# Soft tissue injuries: principles of biomechanics, physiotherapy and imaging

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*Emerg. Med. J.* 2008;25;158-162
doi:10.1136/emj.2007.052555

# Soft tissue injuries: principles of biomechanics, physiotherapy and imaging

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Accepted 30 July 2007

In the second of this series on soft tissue injury, the principles of biomechanics, physiotherapy and imaging are covered. Although injuries vary immensely in severity and according to location, an understanding of key areas helps practitioners to assess and manage injuries from first principles. The "key areas" involved include anatomy, physiology and pathology, subjects which tend to be learned now in less detail than previously.

The ability to assess injuries from first principles is a learning goal, and structured learning combined with supervised clinical teaching should allow all practitioners to develop this expertise. Sufficient volume of clinical caseload is perhaps the rate-limiting factor for many, partly through more sensible rotas, partly because safety in the home, workplace and roads has minimised serious injury, and partly as the gross pathologies of the past tend to be resolved at a much earlier stage.

## HUMAN BIOMECHANICAL PRINCIPLES

Human biomechanics is the science that studies how our bodies function as machines, that is, how they cope with all the stresses and strains of life. It explores the reasons for "component failure" or injury. Biomechanics is a huge subject area; this section can only skim the surface. Readers are referred to *"The Human Machine"*[1] for a very thorough review of the subject. Many of the concepts in this section are taken from that book.

The relationship between joints and muscles is precise. Whatever range of movement a joint possesses, it is surrounded by muscles which can achieve this range. All muscles are arranged in opposing pairs, with perfect balance between them. When one muscle contracts, its opposing partner relaxes, yet maintains enough tone to stabilise the joint.

The complexity of dynamic muscle control can easily be demonstrated. If a healthy human being stands on one leg with closed eyes, he/she will stay upright. Clearly it is dynamically balanced muscle tone that maintains stability. Muscles constantly alter their tone to maintain balance and the stability of the joints.

The most important concept in musculoskeletal medicine is that the proper function of joints is maintained by muscle power, constantly responding to stresses sensed through the stretch and proprioception system. If a joint is "rested", proprioception becomes less efficient and muscles lose tone and bulk. After an acute knee injury, quadriceps wasting occurs within days. The proprioception/muscle "servo" mechanism is the main stabiliser of joints. Failure of simple rehabilitation advice can prolong the time to recovery by months. If a patient is given crutches and does not weight bear after an ankle sprain, after a week they may try to weight bear but the ankle feels "weak" due to poor proprioception and muscle power. If they do not have advice, they may return to non-weight bearing and so enter a vicious circle of non-weight bearing and increasing instability. This *functional instability* is one of the commonest causes of persisting joint symptoms after injury.

- **The major stabiliser of all joints is proprioception and muscle power.**

The human body is a machine; it is a complex system of levers. The forces acting on the system are huge. Figure 1A is a functional diagram of the shoulder holding a 5 kg weight with the arm abducted. This is a second-order lever system. Note that the fulcrum of the lever is very much to one end. This means the tension in the shoulder abductors (ie, supraspinatus and deltoid) can be calculated as follows:

1. Force = mass × acceleration
   - Weight of arm 3 kg + 5 kg load = 8 kg
   - Acceleration of gravity +10 metres/second$^2$
   - Therefore the force on the arm is 8×10 = 80 newtons.
2. The forces acting in a lever system = newton × metres
   - Distance from fulcrum (head of humerus) = 0.5 metres
   - Force is 80 × 0.5 = 40 newton metres
3. The deltoid and supraspinatus are attached very near to the head of the humerus, let us say within 2.5 cm (0.025 metres). Thus, the force developed by the muscles is 40/0.025 or 1600 newtons (equivalent to 160 kg mass).

This is an over-simplification of the system, but it helps us to understand the comparatively large forces involved and the tremendous range of the musculoskeletal system.

## INJURY AND FORCE

Injury is caused by force. The concepts of levers can help understand why seemingly everyday actions can cause injury. Calculations for a healthy human who bends forward with a straight back and lifts a 5 kg weight off the floor are as follows (fig 1B):

1. The upper body weight is 35 kg + the 5 kg weight = 40 kg×10 m/s = 400 newtons.
2. The length of the lever is 1 metre so the moment is 400 newton metres.
3. The distance between the muscle attachments to the pelvis and the L5 vertebra is, say, 10 cm (0.10 metres).

