sacrum/further-reading/aospine-classification>
9. Vaccaro AR, Hulbert RJ, Patel AA, et al. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine*. 2007;32:2365-2374. <https://doi.org/10.1097/BRS.0b013e3181557b92>
10. Whang PG, Patel AA, Vaccaro AR. The development and evaluation of the Subaxial Injury Classification scoring system for cervical spine trauma. *Clinical Orthopaedics and Related Research*. 2011;469:723-731. <https://pmc.ncbi.nlm.nih.gov/articles/PMC3032869/>
11. Vaccaro AR, Lehman RA Jr, Hurlbert RJ, et al. A new classification of thoracolumbar injuries: the importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. *Spine*. 2005;30:2325-2333.

<https://doi.org/10.1097/01.brs.0000182986.43345.cb>

12. Lee JY, Vaccaro AR, Lim MR, et al. Thoracolumbar injury classification and severity score: a new paradigm for the treatment of thoracolumbar spine trauma. *Journal of Orthopaedic Science*. 2005;10:671-675. <https://doi.org/10.1007/s00776-005-0956-y>
13. Kwon BK, Tetreault LA, Martin AR, et al. A clinical practice guideline for the management of patients with acute spinal cord injury: recommendations on hemodynamic management. *Global Spine Journal*. 2024;14(3 Suppl):187S-211S. <https://doi.org/10.1177/21925682231202348>
14. Fehlings MG, Tetreault LA, Hachem L, et al. An update of a clinical practice guideline for the management of patients with acute spinal cord injury: recommendations on the role and timing of decompressive surgery. *Global Spine Journal*. 2024;14(3 Suppl):174S-186S. <https://doi.org/10.1177/21925682231181883>
15. NHS England, Getting It Right First Time. *National Suspected Cauda Equina Syndrome Pathway*. Current online pathway. <https://gettingitrightfirsttime.co.uk/academy-resources/pathways/>
16. National Institute for Health and Care Excellence. *Rehabilitation after traumatic injury*. NG211. <https://www.nice.org.uk/guidance/ng211/chapter/Recommendations>

CHAPTER 7

Plexus injuries

The nervous system converts anatomical survival into purposeful movement and sensation. A fracture may unite and a wound may heal while an injured plexus continues to determine whether a person can lift a cup, hold a child, stand securely or return to work. Plexus care therefore belongs within the first assessment of major trauma and within its long-term philosophy. We preserve life through resuscitation; we preserve possibilities through early recognition, careful localisation and timely access to reconstruction and rehabilitation.

This chapter follows the neural networks from the cervical spine through the shoulder and from the lumbar spine through the pelvis. Four questions connect anatomy to treatment: where is the injury, which structures remain functional, what evidence of recovery is emerging, and which intervention could improve a function the person values? These questions are revisited as swelling resolves, fractures are stabilised and the patient becomes able to participate in examination.



Figure 7.1. Conceptual cartoon: the trauma team protects the connections between brain, limb and everyday activity while planning neurological recovery.

Mechanism and clinical priorities

Traction is an important mechanism. Sudden separation of the head and shoulder, forcible displacement of the arm, or displacement across the pelvic ring can stretch neural structures beyond their tolerance. The result may range from transient conduction block to rupture or root avulsion. Penetration, compression, crush and associated vascular injury can also damage nerves; its structural extent is established through examination, investigation and follow-up. [1,2]

The initial trauma priorities remain resuscitation, haemorrhage control and treatment of immediate threats to the limb. Neurological assessment should begin as soon as the patient's condition permits and should continue through reduction, fixation, transfer and rehabilitation. When participation is limited by sedation, pain or consciousness, record the assessment as incomplete and specify when it will be repeated. [3]

What constitutes a plexus

A somatic nerve plexus is a network formed by anterior, or ventral, rami after spinal nerves have emerged from the vertebral column. Fibres are redistributed through this network into peripheral nerves. Consequently, injury to one plexus element can affect several muscles and sensory territories that belong to different terminal nerves. [2,4]

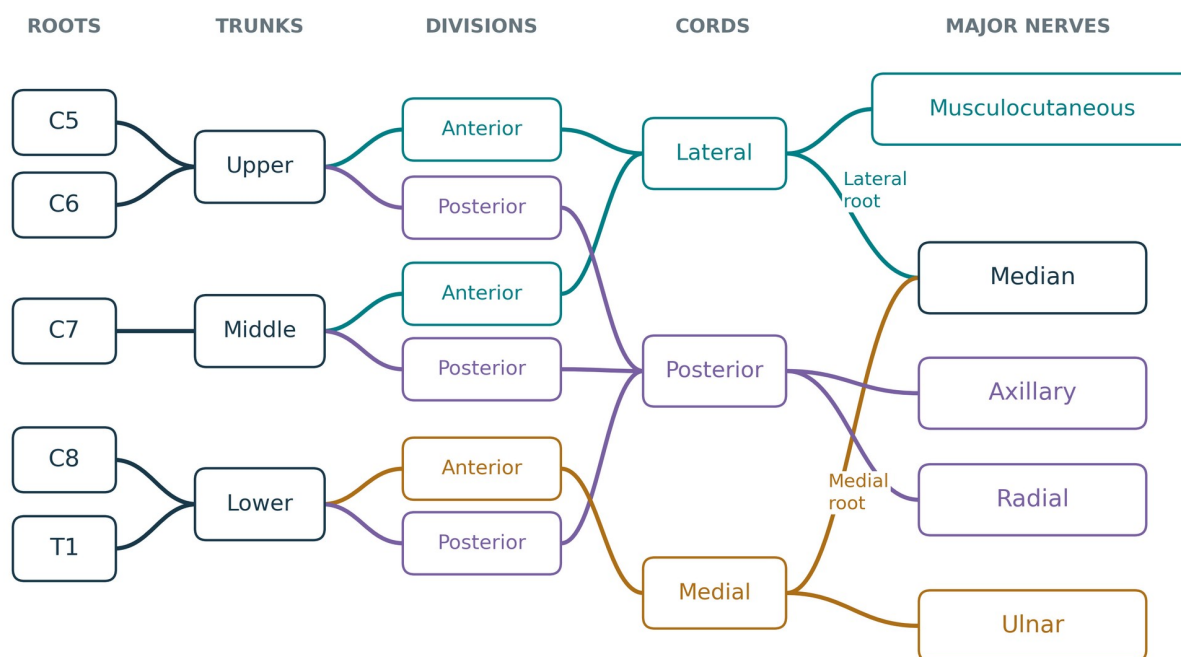
The recognised upper-limb network is the brachial plexus. Its infraclavicular portion extends into the axilla; the axillary nerve is one of its branches. In the lower limb, the lumbar and sacral plexuses communicate through the lumbosacral trunk. The lumbopelvic region brings these networks into close relationship with the posterior pelvic ring, sacrum and adjacent vessels. [4-6]

The brachial plexus

The usual brachial plexus receives C5-T1 anterior rami. These form three trunks, six divisions and three cords before giving rise to the major terminal nerves. C5 and C6 form the upper trunk, C7 continues as the middle trunk, and C8 and T1 form the lower trunk. [2,4]

Clinically, a proximal plexus injury may produce a pattern involving several peripheral nerves. Upper plexus involvement can compromise shoulder control and elbow flexion; lower plexus involvement may substantially impair hand function. Severe trauma can affect the whole plexus or produce mixed injuries at several levels. The examination maps the distribution and severity of each deficit, allowing the mechanical history to guide anatomical localisation. [1,2]

Brachial plexus: major connections



Roots here are the anterior (ventral) rami of C5-T1.

Major connections only: side branches and anatomical variants are omitted. Not to scale.

Figure 7.2. Brachial plexus: major connections from C5-T1 anterior rami to terminal nerves. Smaller branches and anatomical variants are omitted.

The axillary region and axillary nerve

The cords are named by their relationship to the second part of the axillary artery. This close association matters when shoulder-girdle trauma combines neurological loss with vascular injury. The axillary nerve usually carries C5-C6 fibres from the posterior cord. It passes through the quadrangular space and around the surgical neck of the humerus, supplying deltoid, teres minor and a patch of skin over the lateral shoulder. [4,6]

After shoulder dislocation or proximal humeral injury, assess axillary nerve function alongside the rest of the plexus and the circulation. Pain and instability may limit active testing. Record the limitation and repeat the examination when safe; both motor function and sensation contribute to the assessment of axillary nerve integrity. [3,6]

Lumbar and sacral plexuses in pelvic trauma

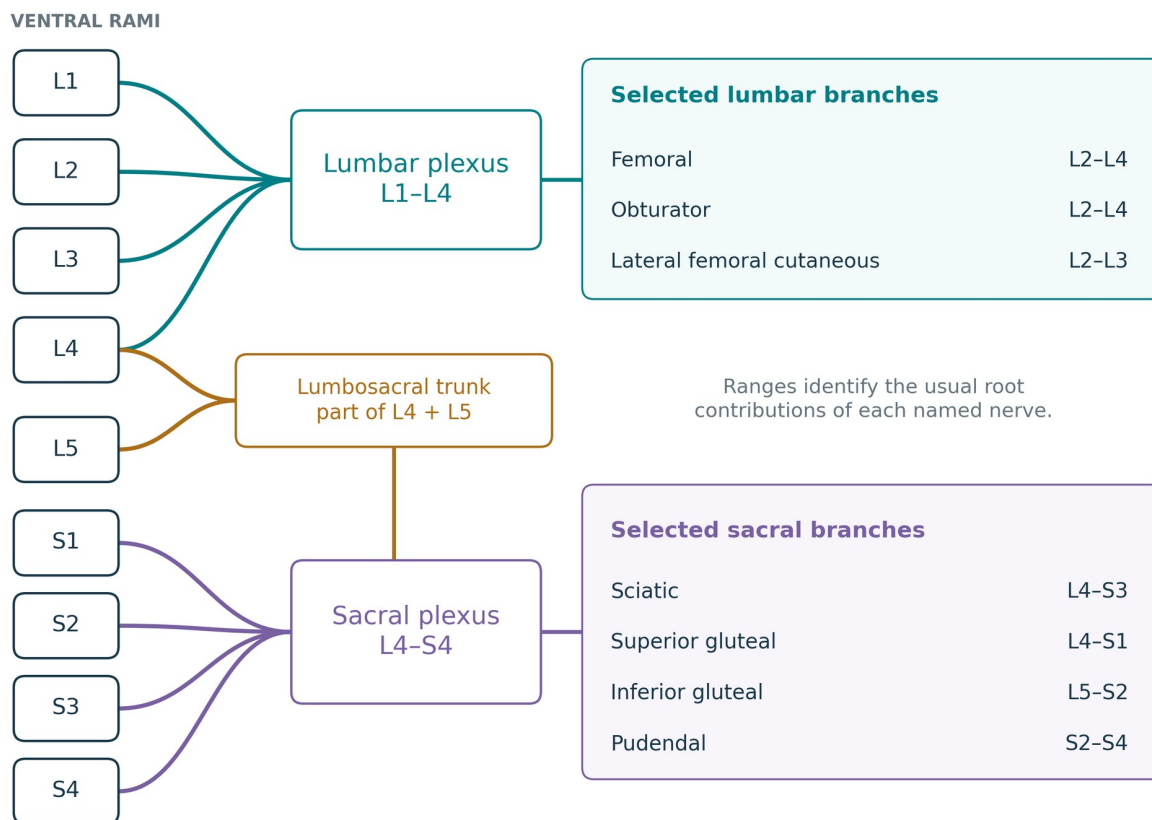
The lumbar plexus is formed mainly by L1-L4 within psoas major, sometimes with a T12 contribution. Part of L4 joins L5 as the lumbosacral trunk, which contributes to the sacral plexus, L4-S4, on the anterior surface of piriformis. Femoral and obturator nerves arise from the lumbar plexus; the sciatic nerve arises from the sacral plexus. [5,17]

Pelvic-ring disruption, sacral injury and regional haematoma may injure these structures. A sciatic deficit associated with acetabular or hip trauma may instead represent an individual nerve lesion.

