SECTION

4

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WOUND MANAGEMENT

4.1 WOUND MANAGEMENT

ED OAKLEY

ESSENTIALS

1 Goals of management of wounds are to avoid infection, minimise discomfort, facilitate healing and minimise scar formation.

2 In children management will often require sedation, adequate local anaesthesia and analgesia.

3 Meticulous wound care and repair should ensure the best possible outcome and functional result.

4 The care of the patient as a whole should be the first management priority.

5 The comprehension level and the co-operation gained from the child influence wound examination and the information gained.

6 Distraction techniques, adequate topical anaesthesia and appropriate use of sedation can all aid in wound assessment in children.

7 Examination of function, sensation and circulation distal to the wound is best performed prior to exploration of the wound and prior to regional anaesthesia.

8 In the child less than 5 years old observation of posture, symmetry and general movement is required.

9 If presence of a foreign body is expected radiological investigation is advised.

10 Sedation should only be undertaken by personnel experienced in its use, able to manage the complications of airway compromise, oxygen desaturation and respiratory depression.

11 Surgical debridement of non-viable tissue is vital to prevent wound infection or delayed wound healing.

12 The technique chosen for wound closure depends on the type and position of the wound.

13 Tissue adhesives are for external use only and should not be placed within wounds or used on mucous membranes.

14 All patients should be provided with written information on care of their wound.

15 Trauma to the distal fingers is often associated with nail-bed injury. An underlying fracture of the distal phalanx should be assessed with radiographs.

16 In general, sutures are removed earlier in children than in adults.

17 Non-accidental injury should be considered especially when the history and injury are inconsistent.

INTRODUCTION

Lacerations account for up to $\frac{1}{3}$ of paediatric emergency presentations, boys represent $\frac{2}{3}$ of these presentations, and 40% of all lacerations involve a fall. The scalp and face account for more than 50% of all lacerations, and about $\frac{1}{3}$ occur on the hands. The goals of management of these wounds are to avoid infection, minimise discomfort, facilitate healing and minimise scar formation. Meticulous attention to wound care and repair should ensure the best possible outcome and functional result. In children this will often require sedation in addition to adequate local anaesthesia and analgesia. It must be remembered that universal precautions should always be followed when assessing or managing any wound. Gloves (preferably sterile), drapes and eye protection are mandatory.

Anatomy of the skin

Skin is composed of two layers – dermis and epidermis. The epidermis acts as a protective layer for the dermis, preventing infection and desiccation. It is avascular and relies on diffusion of nutrients from the dermis. The dermis is rich in collagen and thus provides most of the tensile strength of the skin. It has a rich network of nutrient vessels and capillaries. The subcutaneous fat is composed of loose connective and adipose tissues.

Pathophysiology of wound healing

The stages of wound healing are coagulation, inflammation, proliferation and maturation. Wound healing is a sequential process that begins immediately after tissue injury. Coagulation is initiated by platelet aggregation then by fibrin clot formation. This supplies haemostasis and allows accumulation of neutrophils and monocytes, which herald the inflammatory phase. The inflammatory phase

provides phagocytosis of bacteria, other organisms and foreign matter or dead tissue in the wound. The macrophages release factors that stimulate proliferation of local fibroblasts in the dermis. These provide a collagen network and stimulate new vessel growth. This phase is characterised by pink granulation tissue and wound contraction. A warm moist environment that is supplied either by dressings or scab formation aids this process. Collagen synthesis reaches its peak towards the end of the first week of healing. Remodelling continues to occur for up to 12 months, thus the scar will usually fade and contract over the first 2 to 3 months and the final appearance may not be obvious for up to 6 months post injury.

A number of factors affect the healing of a wound. Adequate nutrition (including vitamins C and A, which are required for collagen formation) is essential. Corticosteroids and immunosuppressive drugs interfere with cellular proliferation and immunity, and anticoagulants inhibit clot formation and initial wound stabilisation. Infection interferes with collagen synthesis and will delay wound healing and cause an increase in scar tissue formation.

Tensile forces of the surrounding skin affect the healing and scar formation of a wound. The most cosmetically pleasing outcome occurs when the long axis of the wound is in the direction of maximum skin tension – along Langer's Lines of skin tension. Wounds that have long axis perpendicular to the lines of skin tension will heal with greater scarring, but there is significant inter-child variability. Dynamic skin tension caused by joint movement also impairs wound healing and causes increased scar formation, and immobilisation of joints while the laceration heals will minimise this effect.

Wound infection

Wound infection is relatively uncommon, occurring in about 5% of all lacerations. In general a wound in a child is less likely to become infected than a similar wound in an adult. Identified risk factors for infection include severe wound contamination, inadequate wound cleansing, inadequate debridement of dead tissue (especially in crush injuries), use of subcutaneous sutures, larger laceration (> 5 cm) and site of injury. Specific sites identified as infection risks include axillae, perineum or groin, and feet. In general limb wounds are at increased risk compared to head and neck wounds.

CLASSIFICATION OF WOUNDS

Lacerations

Lacerations are the most common type of wound seen in the paediatric age group. The edges are usually ragged, if the wound penetrates into the dermal capillaries it will bleed and if it extends into the subcutaneous tissue it will gape. Lacerations can be caused by tension on the skin (usually seen in areas with significant subcutaneous tissue) or by compression of the skin between an object and bone. There is always damage done to surrounding tissues and healing is therefore delayed. Compression injuries usually have more surrounding tissue damage and thus tend to heal more slowly.

Incised wounds

A sharp object such as a knife blade or glass shard makes an incised wound. The wound has margins that are clearly defined and there is little or no surrounding tissue damage. These wounds heal faster than lacerations and, in general, have a lower incidence of infection.

Abrasions

Abrasions are caused by sheering forces on the surface of the skin. The upper layers of the epidermis and sometimes dermis are scraped away. The depth of injury usually varies throughout the wound. If the epidermis alone is involved there is no bleeding, but a transudation of fluid. If the dermis is involved the wound will bleed and there is said to be an increased incidence of infection and foreign body retention.

EVALUATION OF THE PATIENT WITH A LACERATION

The care of the patient as a whole should be the first management priority. The airway, breathing and circulation should be assessed and treated as appropriate and a thorough secondary survey undertaken in most patients to exclude or allow management of serious injuries as well as detecting other minor injuries.

