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AHC Media

Stitches, Staples, and Glue: Wound Repair in the Emergency Department

Introduction

Lacerations are a common reason for patients to come to the emergency department (ED). According to the Centers for Disease Control and Prevention data from 2007, "open wounds (excluding the head)" were the primary leading diagnosis for men between the ages of 15 and 64 years.[1] In the same report, lacerations were repaired in approximately 5.1 million visits to the ED (4.4% of all ED visits).[1]

Wound repair is a common area for litigation in emergency medicine, accounting for 5-20% of all malpractice claims and 3-11% of all monetary awards.[2] Among the most common reasons for litigation are failure to diagnose foreign bodies, wound infections, undiagnosed injuries to underlying structures (such as nerves and tendons), and violation of the joint.[2]

This article presents an evidence-based review on the evaluation and management of lacerations in the ED.

Wound Evaluation

When evaluating a patient with a laceration, it is important that the emergency physician obtain a detailed history prior to inspection of the wound. The mechanism of injury may provide important clues to the depth of the wound, presence of debris or foreign bodies, degree of contamination, and the possibility of injury to underlying structures. The time that the injury occurred is also important, as delays in treatment may alter the manner in which wounds are repaired. The amount of blood lost prior to presentation to the ED may raise the clinician's suspicion of injury to vessels in the area. The patient's symptoms also are important to address. Severe pain to the area out of proportion to the visible injury or a foreign body sensation may be due to an underlying fracture or presence of a foreign body, respectively. Paresthesias or loss of sensation may represent nerve injury or compartment syndrome. The past medical history, such a co-morbid illnesses, and tetanus status should be assessed and documented.

During wound inspection, the clinician should look for and carefully document the presence of gross foreign bodies or debris in the wound. For wounds on the extremities, tendon and muscular function distal to the wound should be assessed. Focused sensory and motor examination of involved areas should be performed prior to administration of local anesthesia.

Wounds that overlay joints should be assessed for violation of the joint capsule. Wounds that penetrate the joint capsule may introduce bacteria, resulting in septic arthritis. Therefore, wounds that violate the joint capsule routinely undergo washout in the operating room.[3] The most common site of traumatic arthrotomy is the knee.[4] If there is clinical suspicion, the saline solution load test may be performed to evaluate for communication between the open wound

Executive Summary

- Wound assessment and preparation should be done carefully to avoid missing foreign bodies or injuries to the tendons, nerves, vessels, and joints.
- Use techniques to close the wound with minimal skin tension to produce the best cosmetic outcome.
- The variants of mattress sutures are very useful to close larger wounds and flap-tips.
- The post-repair wound dressing should keep the wound area moist to encourage epithelial growth.

and the joint capsule. The saline solution load test involves injecting sterile saline into the joint capsule at a site remote from the injury and then performing passive range of motion of the joint. Extravasation of fluid from the traumatic wound site confirms the diagnosis of traumatic arthrotomy. The amount of injected fluid necessary to make the diagnosis of traumatic arthrotomy of the knee has been examined in two recent studies. Although some textbooks have recommended volumes as low as 50 mL for a saline load test of the knee, these two articles found that a minimum volume of 145-194 mL is necessary for the test to achieve 95% sensitivity.[3,4]

Local and distal vasculature should be assessed carefully. If a wound is actively bleeding, direct digital pressure should be applied for 10-15 minutes. Most bleeding from venous sources will stop with properly applied direct pressure. If digital pressure alone does not control the bleeding, a compression dressing of gauze sponges secured with an elastic wrap can be applied. This, in combination with elevation, is an effective method of hemostasis. Absorbable hemostatic agents, such as Gelfoam® or Surgicel®, can be used to control diffuse oozing in wounds that will be left open to heal by secondary intention. If bleeding persists despite these noninvasive techniques, the bleeding vessels may need to be ligated. To ligate a vessel, first clamp the bleeding end with a hemostat under direct visualization. Once hemostasis with the clamp is achieved, pass a 5-0 or 6-0 absorbable suture around the clamp, and tie it. Once the suture is secured, the clamp can be released.[5] If the vessel is too small to be ligated, low temperature (about 600-700°C) electrocautery is another option. If bleeding in an extremity is persistent or severe, a tourniquet may be applied to stop bleeding so that the injured vessel can be identified and addressed. A blood-pressure cuff placed on the extremity proximal to the wound and inflated to a pressure greater than that of the patient's systolic pressure can serve as a tourniquet. Once the source of bleeding has been identified, the vessel can be ligated to achieve hemostasis.

Tetanus Toxoid

Tetanus is a potentially fatal disease resulting in spasm and rigidity of the skeletal muscles. It is caused by the exotoxin of the bacterium *Clostridium tetani*. Injuries that historically have been considered at a high risk for developing a tetanus infection are wounds contaminated with feces, saliva, or soil, burns, frostbite, crush and missile injuries, puncture wounds, and avulsions. As part of ED wound care, tetanus toxoid should be administered according to the most current recommendations by the Advisory Committee on Immunization Practices and the Centers for Disease Control and Prevention published in 2010 (*summarized in Table 1*).[6] Prophylaxis with tetanus-diphtheria toxoid (Td) is not indicated for minor or clean wounds unless the patient has not received a booster within 10 years, has had fewer than three doses, or has an uncertain immunization history.[6] Td should be given to all patients who have contaminated or tetanus-prone wounds (i.e., frostbite, avulsions, burns, crush injuries) and who have not received a dose within the past 5 years, who have had fewer than three total doses, or have an uncertain immunization history. In patients who are 19 to 64 years of age, it is recommended that patients without prior vaccination with Tdap (a combination of tetanus, diphtheria, and acellular pertussis) receive a one-time dose.[6] Td is recommended for those who have received prior Tdap for subsequent boosters. Pregnancy is not a contraindication to receiving the tetanus toxoid (Td/Tdap) and should be given if indicated.[6]

Tetanus immune globulin (TIG) should be administered to patients who have tetanus-prone wounds and have not received prior immunization or if the tetanus immunization history is uncertain. The recommended dose for patients of all ages for postexposure prophylaxis for tetanus is 250 units by intramuscular injection. If Tdap is also given, it should be administered in a different syringe and at a separate site than the TIG.[6]

Radiographs, Fractures, and Foreign Bodies

The presence of a fracture associated with an open wound may alter the treatment plan, depending on the location of the injury. Open fractures of long bones require surgical cleansing in the operating room, while those on the digits may be copiously irrigated in the ED and discharged home. Additionally, open fractures are at high risk for infection and should receive intravenous prophylactic antibiotics. If there is a clinical suspicion that there may be an injury to the underlying bone, a plain radiograph should be obtained.

Wounds potentially may contain

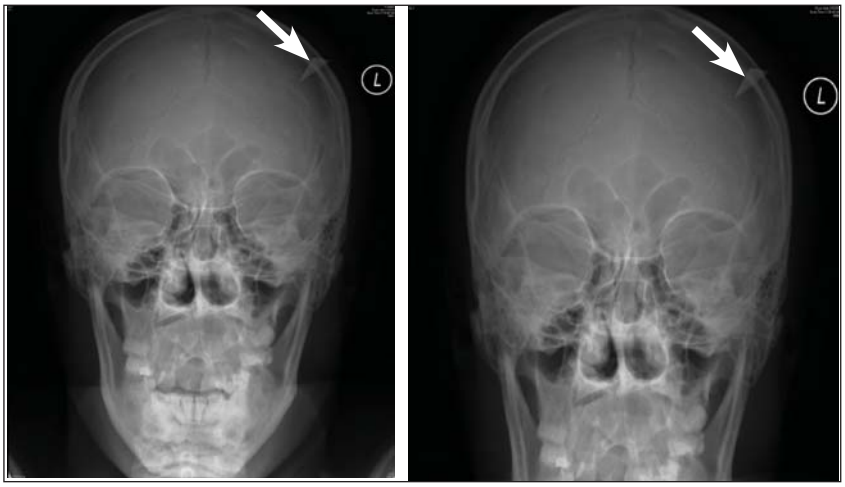
Table 1: Recommended Tetanus Prophylaxis[6]

History of Tetanus Immunization (doses)	Clean or Minor Wounds		All Other Wounds*	
	Td or Tdap	TIG	TD or Tdap	TIG
Less than 3 or uncertain	Yes	No	Yes	Yes
Three or more	No	No	No	No
Last dose greater than 5 years ago	No	No	Yes	No
Last dose greater than 10 years ago	Yes	No	Yes	No
* Such as, but not limited to, wounds contaminated with dirt, feces, soil, or saliva; puncture wounds; avulsions; and wounds resulting from missiles, crushing, burns, or frostbite.				

occult foreign bodies of various compositions, such as metal, plastic, gravel, glass, and wood. Detection and removal of this debris is important as it may delay wound healing, serve as a nidus for local inflammation and potential infection, and may result in subsequent loss of function. In the 1990s, undetected foreign bodies were a significant cause of litigation in the ED, accounting for 14% of all lawsuits and 5% of settlements.[7]

There are several radiologic modalities that can be used to detect foreign bodies in a traumatic wound. In the ED, plain radiographs, computed tomography (CT) scans, and ultrasound imaging are the most commonly available techniques. The sensitivity of each modality varies and is dependent on the composition of the foreign body.

Figure 1: Radiograph of Patient Stabbed in the Head

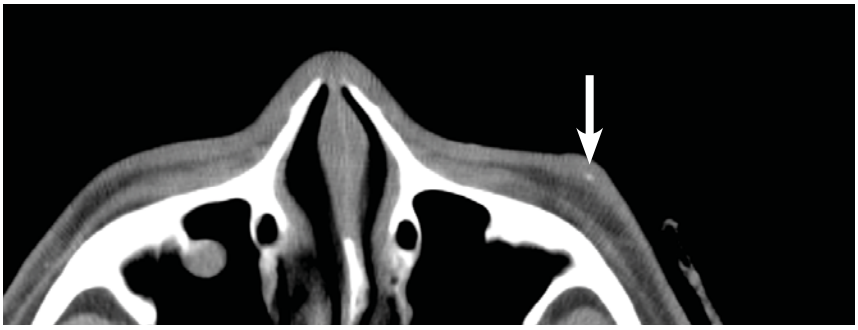


These are A-P and lateral plain radiographs of the skull of a patient who was stabbed in the head with a knife. The arrows point to a metal foreign body that happened to be the tip of the knife that broke off and was retained in the wound.

Plain radiographs are the standard screening method used by emergency physicians to look for foreign bodies in wounds. Although useful for detecting radiopaque objects such as metal and glass, its sensitivity for detection of radiolucent objects, such as plastic and wood, is low. (*See Figure 1.*) In a retrospective study of the clinical characteristics and management of wound foreign bodies in the ED, Levine et al. found that the sensitivity of plain films for detecting foreign bodies was 98.6% for metal, 75.5% for glass foreign bodies, and 7.4% for wood foreign bodies.[8] While computed tomography scanning is 100 times more sensitive in differentiating foreign bodies than plain radiographs,[2] the degree of radiation exposure and cost of the examination limit the use of CT scanning for the sole purpose of detecting foreign bodies. For the last few years, ultrasound has been increasingly used for detecting foreign bodies in the ED. (*See Figures 3 and 4.*) The accuracy of ultrasound to detect foreign bodies is dependent on the equipment specifications, skill of the operator, and size of the foreign body. Several studies comparing foreign bodies of various compositions suggest that ultrasound is a better study to detect foreign bodies such as wood and gravel when compared to plain films.[9,10] While MRI is highly accurate for detecting foreign bodies, its use for this purpose is impractical and should be reserved for cases in which there is suspected vegetative matter that is unseen on other imaging modalities.[11]

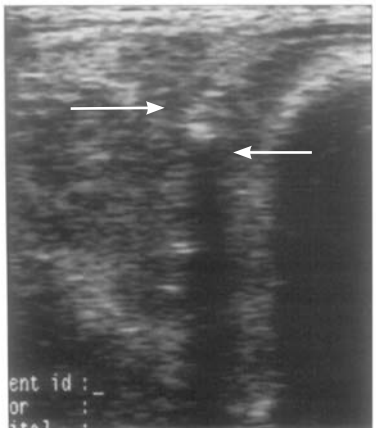
Foreign bodies that are visualized on physical examination should be removed prior to primary closure of the wound. The presence of one foreign body should heighten the clinician's suspicion for additional foreign bodies. If a foreign body is radiographically detected but is not visible in the wound upon inspection, the physician needs to weigh the risk of destroying adjacent tissues in its retrieval against leaving it in the wound. If the foreign body can be located without causing extensive trauma to surrounding tissues, an attempt should be made to locate and remove the object. If there are any small foreign bodies that were detected by radiography but that are not visible on physical exam, the wound should be copiously irrigated. The emergency physician should inform the patient of these findings and that, despite a good faith effort to remove these objects, remnants still may be left in the wound. These

Figure 2: CT of Patient with Multiple Facial Lacerations



This is a CT scan of the head of a patient who had multiple facial lacerations from a motor vehicle accident. The arrow points to retained glass in one of the wounds.