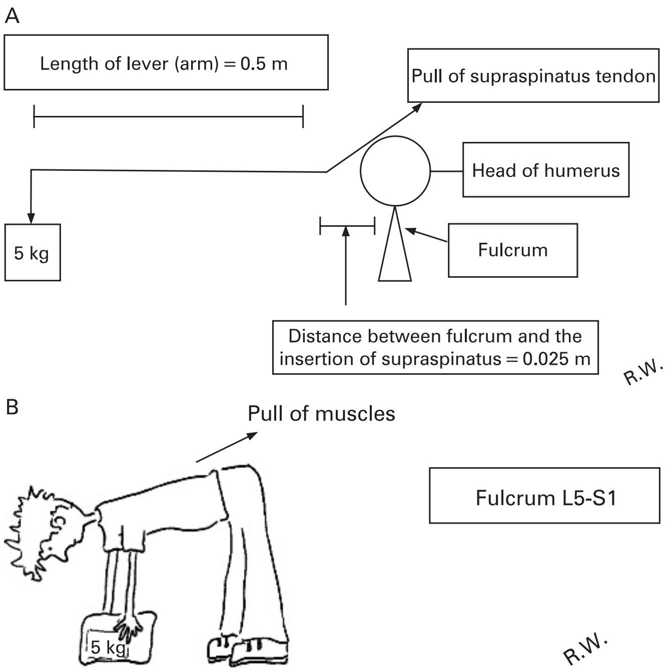


**Figure 1** (A) Functional diagram of the shoulder. (B) Forces involved in lifting.

4. The strain in this area is therefore 4000 newtons (0.4 tonne of force).

This is why we should not pick things up simply by bending with a straight back. Again, this is a vast over-simplification of the system. The muscles of the spine act at many levels to spread the force, and tensing of the abdominal muscles gives support from the front. They also act at different angles, but the introduction of vectors is outside the scope of this very simple description.

## CAPSULAR DAMAGE AND PROPRIOCEPTION

The fact that proprioceptors are involved in such a key way to control muscle dynamics has a bearing on the understanding of injury. When a "simple" ankle sprain occurs, the delicate joint capsule is damaged to a varying degree. Therapeutic manoeuvres should be designed to address this.[2]

## PHYSIOTHERAPY PRINCIPLES

The aim of treatment following an injury is to restore normal function as soon as safely possible and to prevent further injury in the future. To do this, the clinician should use the pathophysiological response to injury as a guide to the treatment approach.[3] This was outlined in the first paper of this series and consists of three phases: inflammation, tissue formation and remodelling.

### Inflammatory phase

The aims of treatment at this stage are to protect the injured tissue from potentially harmful stresses, reduce oedema and maintain the range of movement and muscle strength of joints not directly affected by the injury. To achieve this, many use the time-honoured regime "RICE" (rest, ice, compression and elevation).

#### Rest

Rest should be relative and not complete. Using the example of a medial collateral ligament injury, the use of elbow crutches is advisable to allow the patient to walk with as normal a gait pattern as possible, rather than the asymmetrical antalgic pattern commonly seen with lower limb injuries. Braces or splints may be appropriate during this time in order to prevent potentially harmful tensile stresses. Specific mobility exercises to should be taught (eg, sagittal plane sliding movements for collateral ligament injuries). Static resisted or short range strengthening exercises are taught to reduce the effect of injury and joint oedema on muscle strength.[4]

#### Ice

The most effective application of ice following an acute injury appears to be by repeated applications of melting iced water through a wet towel over a 30 min period,[5] although the evidence for this is not conclusive. Application of intermittent cold therapy is vasoconstrictive and helps reduce bleeding and capillary leakage. Later in the healing process, heat may be more beneficial in increasing collagen elasticity, decreasing joint stiffness and reducing muscles spasm. By increasing blood flow there is a theoretical benefit of enhancing healing by reducing inflammatory infiltrates.[6]

#### Compression

The role of compression in soft tissue injury is questionable, with potential adverse effects.[7] Despite this, the practice of applying a doubled layer tubigrip is very widespread.