History

In evaluating a wound the mechanism of trauma (cut, crush, fall, bite, burn) and the time of injury are important as they may alter the management of the wound. Crush and bite injuries characteristically cause significantly more surrounding tissue damage and thus are more likely to have delayed healing or infection. When possible determine the cleanliness of the inflicting object, the amount of blood loss, the presence of a foreign-body sensation, and the motor function and sensation distal to the affected area. The location of the wound should be noted and the possibility of injury to other structures explored.

The health status of the patient should be explored especially with regard to chronic illnesses that may impact on wound healing – such as diabetes mellitus, obesity, malnutrition, chronic renal impairment, cyanotic congenital heart disease, chronic respiratory illness, tumours, and bleeding disorders. Immunisation history should be obtained and further tetanus vaccination guided by the recommendations of the National Health and Medical Research Council (see Table 4.1.1). Current medications are important for both drug interactions with antibiotics that may be prescribed and for medications that may interfere with wound healing – such as immunosuppressive drugs and corticosteroids. A history of allergies must be determined prior to use of cleansing agents, dressings and tapes and prescription of medication. A history of latex allergy should be specifically sought. In wounds that require management under general

Table 4.1.1 Tetanus prophylaxis in wound management

History of tetanus vaccination	*Time since last dose*	*Type of wound*	*DTP, DT, Td or Tetanus toxoid† (as appropriate)*	*Tetanus immunoglobulin**
≥ 3 doses	< 5 years	All wounds	NO	NO
≥ 3 doses	5–10 years	Clean, minor wounds	NO	NO
≥ 3 doses	5–10 years	All other wounds	YES	NO
≥ 3 doses	> 10 years	All wounds	YES	NO
< 3 doses or uncertain	–	Clean, minor wounds	YES	NO
< 3 doses or uncertain	–	All other wounds	YES	YES

*Recommended dose for TIG is 250 IU to be given as soon as possible after the injury, if > 24 hours has elapsed since the injury 500 IU should be given.
†Tetanus toxoid vaccine should only be used if diphtheria toxoid is contraindicated.
DTP, diphtheria-tetanus-acellular pertussis vaccine; DT, adsorbed diphtheria-tetanus vaccine (paediatric formulation – for < 7 years old); Td, adsorbed diphtheria-tetanus vaccine (adult formulation – for ≥ 7 years old)

anaesthesia or sedation a history of when the child last ate or drank is important. Non-accidental injury should be considered especially when the history and injury are inconsistent.

Examination

Once assessment and management of more serious injuries has occurred the patient should be assessed for the current severity of any chronic illness, and appropriate management initiated.

The co-operation able to be gained and comprehension level of the child influence wound examination and the information gained. Distraction techniques, adequate topical anaesthesia and appropriate use of sedation can all aid in wound assessment. A calm unhurried friendly approach, involving the parents, will maximise the chances of co-operation. Examination of the wound should be done with optimal lighting and with bleeding minimised. Examination of function, sensation and circulation distal to the wound is best performed prior to exploration of the wound and prior to regional anaesthesia.

Functional assessment requires the movement of all joints distal to the wound. In an older child each joint is examined individually on command and the strength documented. In the child less than 5 years old, observation of posture, symmetry and general movement is required. In wounds to the flexor tendons of the hand close attention should be paid to the resting position of the fingers (partial flexion). The finding of extension of one finger at rest and the failure of the finger to flex at play or after application of a noxious stimulus confirms the tendon injury.

Injury to nerves is classically assessed with two-point discrimination and this should be possible in older children. Using a paperclip bent so that its ends are separated 4–8 mm is useful in this process. In upper limb injuries formal assessment of the median, ulna and radial nerves is required. In children less than 5 years old this approach needs to be modified. Noxious stimulus applied to the fingers will illicit sensation but risks losing patient confidence. Another method of determining intact innervation is to look for sweating of the fingers. Since autonomic response includes sweating, denervated fingers do not sweat. An ophthalmoscope can be used to examine for sweat beads or the cleaned body of a pen can be run over the fingers with less resistance in the denervated, thus dry, segment. Arterial circulation is assessed by palpation of peripheral pulses, capillary return distal to the injury, and skin colour and temperature.

Assessment of the wound should include site, size, depth, nature of the edges, cleanliness, and presence of foreign bodies. The wound should be explored to determine the depth and involvement of any underlying tissues including vessels, nerves, tendons, ligaments, muscles, joints, bones and specialised tissues (especially ducts and glands). Bones adjacent to the wound should be palpated for deformity or crepitus and the wound searched for foreign bodies (including the sound of glass on the metal forceps). This assessment and exploration should take place after appropriate anaesthesia of the wound and any required sedation.

Investigation

If presence of a foreign body is expected radiological investigation is advised. In wounds caused by glass all but superficial wounds should be investigated with plain soft tissue X-ray of the region to exclude a glass foreign body. Most glass foreign bodies more than 2–3 mm in size should be visible. If a radiolucent foreign body is suspected, ultrasound can be useful to both confirm the presence of the foreign body and provide a guide to its depth and location in the wound. Other investigations should be determined by the findings of possible injuries to adjacent structures, such as bony X-rays for fractures.

TREATMENT OF WOUNDS

Wound anaesthesia

Analgesia and sedation are discussed in more detail in Chapter 20. Anaesthesia is required to adequately examine and then treat most wounds. Often, in children, analgesia and sedation will also be

necessary, depending on the location of the wound, the involvement of underlying structures, and the age and anxiety of the child.

The options for anaesthesia include topical anaesthesia, local infiltration, regional anaesthesia, dissociative anaesthesia, or general anaesthesia.

Topical anaesthetics include ALA (adrenaline, lidocaine and amethocaine) – commonly known as LET (lidocaine, epinephrine and tetracaine) in North America, or EMLA cream (eutectic mixture of local anaesthetics) – manufactured by AstraZeneca. ALA is highly effective on facial and head wounds but less so on limb wounds. It has replaced TAC (tetracaine, adrenaline and cocaine) in most institutions. Due to the vasoconstricting properties of adrenaline (epinephrine) these anaesthetics should not be used in areas of end arteries (fingers, nose, lips, ears, genitalia). EMLA has been shown to be safe and effective when applied to limb wounds. Topical anaesthetics should be applied in the wound either as a liquid dripped onto cotton wool placed in the wound or as a methyl cellulose gel. The wound is then covered with an occlusive impermeable dressing and adequate anaesthesia is usually obtained within 30 minutes.