Figure 3: Ultrasound Showing Wooden Foreign Body[12]



The echogenic focus and prominent acoustic shadow are signs of foreign body.
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Figure 4: Ultrasound Showing a 2 cm Foreign Body in Longitudinal Section[12]

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facts should be carefully documented in the patient's medical record.

Anesthesia

Adequate anesthesia of the wound is necessary to perform thorough wound exploration, cleansing, and debridement, as well as optimal closure. Local anesthesia may be injected into the intradermal tissues, around regional sensory nerves, or applied topically to the surrounding skin.

Anesthetics are classified into two groups: amides (examples: lidocaine and bupivacaine) and esters (examples: procaine, tetracaine). Since there is little cross-reactivity between the two groups, if there is a reported prior allergic reaction to agents in one class, it is generally safe to use an agent in a different class.

Allergies to lidocaine are rare.[13,14] Reactions are generally attributed to the preservative methylparaben, which is contained in the multiple-dose vials. To complicate matters, methylparaben is molecularly similar to one of the degradation products of the anesthetics in the ester class, and, therefore, use of esters in these patients may also be problematic. In this case, lidocaine from a single-dose source that does not contain a preservative (such as the lidocaine used to treat cardiac arrhythmias) may be used. If a patient reports prior allergic reactions to medications in both the amide and ester groups, local infiltration with diphenhydramine or benzyl alcohol may be used as an alternative. Studies have shown that when infiltrated locally, diphenhydramine and benzyl alcohol provide anesthesia that is comparable to that of 1% lidocaine.[15,16] While local infiltration of benzyl alcohol has been shown to be significantly less painful than diphenhydramine, its duration of anesthesia is shorter when compared to lidocaine but is comparable to diphenhydramine.[15]

Although the onset of action of each agent generally ranges between 2 to 5 minutes, the duration of action and maximum doses vary. (*See Table 2.*) An anesthetic combined with a vasoconstrictive agent, such as epinephrine (5 µg/mL of a 1:200,000 solution), has several advantages. Anesthetic solutions that contain epinephrine may be helpful in achieving hemostasis, as the vasoconstrictive effects reduce local blood flow. It also reduces the rate of vascular absorption, allowing more anesthetic molecules to reach nerve membranes, resulting in greater depth and duration of anesthetic effects.[17]

It has been taught for many years that anesthetics containing epinephrine should not be administered to the tip of the nose, digits, ears, or the penis, as it may theoretically cause irreversible vasoconstriction of the end-arterioles, leading to necrosis. However, this tenet has been refuted by recent studies of digit and hand surgery using epinephrine-containing anesthetics and critical reviews of the literature. Lalonde et al. prospectively studied the use of anesthetic agents containing low-dose epinephrine (≤ 1:100,000) in elective finger and hand surgeries

Table 2: Properties of Common Anesthetics Used for Local Infiltration[20-22]

Anesthetic Agent	Range of Concentration (%)	Maximal Dose	(mg/kg)	Duration of Action (hours)*
		(-) epi	(+) epi	
Amides				
Lidocaine (Xylocaine)	0.5-2	4.5	7	0.5-2
Bupivacaine (Marcaine)	0.125-0.5	2	3	1.5-8
Mepivacaine	0.5-1	4.5	7	0.25-2
Esters				
Procaine (Novocaine)	0.5-1	7	9	0.25-1
* Duration of action is dependent on concentration, location of infiltration, and combined use with a vasoconstrictive agent.				

and found no digital infarction in any of the 3110 enrolled patients (1340 of the cases involved injections into the fingers).[18] The authors do warn that since the contraindications for epinephrine use are not well established, caution should be taken in patients with pre-existing vascular insufficiency.[18,19] The authors also comment that injection of epinephrine-containing anesthetics into digits should be used by those physicians who are well educated in the use of phentolamine for reversal in the event of ischemia.[18,19]

Topical anesthetics have been employed for years in the pediatric population and are an excellent alternative for patients who have aversions to needles. Topical agents contain combinations of various anesthetic and vasoconstrictive substances and are applied directly to the wound or designated area. The ideal location for topical anesthetic use is one that is highly vascular, allowing for maximal and expeditious absorption. TAC (tetracaine, adrenaline, and cocaine) was once a popular agent, but its use has fallen out of favor after it was found to be associated with seizures, cardiac arrest, and death.[23-25] Subsequent combinations with a higher safety profile, such as LET (lidocaine, epinephrine, and tetracaine) and EMLA (eutectic mixture of local anesthesia, which contains 2.5% lidocaine and 2.5% prilocaine), have been developed. Studies comparing EMLA to TAC have found that more wounds initially treated with TAC required subsequent local wound infiltration (55% of TAC-treated wounds vs. 15% of EMLA-treated wounds).[26] However, the onset of anesthesia was faster with TAC (29 minutes) as compared to EMLA (55 minutes).[26] The long onset of action and depth of absorption, which may require additional local infiltration for wounds requiring multiple layer closure, are the main disadvantages to topical anesthetic use for wound closure in the ED.

Pain will be associated with the local injection of the anesthetic agent. The emergency physician may use methods to reduce the discomfort associated with infiltration. Studies have shown that buffering the local anesthetic with 8.4% sodium bicarbonate solution — used in a 1:10 bicarbonate:anesthetic ratio — results in less pain during injection and faster onset of anesthetic effect without adversely affecting the wound infection rate.[27,28] The use of smaller-gauge needles (27 to 30 gauge) will reduce the amount of pain at the site of injection.[22,29] In addition, there are data that show that patients experience less pain with infiltration of local anesthesia when the needle was placed through the wound edges rather than through the surrounding intact skin.[30]

Regional anesthesia, or nerve blocks, involves anesthetizing a specific peripheral nerve remote from the site of injury. Advantages of regional anesthesia over local infiltration include less pain with administration, lower amounts of agent required for desired anesthetic effect, and less tissue distortion, allowing for improved cosmesis. The main disadvantages are that it requires a cooperative patient to achieve infiltration at appropriate landmarks and it carries a risk of inadvertent intravascular injection.

Wound Preparation and Cleansing

Although studies have found no significant difference in infection rates in wounds repaired with the physician wearing non-sterile gloves, implementation of a sterile technique is still recommended for all wound closure in the ED.[22,31] The emergency physician should use clean or sterile powder-free surgical gloves. Cleansing of the surrounding skin with an antiseptic agent should be performed prior to local wound infiltration with anesthetics. The most common antiseptic agents contain either iodophor or chlorhexidine. Caution should be taken to avoid application or inadvertent spillage of these solutions directly into the wounds, as they have been shown to have deleterious effects on wound healing.[29]

When performed properly, wounds that are irrigated prior to primary closure result in improved wound healing and a lower rate of infection. Sterile normal saline is a common solution for wound irrigation; however, the use of tap water for irrigation is acceptable, as some studies have found that tap water irrigation is effective without an increase in wound infection.[32,33] Irrigation with tap water allows for large volumes to be delivered into the wound, but its

use may be limited by the low irrigation pressure from the faucet and the fact that wounds in certain locations may make their positioning over a sink difficult. Agents such as povidone iodine, hydrogen peroxide, or other detergents should not be used to irrigate wounds, as they have toxic effects on tissues, can impair wound healing, and do not alter wound infection rates.[34]

The amount of irrigation fluid used will depend on the size of the wound and the degree of contamination. The efficacy of irrigation to reduce bacterial colonization of a contaminated wound is directly proportional to the pressure applied to the wound surface.[29] Low-pressure irrigation, defined as 0.5 pounds per square inch (psi), is used for relatively clean wounds and may be achieved using a bulb syringe. High-pressure irrigation, defined as 7 psi, is used for wounds that are highly contaminated.[29] High-pressure irrigation may be achieved by using a 19-gauge needle or catheter attached to a 30 to 60 mL syringe.[22,29] Although it significantly reduces the incidence of infection in contaminated wounds, high-pressure irrigation may cause significant tissue damage and theoretically may increase the risk of infection due to dissemination of bacteria.

Surgical consultation should be obtained for highly contaminated wounds requiring extensive wound debridement and/or extensive cleaning.

When irrigating wounds, the emergency physician should use a protective eye shield and a commercial device that reduces the amount of splatter, if available.[35]

When managing wounds that are in areas that contain hair, it is sometimes helpful to remove the surrounding hair to facilitate wound closure. Some literature has shown that use of razors for hair removal releases the normal bacteria flora that resides in the follicles and, thus, results in a higher rate of wound infection.[36] Thus, it is recommended that hair be removed by using scissors to trim the surrounding hair. Eyebrows should never be shaved, as they serve as important cosmetic landmarks for wound approximation and the degree of hair re-growth is unpredictable.

Wound Debridement

Devitalized or heavily contaminated tissue does not promote wound healing, as it acts as a medium for promoting bacterial growth and inhibiting phagocytosis.[29] Debridement is a process by which these tissues are removed from the wound. Although devitalized fat, muscle, and skin are equally capable of promoting bacterial growth, identification of the precise limits of these tissues presents a challenge.[29] The emergency physician should obtain a surgical consultation if there are any questions of tissue viability, if the wounds are heavily contaminated, or if there is involvement of specialized tissues such as tendons or nerves. These wounds frequently require surgical cleansing, exploration, and debridement in the operating room. In general, as little tissue as possible should be removed. Wounds that require extensive debridement or are heavily contaminated are frequently best treated by delayed primary closure, as they are at high risk for infection. In this manner, the risk of infection can be reduced, and the wound and tissue viability may be reassessed.

Time of Closure

When to close a traumatic wound is an important decision and is based on the amount of time between the onset of injury and presentation to the ED, the location of the wound, the degree of contamination, and risk of wound infection.

Primary Closure. Primary closure is when a wound is repaired upon initial presentation within hours of the injury. This method has multiple advantages over other closures because it provides the best functional and cosmetic outcomes, reduces patient discomfort, and speeds wound healing.

The majority of lacerations are repaired using primary closure, which results in more rapid healing and less patient discomfort when compared to secondary closure.[22] The wound-infection rate is relatively low for lacerations primarily repaired in the ED, occurring less than 5% of the time. While most studies of laceration management focus on infection rates as the primary endpoint,[16] investigators have recently found that patients are more concerned with the cosmetic appearance of healed lacerations,[22,37] and research has shifted toward measuring wound cosmesis as the primary outcome.

The main disadvantage of primary closure is the increased risk of infection in contaminated wounds.[38] With contaminated wounds, the emergency physician should strongly consider opting for treatment with delayed primary closure or secondary closure.

Delayed Primary Closure. Delayed primary closure is when a wound is sutured closed 3-5 days after the time of injury. The underlying principle behind delayed primary closure is that bacterial colonization levels decrease over time in wounds that are left open, reaching their lowest point 96 hours after the wound occurs.[38] At this point, there is less of a risk of infection, and closure of the wound is permissible. The wound should be irrigated, debrided, and dressed at the time of presentation. The wound can be irrigated again and closed with sutures in 4 days.[29] Delayed primary closure has a lower risk of infection than primary closure and a better cosmetic outcome than allowing the wound to heal by secondary closure.