Precise localisation connects pelvic anatomy to the functions that require protection and follow-up. [7,8]

Lumbar and sacral plexuses

Connected by the lumbosacral trunk



Selected branches only; variants (including T12 input to the lumbar plexus) are omitted.

Figure 7.3. Lumbar and sacral plexuses: the lumbosacral trunk connects lumbar contributions with the sacral network. Selected branches and usual root contributions are shown.

The structural severity of nerve injury

Seddon's classification connects functional loss to the structural injury within the nerve. The clinical deficit and the structural lesion are assessed together: severe weakness can accompany conduction block, while an externally continuous nerve can contain extensive internal damage. Sunderland adds detail by identifying which supporting tissue layers have been disrupted. [9,10]

Neurapraxia is conduction block with preserved axonal continuity, often associated with focal myelin disturbance. Recovery is generally expected as conduction is restored. Serial improvement helps confirm the diagnosis and establish its recovery trajectory. [10]

Axonotmesis involves interruption of axons and distal Wallerian degeneration. It may affect some or all axons in an injured segment. The supporting connective tissues are preserved to different degrees; recovery depends in part on the pathways available for regenerating axons. [9,10]

Neurotmesis describes complete structural interruption of the nerve. It can follow sharp transection or severe blunt disruption. Useful spontaneous recovery across complete discontinuity is not expected, and reconstructive assessment is required. [10]

Table 7.1. Sunderland grades: structure and implications. [9,18]

Grade	Structural injury	Meaning for recovery
I	Conduction block; axon remains continuous	Neurapraxia: recovery follows restoration of conduction
II	Axon interrupted; endoneurial pathways preserved	Axonal regeneration may follow the original pathway
III	Axon and endoneurium disrupted; perineurium remains	Regeneration may be misdirected and recovery incomplete
IV	Internal fascicular architecture disrupted; epineurium remains	Severe lesion in continuity; specialist reconstruction may be needed
V	Complete loss of nerve continuity	Neurotmesis; recovery across the injury requires reconstruction

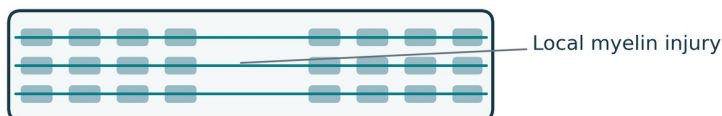
Nerve injury: structure determines recovery

Simplified longitudinal sections through a peripheral nerve

Teal line: axon · Blue segments: myelin · Outer outline: nerve envelope

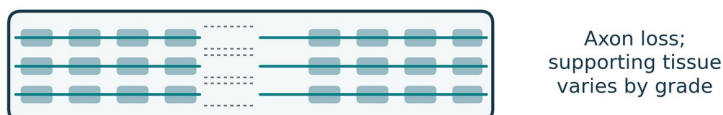
Neurapraxia

Axon remains continuous.
Conduction block may recover.



Axonotmesis

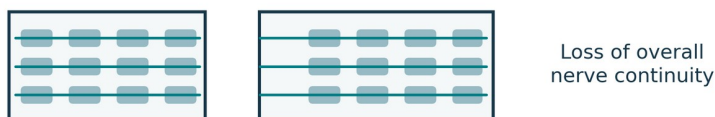
Axon continuity is lost.
Connective tissue: variable.



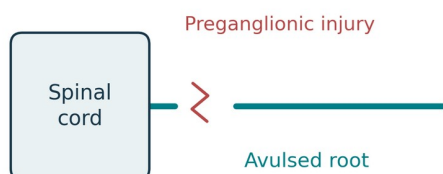
Dashed supporting tubes are illustrative: preservation differs in Sunderland grades II-IV.

Neurotmesis

Complete structural disruption;
spontaneous useful recovery
is not expected.



Root avulsion: a distinct proximal injury



A root is torn from the spinal cord.
There is no usable proximal root stump
for conventional graft repair to the cord.

Specialist reconstruction may use nerve transfers.

Not to scale. Mixed injury grades can coexist within one plexus; clinical recovery also depends on distance and time.

Figure 7.4. Structural patterns of nerve injury: conduction block, axonal disruption and loss of nerve continuity. Root avulsion is shown separately because it changes the reconstructive options.

Mixed grades can coexist within the same nerve or plexus. Prognosis also depends on the distance to the target muscle, associated ischaemia and scarring, and the time during which the muscle remains denervated. Clinical progression, imaging and neurophysiology must be interpreted together. [1,9]

Root avulsion and the level of injury

Preganglionic injury lies proximal to the dorsal-root ganglion; postganglionic injury lies distal to it. In root avulsion, the root is torn from the spinal cord. This is distinct from rupture farther along the plexus. Conventional grafting requires a usable proximal nerve source, which an avulsed root does not provide. Other reconstruction, including nerve transfers, may still be possible. [2,11]

Horner syndrome or other findings suggesting proximal involvement should increase concern, but no isolated sign proves avulsion. Severe traction can produce both preganglionic and postganglionic lesions. Specialist localisation helps identify which components could recover and which require reconstruction. [2,11]

Assessment in the multiply injured patient

Examine the whole patient before assigning weakness to a plexus. Brain, spinal cord, root, cauda-equina, peripheral nerve, muscle and tendon injuries may coexist. Pain, sedation and unstable fractures can make an otherwise meaningful motor test unreliable. The examination should state what was tested, what was found and what could not be tested. [2,7]

Document individual movements and muscle power, sensory territories, relevant reflexes and vascular findings. Record a comparable neurological examination at the first opportunity, after limb interventions, and before and after relevant surgery. Document the time and the examiner. The pattern and evolution of findings are more useful than an entry stating only “neurovascular status checked.” [3]

Table 7.2. A repeatable neurological examination. Safe movement limits are determined by the associated injuries. [2,4,5,7]

Region	Motor examples	Sensory examples
Shoulder and arm	Deltoid contraction, external rotation, elbow flexion and extension	Lateral shoulder and lateral/medial forearm
Wrist and hand	Wrist and finger extension, thumb opposition, finger abduction	Median, ulnar and radial territories separately
Hip and knee	Hip flexion, adduction and abduction; knee extension and flexion	Anterior/lateral thigh and medial leg
Ankle and foot	Dorsiflexion, eversion, plantarflexion, great-toe extension	Dorsum, first web space, lateral border and sole

These findings form a map interpreted by root, plexus and peripheral nerve. Record power, sensation, pain and the reliability of each test.

An ischaemic limb, an expanding haematoma or compartment syndrome needs urgent assessment and treatment alongside the neurological problem. Reduce a dislocation associated with nerve injury immediately through the appropriate trauma pathway, and repeat the examination afterwards. [3]

After pelvic or spinal trauma, new saddle sensory change, sphincter disturbance, or bilateral or progressive neurological loss requires urgent assessment for spinal, cauda-equina or sacral-root injury. They require an urgent central and sacral neurological pathway alongside assessment of the peripheral limb. [7]

Investigation and early specialist advice

Investigation should answer a clinical question: is the lesion in continuity, is a root avulsed, is there compression, and which targets retain a reasonable prospect of reinnervation? Trauma CT defines associated skeletal injury; vascular imaging follows the clinical concern for arterial damage. Dedicated MRI of the relevant spine and plexus, including MR neurography where available, may clarify the neural lesion. Specialists may select CT myelography when additional root detail is required. [1,7,9]

Electromyography and nerve-conduction studies help localise injury, identify axonal loss and follow reinnervation. A baseline study is commonly informative from approximately three to four weeks, with repeat assessment according to the clinical course. Very early testing may underestimate axonal damage. Referral, treatment of compression and indicated exploration should not wait for an EMG appointment. [1]

Preserved sensory nerve action potentials despite sensory loss may support a preganglionic lesion, whereas reduced responses after degeneration has developed support a postganglionic lesion. Mixed injuries and the timing of testing complicate this distinction; a single result should not overrule the full assessment. [2]

The UK BOAST standard distinguishes early specialist advice from the timing of reconstruction. Seek formal advice within 24 hours for a penetrating or lacerating injury with neurological deficit, and for peripheral nerve injury when associated fracture surgery is not indicated. Seek advice before planned internal fixation when a fracture is associated with nerve injury. A damaged nerve found during surgery, or a persistent new postoperative deficit after appropriate simple measures, requires immediate advice. [3]

Referral should include the mechanism, serial neurological findings, vascular status, imaging, associated fractures and the proposed operative plan. The receiving team needs enough information to coordinate nerve care with skeletal stabilisation and soft-tissue treatment. A named team and an agreed review date make observation an active treatment plan.

For a closed stretch injury, recovery may justify a period of observation under a specialist. This should include defined clinical milestones and a decision point for further investigation or reconstruction. An observation period is most useful when the patient knows the next milestone, the review date and the route for earlier advice.

Reconstruction and the limits of waiting

Specialist nerve surgery may involve plastic and reconstructive surgeons, hand surgeons, orthopaedic surgeons or neurosurgeons with appropriate training. The service needs access to neurophysiology, imaging, rehabilitation and the trauma teams treating the associated injuries. Competence in major nerve reconstruction is more important than the name of the parent specialty.