Local infiltration is the classical method of anaesthetising a wound. The anaesthetic is injected into the wound margins. Pain of injection can be minimised by using warmed anaesthetic, buffering the drug with sodium bicarbonate (mix 10 mL of 1% lidocaine with 1 mL of 8.4% sodium bicarbonate), infiltrating slowly, using the lowest concentration possible, and using needles sized 25 gauge or smaller. The most commonly used local anaesthetic is lidocaine 1 or 2% with or without adrenaline (epinephrine) 1:100 000. The onset of action is rapid with duration of action of 30 minutes to 1 hour. Addition of adrenaline (epinephrine) is useful to prolong the duration of action and help minimise bleeding, however adrenaline (epinephrine) should be avoided in regions of end arteries (fingers, nose, lips, ears, genitalia), and its use may increase the risk of infection. The safe dose of plain lidocaine is 3 mg kg^{-1} or 6 mg kg^{-1} for lidocaine mixed with adrenaline (epinephrine).

Regional anaesthesia is useful for facial, hand and foot lacerations where nerves are readily accessible near bony landmarks. A regional nerve block involves anaesthetising the nerve or nerves that supply a specific anatomic region. Regional anaesthesia is especially useful for large lacerations and lacerations where local infiltration causes distortion of tissue anatomy. Regional anaesthesia is especially useful for anaesthetising digits. Lidocaine or bupivacaine hydrochloride 0.5%, which have duration of action of 3 to 6 hours, are the most commonly used agents. The safe dose of bupivacaine is 2 mg kg^{-1}.

Sedation is often required when treating lacerations in children. Options for sedation include benzodiazepines – such as midazolam or diazepam, fentanyl, nitrous oxide or ketamine. Sedation should only be undertaken by personnel experienced in its use and able to manage the complications of airway compromise, oxygen desaturation and respiratory depression. Adequate equipment to deal with these complications should also be available. Some form of physical restraint may also be necessary to prevent excessive movement during repair, however, the aim must be to provide adequate analgesia and anxiolysis.

Wound preparation and cleansing

Hair near the wound should only be removed if it interferes with the meticulous closure of the wound. If hair removal is desired the hair should be clipped, not shaved, as shaving disrupts hair follicles and increases the incidence of wound infection. Eyebrow hair should not be removed because this may lead to abnormal or delayed regrowth.

The surrounding skin and wound edges should be thoroughly cleaned. This should be undertaken in a manner and with a substance that provides adequate antisepsis without tissue damage or impairing wound defence mechanisms. A solution such as aqueous povidone-iodine or aqueous chlorhexidene applied with gauze or cotton wool should be used. Care should be taken to minimise the amount of cleanser to penetrate the wound to minimise damage to wound defences increasing the risk of infection.

Surgical debridement of crushed or non-viable tissue is vital to prevent wound infection or delayed wound healing. However, as little tissue should be debrided as possible. Manual removal with forceps of large particles of foreign material should also be meticulously undertaken. When a heavily contaminated wound contains specialised tissues such as tendons or nerves, consultation is recommended.

Once the wound is adequately anaesthetised it should be thoroughly cleaned. Irrigation is the method of choice for removing dirt and bacteria from wounds. Saline (0.9%) is the irrigation solution of choice, as it causes no tissue damage. The ability of irrigation to decontaminate a wound is directly related to pressure of the irrigating stream, the size of the particles to be removed, and the volume of irrigant. At least 100 to 200 mL per 2 cm of laceration are required. The fluid should be injected from a 30 to 60 mL syringe via an 18 to 20 gauge cannula. Higher pressures should be avoided as they may cause tissue damage and increase the incidence of wound infection. The volume and pressure of irrigation should be modified as necessary according to the location and cause of the wound. High-pressure irrigation does not enhance the dissemination of bacteria into soft tissue wounds, but excessive use can cause local tissue oedema enhancing risk of infection. Use of a device to minimise splashing of the irrigant is desirable and wearing of gloves, goggles and gown mandatory.

Antibiotic prophylaxis

The use of prophylactic antibiotics in wound care is controversial. Decontamination with appropriate irrigation techniques is more beneficial than the use of prophylactic antibiotics. When indicated (see Table 4.1.2) antibiotics should be given as soon as possible. The initial dose should be given intravenously and be relatively large to provide rapid reliable high

tissue concentrations. The first dose should be given before wound closure to ensure an effective concentration of antibiotic in the wound tissue fluid at the time of wound closure. When choosing an antibiotic the likely causative organisms should be born in mind. The organisms contaminating the wound and the commensal organisms found in that region of the body. In general bites and wounds in regions with high bacterial counts (hands, feet, groin) should be treated with antibiotics to cover *Staphylococcus epidermidis*, *S. aureus* and *Streptococcus* sp. Specific circumstances also need to be born in mind. Patients at risk of endocarditis should have all wounds treated with antibiotics to cover *S. aureus* and *S. epidermidis*. Ampicillin/amoxicillin is the currently recommended drug in Australia. However, in communities where the incidence of penicillin resistance is high a cephalosporin and an aminoglycoside are recommended.

Wounds associated with fractures, tendon or muscle involvement should be considered for prophylaxis, as should large wounds, wounds with significant devitalised tissue such as crush injuries and stellate lacerations. Wounds contaminated with faeces should be treated with coverage of coliforms and anaerobic bacteria. Wounds in children with a compromised immune system should all be considered for treatment. Wounds with closure delayed more than 12 hours should also be considered high risk for infection. Treatment should be for 3 to 5 days with a penicillinase-resistant antibiotic such as a first generation cephalosporin or amoxicillin-clavulanic acid (co-amoxiclav).

Table 4.1.2 Indications for antibiotic prophylaxis in wounds

Wound Characteristics:
High risk anatomic site (hands, forefoot, groin, axilla)
Devitalised tissue
Extensive surrounding soft tissue injury
Stellate lacerations
Contaminated with body fluids or organic matter or dirt
Large lacerations (> 5 cm)
Closure delayed (> 12 hours)
High risk for endocarditis:
Prosthetic heart valves
Patent ductus arteriosis
Tetralogy of Fallot
Ventricular septal defects
Coarctation of the aorta
Immunocompromised children

WOUND CLOSURE

The aim of wound closure is to reduce discomfort, aid healing and produce the best cosmetic result possible. The technique chosen for wound closure depends on the type of wound. Most wounds in children can be managed with primary closure, as the risk of infection is relatively low. Infected, heavily contaminated wounds and wounds resulting form high-energy projectiles are best managed by delayed primary closure, with initial cleansing and packing then closure 3 to 5 days later, once the risk of infection has decreased. Wounds with delayed presentation (> 24 hours), or those contaminated with saliva or faeces should also be considered for delayed closure. Some wounds, such as puncture wounds or contaminated wounds in areas of poor perfusion should not be closed but allowed to heal by secondary intention. Once it is decided to close the wound a technique that allows apposition of the wound edges that is secure and accurate and holds the wound edges in apposition until the strength of the wound is sufficient should be chosen. With improved technology the options for wound closure are growing. Those presently available included sutures, staples, tissue adhesives and tapes.