Delayed closure is the method of choice for wounds that are clearly contaminated or at high risk for infection.[38] Other wounds that may be candidates for delayed closure are wounds that present after a delay. There is controversy surrounding the "golden hour" for wound repair. While some studies have found an increased infection rate in wounds closed more than 4 hours after injury, others have found no difference in wounds closed up to 19 hours post injury.[22,39] Wounds on

the scalp and face are less likely to become infected than wounds on the trunk and extremities.[22] Delayed closure may be the option of choice for late-presenting wounds in immunocompromised patients, such as diabetics.[22]

Secondary Closure. Secondary closure (or secondary intention) is when the wound is not repaired but is allowed to heal by the formation of granulation tissue. The disadvantage of secondary closure is that it produces more scarring than primary closure, producing a poorer functional and cosmetic outcome. Secondary closure is the method of choice for infected wounds and contaminated small wounds such as puncture wounds.[38] Superficial eyelid lacerations that comprise less than 25% of the lid also heal well by secondary intention.[40]

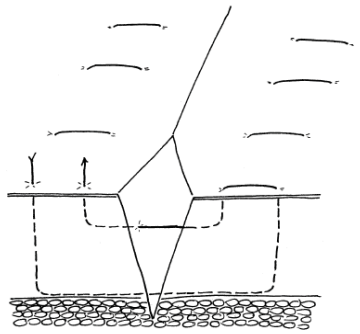
Methods of Closure

Deep Sutures. Deep sutures are those that are placed in tissues below the epidermal layer. Placing deep, dermal sutures helps relieve skin tension and decreases dead space and hematoma formation.[41] There have been animal studies showing that dermal sutures increase the infection rate in highly contaminated wounds.[42] However, other studies have found no effect on infection rate in clean, noncontaminated wounds.[43] Sutures placed through adipose tissue do not hold tension and have been shown to increase infection rates, especially in contaminated wounds and, thus, should be avoided.[22,44,45]

Some studies have found that the placement of deep sutures improves cosmetic outcomes.[45] However, a large retrospective analysis found that the placement of deep sutures had no effect on three-month cosmetic outcome, and wounds with poor cosmetic outcomes tended to be wider than those with optimal cosmesis.[46]

Singer et al. performed a randomized, controlled trial that compared single-layer and double-layer closure of small (less than 3 cm) and nongaping (less than 10 mm wide) facial lacerations. The study found that while the closures performed with deep sutures took longer to perform, there was no difference in cosmetic outcome between single-layer and double-layer closure.[47]

Figure 5: Classic Vertical Mattress Suture[48]



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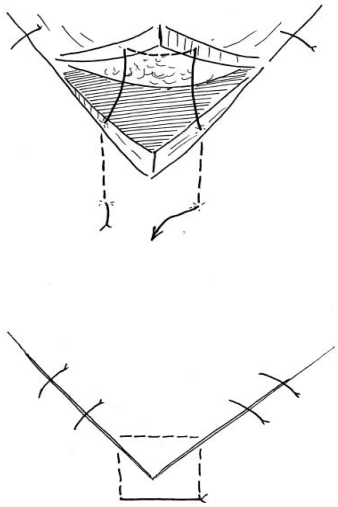
Wound Repair Technique

Simple Interrupted and Running Sutures. Simple interrupted sutures consist of a single loop through the skin and subcutaneous tissues that is secured at the skin. Multiple simple interrupted sutures are usually required along the length of a wound. Simple interrupted sutures have several advantages — they are easily mastered, and they can be adjusted to maintain wound eversion.[48,49] Wound eversion is important to the final appearance of the healed scar. Wounds that are not everted can become inverted or indented as the wound heals, producing a cosmetically unsatisfactory scar.[49]

One major disadvantage of simple interrupted sutures is the tendency to produce cross-hatch scarring along the edges of the wound, especially in wounds under high tension. This can be avoided by placing deep or buried sutures in gaping or high-tension wounds.[48]

A variation on the simple interrupted suture is the running suture, in which the stitch is extended beyond one throw to produce a line of interconnected loops that close the entire defect in one stitch. The advantages of the running suture are that it can be performed rapidly, and tension is evenly distributed across the wound. There are several disadvantages to the running suture. Like the simple interrupted stitch, it can produce cross-hatch scarring. It can also produce puckering of the wound if the skin is too loose or too tight. Unlike interrupted sutures, final adjustments cannot be made without removing the entire suture from the skin. The resulting approximation of the edges may be less accurate than that achieved with interrupted sutures.[48] Running sutures are best used in wounds under low tension and in areas where suture placement is not critical for the ultimate cosmetic result.[48]

Figure 6: The Corner Stitch[48]



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Mattress Sutures. Vertical mattress sutures are often used to close wounds under high tension, since they are able to produce eversion of the wound edges while reducing

Table 3: Classification of Sutures

Absorbable	Suture Type	Nonabsorbable	Suture Type
Plain catgut	Natural monofilament	Nylon	Synthetic monofilament
Chromic catgut	Natural monofilament	Polypropylene	Synthetic monofilament
Polyglactin (Vicryl)	Synthetic polyfilament	Silk	Natural polyfilament
Polyglycolic acid	Synthetic polyfilament	Linen	Natural polyfilament
Polydioxanone (PDS)	Synthetic polyfilament		

wound tension and eliminating dead space.[48,50] Because the external segments of the vertical mattress stitch compress the skin adjacent to the wound, vertical mattress sutures can produce scarring, especially in tissues that are extremely edematous. (*See Figure 5.*)[48] Despite these concerns, one small study that compared the cosmetic results of surgical incisions closed with vertical mattress stitches to those closed with running stitches found that the vertical mattress stitch produced a better cosmetic outcome at six weeks and one year.[50]

Horizontal mattress sutures minimize wound tension and are often suggested as methods of closure for gaping wounds and flap wounds under high tension.[48] Like the vertical mattress stitch, the external segments of the horizontal mattress stitch can compress the surrounding skin and produce scarring.[48]

The corner stitch is a useful variation on the horizontal mattress stitch in which the suture enters through the skin on one side of the flap, is passed through the dermal tissues, and exits through the skin on the opposite side of the flap. (*See Figure 6.*)[48] This avoids penetrating the epidermis of the flap with a loop that could cause strangulation. One study demonstrated improved blood flow (measured by laser Doppler) in the tips of flaps that were closed with a corner stitch as opposed to flaps closed with vertical loop stitches.[51]

Material

The ideal wound-closure device would allow for meticulous wound closure, be rapid and easy to use, painless, result in excellent cosmesis with a low infection rate, be of low risk to the health care provider, and be cost-effective.[22,52] None of the currently available wound closure devices meet all these criteria, and there are advantages and disadvantages to all of the available choices.[52] Currently, sutures are the most common material used for wound closure, with tissue adhesives, staples, and surgical tapes being other options.[22,52]

Adhesive Tapes. A noninvasive choice for wound closure is adhesive tapes. These tapes are not often used for primary wound closure in the ED, mainly due to high rates of wound dehiscence.[41,45] Adhesive tapes alone cannot maintain wound integrity, especially in areas subject to tension.[22,53] However, they are sometimes used after suture removal to decrease tension on the healing wound and can be used to close linear wounds that are under minimal tension.[41,45]

Another disadvantage associated with the use of adhesive tapes is that they require the use of adjuncts, such as tincture of benzoin. These adjuncts have been shown to increase induration and wound infection despite the fact that the tapes themselves are less reactive than other methods of closure.[22,54,55] These adjuncts are also toxic to wounds and must not enter the wound.[22]

Sutures. Sutures offer the greatest tensile strength and lowest risk of wound dehiscence. Sutures can be described based on the following characteristics: composition, handling characteristics, absorption, tissue reactivity, size, and retention of tensile strength.[5] Desirable handling characteristics in a suture include smooth passage through tissues, ease in knot tying, and stability of the knot once tied. Smooth sutures pull through tissues easily, but knots slip more readily.[5] Options for sutures can be described as natural vs. synthetic, monofilament vs. polyfilament, and further classified as absorbable vs. nonabsorbable. (*See Table 3.*)

Nonabsorbable sutures retain most of their tensile strength for more than 60 days, are relatively nonreactive, and are appropriate for closure of the outermost layer of the laceration.[22,41] Nonabsorbable sutures are made from natural fibers, such as silk, and have more tissue reactivity than synthetic fibers. Consequently, natural-fiber sutures increase the risk of infection and should be avoided in wounds with bacterial contamination.[41,45] Removal of nonabsorbable sutures is required.

Absorbable sutures are used for closure of structures deeper than the epidermis. Use of absorbable sutures is generally reserved for deep dermal closure; however, some studies suggest their use for skin closure in children to avoid the discomfort of suture removal is appropriate.[45,56] Synthetic absorbable sutures have less reactivity and greater tensile strength than natural absorbable sutures, such as catgut. The synthetic absorbable sutures increase the time the wound retains 50% of its tensile strength from 1 week to 1-2 months.[42,45] These synthetic absorbable sutures are particularly useful for closures under a lot of tension or for dynamic areas.[41]

A monofilament suture is made of a single strand. This structure is relatively more resistant to harboring microorganisms, thus having lower infection rates compared to polyfilaments. The major disadvantage of monofilaments is premature suture failure due to weakening of the

Table 4: Suture Choices for Wound Closure[5]

Location	Suture Size	Type of Suture
Subcutaneous tissue	4-0 or 5-0	Absorbable
Trunk/extremities	4-0 or 5-0	Nonabsorbable
Face	6-0	Nonabsorbable
Joints	3-0 or 4-0	Nonabsorbable

sutures by crushing or crimping the suture during placement.[57]

Polyfilament sutures are composed of several filaments twisted or braided together. These sutures offer greater tensile strength and better pliability and flexibility than monofilament sutures. Because polyfilament materials have increased capillarity, the increased absorption of fluid may act as a tract for the introduction of pathogens.[57]

In general, monofilament sutures decrease tissue reactivity and infection rates as compared to polyfilament sutures, while polyfilament sutures offer better workability and tensile strength. Synthetic and monofilament sutures have decreased infection rates compared to natural and polyfilament or braided sutures and are generally preferred for this reason.[45,58]

Size of suture material (thread diameter) is related to the tensile strength of the suture threads. In other words, threads of greater diameter are stronger. Choosing the correct suture size to use depends on the tensile strength of that tissue.[5,59,60] The tensile strength of the suture material should be only slightly greater than that of the tissue, because local tissue damage is proportional to the amount of suture material placed in the wound.[5,59,60]

The numbers that classify the suture are inversely related to its size. Thus, 0-0 suture material is larger in diameter than 7-0 suture material. In general, deep structures, such as fascia, can be closed with 3-0 or 4-0 sutures, subcutaneous tissue can be closed with 4-0 or 5-0 absorbable sutures, and skin closure can be performed with 4-0 or 5-0 nonabsorbable material.[5] Exceptions to this are facial wounds, including lips and eyelids, and wounds under high tension, such as wounds over joints. Facial wounds should be repaired with 6-0 or smaller nonabsorbable sutures, while high-tension wounds should be repaired with 3-0 or 4-0 nonabsorbable materials. (*See Table 4.*)[5]

Staples. There are advantages and disadvantages to using staples for wound closure. The major advantages are that they can be applied more quickly than sutures and have been shown to have less tissue reactivity and a lower infection rate than sutures.[5,62-64] It should be noted, however, that the lower rates of bacterial growth and infections with the use of staples as compared to sutures has been shown only in animal models.[63] Other studies have shown that there is limited clinical significance to the differences in bacterial growth and infection rate.[65] The use of staples is also advantageous when saving time is important, such as in mass-casualty incidents or patients with multiple wounds.[46]

The major disadvantage is that staples do not allow for as meticulous a closure as sutures and they cause more discomfort during removal.[45,62] Staple removal also requires a staple-removal device, which may or may not be available at primary care offices.[41] Overall, staples are considered useful for scalp, trunk, and extremity wounds.[61,65]

Tissue Adhesives. Tissue adhesives have been used outside the United States for many years. They were approved for use in the United States in August 1998 and have rapidly gained popularity.[22] This is likely because there have been studies showing superior speed of application, patient preference, and similar short- and long-term cosmesis compared to other standard methods of closure.[66]

The tissue adhesives, as a class, contain cyanoacrylates, which are formed by the condensation of cyanoacetate and formaldehyde.[67] When this molecule comes in contact with anionic substances, such as blood, the cyanoacrylate molecules come together into long chains, forming a solid film that holds the wound edges together.[68] This adhesive film sloughs off in 5-10 days as the outer layer of skin regenerates and the wound heals; thus, there is no need to remove the adhesive.[68]

One initial concern with the tissue adhesives was the histotoxicity associated with the formaldehyde that is part of the cyanoacrylate molecule. However, no significant degradation occurs until the tissue adhesives have sloughed off and, as long as these tissue adhesives are used topically, the formaldehyde does not cause any toxicity.