The operation depends on the lesion. Neurolysis may release a selected nerve from constricting scar. Direct repair joins suitable divided ends without tension. A nerve graft bridges a defect when appropriate proximal and distal targets exist. A nerve transfer redirects a functioning donor nerve or fascicle to a useful recipient, sometimes shortening the distance to the target muscle. The cost to donor function must be considered. [1,11,12]

Timing is individual. Sharp division, compression and suspected avulsion require prompt specialist decisions. For closed stretch or blunt brachial plexus injuries, a systematic review found generally better outcomes when reconstruction took place within six months. A period of about three months may allow evidence of spontaneous recovery to emerge in selected cases. Early referral allows those intervals to be used actively, with timing adapted to the lesion and the reconstructive objective. [13]

When nerve reconstruction cannot restore the desired function, selected tendon transfers or functioning muscle transfers may offer further options. The discussion should identify a practical goal, such as useful elbow flexion, a stable shoulder or improved grasp, and explain the uncertainty, rehabilitation burden and potential donor morbidity. [1]

Reconstruction of the lower plexus

Traumatic lumbosacral plexus reconstruction has a smaller and less consistent evidence base than brachial plexus reconstruction. Lesions may combine compression, traction and avulsion in patients with substantial pelvic, vascular and soft-tissue injury. Published series support individual specialist assessment, with the proposed operation and prognosis matched to the particular lesion. [8,14]

Some patients recover without nerve reconstruction; others have lasting deficits. The injury pattern, serial recovery and functional goals guide the discussion of prognosis. Severe traction and avulsion require particular caution when discussing prognosis. [8]

Expertise is concentrated in specialist services. Lower-plexus surgery is available in centres that explicitly include lumbosacral reconstruction in their practice, including the Royal National Orthopaedic Hospital. A regional referral pathway should make that expertise accessible to the injured person. [15]

Rehabilitation and the patient's future

Rehabilitation begins while the definitive neurological prognosis is still uncertain. Protect an insensate limb from pressure and thermal injury; maintain safe joint movement; support weak joints and prevent avoidable contracture. Exercise and splintage must respect associated fractures, soft-tissue injuries and any nerve repair. Orthoses may support the wrist or assist foot clearance when ankle dorsiflexion is weak. [7,10,16]

Neuropathic pain may persist even when the limb is numb. Pain assessment should distinguish neural symptoms from ongoing mechanical or vascular problems and should address sleep, mood and participation in therapy. Rehabilitation and pain specialists can help tailor treatment and monitor its effect. [10]

The patient also needs practical preparation for daily life: washing and dressing, transfers, walking, work and family responsibilities. Goals should be agreed with the patient and reviewed as function changes. Psychological support and occupational rehabilitation belong within the treatment plan, particularly when recovery is prolonged or incomplete. [16]

Follow-up should connect the original injury to present function. The record should show changes in power, sensation, pain, joint range and meaningful activities, together with relevant neurophysiology. A planned review also needs a route for earlier reassessment if weakness, pain or sensory loss progresses.

The philosophy of care

In major trauma, physiology determines our immediate priorities. Once those priorities are being addressed, we must also think about the life the patient will return to. A technically successful fracture reconstruction does not answer every question about the limb.

For plexus injuries, good judgement combines repeated examination, an honest account of uncertainty and timely access to specialist knowledge. Recovery is a biological process whose direction must be measured. Reconstruction is an opportunity whose usefulness must be judged against the patient's goals. Both depend on continuity of care.

Our responsibility is to preserve options while helping the patient understand them. That begins in the trauma bay and continues through reconstruction, rehabilitation and the practical work of regaining independence.

A team vignette: keeping neurological recovery visible

This fictional teaching vignette illustrates a coordination problem. A motorcyclist has a shoulder-girdle injury, chest trauma and a weak arm. Resuscitation and chest treatment take priority. A clinician documents the movements that can be tested safely and records the remainder as limited by pain. The hand is examined for perfusion; the radiological request identifies the shoulder vessels as a specific concern. After the shoulder is stabilised, the same movements and sensory territories are reassessed.

The orthopaedic and nerve teams agree a single neurological record, an investigation plan and the first review date. The therapist supports the arm, protects the insensate hand and helps the patient practise safe daily activities. At follow-up, the discussion begins with changes in function and the patient's priorities. The value of the pathway lies in preserving a reconstructive opportunity while recovery is observed, and in helping the person live safely during that observation.

Questions for the team

Which parts of the neurological examination are reliable today? Which deficit could reflect ischaemia, compression or central injury? Who owns the next assessment? What function would most change this person's independence? A service that can answer these questions connects its specialist knowledge to a coherent experience of care.

References

1. American Academy of Orthopaedic Surgeons. Brachial Plexus Injuries. OrthoInfo. Adult traumatic injury, diagnosis and treatment. [Source](#).
2. Abraham A, et al. Traumatic Brachial Plexopathy. AAPM&R KnowledgeNow. Updated 5 June 2025. General anatomy and electrodiagnostic localisation. [Source](#).
3. British Orthopaedic Association. BOAST Peripheral Nerve Injury. December 2021. [Source](#).
4. University of Arkansas for Medical Sciences. Anatomy Tables: Nerves of the Upper Limb. [Source](#).
5. University of Arkansas for Medical Sciences. Anatomy Tables: Nerves of the Lower Limb. [Source](#).
6. University of Arkansas for Medical Sciences. Topographical Anatomy of the Upper Limb. [Source](#).
7. American Academy of Physical Medicine and Rehabilitation. Traumatic Lumbosacral Plexopathy. PM&R KnowledgeNow. [Source](#).
8. Garozzo D, Zollino G, Ferraresi S. In lumbosacral plexus injuries can we identify indicators that predict spontaneous recovery or the need for surgical treatment? Results from a clinical study on 72 patients. J Brachial Plex Peripher Nerve Inj. 2014;9:1. doi:10.1186/1749-7221-9-1. [Source](#).
9. Griffith JF, Guggenberger R. Peripheral Nerve Imaging. In: Musculoskeletal Diseases 2021-2024. Springer; 2021. Table 18.1. doi:10.1007/978-3-030-71281-5_18. [Source](#).
10. Royal National Orthopaedic Hospital. Rehabilitation Following a Peripheral Nerve Injury (Brachial Plexus). Patient information guide. [Source](#).
11. Royal National Orthopaedic Hospital. A Patient's Guide to the Brachial Plexus. [Source](#).
12. Leeds Teaching Hospitals NHS Trust. Brachial Plexus Injuries: Your Condition and Treatment. [Source](#).
13. Martin E, et al. Timing of surgery in traumatic brachial plexus injury: a systematic review. J Neurosurg. 2019;130:1333-1345. doi:10.3171/2018.1.JNS172068. [Source](#).
14. Lang EM, Borges J, Carlstedt T. Surgical treatment of lumbosacral plexus injuries. J Neurosurg Spine. 2004;1:64-71. doi:10.3171/spi.2004.1.1.0064. [Source](#).
15. Royal National Orthopaedic Hospital. Peripheral Nerve Injury Unit. Specialist service scope. [Source](#).
16. National Institute for Health and Care Excellence. Rehabilitation after traumatic injury. NG211. 2022. Sections 1.2, 1.11, 1.13 and 1.16. [Source](#).
17. University of Arkansas for Medical Sciences. Anatomy Tables: Nerves of the Pelvis and Perineum. [Source](#).
18. Sunderland S. A classification of peripheral nerve injuries producing loss of function. Brain. 1951;74:491-516. [Source](#).

CHAPTER 8

Vascular injuries

Vascular injuries deserve a separate chapter because they can determine the outcome of major trauma within minutes. They belong prominently under C, circulation, but their consequences extend throughout the patient: cerebral ischaemia, loss of an organ, loss of a limb and the systemic consequences of shock. My starting point is therefore to ask two questions together: where is blood being lost, and which tissues are no longer receiving it?

An obvious bleeding vessel commands attention. An artery injured inside its wall may initially attract very little. This is the particular danger of blunt trauma: stretching, compression and deceleration can damage a vessel without producing an external wound. The challenge is to recognise both the patient who needs immediate haemorrhage control and the patient whose apparently satisfactory circulation conceals an evolving injury.

This chapter develops a physiology-led approach to adult vascular trauma. Mechanism suggests the vessel at risk; repeated examination reveals the evolving consequences; imaging defines anatomy when the patient can tolerate it; and a coordinated team turns that information into haemorrhage control and tissue perfusion. The operative method serves those objectives.



Figure 8.1. Conceptual cartoon: a coordinated vascular and trauma team restores circulation while maintaining attention to the whole patient.

Availability is part of treatment

Vascular expertise must be activated early when the mechanism, examination or physiology suggests serious vessel injury. In practice, a service needs more than a name on a rota. It needs a clinician who can attend promptly, a theatre that can receive the patient, blood products, appropriate imaging and a team capable of acting together. Resident and on-call arrangements vary; the practical question is whether the required skills reach the patient before preventable harm occurs.

I regard this as part of the philosophy of centralised major trauma care. The anaesthetist, trauma surgeon, vascular surgeon, orthopaedic surgeon, interventional radiologist and nursing team contribute different elements of one treatment. In a threatened limb, the sequence of their actions matters as much as their individual technical ability. Early discussion should settle who is leading, where the patient is going and what must happen first.

What has happened to the vessel

Vessels can fail by losing continuity, by losing patency, or by developing an abnormal communication. A partial wall injury may become more important over time. An initially patent artery can thrombose; a contained leak can enlarge; an arteriovenous fistula can remain unrecognised until swelling or a bruit develops.

Table 8.1. The vessel can leak, obstruct or develop an abnormal connection.

Injury	Structural change	Consequence
Intimal tear	Inner lining damaged, sometimes forming a flap	Flow can persist initially, followed by thrombosis or embolisation
Dissection	Blood separates layers of the wall	Narrowing or occlusion of the true lumen
Laceration or transection	Partial or complete wall disruption	Haemorrhage, ischaemia or both
Thrombosis	Injured vessel becomes obstructed	Loss of tissue perfusion, potentially without external bleeding
Pseudoaneurysm	Contained leak connected to the lumen	Expansion, compression, embolisation or delayed bleeding
Arteriovenous fistula	Communication between artery and vein	Abnormal flow, swelling, bruit or thrill

Blunt mechanisms are central to this book, particularly collisions, falls and crush injuries. Penetrating injuries remain an important cause of vascular trauma and may damage adjacent nerves, veins and viscera along the same trajectory. Local injury patterns influence preparedness: a service should understand the blunt, penetrating and crush mechanisms encountered within its population.

Read the physiology over time

The response to resuscitation helps determine whether there is time to investigate. The categories below describe a changing clinical state, not a permanent label. A patient may move rapidly from one category to another.

Table 8.2. Physiological response guides the next action.

Response	Observed trajectory	Clinical purpose
Sustained responder	Perfusion improves and remains satisfactory	Define injury with appropriate imaging while continuing surveillance
Transient responder	Initial improvement followed by deterioration or ongoing transfusion need	Prepare haemorrhage control; make a senior decision about safe, rapid imaging
Non-responder	No sustained improvement	Reassess shock and prioritise control of suspected ongoing bleeding
In extremis	Peri-arrest or profound collapse	Resuscitation and immediate life-saving intervention proceed together

NICE supports immediate CT in patients responding to resuscitation or with normal haemodynamics, while restricting imaging to what is needed to direct intervention in unstable non-responders. A negative FAST examination does not exclude abdominal or retroperitoneal bleeding. The decision integrates the likely diagnostic benefit, the time required and the patient's ability to remain adequately perfused during investigation. [1]

One satisfactory blood pressure should not close the assessment. Review the trend in consciousness, skin perfusion, pulse, pressure, urine output, lactate or base deficit, and blood-product requirement. Repeated examination must also remain open to other explanations for deterioration, including thoracic obstruction or cardiac injury. A vascular diagnosis does not remove the need to reassess the whole patient.