Sutures

Suturing is the traditional method of wound closure. Sutures are divided into two classes on the basis of their degradation properties. Absorbable sutures degrade rapidly in vivo, and lose their tensile strength within 60 days. Sutures that degrade more slowly are classified as non-absorbable (see Table 4.1.3 for individual suture material characteristics).

Absorbable sutures are made from either collagen or synthetic polymers. Gut sutures are manufactured from the submucosa of ovine or bovine intestines. The collagen is then treated to strengthen the material and increase resistance to tissue degradation (plain gut). Coating with chromium trioxide provides more resistance to absorption (chromic gut). These suture materials have a somewhat unpredictable absorption. Synthetic

Table 4.1.3 Characteristics of common suture materials

Suture material	*Ease of handling*	*Tensile strength*	*Degradation (d)**	*Tissue reactivity*	*Infection potential*
Non-absorbable					
Nylon (Ethilon®, Dafilon®)	Average	Good	–	Low	Very low
Polypropylene (Prolene®)	Poor	Very good	–	Very low	Low
Silk	Good	Poor	–	High	High
Absorbable					
Chromic gut	Average	Average	10–14	High	High
Surgical gut	Poor	Average	5–7	High	High
Polyglactin (Vicryl®)	Average	Good	30	Low	Low
Polyglycolic acid (Dexon®)	Good	Good	30	Low	Low
Polydioxanone (PDS)	Average	Very good	45–50	Very low	Low

*Time to loss of 50% of tensile strength.

absorbable sutures have improved strength and delayed and more reliable absorption characteristics. Absorbable sutures are used for closing deep layers of a laceration and can be used for skin closure – especially where removing sutures in a young child may be difficult.

Non-absorbable sutures are made from either natural (silk, cotton, linen) or synthetic (nylon, Dacron®) fibres. They can also be classified according to their physical characteristics. Monofilament sutures are made from a single filament (nylon, Prolene®), and sutures containing multiple fibres are called multifilament (silk, cotton, nylon). Of these sutures only nylon is available in both types of filament. Non-absorbable sutures are used to close fascial layers (where healing is slow) and for skin closure.

Sutures come in varying sizes. The size of the suture to be used depends on the wound location and the tensile strength of the tissue to be sutured. Heavy sutures such as 4–0 or 5–0 should be used in the limbs and trunk, and should also be used on mucous membranes and subcutaneous tissue. Heaviest sutures such as 3–0 should be used on thick skin (such as the sole of the foot) or over large joints. Small sutures such as 6–0 should be used on tissues with light tensions such as facial skin and subcutaneous tissue.

Needles

Needles come in varying sizes and shapes also. Needles are describes by the arc of curvature the needle possesses, and the shape of the needle itself. The most commonly used for skin closure is the $\frac{3}{8}$ circle (135°) needle or the $\frac{1}{2}$ circle (180°) needle (see Fig. 4.1.1). For closure of fascial layers $\frac{1}{2}$ circumference needles are usually used. Needles that have two circumferences of curvature (compound needles) are able to be passed through the tissue with less rotation of the forearm. Needles come with different shapes as well as curvatures (see Fig. 4.1.1). A reverse cutting needle is the most common type used for skin closure. The needle cuts an inverted triangle and the suture sits on the base of the triangle decreasing the likelihood of cutting out. A conventional cutting needle cuts a triangle into the skin and the suture sits in the apex of the triangle. For fascia a taper point needle is used. The cross-section of these needles is a circle that is tapered to a point. It does not cut but pushes the tissues aside causing less tissue damage and reducing the chance of the stitch cutting out. For deep tissues that are stronger (such as tendon) a tapercut, or combination needle is used - it has a tapered body, but the point is a reverse cutting edge.

Needles are grasped with a needle holder. The swage of the needle – the region where the needle is hollowed out to join with the suture – is the weakest point and grasping the needle in this region should be avoided. The needle should be grasped in the body one half or two thirds of the distance from the tip of the needle.

Suturing techniques

For closure of a wound with sutures a number of instruments are needed to maintain a sterile field and to allow manipulation of the tissues and needle (see Table 4.1.4). Finer instruments should be available for facial laceration repair.

Sutures should be placed to allow apposition of all injured layers of the skin. Proper suture placement should result in slight eversion of the wound edges, avoiding a depression of the scar when contraction takes place during wound healing. To ensure eversion of skin edges the skin suture must be placed so that an equal amount of tissue is included on each side of the wound, and so that the needle bite includes a broad base (Figs 4.1.2 and 4.1.3). This is accomplished by lifting the wound edge as the needle is passed through the skin on each side, maximising the deep tissues included in the suture.

Most wounds sutured in the ED are closed with interrupted skin sutures. Synthetic non-absorbable sutures are most commonly used. However, rapidly

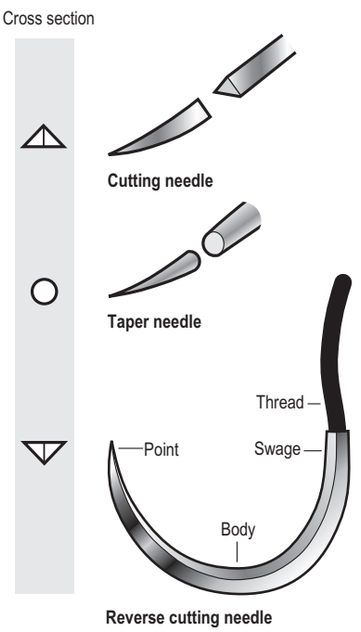

Fig. 4.1.1 Surgical needle characteristics and types. (From an original drawing by Elaine Wheildon)

Table 4.1.4 Example of instruments required for a simple suture tray

1 × Needle holder (Halsey or Hegar)
1 × Toothed dissecting forceps
1 × Curved artery/mosquito forceps
1 × Straight artery/mosquito forceps
1 × Suture scissors
1 × IV scissors
1 × Scalpel handle (e.g. No. 3)
2 × Huck towels
2 × Small bowls or trays