There have been many studies that have examined infection rates and cosmetic outcome in wounds repaired with cyanoacrylates compared to standard suturing methods. One study showed equivalent rates of wound infection, dehiscence, and cosmesis when comparing wounds closed with tissue adhesives vs. sutures.[68] A randomized, controlled trial comparing 900 lacerations and surgical incisions at 10 clinical sites found wound closure to be faster when using cyanoacrylates, but outcomes of wound infection, dehiscence, and cosmesis were comparable.[69] These findings have been replicated in many studies and in a wide range of specialties.[67] A recent meta-analysis concluded that rates of wound infection and cosmetic outcomes were similar after repair of surgical incisions with either sutures or tissue adhesives.[70]

Some studies have shown less comparable results when adhesives were used for traumatic lacerations. A systematic review of eight randomized, controlled trials comparing cyanoacrylates to suturing for traumatic lacerations (including low- and high-tension wounds) and surgical incisions showed a statistically significant increase in the rate of wound dehiscence when cyanoacrylates were

used for traumatic lacerations. They concluded that topical skin adhesives should only be used for low-tension lacerations and surgical incisions.[67,71] Another option is to use deep dermal sutures in combination with tissue adhesives and immobilization for higher-tension wounds.[67,72]

The major advantages of the tissue adhesives is that they can be applied rapidly, do not require local anesthesia, and do not need to be removed.[72] One quoted disadvantage is the cost of the tissue adhesives. However, when you include the cost of suture kits, suture removal kits, and dressings required for standard suturing, tissue adhesives may actually be less costly.[76]

Tissue adhesives should not be used alone for high-tension traumatic lacerations or wounds over major joints.[67] They also should not be used on mucous membranes, hair-bearing areas, or areas exposed to frequent moisture or friction to avoid early sloughing and wound dehiscence.[67]

If the tissue adhesive results in suboptimal wound closure or requires removal for improper placement of the adhesive, applying antibiotic ointment or petroleum jelly may facilitate removal. If rapid removal of the adhesive is required, acetone can also be used.

Antibiotic Prophylaxis

Although it varies from study to study, the incidence of traumatic wound infections ranges between 4.5-6.3%.[39] Whether this rate can be reduced with post-injury prophylactic antibiotics is controversial due to lack of good supportive data, however this practice remains the standard of care in many situations.

For patients who have compromised immune systems (such as those patients who are taking chemotherapeutic or immunosuppressive agents, or have diabetes or HIV), the use of prophylactic antibiotics is less controversial and is recommended.[39] The use of prophylactic antibiotics for traumatic wounds in patients with intact immune systems is not so straightforward, and there are limited data to support this practice. In fact, there are no current data to support the routine use of antibiotic prophylaxis for simple wounds in immunocompetent patients.[39]

Table 5: Antibiotic Prophylaxis Is Recommended for the Following High-risk Traumatic Wounds

- **Open fractures (wounds with underlying fractures)**
- **Wounds violating joint capsules**
- **Grossly contaminated (presence of soil, debris)**
- **Retained foreign body**
- **Wounds involving tendons or cartilage**
- **Animal, marine, or human bites**
- **Delayed presentation prior to closure (> 18 hours)**
- **Puncture wounds or crush injuries**

Traumatic head and neck wounds have been shown to have lower rates of infection, presumably due to the highly vascular nature of these areas.[22,39,77] Antibiotic prophylaxis is still recommended for oral wounds because of the increased levels of the endogenous flora (>106 bacteria per gram of tissue), in spite of the paucity of supportive data.[29] Similarly, antibiotic prophylaxis is advised for hand wounds and wounds involving tendon injuries, although there are no compelling data to support this recommendation.[39]

When compared to shearing injuries, crush or compression injuries are generally considered wounds that are at an increased risk for infection due to the larger amount of energy exerted on the involved tissues resulting in reduction of blood flow to the wound edges.[29]

There are certain high-risk wounds that require antibiotic prophylaxis regardless of the location of the wound and the immunocompetency of the patient. Animal and human bites, wounds that contain debris or soil, or those that have underlying fractures require antibiotics due to the increased risk of infection.

The choice of antibiotics for prophylaxis should be similar to that for established infections and should cover the routine skin flora in addition to any site- and source-specific flora. Although administration of a parenteral dose prior to discharge will expedite adequate tissue concentrations, this practice has been shown to have no advantage over the oral route.[78] The course of prophylactic treatment should be between 3 and 5 days.[39] Recent literature has shown community-acquired methicillin-resistant *Staphylococcus aureus* (MRSA) to be the most common source of skin infections; however, since the overall carriage rates for MRSA among the general population are low, the routine use of antibiotic prophylaxis to specifically cover this organism has not been recommended.[79,80]

Current recommendations for prophylactic antibiotic use for open fractures are dependent on the classification of the fracture. Patients with Type I (fracture with an open wound that is clean and less than 1 cm) and Type II (fractures with an open wound that is greater than 1 cm in length and without extensive soft-tissue damage) injuries should receive a first- or second-generation cephalosporin to cover gram-positive organisms. A fluoroquinolone may be given as an alternative to the cephalosporin. Antibiotics should be initiated as soon as possible following the injury and continued for no longer than 24 hours after wound closure.[73,74] Type III injuries have extensive soft-tissue damage and require broader coverage to include gram-negative organisms; therefore, a cephalosporin plus an aminoglycoside (i.e., gentamicin) is recommended.[73-75] Because of a high failure rate when used alone in Type III fractures, fluoroquinolones should be given in combination with a cephalosporin. Patients with Type III open fractures should receive antibiotics for 72 hours following the injury or no longer than 24 hours

after soft-tissue coverage has been achieved.[73] For injuries that are contaminated with feces or are at high risk for infection with Clostridium species, such as farming accidents, high-dose penicillin should be added to the regimen.[73,75]

Although many emergency physicians use topical antibiotics, such as neomycin and bacitracin, there are no definitive studies that show its use to be efficacious in preventing wound infections.[39]

Animal and Human Bites

Animal Bites. The majority of bites are from dogs and comprise 85-90% of all bite wounds seen in the ED. Other causes include bite wounds from cats (5-10%), rodents, and humans (2-3%).[81] According to the CDC data from 2007, dog bites accounted for approximately 365,000 visits to the ED nationwide.[1]

Dog bites often produce lacerations, puncture wounds, and superficial abrasions.[81] Cultures of infected dog bites grow multiple organisms; however, *Pasteurella multocida* is the most commonly isolated organism. Other commonly found species include alpha-hemolytic streptococci, *Staphylococcus aureus*, and anerobes.[82]

Cat bites are likely to be puncture wounds rather than abrasions or lacerations due to the long, sharp nature of cat teeth.[81] The puncture nature of these wounds, coupled with the higher incidence of *Pasteurella multocida*, makes cat bites more prone to infection than dog-bite wounds.[81]

In patients presenting with a dog or cat bite, the need for rabies prophylaxis should be addressed. The rabies virus is transmitted through the saliva and brain or nervous system tissue of infected animals. Any mammal may contract the rabies virus, but the most common wild reservoirs are skunks, bats, foxes, and raccoons. In the United States, the most commonly reported domestic animals infected with rabies are cats, cattle, and dogs.

Very small rodents, such as rats, mice, squirrels, and gerbils, tend not to survive infection with the disease and, thus, do not serve as reservoirs. Likewise, rabbits and other lagomorphs are not thought to be reservoirs for the disease. Prophylaxis is not recommended after bites from these animals. Very large rodents, such as beavers and woodchucks, can carry rabies.[83]

In the United States and other developed countries, bites from domestic animals account for fewer than 10% of all reported cases of rabies. The vast majority of cases are caused by exposure to wild animals, such as raccoons, skunks, foxes, coyotes, and, especially, bats. It should be noted that even casual contact with bats can result in infection with the disease.[83]

Rabies prophylaxis is unnecessary in bites from healthy dogs and cats, and from animals that can be observed for 10 to 14 days.[81] A reduced, 4-dose vaccine schedule for postexposure prophylaxis is recommended by the Advisory Committee on Immunization Practices. It has been found that four rabies vaccine doses in combination with rabies immunoglobulin elicited adequate immune response; the fifth dose previously recommended did not contribute to more favorable outcomes.[84] The first dose of the rabies vaccine should be administered as soon as possible after the exposure in combination with the rabies immunoglobulin, and additional doses of the vaccine are to be given at days 3, 7, and 14.[84] For immunocompromised patients, the 5-dose postexposure prophylaxis schedule with vaccinations on days 0, 3, 7, 14, and 28 is still recommended. As part of the postexposure prophylaxis, it is also recommended that rabies immune globulin (20 mg/kg) be administered by injecting half of the dose via intramuscular route and the remaining half infiltrated into and around the wound.[84]

Human Bites. Human bites occur by two mechanisms: occlusion, which occurs by the actual biting of a body part, and clenched-fist injury, which occurs when the fist of the patient contacts the teeth of an adversary at the metacarpal-phalangeal joint (MCP).[85] These bites produce crushing or tearing injuries.

Infections from human bite wounds are polymicrobial, with Streptococci and *Staphylococcus aureus* as the most common species, followed by Eikenella and anaerobes.[82,84]

Particular attention should be given to clenched-fist injuries, which can be deceptively serious.[87] When the patient's fist strikes the other person's teeth, the teeth can penetrate through the skin all the way to the head of the metacarpal bone. When the patient extends his MCP joints after the injury, the inoculated tissue is retracted proximally. It is important to examine the wound throughout the full range of motion to look for injuries to the underlying bones, tendons, and joints.[81,87] Radiographs should be obtained in these patients to exclude foreign bodies (such as tooth fragments) and fractures. Fractures in these patients are open and should be treated with debridement in the operating room.[87]

Patients with clenched-fist injuries who present early without evidence of joint involvement and without fracture can be managed with extensive irrigation in the ED. The wound is then left open, splinted, and allowed to heal by secondary intention. Patients who present after 24 hours, who have fractures or joint involvement, or who present with signs of infection should be managed operatively.[87]

Management of Bite Wounds. There is some controversy about whether primary repair of bite wounds is safe. It was standard practice to allow bite wounds to heal by primary delayed closure or secondary closure since they are considered contaminated wounds. An exception to this principle would be if optimal cosmetic outcome is a concern, such as with a facial wound. Whether primary closure would be a reasonable approach was partially answered from a retrospective review performed on 122 patients with dog and human bite wounds that found an infection

rate of 7% after primary repair.[88] Thus, depending on the severity, bite wounds may be repaired with primary closure with close outpatient follow-up. Another option would be to use delayed primary closure or secondary closure with scar revision at a later time.

While antibiotics are commonly administered to patients after bite wounds, there is little clinical trial evidence to support this practice in general.[89] A recent systematic review concluded that antibiotic administration was associated with a statistically significant reduction in the rate of wound infections in patients with human bites and with bites on the hand, but not in patients with cat and dog bites in other locations.[89]

Amoxicillin-clavulanic acid is a frequently chosen antibiotic for dog, cat, and human bites. Amoxicillin-clavulanic acid has been shown to be effective in treating both infected human and dog bites.[82] Patients who are allergic to penicillin can be treated with a fluoroquinolone with enhanced aerobic activity, such as moxifloxicin.[86] In patients who present with infected wounds, wound cultures can be obtained and used to guide antibiotic choice.