Coagulation and resuscitation

Anatomical haemorrhage and traumatic coagulopathy must be treated together. Check haemoglobin, platelets, coagulation tests, fibrinogen, blood gas, temperature and ionised calcium, with repeated testing and viscoelastic assessment where available. An initially reassuring haemoglobin concentration does not reliably quantify acute blood loss. Ask about anticoagulants and antiplatelet drugs and arrange appropriate reversal when indicated. [2]

Activate the local major haemorrhage protocol when required. Use blood-product resuscitation with subsequent laboratory or viscoelastic guidance, maintain warmth, correct hypocalcaemia and avoid unnecessary crystalloid dilution. Give tranexamic acid promptly for significant traumatic bleeding or its risk, within three hours of injury according to the applicable protocol; it does not replace haemorrhage control. Blood-pressure targets must account for associated brain injury, where cerebral perfusion is a competing priority. [2]

Repair and resuscitation are mutually dependent. Warmth, calcium, coagulation and perfusion influence whether a vascular reconstruction can succeed biologically. Haemorrhage control then

creates the conditions for sustained physiological recovery. The team should announce progress in both tasks during the operation.

Examination and its limits

Expose and examine the injured region, document findings and compare with the opposite limb where appropriate. Record palpable pulses by name, temperature, colour, capillary refill, motor function and sensation. Repeat the assessment after realignment, reduction, splinting, intervention and transfer. The record should show when the examination occurred and what changed.

Pulsatile haemorrhage, an expanding haematoma, a bruit or thrill, and a significant pulse deficit are classic hard signs. Diminished or asymmetric pulses, a history of substantial bleeding, a stable haematoma and an adjacent neurological deficit are concerning even when less dramatic. These findings must be interpreted alongside the mechanism and overall perfusion. [3]

NICE specifically cautions against using capillary refill or a Doppler signal to exclude vascular injury. Persistent hard signs after necessary limb alignment or joint reduction require immediate surgical exploration; imaging must not delay revascularisation of a devascularised limb. [4]

The presence of some distal flow does not prove that the vessel wall is normal. Equally, a poor signal during profound shock does not identify the exact site of injury. We need an explanation that fits the mechanism, the limb and the patient. A finding that does not fit should prompt reassessment, not reassurance.

Doppler and the ankle brachial index

Handheld Doppler detects flow; duplex ultrasound combines anatomical imaging with flow assessment. They are different examinations. Duplex can help with accessible vessels and follow-up, but pain, swelling, wounds, dressings and the urgency of polytrauma may limit its practical value. A positive flow signal can coexist with an intimal injury.

The ankle-brachial index compares ankle and brachial systolic pressure. Older EAST guidance uses an ABI below 0.9, or an abnormal examination, to trigger further investigation in selected penetrating lower-limb injuries. That guidance should not be applied as a universal clearance rule in blunt polytrauma. [3]

Current ESVS guidance places clinical examination and CTA at the centre of suspected extremity vascular injury and does not recommend ABI as a diagnostic exclusion test. [5] The pressure ratio must therefore be understood in the context of the selected pathway and injury population. In blunt polytrauma, unresolved concern about an artery warrants direct specialist assessment and appropriate imaging.

CT angiography must answer the question

When the patient can safely undergo imaging, CTA is central to identifying the vessel, the lesion and the tissues at risk. Arterial phase contrast timing, anatomical coverage and image quality matter; a routine scan does not automatically provide a diagnostic study of every artery.

ESVS recommends arterial and venous phase CTA as first-line investigation for suspected vascular trauma without clinical evidence of active bleeding. Patients too unstable for CTA should proceed

immediately to operative intervention. Potential renal impairment alone should not postpone urgent CTA for a life- or limb-threatening injury in a haemodynamically stable patient. [5]

Ask a focused question of the study: is there leakage, wall injury, narrowing, occlusion or distal perfusion? Does the scan include the entire region of concern? If findings and examination disagree, speak directly to the radiologist and treating surgeon. A report is one part of the assessment; it cannot resolve an inadequately imaged vessel by declaring the rest of the scan satisfactory.

Common patterns across the body

The following patterns should guide suspicion rather than replace examination. Several can coexist in one patient.

Neck and cerebral circulation

Blunt carotid or vertebral injury can follow neck loading and associated cervical spine or craniofacial trauma. Dissection and thrombosis may produce cerebral ischaemia after an initially symptom-free interval. A new focal deficit, or a neurological finding inadequately explained by the brain scan, should reopen the vascular assessment.

EAST recommends a screening protocol for blunt cerebrovascular injury, with CTA for high-risk cervical injuries and consideration in lower-risk cervical injuries. Confirmed injury generally calls for antithrombotic treatment as early as safely possible, agreed with the teams managing intracranial or other bleeding. Routine stenting of grade II or III blunt cerebrovascular injuries is not recommended. Surveillance and treatment must be individualised. [6]

Penetrating neck injury adds the immediate threats of haemorrhage and an expanding haematoma compromising the airway. Airway and vascular planning therefore need to occur together. A difficult anatomical location should trigger early expert involvement, not repeated uncontrolled attempts at local haemostasis.

Thoracic aorta and shoulder girdle

Sudden deceleration can injure the thoracic aorta, often near the isthmus. Survivors may have a contained injury rather than free rupture. Contrast CT is the principal diagnostic investigation. When repair is indicated, endovascular treatment is generally favoured where anatomy and expertise permit. Selected

stable patients may undergo delayed repair while other injuries are managed; suspected rupture or instability demands urgent action. Blood-pressure control is appropriate only in the context of adequate perfusion and competing injuries. [7]

Around the shoulder, subclavian and axillary vessels may be injured by displacement, traction or penetrating trauma. Associated brachial plexus injury can dominate the presentation. Examine the circulation and nerve function separately: a neurological explanation for a weak arm does not establish that its blood supply is intact. The clavicle and surrounding structures can also make proximal access difficult.

Abdomen and renal vessels

Abdominal vascular trauma may present as concealed haemorrhage, visceral ischaemia, or both. Consider the aorta, inferior vena cava, iliac vessels and the arterial and venous supply to individual organs. The location of a haematoma matters, but opening a contained haematoma without an agreed means of control may remove the tamponade on which the patient depends.

The renal pedicle is vulnerable to deceleration, including intimal disruption and thrombosis. Haematuria may be absent despite important vascular injury. Contrast CT in a sufficiently stable patient evaluates perfusion and associated damage; selective embolisation can control suitable arterial bleeding. Main-vessel occlusion, pedicle disruption and bilateral injury require urgent specialist decisions that account for perfusion time, renal function and the other kidney. [8]

Mesenteric injury can interrupt bowel perfusion as well as cause bleeding. A satisfactory blood pressure does not establish bowel viability. These injuries belong in a shared discussion with the abdominal trauma surgeon, especially where reconstruction, resection or later reassessment may be required.

Pelvis

Pelvic haemorrhage can arise from venous plexuses, fractured bone and arterial injury. Pelvic stabilisation, packing and embolisation address different components of that problem. A binder or stabilised ring does not establish that arterial bleeding has stopped, and arterial embolisation does not correct every source of pelvic blood loss. The sequence depends on physiology and rapid local access to treatment. [9]

Injury to the common or external iliac artery may also threaten a lower limb. In a patient with pelvic disruption, distal limb examination must remain part of the assessment rather than being postponed until attention turns away from the pelvis.

Upper and lower limbs

Fractures, dislocations, crush injuries and penetrating wounds can injure an adjacent artery. Useful anatomical associations include the axillary artery at the shoulder, brachial artery at the elbow, femoral vessels in the thigh and popliteal artery around the knee. The examination must include the hand or foot beyond the visibly injured segment.

Knee dislocation deserves particular vigilance, including when the joint has reduced before arrival. The important question is what happened at the time of injury. Original clinical studies support structured examination and selective imaging in defined populations, but also show the limitations of relying on an isolated finding. Serial assessment remains essential when immediate imaging or exploration is not undertaken. [10]

Control haemorrhage and restore perfusion

Proximal control is fundamental to operative management of a bleeding vessel. The team must anticipate the source of inflow, the possibility of distal back-bleeding and the consequences of opening the injured region. Temporary control creates the opportunity to assess and repair; it is not the end of treatment.

For external limb haemorrhage, immediate pressure, appropriate packing or a tourniquet may be required. Blind clamping should be avoided. Record tourniquet application time and communicate

it during every handover. An unstable patient with uncontrolled bleeding needs resuscitation and surgical intervention together. [11]

Definitive treatment may involve repair, an interposition graft, bypass, or selected endovascular treatment according to anatomy and purpose. [5] Selected non-occlusive lesions may be observed within a documented specialist plan. [3] The aim is appropriate haemostasis and perfusion with a repair the patient and injured tissues can tolerate. Observation means continuing responsibility for reassessment and follow-up.

Major venous injury must not be underestimated. It may cause profound blood loss and, in a limb, impair outflow after arterial flow is restored. Repair or ligation requires judgement about physiology, accessibility and the consequences of venous obstruction. Arterial patency alone is not a complete assessment of circulation.

Resuscitative endovascular balloon occlusion of the aorta requires particular selectivity, expertise and immediate access to definitive haemorrhage control. The UK randomised REBOA trial did not demonstrate a survival advantage and raised concern about harm. These findings support disciplined use within specialist pathways, with attention to the time and physiological costs of the intervention. [12]

The threatened limb and the order of reconstruction

For arterial injury associated with musculoskeletal trauma, the June 2026 BOAST emphasises that there is no safe ischaemic interval and that emergency revascularisation should commence within one hour of hospital arrival. This standard expresses the urgency of restoring perfusion; the operation should begin as soon as the necessary team is ready. [11]

BOAST recommends temporary shunting to restore flow rapidly, followed by skeletal reduction and stabilisation before definitive revascularisation. This addresses the practical conflict between a limb needing blood now and a repair needing a stable skeleton. ESVS guidance supports immediate definitive repair when it can restore perfusion promptly and temporary shunting when definitive reconstruction would introduce harmful delay. [5,11]

The decision should be made jointly and communicated clearly, with one agreed sequence of reperfusion, stabilisation, repair and coverage. What is the shortest route to reperfusion? Will fixation delay it? Will an unstable fracture threaten the repair? How will the graft be protected and covered? These questions are more useful than a rigid rule divorced from the injury.

Reconstruction must also consider muscle viability, nerve damage, contamination, soft-tissue loss and the patient's overall condition. A useful limb requires perfusion integrated with viable muscle, reconstructible soft tissues, skeletal stability and a realistic neurological prognosis. Decisions about amputation should include the patient when possible and appropriate senior multidisciplinary judgement, with the reasoning documented.

Reperfusion and compartment syndrome

Restoring flow can be followed by swelling and compartment syndrome. Crush injury, prolonged ischaemia and combined arterial and venous injury increase concern. Observational data associate earlier fasciotomy in selected vascular injury patients with better limb outcomes, but cannot establish a universal timing rule

for every injury. [13] Reperfusion also requires systemic monitoring for metabolic disturbance, rhabdomyolysis and renal dysfunction. [15]

Repeated assessment must include pain, pain with passive stretch, compartment tension, neurological findings and analgesic requirement. A palpable pulse does not exclude compartment syndrome. In an unconscious or otherwise unassessable patient, clinical silence is not reassurance; pressure measurement may be needed. Confirmed acute compartment syndrome requires immediate decompression. BOAST recommends hourly documented assessment in patients at risk. [14]

Fasciotomy must always be considered after revascularisation in musculoskeletal arterial trauma; a decision against it should be documented by the senior decision maker. [11] Follow-up must include the wounds and the functional limb, as well as the repaired vessel.