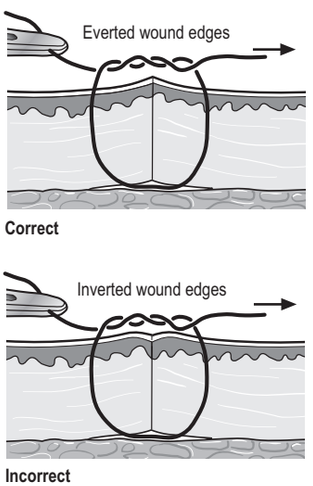

Fig. 4.1.2 Normal suture. Suturing technique for wound edge eversion.

absorbable sutures can be used to close the skin in children, avoiding the discomfort of suture removal. To place a simple interrupted suture the needle is held so the tip enters the skin at a right angle, and the hand rotated to ensure the needle remains at right angles to the skin throughout its passage, this aids in maximising the deep tissues captured in the bite. The stitch should be secured with an instrument tie and the knots secured to one side of the wound to minimise inflammation to the healing tissue. The initial throw should include two wraps of the suture material around the needle holder, subsequent throws should be wrapped once. The knot should be tied just tight enough to appose the skin edges. Tying the knot too tightly will cause a reduction in the blood supply to the wound edges and increase the risk of infection and poor cosmetic outcome. Synthetic sutures with poor handling should have 4 or 5 throws per knot.

The more sutures placed per centimetre the finer the control over the wound edge. For facial lacerations the skin sutures should be placed approximately 3 mm apart and enter the skin about 3 mm from the wound edge. For other areas of the body sutures should be placed 4 to 5 mm apart and should pierce the skin about 5 mm from the wound edge. The number of sutures used to close a wound should be the minimal number that allows a desired cosmetic outcome. In general, the better the blood supply, the closer together sutures can be placed.

There are generally two methods for closing a laceration, either suturing from one end to the other, or placing sutures that serially bisect the wound. A small linear wound is easily sutured from end to end, and long wounds without good landmarks on either side are most easily closed by placing the first stitch in the middle and then serially subdividing the wound. In wounds with definite landmarks such as palmar skin creases or the vermillion border of the lip the first suture should be placed to align these landmarks.

Deep sutures should be placed where there are multiple layers of tissue involved and the skin sutures would be under tension. They are placed to reapproximate the dermal layers of the skin and remove skin tension, thus improving cosmetic outcome. Placing deep sutures inserts a foreign body into the wound and increases the risk of wound infection so they should only be placed when necessary and the minimum number necessary used. For this reason, deep sutures should be avoided in the hands and feet. Deep sutures placed close to the skin are sometimes extruded through the wound. To place a deep suture the needle is placed at the depth of the wound and removed at a more superficial level. The needle is then placed at the same superficial level on the opposite side of the wound and exits deeply so the knot is tied deeply in the wound (see Fig. 4.1.3).

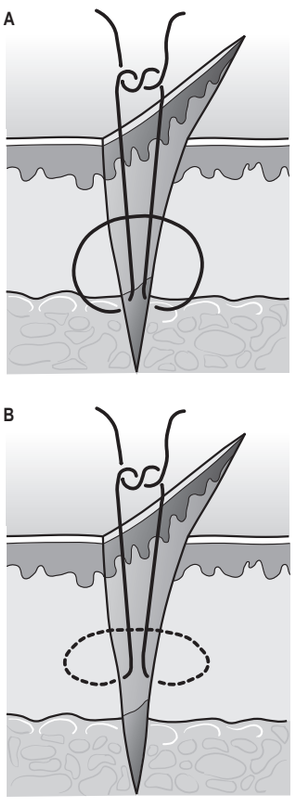

Fig. 4.1.3 Deep sutures. (A) The buried subcutaneous suture; (B) the horizontal dermal stitch.

Special suturing techniques

A variety of special suturing techniques are available with the sole purpose of aiding the provision of skin apposition with everted wound edges. The vertical mattress suture is useful in regions with minimal subcutaneous tissue where the edges are difficult to maintain in eversion. The technique is begun the same way as a simple skin suture, but after the suture loop is made the skin is re-entered 1 to 2 mm from the wound edge and then tied (see Fig. 4.1.4). The horizontal mattress suture reinforces the subcutaneous tissue and relieves skin tension, but does not provide wound edge approximation

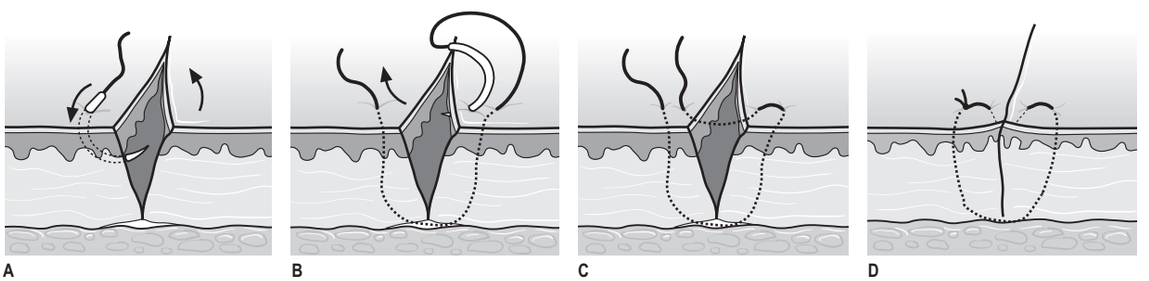

Fig. 4.1.4 The vertical mattress suture technique is useful to evert wound edges with a natural tendency to roll inwards despite correctly placed simple sutures. (From an original drawing by Elaine Wheildon)

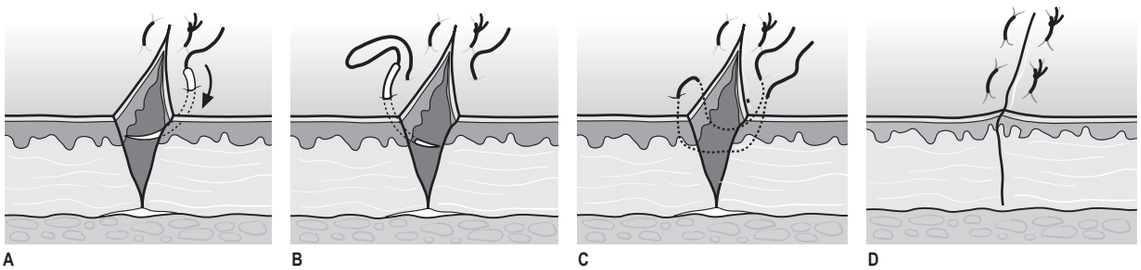

Fig. 4.1.5 The horizontal mattress suture redistributes tension and everts wound edges. (From an original drawing by Elaine Wheildon)