Wound Care and Suture Removal

Patients who are discharged from the ED should receive detailed instructions on wound care. Since the epithelialization phase of wound healing occurs within the first 48 hours, wounds should be kept clean.[29] For wounds that undergo primary closure in the ED, patients can be instructed to use a nonadherent, semi-occlusive, and semi-absorbable dressing. There are no data that demonstrate the benefit of one type of dressing over another. Although a national survey of emergency physicians from the early 1990s revealed that emergency physicians most commonly use simple dry gauze with a topical antibiotic ointment, there is no consensus among emergency physicians about a superior dressing for simple wounds.[90,91] Surgical tape and tissue adhesives do not require dressings.

Wounds closed with skin adhesives should be kept clean and dry to prevent premature sloughing of the adhesive. Patients should avoid picking, scrubbing, or soaking the wound and they should be cautioned that swimming and heavy perspiration may also cause premature sloughing. Dry dressings are acceptable; however, no liquids or ointments, including topical antibiotics, should be applied over wounds closed with tissue adhesives, as this may cause the adhesive film to loosen.

It is permissible for wounds to be cleansed gently after 24 hours, but patients should be instructed to abstain from swimming or submerging the wound for prolonged periods of time.

Patients should be instructed on what medications to take for management of their pain. Patients should also be instructed, in layman's terms, to seek medical attention if the wound appears erythematous, inflamed, has purulent drainage, or if there is an associated fever. Bite wounds should be closely followed, and patients should return within 48 hours for a wound check.

Surgical tapes and skin adhesives do not require the patient to return for removal; however, if sutures or staples are placed, the patient should be instructed when to return for removal. While removal of sutures and staples after 7 days is sufficient for most areas of the body, there are a few exceptions.[45] To help prevent poor cosmetic outcome from formation of sinus tracts, facial sutures should be removed within 3 to 5 days.[41,45] In contrast, sutures placed in areas of high tension, such as over joints, should be kept in longer, for 10-14 days, before removal. (*See Table 6.*)[41,45]

Table 6: Optimal Time for Suture Removal

Location	Number of Days
Face	3-5
Scalp	7
Trunk	7-10
Upper extremity	7-10
Hand	10
Elbow	10-14
Lower extremity	7-10
Knee	10-14
Foot	7-10

Source: Modified from Capellan O, Hollander JE. Management of lacerations in the emergency department. *Emerg Med Clin North Am* 2003;21:205-231.

Summary

Wound repair is a common procedure performed in EDs throughout the country and is a common area of litigation for emergency physicians. The ultimate goal for wound repair is to evaluate and treat in a timely manner, minimize patient discomfort and the risk of wound infection, and optimize cosmetic outcome. Careful evaluation of each wound is necessary to identify potential foreign bodies and concomitant injuries to underlying structures such as tendons, nerves, and bones. Aside from diagnosing fractures, plain films are useful for the identification of retained objects made of metal and certain types of glass; however, ultrasound has an advantage over plain radiographs for the detection of foreign bodies made of plastic or wood. The type of anesthetic agent and method of its infiltration is dependent upon the size and location of the wound, patient compliance, and physician preference. When performing anesthesia for wound repair, the emergency physician should use techniques to keep the patient's pain at a minimum.

Most wounds are closed at the time of injury, but delayed closure or healing by secondary intention are more appropriate options for wounds that are highly contaminated or at risk for infection. Appropriate wound cleansing and debridement is essential for promotion of wound healing and decreasing the risk for infection.

All wounds should be repaired using sterile technique. The choice of suture material is dependent on physician preference and location of the wound. Deep sutures are used for wounds that involve multiple layers and allow for better wound approximation and relieve surface tension.

Wounds that are at an increased risk for infection are those contaminated with feces, saliva, or soil, crush injuries, and bites by humans and animals. Tetanus prophylaxis with Td or Tdap and TIG should be given to those patients with highly contaminated wounds who are in need of a booster, or who have incomplete immunization or unknown immunization history. Although there is a paucity of supportive data for its routine use, antibiotic prophylaxis is recommended for patients who are immune incompetent and/or have wounds that are contaminated with feces, saliva, or soil, crush injuries, those with underlying fractures, tendon or cartilage injury, or those with delayed presentation to closure.

Patients discharged from the ED should receive detailed instructions on wound care, follow-up, and pain management.

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Physician CME Questions

101. Which of the following is true about different methods of suturing?
   A. Running sutures are best used in cosmetically important areas.
   B. Simple interrupted sutures are the method of choice in wounds under high tension.
   C. Use of the corner stitch has been shown to reduce blood flow to the tip of flaps.
   D. Vertical mattress sutures produce wound eversion and reduce wound tension.
   E. Wound inversion produces an optimal cosmetic result.

102. What is the most common organism in infected cat bites?
   A. Alpha-hemolytic streptococci
   B. Anaerobes
   C. Eikenella
   D. *Pasteurella multocida*
   E. *Staphylococcus aureus*

103. Which of the following is true of human bite injuries?
   A. Eikenella is the most common organism in infected human bites.
   B. Human bite infections are rarely polymicrobial.
   C. Lacerations produced by clenched-fist injuries should be closed primarily and splinted in the ED.
   D. Patients with clenched-fist injuries who have bone or joint involvement can be managed with extensive irrigation and splinting in the ED.
   E. Radiographs should always be obtained in clenched-fist injuries to look for the presence of foreign body or fracture.

104. Which of the following is true regarding monofilament sutures?
   A. They cause more tissue reactivity compared to polyfilament suture material.
   B. They offer greater tensile strength than polyfilament suture material.
   C. They have lower infection rates compared to polyfilament suture material.
   D. They offer greater pliability and flexibility than polyfilament suture material.

105. Tissue adhesives are appropriate for wound closure in which of the following locations?
   A. hair-bearing areas
   B. high-tension traumatic lacerations
   C. linear, low-tension lacerations
   D. mucous membranes
   E. wounds over joints

106. What is the optimal time for suture removal of wounds over joints such as the knee or elbow?
   A. 3-5 days
   B. 5-7 days
   C. 7-10 days
   D. 10-14 days

107. Which of the following is true regarding post-closure wound care?
   A. Facial sutures should remain in place at least 7 days to prevent sinus tract formation.
   B. Swimming and heavy perspiration may cause premature sloughing of tissue adhesives.
   C. Topical antibiotics should be applied over wounds closed with tissue adhesives.
   D. Wounds closed with adhesive tapes should be kept covered with a dry occlusive dressing at all times.

108. Which of the following is true regarding tetanus?
   A. Crush injuries are considered tetanus-prone wounds.
   B. If tetanus immunoglobulin is administered due to uncertain vaccination history, it can be given at the same site as the Tdap vaccine.
   C. Patients presenting with tetanus-prone wounds should receive Td if they have not received a dose within the past 10 years, have had fewer than three total doses, or have an uncertain immunization history.
   D. Patients presenting with minor, clean lacerations should receive Td if they have not had a booster within 5 years.
   E. Pregnancy is a contraindication to tetanus prophylaxis.

109. Regarding wound preparation, which of the following is true?
   A. Eyebrows should be shaved prior to wound closure to decrease wound infection due to the amount of normal bacterial flora that resides in the hair follicles.
   B. Irrigating the wound with hydrogen peroxide has been shown to decrease wound infection rate.
   C. Low-pressure irrigation, 0.5 psi, should be used to irrigate contaminated wounds such as dog bite.
   D. Spilling of antiseptic agents such as iodophor or chlorhexidine into the wound has been shown to have deleterious effects on wound healing.

110. In the detection of foreign bodies in wounds, which of the following is true?
   A. Plain radiographs are highly sensitive for detection of radiolucent objects, such as plastic and wood.
   B. Plain radiographs are useful for detecting radiopaque objects such as metal and certain types of glass.
   C. Plain radiographs are 100 times more sensitive in differentiating foreign bodies than CT scan.
   D. CT scan is a practical and cost-effective screening modality.

CME Answer Key

101. D; 102. D; 103. E; 104. C; 105. C; 106. D; 107. B; 108. A; 109. D; 110. B

Emergency Medicine Reports

CME Objectives

Upon completion of this educational activity, participants should be able to:

- recognize specific conditions in patients presenting to the emergency department;
- apply state-of-the-art diagnostic and therapeutic techniques to patients with the particular medical problems discussed in the publication;
- discuss the differential diagnosis of the particular medical problems discussed in the publication;
- explain both the likely and rare complications that may be associated with the particular medical problems discussed in the publication.

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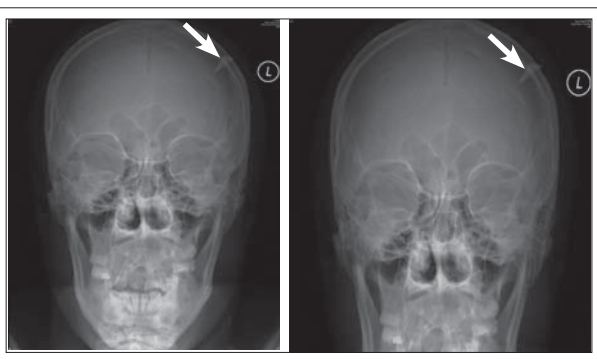
Emergency Medicine Reports
The Practical Journal for Emergency Physicians

Stitches, Staples, and Glue: Wound Repair in the ED

Recommended Tetanus Prophylaxis

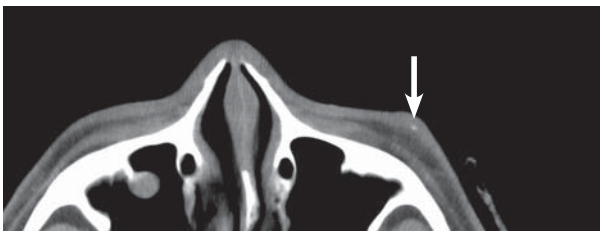
History of Tetanus Immunization (doses)	Clean or Minor Wounds		All Other Wounds*	
	Td or Tdap	TIG	TD or Tdap	TIG
Less than 3 or uncertain	Yes	No	Yes	Yes
Three or more	No	No	No	No
Last dose greater than 5 years ago	No	No	Yes	No
Last dose greater than 10 years ago	Yes	No	Yes	No
* Such as, but not limited to, wounds contaminated with dirt, feces, soil, or saliva; puncture wounds; avulsions; and wounds resulting from missiles, crushing, burns, or frostbite.				

Radiograph of Patient Stabbed in the Head



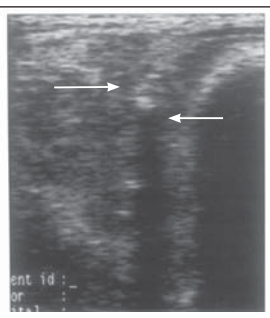
These are A-P and lateral plain radiographs of the skull of a patient who was stabbed in the head with a knife. The arrows point to a metal foreign body that happened to be the tip of the knife that broke off and was retained in the wound.

CT of Patient with Multiple Facial Lacerations



This is a CT scan of the head of a patient who had multiple facial lacerations from a motor vehicle accident. The arrow points to retained glass in one of the wounds.