#### Elevation

Elevation of the injured part above the level of the heart is effective in reducing oedema. Active movements of the distal limb while in elevation may also help reduce oedema by using the muscle pump effect.

### Tissue formation (regeneration) phase

The transition to this phase is a gradual process and depends on tissue type, health and age and severity of the injury, but will generally occur at 4–6 days. While the principles outlined above still largely apply in the early stages of this phase, gradual introduction of tensile stresses to the damaged tissue should occur at this time. Initially, slow controlled movements which provoke a mild stretch or painful sensation are applied with the aim of encouraging the correct alignment of newly formed collagen tissue without causing its breakdown. Rapid movements and strong sensations of pain or stretch should be avoided at this time.

Graduated introduction of more functional exercise with the aim of producing full joint range and muscle function should occur during this time. This should be ongoing until the third or fourth week after the injury.

### Remodelling phase

During the early stages of this phase, recently healed tissue may not have achieved maximum strength and, as such, is in danger of re-injury if exposed to high loads. The clinician should be aware of activities specific to the patient that may cause such injury such as footballers or manual workers. Particular attention should be paid to joint range, muscle extensibility and strength and proprioception. If any of these factors is overlooked, the risk of re-injury is increased. Patients should be advised to continue with specific exercises once discharged.

## IMAGING PRINCIPLES

The key to optimising imaging is the history and examination. This will provide the working diagnosis and allow the mechanism

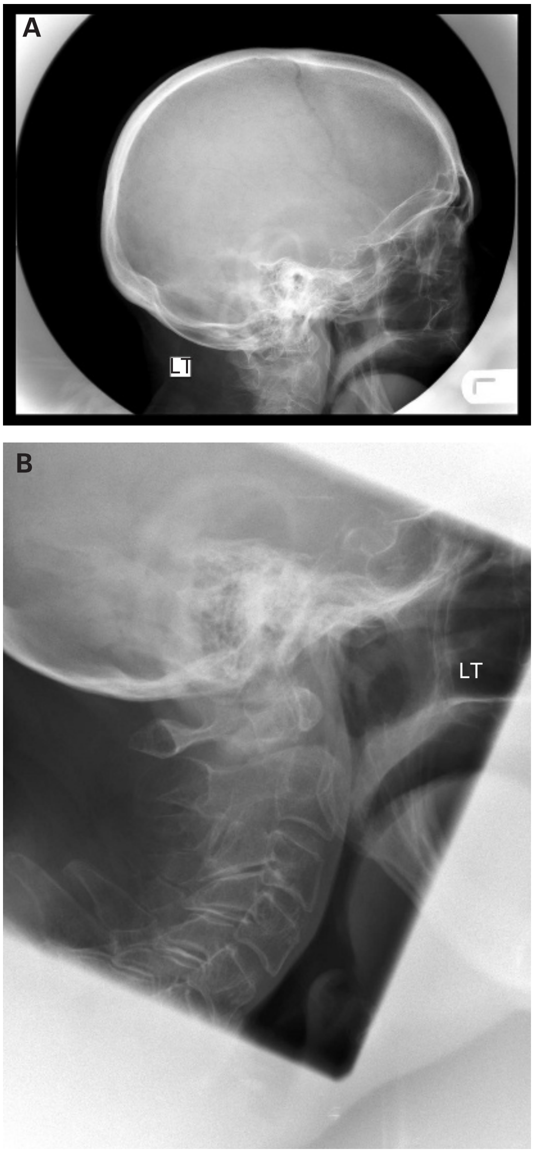


**Figure 2** (A) Lateral skull radiograph taken as part of an assessment in a 90-year-old woman who had fallen on her face. Careful review of the whole image revealed a fracture to the odontoid peg. (B) Lateral C-spine view taken later clearly showing the C2 fracture with substantial displacement.