Continuing responsibility

The handover should specify the injured vessel, the lesion, treatment performed, remaining uncertainty, limb and neurological findings, tourniquet or ischaemia times where known, and the agreed surveillance plan. It should identify who must be called if perfusion changes. A further examination after transfer provides the receiving team with its own baseline.

Longer-term review should address recurrent ischaemia, delayed swelling or bleeding, graft or stent surveillance where appropriate, wound healing, nerve recovery and rehabilitation. Antithrombotic treatment and venous thromboembolism prevention need explicit decisions that take account of competing bleeding risks. The patient should understand which symptoms require urgent reassessment and which team owns follow-up.

For me, the central lesson is that vascular care is continuous. It begins with suspicion, develops through repeated examination and physiological assessment, and continues after the immediate threat has passed. The patient who is bleeding needs control without avoidable delay. The patient with a hidden vessel injury needs us to keep questioning an incomplete explanation. Both depend on a team that recognises when the next decision has become urgent.

A team vignette: the shared clock

In this fictional teaching case, a patient arrives with a deformed knee and a cool foot after a collision. Reduction and splinting are followed immediately by a documented reassessment. Perfusion remains unsatisfactory. The trauma leader activates the vascular and orthopaedic teams together, while anaesthesia and theatre staff prepare for emergency intervention. The same handover communicates injury time, examination changes and competing torso injuries.

At the brief, the teams agree how perfusion will be restored and how subsequent stabilisation will protect the repair. One clinician states the physiological limits of the operation; another confirms the equipment and personnel required. Following revascularisation, the nursing handover includes the baseline examination, compartment surveillance and the contact for deterioration. Successful collaboration is visible in the sequence of actions and in the clarity of responsibility after the operation.

Questions for the service

How quickly can the team capable of restoring blood flow assemble? Can arterial-phase imaging be incorporated into the initial scan when indicated? Who records the limb examination after each transfer? What happens when reperfusion is followed by increasing swelling? Preparing these answers before the next injury is part of treating the next patient.

References

1. National Institute for Health and Care Excellence. Major trauma assessment and initial management. NG39. 2016. Recommendations on haemorrhage and imaging. [Source](#).
2. Rossaint R, Afshari A, Bouillon B, et al. The European guideline on management of major bleeding and coagulopathy following trauma sixth edition. *Critical Care*. 2023;27:80. [Source](#).
3. Eastern Association for the Surgery of Trauma. Penetrating lower extremity arterial trauma evaluation and management. 2012. [Source](#).
4. National Institute for Health and Care Excellence. Fractures complex assessment and management. NG37. Recommendations 1.2.1-1.2.5. [Source](#).
5. Wahlgren CM, Aylwin C, Davenport RA, et al. European Society for Vascular Surgery 2025 clinical practice guidelines on the management of vascular trauma. *European Journal of Vascular and Endovascular Surgery*. 2025;69:179-237. Recommendations 9- 14 and 82-84. [Source](#).
6. Eastern Association for the Surgery of Trauma. Blunt cerebrovascular injury evaluation and management. 2020. [Source](#).
7. Eastern Association for the Surgery of Trauma. Blunt aortic injury evaluation and management. 2015. [Source](#).
8. Coccolini F, Moore EE, Kluger Y, et al. Kidney and uro-trauma WSES-AAST guidelines. *World Journal of Emergency Surgery*. 2019;14:54. [Source](#).
9. Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma WSES classification and guidelines. *World Journal of Emergency Surgery*. 2017;12:5. [Source](#).
10. Weinberg DS, Scarcella NR, Napora JK, Vallier HA. Can vascular injury be appropriately assessed with physical examination after knee dislocation? *Clinical Orthopaedics and Related Research*. 2016;474:1453-1458. [Source](#).
11. British Orthopaedic Association, BAPRAS and Vascular Society. Diagnosis and management of arterial injuries associated with musculoskeletal trauma. BOAST. Updated June 2026. [Source](#).
12. Jansen JO, Hudson J, Cochran C, et al. Emergency department resuscitative endovascular balloon occlusion of the aorta in trauma patients with exsanguinating hemorrhage the UK-REBOA randomized clinical trial. *JAMA*. 2023;330:1862-1871. [Source](#).
13. Farber A, Tan TW, Hamburg NM, et al. Early fasciotomy in patients with extremity vascular injury is associated with decreased risk of adverse limb outcomes a review of the National Trauma Data Bank. *Injury*. 2012;43:1486-1491. [Source](#).
14. British Orthopaedic Association. Diagnosis and management of compartment syndrome of the extremities. BOAST. Updated July 2025. [Source](#).
15. Kodadek L, Carmichael SP II, Seshadri A, et al. Rhabdomyolysis an American Association for the Surgery of Trauma Critical Care Committee clinical consensus document. *Trauma Surgery and Acute Care Open*. 2022;7:e000836. [Source](#).

CHAPTER 9

Extremity injuries

A limb injury may be the most visible part of major trauma. Deformity, an open wound or exposed bone naturally attracts attention. The task is to recognise its importance without losing the rest of the patient. A threatened limb can demand immediate action, while a technically complex reconstruction may need to wait until circulation, breathing and temperature have recovered.

The arms and legs are mobile structures exposed to direct impact, traction, torsion, bending and penetration. The mechanical event can damage skin, muscle, vessels, nerves, tendons, ligaments, cartilage and bone together. Understanding the limb therefore requires a synthesis of mechanism, soft-tissue biology and physiological reserve. The purpose of reconstruction is the best attainable function within the person's life.



Figure 9.1. Conceptual cartoon: orthopaedic, plastic, vascular, nursing and rehabilitation colleagues combine their skills around one injured person.

The soft tissues tell part of the story

A closed fracture has no communication between the fracture and the external environment through a wound. An open fracture does. The opening may be small, remote from the most obvious fracture level or produced by a fragment emerging through the skin. Bone need not be visible for the fracture to be open.

The direction of injury helps explain the biological problem. An inside-out puncture may result from a bone fragment passing through the skin; an outside-in impact may drive contamination and crushing into the deeper tissues. Energy transfer, contamination, tissue loss, periosteal stripping and arterial damage together determine the injury's severity and guide Gustilo-Anderson grading. The visible opening is one feature within that larger zone of damage. [1]

An intact skin surface can also be misleading. A closed injury may include major muscle contusion, degloving, vascular disruption or evolving compartment syndrome. Repeated examination should therefore ask whether the skin remains viable, whether swelling is increasing and whether the neurological or circulatory findings have changed.

Assessment that can be repeated

Record the mechanism, injury time, wounds, deformity, skin condition, distal perfusion and named motor and sensory findings. Document what cannot be tested. Repeat the examination after reduction, splinting, transfer and surgery. A precise record allows the next clinician to recognise change promptly. [2,3]

Inspect the joint above and below a fracture and the remaining limb. Complete the secondary and tertiary surveys when safe. An injured hand or foot can be overlooked while larger injuries dominate the first hours. The patient who later cannot use a walking aid or bear weight may be revealing an injury that was never adequately assessed.

Classification should describe the injury

Tscherne and Oestern developed a classification of soft-tissue injury in both open and closed fractures. For closed injuries, grades 0 to 3 describe increasing damage: from little or no injury, through superficial abrasion or contusion, to deep tissue damage and extensive crushing or degloving. The grade communicates the soft-tissue burden while compartment perfusion remains a separate, repeated clinical assessment. [4]

Gustilo-Anderson grading should be reassessed after operative exploration and wound excision reveal the injury zone. The simplified descriptions below support communication; the operative record should describe the actual structures, contamination and tissue loss. [1,5]

Table 9.1. Open-fracture severity: Gustilo-Anderson. The definitive description is based on the injury exposed during formal wound assessment and excision. [1,5]

Type	Core description
I	Small, usually less than 1 cm, relatively clean wound with limited soft-tissue damage
II	Wound larger than 1 cm without the extensive soft-tissue injury of type III
IIIA	Severe injury with adequate viable tissue available to cover the bone
IIIB	Extensive tissue loss and periosteal stripping; exposed bone requires reconstructive coverage
IIIC	Arterial injury requiring repair to maintain viability, regardless of wound size

Table 9.2. Closed-fracture soft-tissue injury: Tscherne-Oestern. [4]

Grade	Soft-tissue pattern
0	Minimal soft-tissue damage, often after an indirect mechanism
1	Superficial abrasion or contusion associated with the fracture
2	Deep abrasion, skin or muscle contusion and substantial local soft-tissue injury
3	Extensive crushing, subcutaneous degloving or destruction; vascular injury or compartment syndrome may coexist