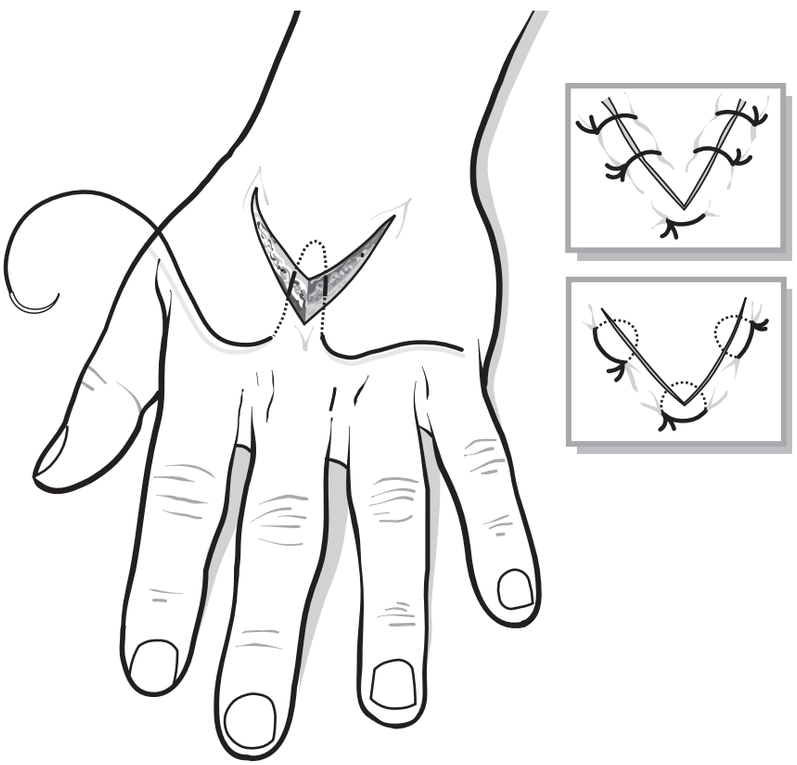

Fig. 4.1.6 Closure of a flap requires an initial suture of the apex, after which either simple or horizontal mattress sutures may be used. (From an original drawing by Elaine Wheildon)

as well as the vertical mattress suture (see Fig. 4.1.5). The modified or half-buried horizontal mattress suture (or corner stitch) is the method of choice for closing a flap. It relieves tissue tension and avoids vascular compromise when approximating the tip of the flap (see Fig. 4.1.6).

A continuous suture can be used to close the laceration. It is faster to place than interrupted sutures, removal of sutures is easier and faster, and the tension is spread evenly along the wound. The continuous suture can be percutaneous or subcutaneous and made with absorbable or non-absorbable suture material. The disadvantages are that if one part of the suture breaks the integrity of the whole wound is lost, and if the wound becomes infected the whole wound needs to be opened to drain the pus. To place a percutaneous running stitch an interrupted suture is placed at one end of the wound and only the free end of the suture is cut. Suturing is continued along the wound in a coil pattern ensuring that the needle passes perpendicularly across the wound with each pass. The loop is tightened after each pass and the last stitch placed beyond the end of the laceration. The stitch is tied using the last loop as the tail.

Correction of dog ears

A dog ear is the term given to a conical pucker of redundant skin that may develop at the ends of the wound during suturing. It is avoided by suturing the wound from the middle by sequentially bisecting the wound. Dog ears can be removed in many ways the simplest of which is the overlap excision technique. The redundant skin is pulled across the wound from one side and excised along the line of the wound. Redundant skin from the opposite side is pulled across the wound and also excised along the line of the wound. The wound is then closed (see Fig. 4.1.7).

Staples

Stainless steel staples can be applied more rapidly than sutures, and they are associated with a lower rate of foreign body reaction and infection. Staples are generally considered especially useful for lacerations of the scalp, trunk, and limbs. However, they do not allow such meticulous wound apposition as sutures, and are slightly more painful to remove. They should not be used on the face or in any other wound where cosmetic outcome is a high priority.

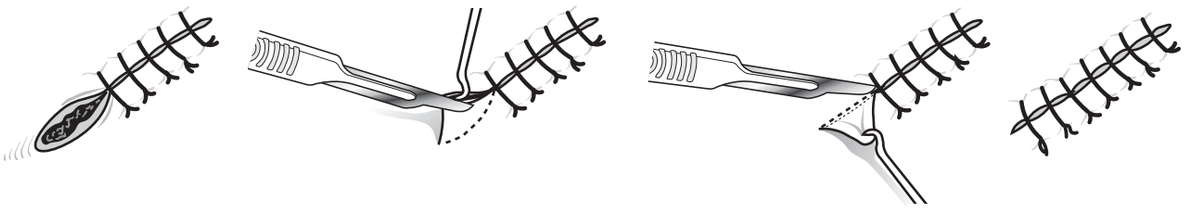

Fig. 4.1.7 Dog ear. Direct overlap excision technique. (From an original drawing by Elaine Wheildon)

Tissue adhesives

Tissue adhesives have now been in use for several decades. The basis of the adhesive is a cyanoacrylate polymer. The cyanoacrylate polymerise in the presence of hydroxyl ions – found in water or blood – allowing them to bind to the skin. Tissue adhesives are for external use only and should not be placed within wounds or used on mucous membranes.

It is in the repair of lacerations to young children that tissue adhesives have become most popular. They are easy and relatively painless to apply and provide a cosmetic result that is as good as suturing, with no risk of causing suture marks. No removal is required, as they slough off in 7 to 10 days. They are, however, not suitable for use in all wounds. If the laceration cannot be approximated and the wound edges brought together with minimal tension then tissue adhesive is not appropriate. Care should be taken not to apply too much tissue glue and to avoid placement over currently bleeding wounds as the polymerisation is exothermic and the patient will notice a heat sensation. Also, contact with excess blood causes polymerisation above the skin limiting the tensile strength of wound-edge closure.