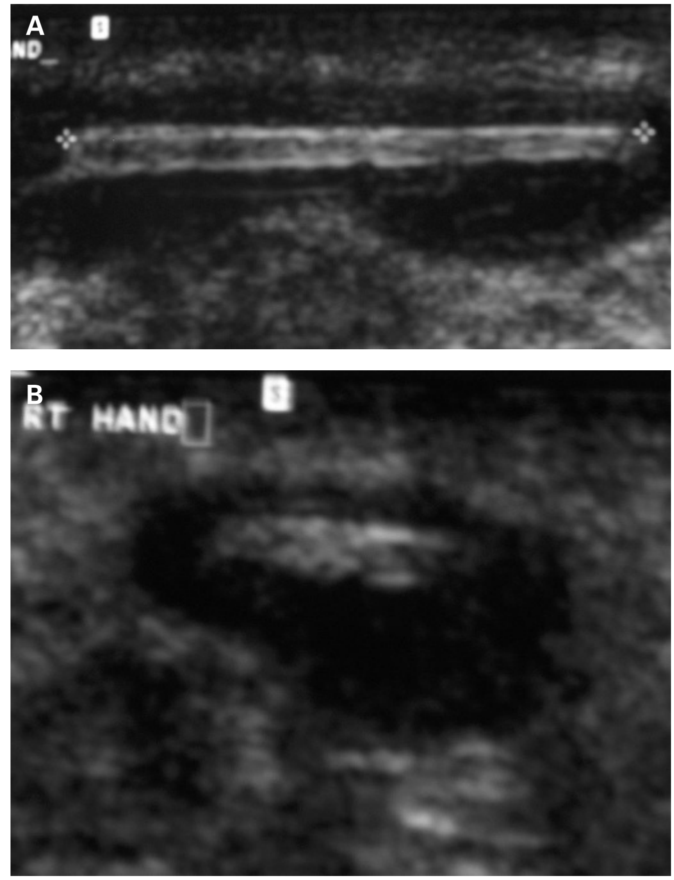


**Figure 3** (A) Longitudinal and (B) transverse ultrasound images clearly showing a wooden splinter with associated foreign body reaction.

of injury to be deducted. Clinicians can then predict the type of injuries and plan investigation and management as necessary.

This then leads onto whether imaging will make any significant change to the management of the patient. Radiologists using this line are seen as unhelpful and obstructive by junior staff. Taking a step back though, this is an important question before subjecting a patient to any investigation.

The reasons are that once a test is ordered there is, by definition, a significant time penalty even in the most efficient hospitals. Therefore, even the simplest of minor injuries then runs the risk of breaching the current 4-hour criteria and, if unhelpful tests can be avoided, the efficiency of the emergency department is greatly enhanced. In addition, many radiological investigations have radiation considerations and therefore by law they have to be justified.[8]

Deciding on the best course of action can be seen as almost impossible for inexperienced staff. To address this, nearly all hospitals have well developed guidelines for common problems. The development of such guidelines has been most vigorously pursued in Canada where there is a major impetus to reduce the unnecessary use of imaging, both from a financial and radiation standpoint. The best known of these is the Ottawa ankle rule.[9] This rule is well established having undergone rigorous multicentre prospective validation, and it is now internationally accepted.

Where no guidelines are available in the department, the next step would be to look up the small handbook produced by the Royal College of Radiologists.[10] This should be available in all departments and lists all the available radiological investigations, appropriate indications and the level of evidence to support their use.

Once further investigation has been justified, it is important to determine what will be the best next step.

## Plain radiographs

These are the staple emergency room investigation and have a broad application. The majority of requests for these are for bony trauma, acute chest and acute abdominal problems. The key to the best use of these is to ask for the correct examination of the correct area using knowledge of the mechanism of injury to predict what further views would be beneficial. If in doubt, asking the radiographers for their opinion is often invaluable.

It is important to focus the examination upon the correct area (fig 2A, B). A common error is to ask for a radiograph of the hand when the area of interest is the finger. Large field of view