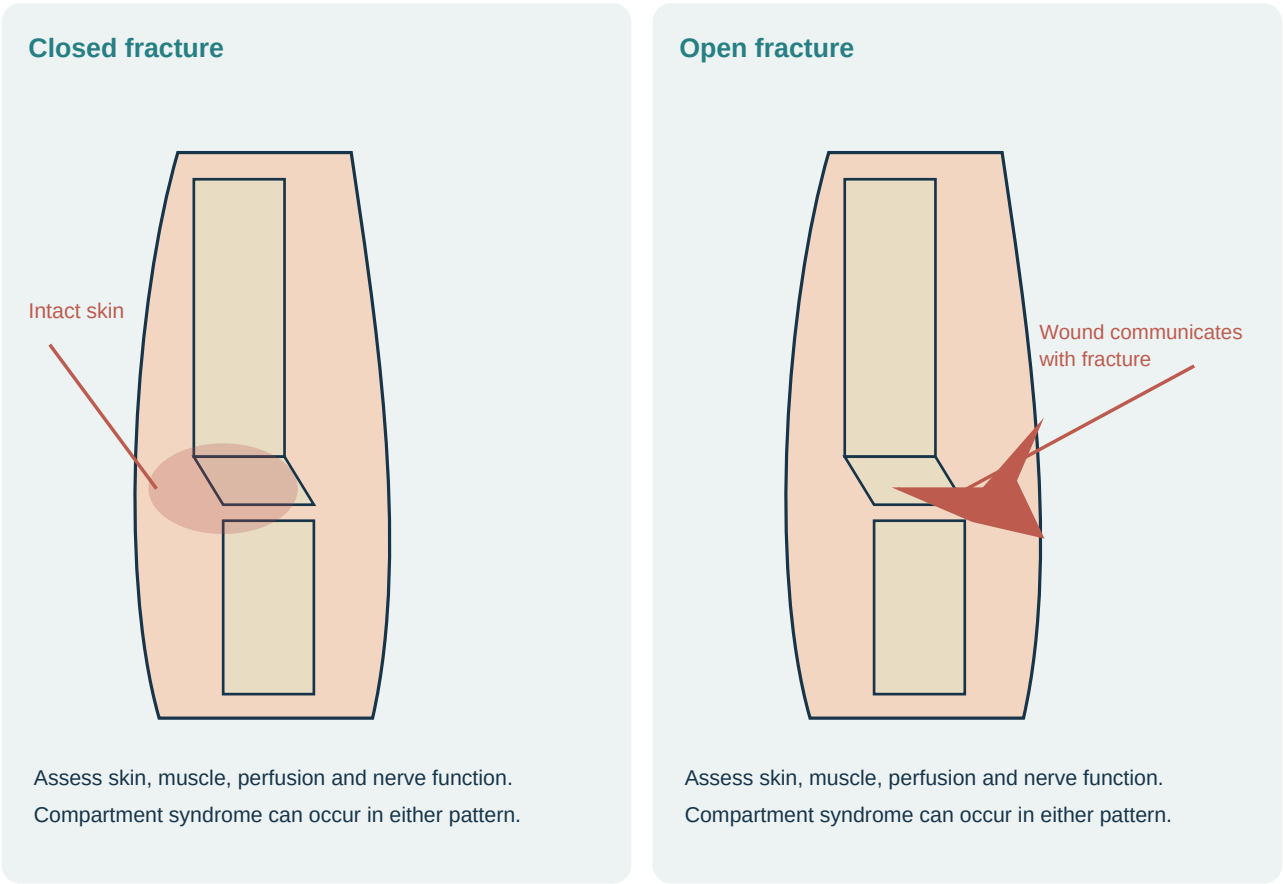


Figure 9.2. Closed and open fractures. An open wound communicates with the fracture; visible wound size alone does not describe the deeper soft-tissue injury. Both patterns require assessment for compartment syndrome. Schematic, not to scale.

Ask what must happen first

The first decision is the immediate purpose of treatment. Is the limb bleeding? Is it ischaemic? Is a dislocation stretching the skin, nerve or vessel? Is there compartment syndrome or gross contamination? These questions have priority over choosing the final implant.

A patient can need urgent limb treatment despite being too unstable for definitive fracture reconstruction. Conversely, a resuscitated patient may be suitable for definitive treatment without

an unnecessary period of temporary fixation. The reasoning described in Chapter 1 applies to each operation and should be reconsidered as the physiological course changes.

Early care of the open fracture

For open long-bone, hindfoot and midfoot fractures, activate the orthoplastic pathway. Give intravenous prophylactic antibiotics promptly, ideally within one hour of injury, under the network antibiotic policy. Record administration and address tetanus protection. Carefully realign and splint the limb. Remove gross surface contamination, document the wound appropriately and cover it with saline-moistened gauze and an occlusive dressing. Repeated emergency-department washouts add handling without replacing formal wound excision. [2]

BOAST specifies immediate debridement for highly contaminated wounds or vascular compromise, within 12 hours for other solitary high-energy open fractures, and within 24 hours for lower-energy injuries. These timeframes organise prompt access to appropriate expertise; clinical deterioration increases urgency. Orthopaedic and plastic surgeons should plan debridement, skeletal fixation and coverage together. Definitive closure or coverage should be achieved within 72 hours if not possible at the initial operation. [2]

The first operation needs a clear account of skin, muscle, tendon, nerve, vessel and bone injury. Wound excision establishes the viable boundaries of the injury. The operative endpoint is a biologically sound foundation for coverage and fixation, with a clear account of any area that requires reassessment.

Stability and coverage belong in one plan

The choice of external or internal fixation depends on physiology, fracture pattern, contamination, the soft-tissue envelope and the next operation. Temporary fixation should preserve alignment while leaving useful access for later reconstruction. The position of pins, bars and incisions has consequences for flap design, nursing and the definitive construct.

NICE recommends coordinated wound excision, fixation and definitive cover. When definitive internal fixation is selected for an open fracture, soft-tissue cover should take place at the same time. An interim dressing protects the wound during the interval to planned definitive coverage. The exact combination depends on the injury and the resources of the treating orthoplastic service. [6]

This is a practical example of why centralisation matters. Expertise in fixation and expertise in tissue coverage need to meet before the patient has accumulated avoidable procedures. The team should be able to explain why an operation is definitive, why it is staged, and what must happen before the next stage.

The limb with vascular compromise

Haemorrhage control and restoration of perfusion are related but different objectives. A tourniquet may control life-threatening external bleeding while creating an obligation to record the application time and arrange prompt definitive care. Blind clamping can injure neighbouring structures and should be avoided. [3]

Urgently realign and splint a pulseless, deformed limb, then reassess. Persistent ischaemia requires emergency consultant-led treatment. CT angiography is useful when it can define the lesion without delaying necessary reperfusion. A Doppler signal or reassuring capillary refill must not close the assessment when arterial injury remains possible. [3,6]

The June 2026 BOAST treats revascularisation as an emergency and specifies commencement within one hour of hospital arrival. Temporary shunting may rapidly restore flow, allowing prompt skeletal stabilisation before definitive vascular reconstruction. The sequence must be agreed by the treating teams. Every avoidable interval of ischaemia matters. Consider fasciotomy after revascularisation and record the senior decision. [3]

Compartment syndrome requires active surveillance

Rising pressure within a closed muscle compartment threatens tissue perfusion. Pain disproportionate to the apparent injury and pain on passive stretch are important findings, but reduced consciousness, neurological injury and analgesia may complicate interpretation. A palpable pulse does not exclude compartment syndrome.

The 2025 BOAST recommends hourly documented assessment in patients at risk. Where findings are inconclusive or examination is incomplete, senior review and pressure monitoring should be considered, with concurrent blood-pressure measurement. Release constricting circumferential dressings and reassess promptly while arranging definitive assessment. Once the diagnosis is made, immediate surgical decompression is required. [7]

A diastolic-minus-compartment pressure difference below 30 mmHg indicates increased risk; an absolute pressure above 40 mmHg is another reason to consider urgent decompression. These values require consultant interpretation with the clinical course. Pressure measurement must not delay treatment of an established clinical diagnosis. Decompress all involved compartments and document tissue viability and the subsequent wound plan. [7]

An open fracture does not reliably decompress every compartment. Reperfusion can also change the risk after an initially ischaemic limb has been restored. Surveillance therefore continues through the operation and handover; postoperative care includes the same vigilance for a changing limb.

Nerves, joints and the apparently smaller injury

A neurological deficit requires anatomical localisation, a description of severity and a plan to measure change. Record individual movements, sensory territories and the effect of pain or sedation. Associated dislocation, vascular injury, compression or an open nerve wound changes urgency. Chapter 7 develops the distinction between root, plexus and peripheral-nerve injury.

The BOAST peripheral-nerve standard requires early specialist advice for defined patterns, including advice before planned internal fixation of a fracture associated with nerve injury. A newly identified intraoperative injury or persistent new postoperative deficit needs immediate specialist discussion. Observation should include a named service, serial assessment and a review date. [8]

Joint injury can affect recovery even when the shaft fracture receives most of the early attention. An open joint, unstable dislocation, tendon disruption or threatened skin requires its own plan.

After reduction, confirm the result, reassess circulation and neurology, and investigate residual incongruity or instability. Avoid forcing a joint through painful movement merely to complete a checklist.

Hands provide grip and support for transfers; feet provide the contact through which walking becomes possible. Their assessment has to fit within safe movement limits, but it must not disappear from the major-trauma record. A satisfactory whole-body CT does not establish that every small bone, tendon or ligament has been examined.

Reconstruction or amputation

The objective is a surviving person with the best attainable function. Sometimes this requires limb salvage; sometimes amputation is the appropriate treatment. A limb that can technically be retained may still impose repeated operations, prolonged dependence and uncertain useful function. The discussion should make those burdens visible without assuming that disability makes a life less valuable.

NICE advises against using an injury-severity score alone to decide salvage or amputation. Emergency amputation may be required for uncontrollable life-threatening bleeding, unacceptable risk to life from attempted salvage, or an unsalvageable limb after specialist assessment. Other decisions require multidisciplinary input, including reconstruction and rehabilitation expertise, with the patient and family or carers involved where possible. [6]

An early sensory deficit should be interpreted in its anatomical and clinical context. It is not a substitute for the whole decision. Where time allows, explain expected operations, likely restrictions, pain, prosthetic or orthotic options and the uncertainty of each route. The patient should understand which questions are known and which remain open.

The first operation should help the next stage

Restoring length, alignment and useful stability can make nursing and rehabilitation possible. It can also impose blood loss, operative time and a physiological burden. The team should agree what benefit is needed now and what deterioration would change the plan. The first operation should deliver a defined benefit at a physiological cost the patient can tolerate.

Persistent drainage, wound breakdown, new neurological loss, increasing pain or failure to progress requires a fresh explanation. Follow-up must distinguish normal uncertainty from evidence of infection, mechanical failure, nonunion, vascular compromise or another remediable problem. The original treatment plan remains a hypothesis that the patient's recovery can challenge.

Write instructions that permit rehabilitation

Record weight-bearing status separately for each affected limb. BOAST uses non-weightbearing, limited weightbearing and unrestricted weightbearing. Restrictions should state the clinical reason, functional limits, duration, aids and review plan. Ambiguous labels or percentages of body weight are poor substitutes for instructions the patient can use. [9]

Ask how those instructions work together. A patient with an injured shoulder and a protected lower limb may be unable to use crutches. A patient with bilateral injury may need a different

transfer plan. Physiotherapy, occupational therapy, nursing and the surgical teams should resolve these problems before they become barriers to discharge.

The rehabilitation plan should address symptoms, function and the person's environment. NICE recommends coordinated assessment and goals agreed with the patient. The same injury may have different consequences for someone who climbs for work, cares for a relative or lives above several flights of stairs. Those circumstances belong in the clinical conversation. [10]

The philosophy of limb care

For me, the guiding question is what this treatment will allow the person to do. Bone union, soft-tissue survival and restored blood flow are necessary achievements, but the patient lives with their combined result. Pain, sensation, joint movement, strength and confidence determine whether that result becomes useful.

Good extremity care therefore begins with the whole patient and continues with the whole limb. It combines urgent treatment of time-critical threats with attention to tissue biology and realistic functional goals. Rehabilitation is the next expression of the same responsibility, and it is the subject of the final chapter.

The biological and physiological reasons for staging

Damage-control orthopaedics, early appropriate care and early total care describe strategies serving a common purpose: timely treatment matched to the patient. The decision incorporates the trajectory of resuscitation, associated organ injury, expected operative burden and local tissue conditions. A closed fracture beneath extensively bruised or blistered skin may require a different soft-tissue plan from a fracture in a healthy envelope, even when the patient's systemic physiology is similar.

Temporary stabilisation should be designed with the definitive reconstruction in mind. It can facilitate wound access, improve comfort, maintain length and make nursing safer. The subsequent conversion is a planned stage with an explicit indication, rather than a procedure attached to a fixed calendar. Equally, when physiology and tissue conditions permit definitive care, its benefits can include a stable platform for mobilisation and avoidance of additional anaesthetics. The team's task is to articulate the reason for its choice and the findings that would change it.