Ultrasound Showing Wooden Foreign Body



The echogenic focus and prominent acoustic shadow are signs of foreign body.
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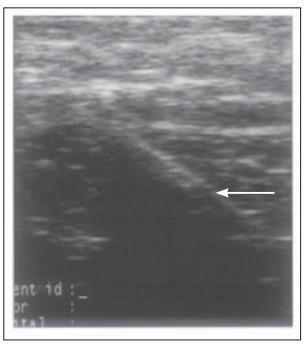
Ultrasound Showing a 2 cm Foreign Body in Longitudinal Section



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Classification of Sutures

Absorbable	Suture Type	Nonabsorbable	Suture Type
Plain catgut	Natural monofilament	Nylon	Synthetic monofilament
Chromic catgut	Natural monofilament	Polypropylene	Synthetic monofilament
Polyglactin (Vicryl)	Synthetic polyfilament	Silk	Natural polyfilament
Polyglycolic acid	Synthetic polyfilament	Linen	Natural polyfilament
Polydioxanone (PDS)	Synthetic polyfilament		

Properties of Common Anesthetics Used for Local Infiltration

Anesthetic Agent	Range of Concentration (%)	Maximal Dose	(mg/kg)	Duration of Action (hours)*
		(-) epi	(+) epi	
Amides				
Lidocaine (Xylocaine)	0.5-2	4.5	7	0.5-2
Bupivacaine (Marcaine)	0.125-0.5	2	3	1.5-8
Mepivacaine	0.5-1	4.5	7	0.25-2
Esters				
Procaine (Novocaine)	0.5-1	7	9	0.25-1

* Duration of action is dependent on concentration, location of infiltration, and combined use with a vasoconstrictive agent.

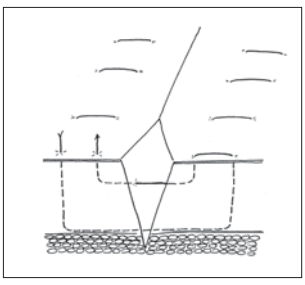
Suture Choices for Wound Closure

Location	Suture Size	Type of Suture
Subcutaneous tissue	4-0 or 5-0	Absorbable
Trunk/extremities	4-0 or 5-0	Nonabsorbable
Face	6-0	Nonabsorbable
Joints	3-0 or 4-0	Nonabsorbable

Antibiotic Prophylaxis Is Recommended for the Following High-risk Traumatic Wounds

- Open fractures (wounds with underlying fractures)
- Wounds violating joint capsules
- Grossly contaminated (presence of soil, debris)
- Retained foreign body
- Wounds involving tendons or cartilage
- Animal, marine, or human bites
- Delayed presentation prior to closure (> 18 hours)
- Puncture wounds or crush injuries

Classic Vertical Mattress Suture



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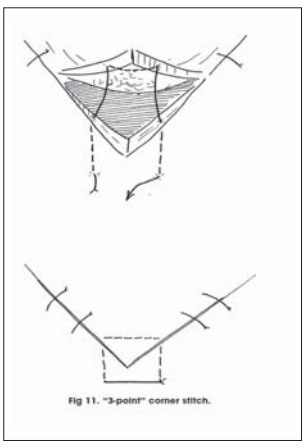
The Corner Stitch



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Optimal Time for Suture Removal

Location	Number of Days
Face	3-5
Scalp	7
Trunk	7-10
Upper extremity	7-10
Hand	10
Elbow	10-14
Lower extremity	7-10
Knee	10-14
Foot	7-10

Source: Modified from Capellan O, Hollander JE. Management of lacerations in the emergency department. *Emerg Med Clin North Am* 2003;21:205-231.

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Trauma Reports

EVIDENCE-BASED MEDICINE FOR THE ED

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AHC Media

Trauma in Pregnancy

Resuscitation in the pregnant patient is an uncommon occurrence, estimated at 1 in 30,000 deliveries,[1] yet it is unique in its potential to save not one, but two lives. Trauma is estimated to occur in approximately 5% of pregnant patients,[2,3] and it is the leading cause of nonobstetric mortality in this population.[3,4] The physiologic changes of pregnancy, and the need to balance the care of mother and fetus, make the care of a critically injured pregnant patient a challenge for any physician. This article reviews physiologic changes of pregnancy and injuries unique to pregnancy, and discusses the assessment and management priorities of the pregnant trauma patient.

—The Editor

Physiologic Changes of Pregnancy

To effectively manage the injured pregnant patient, it is essential to understand a number of predictable changes in maternal physiology. These changes have the potential to impact vital signs, the physical examination, and results of laboratory studies. Most importantly, physiological alterations associated with a normal pregnancy have a significant effect on cardiopulmonary reserve and injury tolerance.

Respiratory. During pregnancy, the resting oxygen requirement and minute ventilation increase to meet increasing metabolic demands. At the same time, the functional residual capacity decreases by 20%,[5,6] due to elevation of the diaphragm by the gravid uterus. With greater oxygen demand, and less physical space for expansion of the lungs, the pregnant patient functions with a significantly decreased oxygen reserve.

While the pregnant patient will desaturate quickly, the fetus is even more vulnerable to hypoxia. The reason for this difference is that the umbilical vein and artery have a much lower partial pressure of oxygen than the maternal circulatory system. Maternal oxygenation is important for fetal well-being, as fetal oxygenation remains constant until maternal paO_2 drops below 60 mmHg.[7] As a general rule, the fetus has roughly two minutes of oxygen reserve. Animal studies reveal that significant maternal hypoxia results in a 30% reduction in uterine blood flow, further compromising fetal outcome.[8]

The pregnant patient is also at significant risk for aspiration. During pregnancy, progesterone acts to decrease gastrointestinal motility[6] and increase laxity of the lower gastroesophageal sphincter.[9] This effect, in concert with the anatomical compression of the stomach by the uterus, renders the pregnant patient more prone to aspiration. Increased and more frequent oral intake further increases the chance of aspiration.

Pregnancy is an edematous state. These changes affect the entire body, including the tongue and supraglottic soft tissues.[1,10] Capillary engorgement due to increased blood volume and decreased plasma oncotic pressure causes swelling of the respiratory tract mucosa and easy bleeding that may complicate intubation. (*See Table 1.*)

Cardiovascular. Several cardiovascular changes of pregnancy should be considered when caring for the pregnant trauma patient. Beginning in the eighth

Executive Summary

- Tachycardia and hypotension should be viewed as late signs of severe hemorrhage in the pregnant patient.
- Placental abruption can also occur after a minor mechanism of injury, with a rate as high as 5%. The absence of clinical findings in this setting does not reliably exclude the diagnosis.
- As little as 0.001 mL of Rh-positive fetal blood can cause maternal sensitization in the Rh-negative mother.
- Missed abdominal injuries are especially common in: patients with neurological impairment due to brain injury or alcohol; patients with multiple coincident injuries; and patients with severe or "distracting" injuries.

week of pregnancy, increasing progesterone causes smooth muscle relaxation and a significant decrease in total peripheral resistance. By week 12, blood pressure starts to gradually decline to a nadir around week 28, with a total systolic and diastolic blood pressure drop of 5 to 15 mmHg.[6,9] These effects are seen in central venous pressure as it drops 9 mmHg to around 4 mmHg in the third trimester.[11] Due to an increase in alpha receptors stimulated by estrogen within the myometrium, heart rate increases 10 to 15 beats per minute, and cardiac output increases to 30-50% above normal during the second trimester.[11] As gestation advances, maternal blood volume increases steadily, peaking at 40% above pre-pregnancy levels at term.

These changes, which help the pregnant patient tolerate the increasing metabolic demand of the fetus and prepare her for the expected hemorrhage of childbirth,[12] may easily conceal the presence of shock. Hemodynamic changes are often not apparent until 35% total blood volume loss.[11] Therefore, tachycardia and hypotension should be viewed as late signs of severe hemorrhage in the pregnant patient. To preserve maternal circulation during hemorrhage, blood is shunted away from the uterus and fetus via uteroplacental vasoconstriction,[6,11] making fetal distress, such as decelerations or low variability of the fetal heart rate (the fifth vital sign in obstetrics[6]), a subtle sign of compensated shock in the mother.

Table 1. Changes in Respiratory Physiology

Alteration	Implication	Action
• Upper airway edema	• Potentially difficult laryngoscope	• Protect the airway early • Preparation is essential
• Increased gastric pressure	• Increased aspiration risk	• Be cautious during RSI
• Elevation of the diaphragm	• Decreased FRC • Decreased respiratory reserve • Chest tube misplacement into the abdominal cavity	• Aggressively manage blunt and penetrating chest injury • Probe the hole with your finger before inserting a chest tube

When a pregnant patient is in a supine position, uterine compression of the great vessels (inferior vena cava, abdominal aorta, and iliac arteries) can cause a significant decrease in venous return. This aortocaval compression, or "supine hypotension syndrome," can result in a 30% decrease in cardiac output.[9] It also should be noted that the increased venous pressure caused by the gravid uterus may contribute to dangerous hemorrhage from lower-extremity wounds.[11] (*See Table 2.*)

Gastrointestinal. The anatomic changes that develop within the pregnant abdomen may hide significant injury despite a reassuring abdominal exam. As the uterus gradually enlarges, the stretched peritoneal cavity becomes less sensitive to irritation, and the attenuated rectus muscles may prevent guarding.[2,13] The spleen becomes engorged and is at greater risk of rupture. The small bowel is displaced cephalad, increasing the risk of bowel injury after penetrating trauma.[13,14] (*See Table 3.*)

Genitourinary. The most significant genitourinary change during pregnancy is the gradually enlarging uterus. During the first trimester, it remains encased and protected by the bony pelvis. By the 12th week of gestation, the uterus rises above the pelvic brim, becoming an abdominal organ. The fetus is small and well-cushioned by a large amount of amniotic fluid throughout the second trimester. In the third trimester, however, the uterus is larger and thin-walled, making it more

Table 2. Changes in Cardiovascular Physiology

Alteration	Implication	Action
• Decreased resting blood pressure • Increased resting heart rate	• Misinterpretation of vital signs • Delayed recognition of shock	• Monitor carefully • Obtain objective measures of perfusion (e.g., serum lactate)
• Uterine vasoconstriction during shock states	• Increased risk of fetal hypoxemia	• Early fetal monitoring • Fetal distress equals maternal hemorrhage until proven otherwise
• Compression of the inferior vena cava by the gravid uterus	Supine hypotension syndrome: • Decreased venous return • Impaired cardiac output	• Deflect the uterus to the left (or elevate one side of the back board) • Optimize resuscitation

Table 3. Changes in Gastrointestinal Physiology

Alteration	Implication	Action
• Peritoneal stretching	• Physical examination less reliable	• Bedside FAST • Lower threshold for imaging
• Splenic engorgement	• Increased risk of injury	• Bedside FAST • Lower threshold for imaging
• Viscera pushed cephalad by the enlarged uterus	• Increased risk of injury with penetrating upper abdominal wounds	• Lower threshold for imaging and consultation

susceptible to injury.[12,13] Further, the marked increase in uterine blood flow in late pregnancy potentiates rapid exsanguination following an injury to the uterus or uterine vessels.[14]

Toward the end of pregnancy, the fetal head drops into the pelvis and may be injured with maternal pelvic fractures.[9] The bladder is more susceptible to injury as the uterus pushes the bladder into the abdomen and out of the protective bony pelvic rim.

Pelvic radiographs may be difficult to interpret in later pregnancy as the pelvis changes in preparation for delivery. These changes include widening of the pubic symphysis and sacroiliac joint space. These areas, therefore, may appear abnormal on pelvic radiographs.