Emerg Med J 2008;25:158–162. doi:10.1136/emj.2007.052555

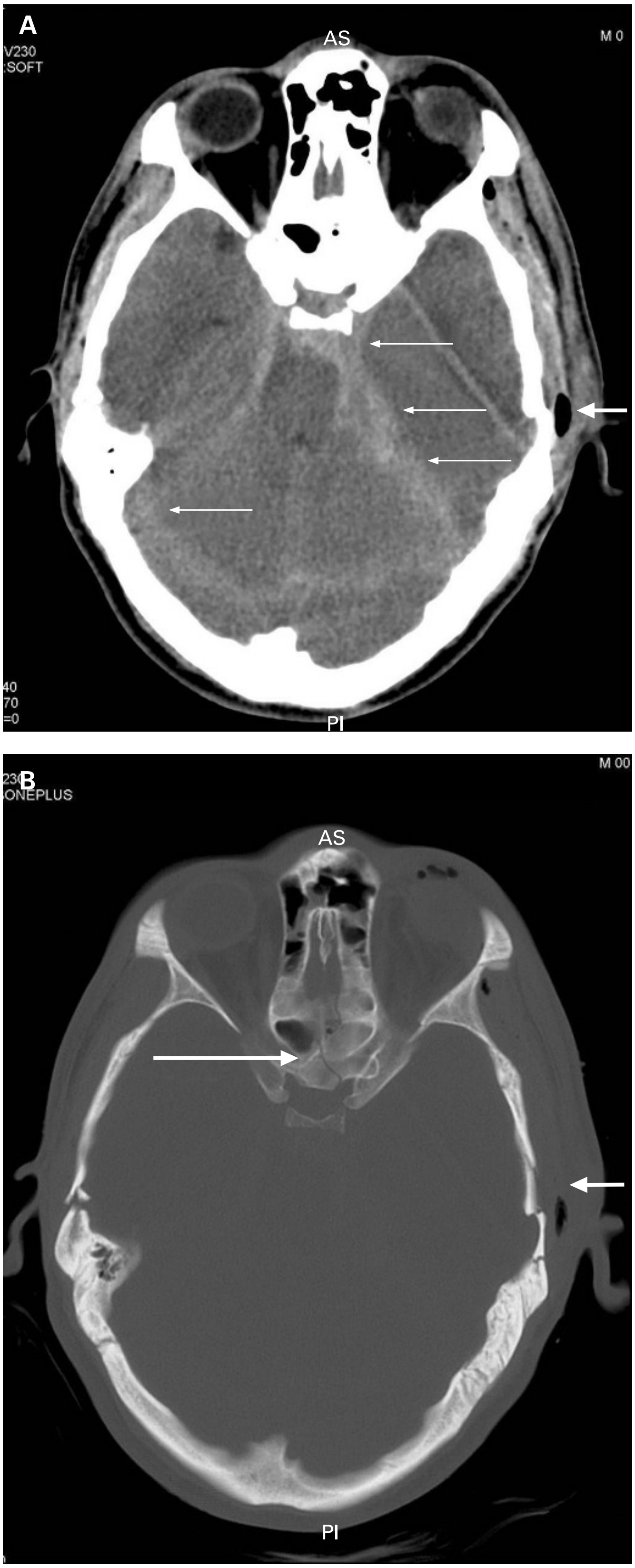


**Figure 4** CT examination of the head for trauma. The first image shows extensive subarachnoid blood (arrows) as well as subcutaneous emphysema (large arrow). Post-processing the same image to look at the bones clearly shows the multisegemental temporal fracture and the sphenoid fracture.

examinations are bad practice and subtle injuries can easily be missed.

Always ask for two views when a fracture is suspected as undisplaced fractures can be invisible unless the *x*-ray beam is parallel to the fracture line $\pm 15^{\circ}$. When the radiographs are returned, the radiographic findings should always be correlated with the clinical findings. Therefore, if there is strong concern for a fracture but the radiographs appear normal, patients should still be treated as though they have a fracture until proved otherwise. This can be done by obtaining a senior opinion on the radiographs, alternative views, delayed imaging or, in some cases, different imaging.

## Ultrasound

This has developed significantly over the past 10 years, both in improved image quality and also in the applications for which it may be used. For trauma imaging it has found a role in focused assessment sonography of trauma (FAST), musculoskeletal soft tissue trauma and foreign bodies. The latter is now a well established way of looking for radiolucent foreign bodies such as wood, with additional information possible concerning the exact location and involvement of adjacent structures (fig 3A, B). The major problem with this technique is that the necessary expertise to provide these services is very centre-specific.

## Computed tomography (CT)

This has shown an exponential increase in image quality, speed and applications over the past 10 years. CT scanning is now the cornerstone of trauma imaging, with the new multislice scanners being capable of scanning from the patient's vertex to the symphysis in one pass where necessary. High quality images of the whole torso are possible with reformats providing diagnostic information concerning the spine.