A team vignette: reconstructing useful function

A fictional patient has an open tibial fracture and an injured opposite wrist. The initial orthoplastic discussion covers wound excision, fixation and coverage. At the same time, physiotherapy identifies that ordinary crutch use will be difficult. Occupational therapy explores transfers and the home entrance. These findings are brought back to the surgical team before discharge instructions are finalised.

The reconstruction remains governed by safety and tissue biology, but its practical consequences become clearer. The team selects suitable aids, agrees a feasible transfer method and writes separate instructions for the leg and wrist. The patient understands the next operative or clinic

milestone. One coordinated plan now links the wound, the skeleton and the activities through which recovery will become meaningful.

Questions for the team

What did the mechanism do to the soft tissues beyond the fracture? Which problem is time critical? What is the purpose and stopping point of the next operation? How will this patient transfer, wash and move safely afterwards? These questions keep limb surgery connected to the whole philosophy of trauma care.

References

1. AO Foundation. Principles of management of open fractures. AO Surgery Reference. Classification and soft-tissue assessment. [Source](#).
2. British Orthopaedic Association. BOAST Open Fractures. December 2017. [Source](#).
3. British Orthopaedic Association, BAPRAS and Vascular Society. Diagnosis and management of arterial injuries associated with musculoskeletal trauma. June 2026. [Source](#).
4. Tscherne H, Oestern HJ. A new classification of soft-tissue damage in open and closed fractures. Unfallheilkunde. 1982;85:111-115. [Source](#).
5. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III severe open fractures. A new classification of type III open fractures. J Trauma. 1984;24:742-746. [Source](#).
6. National Institute for Health and Care Excellence. Fractures complex assessment and management. NG37. Recommendations. [Source](#).
7. British Orthopaedic Association. Diagnosis and Management of Compartment Syndrome of the Extremities. Updated July 2025. [Source](#).
8. British Orthopaedic Association. BOAST Peripheral Nerve Injury. December 2021. [Source](#).
9. British Orthopaedic Association. Mobilisation and weightbearing after orthopaedic surgery or musculoskeletal injury. August 2024. [Source](#).
10. National Institute for Health and Care Excellence. Rehabilitation after traumatic injury. NG211. 2022. [Source](#).

CHAPTER 10

Rehabilitation and functional return

The responsibility that follows survival

Major trauma can change the direction of a person's life in a few seconds. The immediate injuries demand resuscitation, surgery and intensive nursing care, but their consequences extend beyond the hospital admission. A person who previously worked, cared for a family and moved freely through the community may face a prolonged period of dependence. Some recover much of their previous function; others live with lasting disability. Our responsibility must include both possibilities.

Throughout this book, I have argued that the injured person must be understood as a whole. The energy transferred during trauma may damage several organs, and the effect of those injuries cannot be understood by considering each operation separately. In rehabilitation, this becomes particularly clear. A repaired lower limb may be ready for mobilisation while an injured upper limb prevents the use of walking aids. A satisfactory radiograph may coexist with disabling fatigue, fear or pain. The next useful treatment depends on how these problems interact.



Figure 10.1. Conceptual cartoon: an injured person and family work with rehabilitation colleagues towards home, relationships and meaningful daily activity.

I regard functional return as the final purpose of major trauma care. We should ask what the person needs to regain control over daily life, sustain relationships and participate in activities

they value. That question belongs in the first admission and should remain visible through reconstruction, rehabilitation and community follow-up.

This closing chapter brings the clinical and human themes of the book together. Physical capacity, cognition, mental health, home circumstances and employment influence one another throughout recovery. Specialist brain, spinal cord, nerve and amputation rehabilitation contribute within a shared plan directed by the person's needs and aspirations.

What functional return means

Rehabilitation seeks to improve functioning within the person's actual environment. The World Health Organization places everyday activities, participation and the interaction between health and environment at the centre of this approach. A disability therefore cannot be described adequately by an anatomical diagnosis alone. [1,2]

Consider two people with similar mobility limitations. One can enter an accessible home, reach a bathroom and travel to work. The other faces stairs, unsuitable transport and a job requiring prolonged standing. Their injuries may be comparable, but the practical consequences are different. Changing the environment can be as important to independence as improving strength or range of movement.

We should also distinguish returning to an activity from sustaining it. Walking across a therapy room does not establish that a person can manage a shopping trip. Completing one shift does not establish that the following week will be manageable. Useful assessment asks about effort, symptoms afterwards, the help required and whether the activity can be repeated safely.

The patient's own priorities give these assessments meaning. Being able to wash without assistance, take a child to school, resume study or visit friends may matter more than a small change in a clinical score. Goals should be ambitious enough to offer direction and realistic enough to guide the next step. When recovery changes, the goals can change without implying failure.

Rehabilitation begins during acute care

Early rehabilitation requires physiotherapy and occupational therapy to contribute alongside medical and nursing care. NICE recommends a coordinated assessment, an individual rehabilitation plan and review of agreed goals. Rehabilitation should begin as soon as clinically appropriate, with the intensity and content adapted to the person's condition. [3]

For patients who have required critical care, weakness and reduced endurance may be accompanied by cognitive and psychological difficulties. Assessment should address physical and non-physical morbidity, nutrition and the person's capacity to participate. Information and rehabilitation plans must follow the patient when they leave critical care. [4]

Early does not mean forcing activity through instability or ignoring a surgical reconstruction. The team needs explicit instructions about weight-bearing, joint movement, wound protection and any neurological or vascular precautions. Restrictions should identify the relevant limb or structure, the permitted activity and the point at which the instruction will be reviewed. An unexplained instruction to remain non-weight-bearing is an incomplete rehabilitation plan.

As a surgeon, I believe we should make the functional consequences of our decisions visible. If several limbs are injured, how will the patient transfer? If further surgery is planned, what can be

achieved safely in the interval? If immobilisation is necessary, how will we protect the rest of the person's function? These questions belong in the discussion of treatment, alongside fixation and tissue healing.

Rehabilitation medicine can help integrate competing restrictions and complex needs. Physiotherapy develops movement and physical capacity. Occupational therapy examines how the person performs daily activities and what adaptation or equipment would help. Rehabilitation nursing carries agreed approaches into everyday care. Speech and language therapy, dietetics, psychology, prosthetics and orthotics contribute according to need. These disciplines form part of the broader rehabilitation workforce described by WHO. [1]

Shared goals and clear responsibility

Centralisation brings specialist expertise together, but the benefit can be lost when the patient moves between services. A person should not have to reconcile contradictory instructions or explain the entire admission repeatedly. NICE supports a shared rehabilitation plan, coordinated handover and early discharge planning. [3]

My practical expectation is that each important goal has a named person or service responsible for moving it forward. A referral is the beginning of a handover. The team should know whether it has been accepted and

what happens while the patient waits. The following questions can keep multidisciplinary discussions connected to the patient's daily life.

Table 10.1. Questions for a coordinated rehabilitation review.

Domain	Question to resolve
Physical recovery	What is safe now, and which restriction needs review?
Daily activities	What can the person do independently, and where is help needed?
Mental health and cognition	What affects understanding, distress, safety or participation?
Home and family	Will the proposed arrangements work in this household?
Work or education	What demands must be assessed before a sustainable return?
Continuity	Who owns the next action, and whom can the patient contact?

Mental health is health

Mental health is integral to trauma care. Patients living with psychiatric illness, and patients injured through self-harm, require the same careful physical assessment, reconstructive ambition and access to rehabilitation as every other injured person. Their mental health needs should be addressed alongside those physical needs, with compassion and appropriate expertise.

A major trauma admission may bring previously unrecognised mental health needs to attention. Other patients develop distress during recovery, or experience a recurrence of an existing illness.

We should avoid assuming that every person who is frightened, withdrawn or angry has the same problem. Pain, sleep disruption, delirium, brain injury, medication effects and difficulty communicating may all require consideration before behaviour is interpreted.

Compassion requires practical changes as well as respectful language. A person with a learning disability, sensory impairment or communication difficulty may need accessible explanations, additional time, an interpreter or support from someone who knows them well. Participation improves when the service adapts its communication. These principles are consistent with NICE guidance on patient experience. [5]

Psychologists and psychiatrists have complementary roles. Psychological assessment can help the team understand distress, adjustment and barriers to rehabilitation. Liaison psychiatry is especially important when there is serious mental illness, diagnostic uncertainty or concern about self-harm. Patients and families should understand why a referral is offered; it should not be presented as punishment for difficult behaviour.

After self-harm, psychosocial assessment should proceed alongside physical treatment as soon as the person can participate. NICE advises against waiting until medical treatment is complete and against using risk scores or broad risk categories to decide treatment or discharge. Assessment should identify the person's needs, circumstances and immediate safety concerns, with a collaborative care and safety plan. [6]

Psychological treatment must fit the identified problem. For adults with clinically important post-traumatic stress symptoms or PTSD, NICE recommends trauma-focused therapies, including trauma-focused cognitive

behavioural therapy; EMDR is another recommended option in appropriate circumstances. Routine psychologically focused debriefing is not recommended. A person should not be compelled to recount the event as a condition of receiving support. [7]

When participation becomes difficult, the team should ask what the person has understood, what they fear, whether symptoms are controlled and whether the proposed activity is achievable. Learning disability, communication differences, psychiatric illness and complex physical needs call for an adapted approach. The service demonstrates its quality by making rehabilitation accessible to the person in front of it.

Our Swedish study of high-energy pelvic injuries identified an association between intentional falls from height and mortality within the first year. In the context of that cohort, the finding strengthens the argument for coordinated physical and mental healthcare extending beyond the acute admission. Each person's rehabilitation potential remains a matter for individual assessment. [8]

Pain and the pace of recovery

Persistent pain can limit activity and confidence long after the emergency has passed. In the Victorian longitudinal study led by Gabbe, half of respondents at three years reported pain or discomfort on the EQ-5D questionnaire. This describes a substantial continuing burden, although it does not specify the cause of pain in each person. [9]

Continuing pain deserves a fresh clinical explanation even after fracture union. The clinical question remains whether there is a remediable problem, a neuropathic component, a mechanical

limitation or a need for specialist pain rehabilitation. The management plan should explain what has been considered and how progress will be judged.

Pain treatment and functional goals should be discussed together. The aim may initially be to tolerate dressing, sleep more consistently or take part in a short therapy session. Progress does not have to mean complete symptom resolution. Equally, a sudden deterioration or a new symptom should prompt reassessment rather than an automatic instruction to persevere.

Recovery often changes pace. Further surgery, a setback at home or loss of confidence may require the plan to be revised. We should explain uncertainty honestly and maintain access to review. A person who needs a different route through rehabilitation has not failed the original plan.

Returning home and supporting the household

Going home is a major transition. The patient leaves an environment where help is close and enters one where small practical obstacles can determine the whole day. Home adjustment must therefore be considered before discharge, with the patient, family or carers, occupational therapy and relevant community services. Equipment, support and follow-up should be arranged around the assessed needs. [3]

A discharge destination should be tested against ordinary activities. Can the person enter the property, get to the toilet at night, prepare food and obtain medicines? Can they use the equipment in the available space? Who will help when the person who usually provides support is at work? The discharge plan should document how these ordinary activities will be managed.