The tissue glue is applied over the surface of the wound once its edges have been approximated by digital pressure. A thin layer of glue is applied across the wound and the wound held approximated for about 30 seconds. Care is taken not to allow glue to spill into eyes or orifices, and to avoid fixing forceps or gloves to the patient. The cyanoacrylates also act as their own dressing providing moist wound healing conditions under the glue, and have a degree of intrinsic antimicrobial activity. Careful attention to wound cleansing is still needed to avoid wound infections. In general, they are less expensive than sutures or staples and are strongly preferred by patients and families. A comparison of the various methods of wound closure is found in Table 4.1.5.

Table 4.1.5 Characteristics of wound closure techniques

Technique	*Advantages*	*Disadvantages*
Suture	Greatest tensile strength Meticulous closure	Requires removal Painful Slow application Costly Slow to apply Increased tissue reaction
Staples	Rapid application Low cost Low tissue reactivity	Less meticulous closure Discomfort of removal
Tissue adhesives	Painless Rapid application No removal needed Low cost No risk of needle stick	Lower tensile strength Not for use over joints
Surgical tapes	Least reactive Rapid application Patient comfort No risk of needle stick Low cost	Low tensile strength Difficulty maintaining adhesion Requires use of toxic adjuncts

Skin tapes

Skin tapes can be used to close small wounds with low tensile forces. They cannot be used over areas of motion such as over joints. Wound haemostasis is vital as the tapes will not stick to wet skin. Application of an adhesive agent to the skin adjacent to the wound is necessary to provide adequate adhesion of the tapes. These adhesive agents (e.g. Tinc benz®) are toxic to tissues and cause pain, so great care should be taken not to spill them into the wound. Tapes are not suitable for use in small children as they frequently pull them off. Tapes are a useful adjunct to wound closure, for example after suture removal or tissue adhesive application to decrease tension on the wound.

POST-WOUND-CLOSURE CARE

All patients should be provided with written information on care of their wound. Parents and children must understand the importance of ongoing wound care and be provided with instructions about follow up.

Dressing and suture removal

After the wound has been sutured it should be covered with a non-adherent

occlusive or semi-occlusive dressing to protect the wound from bacterial invasion and provide a moist healing environment and speed wound healing. Ideally the dressing is left intact until suture removal. The dressing should only be removed if it becomes saturated or there is a risk of infection and inspection is warranted. If the wound is not covered with a waterproof dressing the dressing can be removed every few days for showering. Non-absorbable sutures should be removed at the appropriate time, depending on the location of the injury. Removal of the sutures too early risks dehiscence, leaving sutures too long increases tissue reaction and the risk of cross-hatching and wound infection (see Table 4.1.6). In general, sutures are removed earlier in children than in adults. Wounds closed with tissue adhesive should not be covered with an occlusive dressing, as the extra moisture will more rapidly decrease the ability of the glue to maintain wound edge apposition. The wound should be kept dry for three days, after which the patients may shower but should avoid bathing and swimming. Wounds closed with skin tapes should be kept dry to prevent premature removal.

Immobilisation and drains

Wounds that cross joints or are in areas of highly mobile skin should be immobilised. The joint should be splinted in the position of function for 7 to 10 days. Plaster of Paris can be used to make a cheap and easily applied splint, or a bulky dressing can be used to limit motion and prevent the child tampering with the wound.

Table 4.1.6 Timing of suture removal

Wound location	*Time of removal (days)*
Face	4
Scalp	5
Upper limbs, trunk	7–10
Lower limbs	8–10
Over joints	10–14

In general, drains should not be used in wound that have been closed as they promote wound infection. If a wound is considered at high risk for infection delayed primary closure should be undertaken rather that closure and drainage.

TREATMENT OF SELECTED INJURIES

Abrasions

In abrasions the underlying tissues are relatively uninjured, providing a degree of protection against infection. Cleansing the abrasion is important to flush away bacteria and remove particulate matter, which should be removed to prevent infection or tattooing. Large abrasions or those heavily contaminated may need cleaning under general anaesthesia. After adequate cleansing and debridement the wound should be covered with a non-adherent occlusive or semi-occlusive dressing. A moist environment enhances healing, and the environment under a scab is ideal. However, wounds without extensive scab formation are more comfortable, so a dressing provides the moist environment. Children with large or deep abrasions should be reviewed in 2 to 3 days to check the wound. Ongoing review should be once or twice weekly.

Eyelid lacerations

A thorough eye examination needs to be performed for all eyelid lacerations. Attention should be given to the possibility of a ruptured globe (eccentric pupil) or trauma to the globe (hyphaema, dislocated lens or retinal detachment). Visual acuity should be measured and documented. Any wound that penetrates the tarsal plate or the inner canthus requires specialist attention, as do wounds involving the lid margins. Any wound that cannot be adequately assessed (e.g. in a young child) should be referred for evaluation under anaesthesia.

Superficial wounds of the eyelid are relatively easily repaired with 6–0 fast absorbing gut with sutures placed close to the wound edge. Care must be taken not to suture into the tarsal plate or other deep structures.

Lip lacerations

Inspection of the teeth and oral mucosa is mandatory in all lip lacerations. Tooth injuries should be documented and referred for management where necessary, missing teeth warrant investigation to ensure they have not been inhaled or imbedded in the soft tissues of the mouth. Ideal anaesthesia is via nerve block of the mental or alveolar nerves for the lower lip or the infra-orbital nerve for the upper lip. Alternatives include sedation and direct infiltration, with or without application of methylene blue to the margins of the vermillion border.

Wounds that involve the vermillion border (the junction of the dry oral mucosa and the facial skin) must be exactly realigned to achieve acceptable cosmetic results. A 6–0 suture should be used with the first suture placed to exactly reappose the vermillion border. Further sutures should close the skin and the dry mucosal surface of the lip with the wet mucosal surface only closed if it is gaping significantly.

Deep or through and through lacerations of the lip require deep sutures to repair the orbicularis oris muscle, if this is the case, an absorbable 6-0 suture should be used. The deep sutures should be placed after the initial suture is placed at the vermillion border and before tying that stitch.

Tongue lacerations

Most tongue lacerations can be left to heal without intervention with good results. Large lacerations involving the free edge of the tongue should be repaired to avoid healing with a notch, interfering with the function of the tongue. Large flaps and lacerations that continue to bleed should also be repaired. Care should be taken when repairing these injuries because of the risk of airway compromise, especially considering moderate to deep sedation is likely to be necessary.