Renal changes include increased renal blood flow by 60% and increased glomerular filtration rate (GFR). As a result, serum creatinine decreases by half. Thus, a "normal" creatinine in a pregnant trauma patient is an important marker of renal impairment.[12] In addition, the increased GFR results in an increased urination frequency and renders urine output a poor indicator of shock.[13]

The elevated levels of progesterone in pregnancy stimulate the medullary respiratory center, increasing ventilatory drive. The physiologic effect is a decrease in pCO_2 to 25-30 mmHg, and a compensatory renal excretion of sodium bicarbonate to maintain a normal pH. As a result, maternal buffering capacity is impaired, placing the patient at greater risk for lactic acidosis following hemorrhage.[11] (*See Table 4.*)

Hematology. During pregnancy, there is a disproportionate increase in red blood cells by 20-30% and plasma volume by 50%, resulting in a "physiologic anemia of pregnancy." A normal hematocrit in pregnancy ranges from 31-34%.[11] Pregnancy also causes an increase in all coagulation factors and a decrease in fibrinolysis, creating a hypercoagulable state. This protects against hemorrhage but increases the risk of thromboembolism.[13] (*See Table 5.*)

Injuries Unique to Pregnancy

Placental Abruption. The uterus is made of elastic tissue that can respond to the acceleration and deceleration forces involved in blunt trauma. In contrast, the placenta does not contain elastic tissue and lacks the ability to expand and contract. As a result of the differing properties of these two adjacent structures, trauma may lead to a shearing force that causes a separation of the placenta from the uterus with bleeding into this space, known as placental abruption. Placental abruption is not uncommon and is noted in 40% of cases of severe maternal trauma.[6] In these cases, the rate of fetal demise can be as high as 60%,[6] making placental abruption the second most common cause of

Table 4. Changes in Genitourinary Physiology

Alteration	Implication	Action
• Increased uterine mass and blood flow	• Risk of exsanguination with major uterine injury	• Early sonographic assessment and OB/GYN consultation
• Increased GFR • Decreased BUN/Cr • Increased urine output	• A "normal" BUN/Cr indicates renal dysfunction • Urine output is not a reliable guide of tissue perfusion	• Understand laboratory changes • Use objective measures of resuscitation (e.g., serum lactate)
• Respiratory alkalosis and compensatory excretion of bicarbonate	• Limited serum buffering capacity	• Optimize resuscitation • Assess and treat metabolic acidosis
• Pelvic symphysis during late pregnancy	• Pelvic radiographs can be difficult to interpret	• Consider pelvic injury in the right clinical setting

Table 5. Changes in Hematologic Physiology

Alteration	Implication	Action
• 20-30% increase in red cell mass • 40-50% increase in plasma volume	• Physiologic anemia • Normal Hct 31-34%	• Understand laboratory changes
• Hypercoagulable state	• Increased risk of thromboembolic complications	• Employ DVT prophylaxis

fetal death in trauma after maternal injury.

Concern should be high for placental abruption in the patient with abdominal pain, uterine contractions, back pain, or vaginal bleeding. A rigid uterus or "large for dates" fundal height is highly suggestive of the diagnosis. When uterine abruption is strongly suspected, uterine sonography and cardiotocographic monitoring are recommended. Ultrasound is highly specific for placental abruption, but has a sensitivity of only 50%. This is especially true for small abruptions and those located along the posterior wall of the uterus.[3] Abnormalities on fetal monitoring are a highly sensitive marker of fetal distress in the setting of placental abruption, although these findings are nonspecific. The complementary use of these two tools is logical in the ED evaluation of placental abruption. (*See Figures 1 and 2.*)

Placental abruption can also occur after a minor mechanism of injury, with a rate as high as 5%.[3] The absence of clinical findings in this setting does not reliably exclude the diagnosis. For stable patients with a viable pregnancy suffering minor trauma, 4-6 hours of continuous fetal monitoring are recommended.

Uterine Rupture. During pregnancy, the uterus enlarges to accommodate the growing fetus. As this occurs, the uterus extends out of the pelvis and into the abdomen, where it is much more susceptible to trauma. Uterine rupture occurs in less than 1% of pregnant trauma patients.[10] While this is a rare event, it almost always results in fetal demise, and carries a 10% maternal mortality rate.[10] Uterine rupture most commonly occurs in patients who have had a previous cesarean section. Patients will typically present with severe abdominal pain, clinical signs of peritonitis, and hemodynamic instability. Often, fetal parts or uterine irregularity can be palpated on abdominal exam. The combination of shock and an acute abdomen in a pregnant trauma patient should prompt immediate evaluation for uterine rupture, in addition to the traumatic abdominal injuries seen in the general population.

An abdominal radiograph will typically show an uncoiled fetus, and this diagnosis may be confirmed by ultrasound. As time to diagnosis and definitive surgical treatment is critical, time-consuming diagnostic studies should be avoided. The diagnosis of uterine rupture should prompt immediate actions to stabilize the mother and obtain emergent obstetrical consultation.

Fetal-Maternal Hemorrhage. Fetal-maternal hemorrhage occurs when injury provokes the mixing of fetal and maternal blood. This becomes clinically relevant when Rh-positive fetal blood is introduced into the circulation of an Rh-negative mother. As little as 0.001 mL of Rh-positive fetal blood can cause maternal sensitization in the Rh-negative mother.[9] If

Figure 1. Marginal Abruption

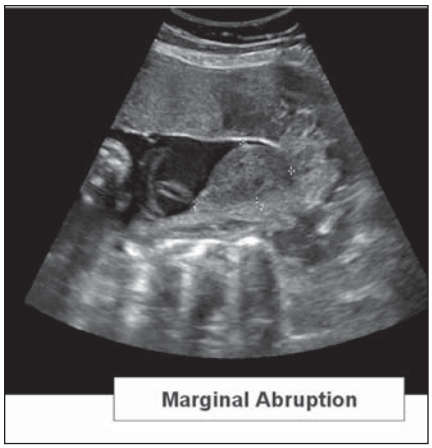

Figure 2. Retroplacental Abruption

sensitization occurs, future pregnancies could be complicated by erythroblastosis fetalis, resulting in fetal anemia, hypoxia, and even death. Rh status should be determined in all pregnant trauma patients unless the injury is isolated and remote from the uterus (for example, a penetrating injury to the extremity). Universal determination is particularly important, as injury severity is not related to the incidence of fetal-maternal hemorrhage.

Immune globulin should be administered to all Rh-negative trauma patients within 72 hours of injury. During the first trimester, a dose of 50 mcg may be used instead of the traditional dose of 300 mcg, which is used after 13 weeks gestation. If significant fetal-maternal hemorrhage (> 30 mL) is suspected, higher doses of immune globulin may be required. In these cases, a Kleihauer-Betke test may be useful to quantify the degree of transplacental hemorrhage. Recent data also suggest that a positive Kleihauer-Betke test is correlated with uterine contractions and with risk for preterm labor following trauma.[15] Patients with a positive Kleihauer-Betke test, therefore, may require more extensive monitoring following trauma.

Assessment and Management

Initial Assessment. The assessment of the injured pregnant patient should be nearly identical to that of the injured nonpregnant patient, with the following important exceptions:

1. The pregnancy must be immediately recognized. This is especially relevant in women who may not realize they are pregnant and in those unable to communicate due to head injury, intoxication, severe respiratory distress, or profound shock. When pregnancy is not clinically obvious, a urine pregnancy test should be done in 100% of injured women of childbearing age. When pregnancy is clinically obvious, the assessment of the fetus occurs during the secondary survey.
2. The normal changes in physiology resulting from the pregnancy must be interpreted in the context of injury.
3. The ability of the pregnant mother to tolerate and respond to specific injuries must be understood.
4. The team must not be distracted by an obviously gravid uterus when a focused assessment and critical interventions are needed to stabilize the mother.
5. Once the mother has been assessed, an appraisal of fetal viability should be performed.

Unique features of the primary assessment and the secondary survey are outlined below.

Airway. The physiologic and anatomic changes of pregnancy significantly affect the respiratory system and airway management. These changes necessitate aggressive airway management and preparation for a potentially difficult airway. All steps should be taken to maximally oxygenate mother and fetus. During advanced stages of pregnancy, the airway will be difficult for two reasons: the upward excursion of the uterus reduces lung volumes, functional residual capacity, and respiratory reserve; and increased intragastric pressure increases the risk of regurgitation. When intubating the pregnant trauma patient, precautions for both aspiration and cervical spine injury should be taken.

Rapid sequence intubation (RSI) is the preferred method for intubation. Traditional RSI medications are safe in pregnancy in the absence of other contraindications. Both depolarizing and non-depolarizing paralytic agents cross the placenta and may result in a flaccid, apneic infant if immediate delivery were to ensue.

Once paralyzed, rapid desaturation is the rule rather than the exception. This is worsened in the presence of acute chest injury. As such, all trauma airways in the pregnant patient should be considered high-risk. To decrease this risk of aspiration, cricoid pressure is vital during airway management.[9] Keep in mind that a smaller endotracheal tube than usual may be necessary for successful intubation in the setting of edematous periglottic tissue. Once intubation is accomplished, gastric decompression should be performed to decrease the risk of aspiration.

Breathing. For the reasons outlined above, significant trauma in the second or third trimester of pregnancy is associated with a potentially compromised respiratory status. With limited respiratory reserve, blunt or penetrating chest injuries are not well tolerated. The goal of the physical examination is to identify clinical findings suggestive of chest injury, i.e., tachypnea or respiratory distress, external chest trauma, and clinical signs of rib fractures, flail segments, pneumothorax, or hemothorax. The gradual 4 cm elevation of the diaphragm by the growing uterus is important to remember when placing a chest tube. It should

be inserted one to two intercostal spaces higher than standard to avoid diaphragmatic, liver, or spleen injury. Prior to insertion, the chest-tube tunnel should be digitally palpated to ensure proper placement.[7]

Circulation. In the first trimester, the assessment of circulation is unchanged. In the second and third trimesters, predictable increases in blood volume will mask the typical response to hemorrhage, i.e., hypotension and tachycardia. In essence, the maternal "tank" is over-filled; thus, proportionally larger volumes of blood loss will be required to mount a detectable cardiovascular response. It is equally important to understand that while maternal heart rate climbs in the third trimester, tachycardia (a heart rate ≥ 100 bpm) is not a normal finding.

Large-bore IV access should be obtained as in any trauma patient, and aggressive resuscitation with crystalloid should be initiated if shock is either evident or suspected. If hemodynamic compromise continues despite this, transfusion of type-specific blood is recommended. If time does not allow for this, however, type O, Rh-negative blood should be used.

Vasopressor therapy should be avoided whenever possible. The disadvantage of vasopressor therapy in the pregnant patient is that this compromises perfusion to the uteroplacental unit and, therefore, the fetus.[10] If aggressive volume replacement and blood products are ineffective, vasopressor therapy should be initiated at the lowest possible dose to maintain maternal perfusion. Ephedrine and mephentermine offer a theoretical advantage, as these agents do not compromise uterine perfusion to the same extent that epinephrine and norepinepherine do.[10]

When hypotension is noted in a patient who is greater than 20 weeks gestation, attempts should be made to displace the uterus from the great vessels and restore cardiac output. This is typically achieved by placing the patient in the left lateral decubitus position. In circumstances where spinal precautions must be maintained, displacement of the gravid uterus from the vena cava may be achieved with manual displacement or by raising the backboard to a 15- to 30-degree angle.[11] Manual displacement is achieved by manually lifting the uterus and displacing it to the left and toward the patient's head.

If CPR is required, chest compressions should be modified in the pregnant patient. These patients require deeper compressions (1.5-2 inches) with more force than the general population. This is due to decreased chest-wall compliance caused by elevation of the diaphragm. The position of chest compressions also should be shifted from the traditional mid-sternum to slightly above the mid-sternum. Standard ACLS protocols for pharmacologic agents and defibrillation should be followed in the pregnant patient. Electrical therapy with standard joule delivery has never been found to have injurious effects on the fetus.[1,16]

When obtaining central venous access, lower-extremity sites should be avoided if possible. Drugs administered to sites below the uterus will have difficulty reaching the central circulation due to aortocaval compression.

The Secondary Survey. The secondary survey should be done in the same order and with the same cadence as in any other trauma patient. A methodical head-to-toe examination will help identify injuries posing a threat to both patients.

The examination of the abdomen is especially relevant. Severe tenderness may reflect an injury to maternal viscera or to the enlarged uterus. A large-for-dates uterus may occur following uterine abruption and retroplacental hemorrhage. (*See Figure 2.*) Palpation of fetal parts outside the uterus reflects uterine rupture.

In the pregnant patient suffering severe multisystem trauma, the pelvic examination should not be overlooked. The exam may reveal vaginal bleeding, rupture of membranes, or vaginal lacerations resulting from pelvic-ring fractures.

It is important to recognize that the physical assessment of the trauma patient has limitations. For example, large studies describe a 5% to 10% rate of "occult" abdominal injuries when patients are evaluated with physical examination alone.[17-19] Missed abdominal injuries are especially common in: patients with neurological impairment due to brain injury or alcohol; patients with multiple coincident injuries; and patients with severe or "distracting" injuries. It is logical that the same would apply to the pregnant trauma patient.