In North America it is now routine for all trauma patients to have a CT scan as part of their initial investigation. Unfortunately, there are very few centres in the UK who can provide the 24/7 imaging service that this requires because of financial restraints of UK practice and the massive under-provision of both radiographers and radiologists. This has been highlighted by the National Institute for Health and Clinical Excellence (NICE) head injury guidelines.[11] There is no doubt that CT scanning is the modality of choice for head injuries (fig 4A, B). However, this relies on rapid access to CT for most significant head injuries with an associated large increase in demand. Although these guidelines are supposed to be cost neutral overall, the savings made in other departments rarely find their way back to radiology to fund this. As a result, many hospitals have had to instigate local protocols to address this problem and skull radiographs are still in widespread use as a result.

**Acknowledgements:** The authors thank Rebecca Wilby for artwork (fig 1).

**Competing interests:** None declared.

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# Images in emergency medicine

## Intracranial bilateral symmetric calcification in hypoparathyroidism

A 42-year-old woman presented to the emergency department with a complaint of tremors in both extremities, torticollis, and agitation that had lasted 10 h. When she was 24 years old, she underwent a total thyroidectomy due to thyroid cancer. The results of her laboratory tests were consistent with hypoparathyroidism, probably secondary to undiagnosed chronic hypoparathyroidism after thyroidectomy 18 years earlier.

Intracranial calcifications may be an incidental finding, but they can result from many causes. Chronic hypoparathyroid syndrome is characterised by the presence of extrapyramidal signs (dyskinesia, choreiform, and athetoic movements, tremors, and cogwheel rigidity), cerebellar manifestations (dysarthria, ataxia), psychosis, and epilepsy.[1]

These computed tomography findings (fig 1) can be found in Fahr disease. It has also been reported predominantly in cases of autosomal dominant inheritance. A thorough laboratory workup, however, ruled out other conditions associated with brain calcifications, including hypoparathyroidism, systemic lupus erythematosus, and other infectious, genetic, or metabolic diseases.

Intracranial calcification, even in symptomatic patients, tends to be diagnosed easily as a normal variant or haemorrhage. Emergency physicians should not overlook the possibility of pathological findings in the brains of these patients.

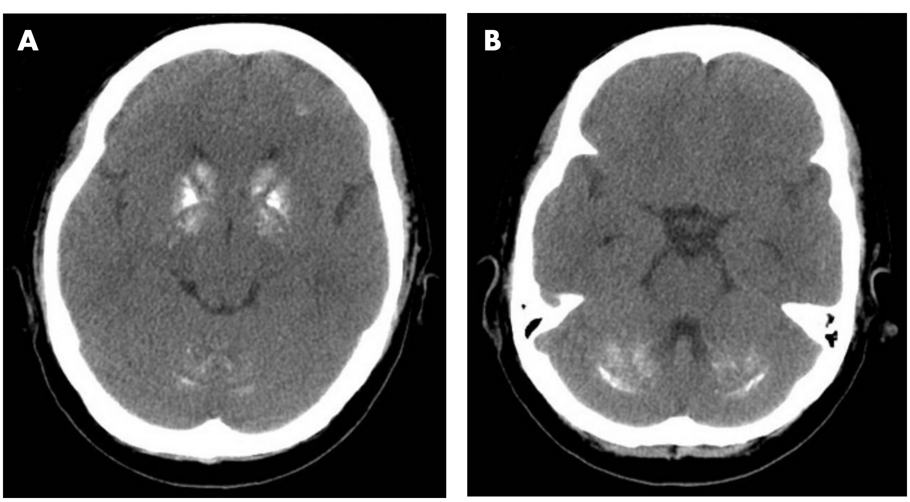


**Figure 1** Brain computed tomography scan showing (A) bilateral and relatively symmetrical hyperdense images consistent with calcifications in the basal ganglia, and (B) cerebellum.


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**Funding:** None.

**Competing interests:** None.


Informed consent was obtained for publication of the person's details in this report.


*Emerg Med J* 2008;**25**:162.
doi:10.1136/emj.2007.051052


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