Families need to be partners in planning, with the patient's agreement. They also need an honest discussion about what they can sustain. We should not assume that a relative can provide unlimited care, lift safely or

give up employment. The impact on children and other dependants deserves attention, as does the possibility that the injured person was previously the main carer.

Social workers, housing teams, community rehabilitation and relevant public agencies may need to coordinate their contributions. Where adaptations or support are delayed, I favour an explicit interim plan with a named contact and a review date. Responsibility should remain visible while the patient moves through administrative processes.

Returning to society also includes privacy, intimacy, cultural life and companionship. These subjects can be difficult to raise on a busy ward, but they may become central once immediate survival is secure. The patient should have a private opportunity to explain what matters and be directed to appropriate expertise.

Work, education and financial recovery

A previous job may no longer match the person's physical or cognitive capacity. This can threaten income, identity and confidence at the same time. We should introduce the possibility of vocational rehabilitation early, without making promises about dates or implying that paid employment determines the value of recovery.

Occupational therapy and occupational health make complementary contributions. Occupational therapy addresses meaningful activity and daily function. Occupational health helps assess work

demands and suitable workplace arrangements. With the person's agreement, discussion with the employer can address phased hours, modified duties, equipment and review points. NICE guidance on long-term sickness absence emphasises agreed adjustments and sustainable return. [10]

The work itself must be understood. A job title rarely explains the need to climb, lift, drive, concentrate, make safety-critical decisions or cope with an unpredictable shift. Travel to work and recovery afterwards also affect feasibility. Where the previous role remains unsuitable, retraining, further education or a different role may offer a realistic route forward.

Return should be assessed over time. Collie, Gabbe and colleagues followed 1,086 people who had been working or in full-time education before major trauma. Over four years, the study identified early sustained, delayed, failed and absent return. This supports asking whether participation lasts, rather than recording only the first day back. These trajectories help services plan follow-up while individual recovery is assessed over time. [11]

Financial support deserves a place in clinical planning because financial insecurity can make practical recovery harder. Patients may need independent advice about benefits, employment arrangements, insurance or compensation. Advice should be tailored to their circumstances and jurisdiction. People who were retired, unemployed or providing unpaid care before injury need equally serious attention to their goals.

Day One and support from lived experience

At Leeds General Infirmary, Day One Trauma Support offers an important example of support extending beyond the immediate treatment of injuries. Professor Peter Giannoudis and former patients established Day One in 2014. It became an independent national charity in May 2021. Its development reflects the recognition that patients and families need practical and emotional help while rebuilding their lives. [12]

Day One describes support including small grants, benefits and welfare advice, legal support, counselling and contact with peers who have experienced major trauma. These services address concerns that may be difficult

to resolve within a surgical consultation. Availability and individual arrangements should be checked with the charity. [13]

I regard the contribution of charities and people with lived experience as an essential part of a humane trauma community. A peer supporter may help someone formulate a question they have not yet found words for. Families may find reassurance in speaking to others who understand the uncertainty of recovery. Such relationships should respect the person's preferences and readiness.

Charitable support should strengthen a properly funded rehabilitation system. Patients should receive clinical care and necessary social support according to need, with voluntary organisations contributing their particular expertise. Fundraising and public awareness can also help society understand why the consequences of trauma continue after discharge.

What long-term research tells us

Professor Belinda Gabbe and colleagues in Australia have made a substantial contribution by following patients beyond the acute admission. Their study of severe pelvic ring fractures is particularly relevant to orthopaedic trauma. Of 114 eligible survivors, 111 participated in follow-up. At 24 months, 78 of 101 assessed participants were living independently; among previously employed participants with work data at that point, 40 of 68 had returned to work. Independent living and return to work capture distinct dimensions of recovery. [14]

Those findings demonstrate both the possibility of improvement and the extent of continuing need. Individual prognosis also reflects associated injuries, previous health and the environment to which the person returns. The study concerned selected severe pelvic injuries treated at two Australian major trauma centres; associated injuries, complications and social circumstances influence interpretation.

The wider Victorian study of long-term health found persistent difficulties with mobility, daily activities, pain and emotional health at three years. Its anxiety and depression measure recorded questionnaire-reported problems, not confirmed psychiatric diagnoses. The authors also identified responder bias. The implication is that trauma systems need continuing outcome assessment, while recognising the limitations of the data they collect. [9]

Research also informs the use of resources. An Australian observational evaluation by Gabbe and colleagues compared baseline care, a new ward environment and then a new allied-health model. The allied-health phase was likely to be cost-effective compared with both earlier phases. The study supports evaluation of rehabilitation investment while local service design and costs determine how its findings translate into another health system. [15]

For commissioners, insurers, healthcare leaders and elected representatives, I believe the relevant question is the total consequence of injury over time. A hospital budget captures only part of that consequence. Continuing care, home adaptations, interrupted employment and the work of relatives also matter. Funding decisions should examine whether services help people regain and sustain participation, as well as what those services cost.

Measuring recovery that matters

Mortality, complications and readmission remain essential measures, but they cannot describe the whole result of trauma care. Follow-up should also capture what the person can do and how they experience life. Validated measures such as EQ-5D, the Glasgow Outcome Scale Extended in appropriate populations, and

WHO's WHODAS 2.0 can contribute. Their results need to be interpreted alongside the patient's own goals and injury-specific assessments. [9,14,16]

The following domains provide a practical framework for discussion. They are not a new validated scoring system. I would use them to prevent a technically successful reconstruction from obscuring an unresolved problem in daily life.

Table 10.2. Recovery that matters to the person. This framework supports discussion and is not a validated score.

Domain	Meaningful evidence of progress
Independence	Daily activities become safer or require less unwanted assistance
Symptoms and capacity	Pain, fatigue and endurance allow more consistent activity
Mental health and cognition	Distress, understanding and safety needs are recognised and addressed
Participation	Chosen family, community or leisure activities resume
Work and education	Participation is appropriate, supported and sustainable
Patient priorities	Progress reflects goals the person continues to value

The final purpose of major trauma care

The early chapters of this book ask what must happen now to preserve life and prevent further injury. This final chapter asks what must happen afterwards to make that survival meaningful to the person who has lived through it. These responsibilities are connected. The choices made during resuscitation and reconstruction shape the possibilities for rehabilitation, while the patient's future life should inform how we judge the success of treatment.

Some people will return to their previous activities. Others will need adaptations, a different occupation or continuing assistance. Our task is to support the best attainable recovery without withdrawing ambition or denying the reality of lasting impairment. A person can live a valuable and fulfilling life with disability, and should have access to the support that makes this possible.

For me, a mature major trauma service continues to care about the person after the wounds have healed and the immediate danger has passed. It treats mental health with the same seriousness as physical health. It listens to families, works with rehabilitation and community colleagues, and learns from long-term outcomes. Functional return is the expression of that continuing responsibility: helping the injured person regain agency and a place in the life they choose.

A team vignette: recovery in the real household

In this fictional teaching case, a person recovering from pelvic and upper-limb injuries can walk a short distance on the ward. The home is reached by stairs, the main bathroom is upstairs and the patient usually cares for an older relative. The ward achievement is valuable, yet the next stage requires more than a distance recorded in the notes.

A coordinated review begins with the patient's account of an ordinary day. Therapy staff assess transfers and endurance; nursing colleagues explain the assistance still needed; the surgical teams review restrictions; and the discharge coordinator identifies equipment and community support. With the patient's agreement, the family describes what help it can sustain. The rehabilitation plan now addresses both the injured person's recovery and the responsibilities that previously organised the household.

The follow-up conversation asks whether the plan works. Difficulties are treated as information for revision. This approach turns discharge into a supported transition and gives the patient a clear route back to the team when the real environment exposes an unmet need.

Questions that should outlive the admission

What does the person most want to regain? Which barriers can treatment change, and which require an adaptation of the environment? Who remains responsible when care crosses an organisational boundary? How will the service know whether its patient can sustain the activities that have resumed? A trauma system becomes mature when these questions remain visible after immediate survival is secure.

References

1. World Health Organization. Rehabilitation. Fact sheet. 2024. [Source](#).
2. World Health Organization. International Classification of Functioning, Disability and Health. [Source](#).
3. National Institute for Health and Care Excellence. Rehabilitation after traumatic injury. NICE guideline NG211. 2022. Sections 1.1 to 1.8, 1.11 and 1.13. [Source](#).
4. National Institute for Health and Care Excellence. Rehabilitation after critical illness in adults. Clinical guideline CG83. 2009. [Source](#).
5. National Institute for Health and Care Excellence. Patient experience in adult NHS services. Clinical guideline CG138. 2012. [Source](#).
6. National Institute for Health and Care Excellence. Self-harm: assessment, management and preventing recurrence. NICE guideline NG225. 2022. Sections 1.5, 1.6 and 1.11. [Source](#).
7. National Institute for Health and Care Excellence. Post-traumatic stress disorder. NICE guideline NG116. 2018. Sections 1.6.5 and 1.6.15 to 1.6.20. [Source](#).
8. Bakhshayesh P, Weidenhielm L, Enocson A. Factors affecting mortality and reoperations in high-energy pelvic fractures. *European Journal of Orthopaedic Surgery and Traumatology*. 2018;28(7):1273-1282. doi:10.1007/s00590-018-2203-1. [Source](#).
9. Gabbe BJ, Simpson PM, Cameron PA, Ponsford J, Lyons RA, Collie A, et al. Long-term health status and trajectories of seriously injured patients: A population-based longitudinal study. *PLoS Medicine*. 2017;14(7):e1002322. doi:10.1371/journal.pmed.1002322. [Source](#).
10. National Institute for Health and Care Excellence. Workplace health: long-term sickness absence and capability to work. NICE guideline NG146. 2019. Sections 1.6 and 1.7. [Source](#).
11. Collie A, Simpson PM, Cameron PA, Ameratunga S, Ponsford J, Lyons RA, et al. Patterns and Predictors of Return to Work After Major Trauma: A Prospective, Population-based Registry Study. *Annals of Surgery*. 2019;269(5):972-978. doi:10.1097/SLA.0000000000002666. [Source](#).
12. Day One Trauma Support. Our story. [Source](#).
13. Day One Trauma Support. I have had a traumatic injury and need support. [Source](#).
14. Gabbe BJ, Hofstee DJ, Esser M, Bucknill A, Russ MK, Cameron PA, Handley C, de Steiger RN. Functional and return to work outcomes following major trauma involving severe pelvic ring fracture. *ANZ Journal of Surgery*. 2015;85(10):749-754. doi:10.1111/ans.12700. [Source](#).
15. Gabbe BJ, Reeder S, Ekegren CL, Mather A, Kimmel L, Cameron PA, Higgins AM. Cost-effectiveness of a purpose-built ward environment and new allied health model of care for major trauma. *Journal of Trauma and Acute Care Surgery*. 2023;94(6):831-838. doi:10.1097/TA.0000000000003950. [Source](#).
16. World Health Organization. WHO Disability Assessment Schedule WHODAS 2.0. [Source](#).