The tongue should be maintained in position by a gentle pull using a towel clip or 4–0 suture placed through the tip. Interrupted 4–0 absorbable sutures should be placed using full thickness bites to include both mucosal surfaces and the lingual muscle in each stitch. Multiple

knots should be used to secure the sutures and the parents warned that while the tongue is anaesthetised the child may bite through the stitch.

Fingertip amputation

Young children tend to injure their fingertips in doors and windows. Most of the injuries in young children are contused lacerations of or partial amputations and complete amputation is less common. Older children are more prone to injury with knives or tools. Fractures are less common in the older age group. These wounds should be evaluated for tissue loss and with radiography for bony injury.

If the amputated fragment has been retained and involves any of the nailbed some surgeons will reimplant as a graft with approximately 50% chance of the graft taking. If the tissue is not retained or is small, and there is no bone on view, it is most appropriate to allow the wound to heal by secondary intention. Fingertips allowed to heal naturally have greater length and better sensory outcome than those treated with grafts. These wounds should be covered with a non-adherent occlusive or semi-occlusive dressing to allow moist wound healing after thorough cleaning and debridement as needed. Follow up should be maintained until the wound is healed.

Injuries involving just the fingertip but not the nail heal very well. Injuries involving the nailbed or nail, but sparing bone, heal well. Those that involve the nailbed, nail and distal phalanx heal less well. Any injury with bone on view should be referred for specialist care.

Nailbed lacerations

Trauma to the distal fingers is often associated with nailbed injury. An underlying fracture of the distal phalanx should be assessed with radiographs. Unrepaired nailbed lacerations can permanently disfigure the growth of the new nail from the matrix.

If the nail is lacerated, completely avulsed, or only loosely attached the nail bed must be explored. This can be done under local anaesthesia with a ring block of the digital nerves or under general anaesthesia. The nail must be removed and the nailbed repaired with 5–0 or 6–0 absorbable suture material. The space between the nailbed and nailfold must be packed with xeroform gauze or the nail replaced to prevent adhesions. If a fracture is present antibiotics should be given. If the nail is partially avulsed only and is tightly adherent to the nailbed it is reasonable to leave this intact as it will adequately splint and maintain apposition of any nailbed injury.

Subungual haematoma

A subungual haematoma is a collection of blood between the nail and nailbed. It is most commonly seen with blunt fingertip injuries and may be associated with a fracture of the distal phalanx. Drainage of the haematoma usually provides symptomatic relief and should be undertaken whenever the haematoma is causing pain. Generally no local anaesthesia is required to drain the haematoma with cautery or needle burring using a 19-gauge needle. If there is an underlying fracture antibiotics should be administered. There is no size of haematoma that requires nail removal for inspection of the nailbed.

Puncture wounds to the foot

Puncture wounds to the foot carry a high risk of infection and retained foreign body. All puncture wounds should be assessed for retained foreign body with radiography, and ultrasound for radiolucent foreign bodies. Anaesthesia with local infiltration or a posterior tibial nerve block is needed. The wound should be soaked to remove any scab on the surface, debrided and irrigated. The wound should be left open once any foreign material has been removed. The wound should be cleaned with an antibacterial solution (such as Betadine®) and dressed with a non-adherent dressing. Close review is important to detect infection early. Prophylactic antibiotics have not been shown to prevent infection and may predispose to *Pseudomonas* infection.

Bites

Animal bites

Animal bites are a common presenting problem for the ED. Dog and cat bites account for virtually all bites seen in the ED with dog bites being about six-times more common. Rodents and other animals account for less than 1 to 2% of bites.

Dog-bite injuries tend to be relatively large, relatively superficial crush injuries, which are seen most commonly on the face, neck and scalp in children. The overall infection rate for dog bites is about 10%, with facial wound infection rates of about 5%. Dog-bite wounds are infected with multiple organisms on all occasions, with both aerobic and anaerobic bacteria. It is reasonable to cleanse and close most dog bites with antibiotic prophylaxis provided only to wounds that are high risk for infection (see Tables 4.1.7 and 4.1.8).

Cat bites on the other hand are typically puncture wounds with less surrounding tissue injury. They have bacteria inoculated deep into the wound, which is difficult to explore, irrigate or debride. The risk of infection is significantly higher than in dog bite – at least twice as likely – because of the puncture type wound, the most common location of the bite being

Table 4.1.7 Wound infection risk factors

	High risk	*Low risk*
Biting species	Cat Human	Dog Rodent
Location of wound	Hand Over a joint Below knee Through and through oral	Face Scalp Mucosa
Wound type	Puncture Extensive crush Old	Large Superficial Recent

the hand, and the high incidence (about 80%) of *Pasteurella multocida* found in cats' mouths. *P. multocida* is a facultative, anaerobic Gram-negative rod that often results in rapidly progressive cellulitis. It is sensitive to the penicillins and variably sensitive to macrolides and first-generation cephalosporins. All these drugs have been documented as adequately treating infections of *P. multocida*, but treatment failures have been documented for erythromycin and first-generation cephalosporins. It is recommended that all cat bites receive prophylactic antibiotics (see Table 4.1.7).

Human bites

Most human bites are probably at no more risk of infection than ordinary lacerations and they are not considered to carry a high risk of HIV transmission. However, the clenched-fist injury (or fight bite), which commonly causes a ragged laceration over the fourth or fifth metacarpophalangeal joint is at high risk of infection. These latter wounds should all receive prophylactic antibiotics, as should human bites (including self-inflicted bites) that have high-risk properties (see Tables 4.1.7 and 4.1.8.).

Table 4.1.8 Management of bite wounds

Species	*Suturing*	*Antibiotics*
Dog	Yes	High-risk wound type only
Cat	Face only	All
Rodent	Yes	No
Human – hand bites	No	Yes
Human – other bites	Yes	High risk only

CONTROVERSIES

❶ Subcutaneous sutures close deep wound dead space reducing fluid collection and infection, deep sutures of themselves can cause infection by acting as a foreign body.

❷ Dressings for all wounds is changing to promote moist wound healing, this speeds rate of healing and improves wound comfort.

❸ A number of topical anaesthetic creams are being used in extremity wounds despite not being licensed for this use.

❹ Wound drains are not indicated in the management of wounds in the ED, and delayed primary closure is a preferred technique.

❺ Debridement should remove as little tissue as possible to maximise cosmetic outcome.

❻ Prophylactic antibiotics, while intended to prevent infection, have been shown in some wounds to increase the risk of infection with unusual organisms.