Fetal Assessment. Fetal assessment is initiated during the secondary survey of the pregnant trauma patient. Initially, the presence of fetal cardiac activity should be confirmed

Figure 3. Fetal Monitoring Strip

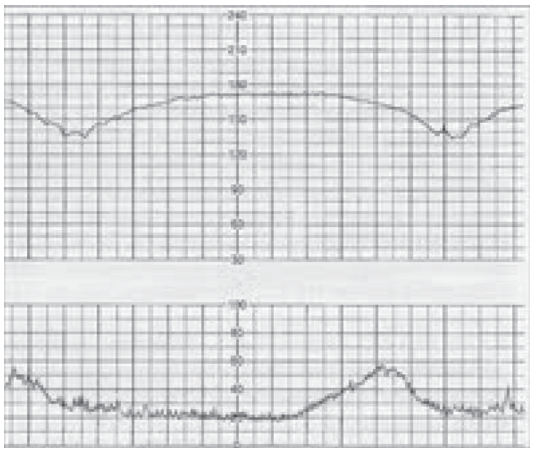

Figure 4. Fetal Monitoring Strip

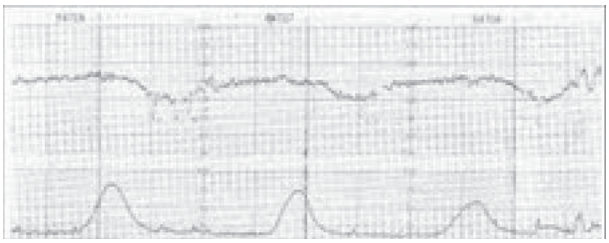

Table 6. Medications[20,21]

	Resuscitative Medications	Analgesics	Sedatives/ Paralytics	Other
USED				
	Magnesium (B)	Acetamino-phen (B)	Rocuronium (B)	Ondansetron (B)
	Atropine (C)	Oxycodone (B)	Vecuronium (B)	Cefazolin (B)
	Epinephrine (C)	Fentanyl (C)	Propofol (B)	Promethazine (C)
	Etomidate (C)	Morphine (C)	Succinylcholine (C)	
	Lidocaine (C)	Hydromor-phone (C)		
	Bicarbonate (C)			
	Dopamine (C)			
	Dobutamine (C)			
	Adenosine (C)			
	Bretylium (C)			
AVOIDED				
	Ketamine (D)			

by Doppler ultrasound. Once this has been established, if a fetus is viable (> 23 weeks gestation), continuous external fetal monitoring should be initiated. Fetal monitoring can be useful for both fetal and maternal assessment, as fetal distress is often an early marker of impending maternal hemodynamic compromise. When significant hemorrhage or hypotension occurs, blood is first shunted away from the uteroplacental unit,[1] and fetal distress may be seen before maternal vital signs become abnormal. It is for these reasons that the fetal heart rate is often considered the "fifth vital sign" in the pregnant patient.[10]

Normal fetal heart rate varies between 120 and 160 beats per minute. Fetal distress can be manifested by bradycardia, tachycardia, loss of beat-to-beat variability, or heart-rate decelerations. A fetal monitoring strip showing a late deceleration is shown in Figures 3 and 4.

Assessment of Gestational Age. During the secondary survey, palpation of the fundal height provides a crude assessment of whether the fetus is viable outside of the uterus (≥ 20 weeks gestation) or unlikely to survive outside the uterus (≤ 20 weeks gestation; "pre-viable"). A fundal height at or above the umbilicus identifies a fetus at greater than or equal to 20 weeks gestation. Bedside sonography with measurement of crown-rump length and/or biparietal diameter is a useful adjunct when making this determination.

Pharmacology

Acknowledging limited data, most medications used in the trauma setting have not been proven to be harmful in the human fetus. The pharmacologic strategy used during the resuscitation of the pregnant patient should follow standard American Heart Association guidelines. Successful resuscitation of the mother provides the greatest potential for fetal survival. The following are the safety categories in pregnancy:

A: Controlled studies in pregnant women fail to demonstrate a risk to the fetus in the first trimester with no evidence of risk in later trimesters. The possibility of harm appears remote.

B: Animal studies show no risk or adverse fetal effects, but controlled, human, first-trimester studies are not available; no evidence of second- or third-trimester risk; fetal harm possible but unlikely.

C: Animal studies show adverse fetal effects, but no controlled human studies OR no animal or human studies; weigh possible fetal risk vs. maternal benefit.

D: Positive evidence of human fetal risk; maternal benefit may outweigh fetal risk in serious or life-threatening situations. (*See Table 6.*)

Imaging in Pregnancy

Choosing appropriate imaging modalities for the pregnant patient can be anxiety-provoking for the emergency physician (EP) due to concerns about fetal radiation exposure. The imaging strategy should carefully balance the need to rapidly detect and prioritize injuries with the radiation dose required to achieve this goal. Because trauma is the leading non-obstetric cause of maternal death, fast, accurate diagnostics are imperative for both maternal and

fetal well-being. Ultimately, injury detection takes priority, and concerns about radiation exposure should neither deter nor delay radiographic imaging in the pregnant trauma patient.[22,23]

Effects of Ionizing Radiation Exposure to the Fetus. The effects of ionizing radiation exposure to the fetus depend on gestational age and radiation dose. Most effects are seen at doses that far exceed those typically used for diagnostic imaging. See Table 7 for an overview of the estimated mean fetal-absorbed dose from various radiologic studies. Before implantation (0-2 weeks after conception), there is an all-or-none risk of either death of the embryo or no consequence at all at threshold doses 50-100 mGy.[22,24] There is some variable evidence to suggest increased risk of childhood leukemia by a factor of two with a single pelvic CT scan within the first two weeks after conception, but the increase in absolute risk is very low.[25] During organogenesis (2-8 weeks after conception), congenital anomalies are seen at 200 mGy and growth retardation at 200-250 mGy. At 8-15 weeks, the risk of severe mental retardation is seen in doses of 60-310 mGy, and at 16-25 weeks in doses of 250-280 mGy.[22]

Computed Tomography. Computed tomography (CT) is often the imaging modality indicated in trauma evaluation, and this imaging should be pursued without hesitation, although with efforts to use the lowest dose possible to achieve necessary information. When the fetus is out of the imaging field, such as with CT of the head, cervical spine, chest, and extremities, the radiation exposure to the fetus is low, and these images can be safely obtained during any trimester of pregnancy. Because the fetus is in the direct line of radiation for CT of the abdomen and pelvis, the theoretic risk to the fetus is greater, and the EP should work with the radiologist to minimize the radiation dose.[23,24] When possible, studies such as ultrasonography and magnetic resonance imaging (MRI) that do not have ionizing radiation should be used for the pregnant patient.[22] Shielding of the fetus should be performed for all radiographs, with the exception of pelvic X-rays. Careful attention should be paid to avoid radiographic redundancy.[25]

Table 7. Imaging and Fetal Exposure Levels[22,23,26,27]

Modality	Fetal Exposure
Chest X-ray	0.0002-0.0007 mGy
Abdominal X-ray	1 mGy
Pelvis X-ray	2 mGy
CT Scan Head or Chest	< 10 mGy
CT Scan Abdomen or Pelvis	35 mGy

Focused Assessment with Sonography for Trauma (FAST). Ultrasound is not associated with known adverse fetal effects.[23] Both the technique and the areas of fluid accumulation are the same. The sensitivity and specificity for detection of intra-abdominal injury in the pregnant patient range from 61-83% and 94-100%, respectively.[22] Given the possibility of false negatives, a CT scan is often needed for further examination.[28]

Concluding recommendations from the 2010 EAST practice management guidelines work group as published in *The Journal of Trauma* are as follows:

"Level II: clinical studies in which data were collected prospectively and retrospective analyses that were based on clearly reliable data. Types of studies so classified include observational studies, cohort studies, prevalence studies, and case-control studies.

1. Concern about possible effects of high-dose ionizing radiation exposure should not prevent medically indicated maternal diagnostic X-rays whenever possible.

2. Exposure to < 5 rad has not been associated with an increase in fetal anomalies or pregnancy loss and is herein deemed to be safe at any point during the entirety of gestation.

3. Ultrasonography and magnetic resonance imaging are not associated with known adverse fetal effects. However, until more information is available, magnetic resonance imaging is not recommended for use in the first trimester.

4. Consultation with radiology should be considered for the purposes of calculating estimated fetal dose when multiple diagnostic radiographs are performed."[25]

Special Considerations

Perimortem Cesarean Section. A perimortem cesarean section should be performed in cases of traumatic arrest if there is a potentially viable fetus (> 23 weeks). It should be performed by a provider trained and credentialed to perform the procedure. If gestational age is unknown, a rapid method to estimate gestational age is to assume viability if the fundus is palpable above the level of the umbilicus. A bedside ultrasound also may be used to rapidly assess for fetal cardiac activity if immediately available; however, this should not delay the procedure. A study assessing fetal outcome in 33 infants following perimortem cesarean section found that there were survivors as early as 26 weeks gestation, and that none of the 13 infants delivered despite absent fetal heart tones survived.[29] This suggests that a rapid assessment for gestational age and fetal heart tones can help the physician determine if a patient is appropriate for perimortem cesarean section.

A perimortem cesarean not only allows for further resuscitation of the infant, but it also relieves uterocaval compression; this increases maternal venous return and cardiac output. In this situation, return of maternal

circulation may also occur. CPR and ACLS protocols should be continued during the procedure. Ideally, perimortem cesarean section should begin within 4 minutes of maternal cardiac arrest, with a goal of delivery within 5 minutes of maternal cardiac arrest. This timing is recommended because improved fetal outcome has been demonstrated when delivery is within 5 minutes of maternal cardiac arrest.[30,31] Data from Katz's study demonstrate that 70% of infants who survived perimortem cesarean section were delivered within 5 minutes of maternal arrest. However, there have been case reports of return of spontaneous maternal circulation and normal fetal neurologic outcome after more than 15 minutes following maternal arrest, so arrest time greater than 5 minutes is not a contraindication to perimortem cesarean delivery.[32]

Domestic Violence During Pregnancy. When caring for the pregnant trauma patient, careful consideration should be made for the possibility of physical abuse. Domestic violence rates are increased during pregnancy, as this is frequently a time of both emotional and financial strain. The rate of violence during pregnancy is estimated at 10-15%.[3] Furthermore, the vast majority of physical assaults on pregnant patients are perpetrated by boyfriends and spouses, and are likely to be significantly underreported. Assaults on pregnant patients tend to recur and to increase in severity throughout the pregnancy. Common areas of injury during pregnancy include the abdomen, breasts, and genitals.[32] Other warning signs include frequent office or emergency department visits, depression, substance abuse, and a history inconsistent with injury. It is recommended that all pregnant trauma patients be screened for domestic violence. If possible, screening should be performed without the presence of partners or family members.

Burns. Approximately 7% of women seen for the treatment of burns in the United States are pregnant. Most of these events occur in the workplace.[26] Fetal outcomes are closely linked to burn severity. As the total body surface area (TBSA) of the burn increases, so does the risk of poor fetal outcomes and fetal death. In general, uncomplicated burns of less than 20% TBSA will have little effect on fetal well-being. Burns greater than 30% can lead to fetal distress and premature labor. Fetal survival is uncommon when burns exceed 60% TBSA.[34]

There are insufficient data in the literature to develop specific guidelines for the management of burns in the pregnant patient. Most recommendations are based on small case series or are extrapolated from nonpregnant patients. With that in mind, several recommendations can be made with regard to airway management and fluid resuscitation.

In the patient suffering major burns and/or smoke inhalation, careful and early attention to airway management is of paramount importance. In the third trimester, tidal volume and minute ventilation both increase by 30% to 50%. As such, impaired ventilation and gas exchange due to upper airway edema, inhalation injury, or concomitant chest injury can profoundly impair maternal and fetal physiology.

RSI is the technique of choice when intubation is required. Because gravid patients desaturate rapidly following paralysis, careful preparation and planning are fundamental. It is important to recall that acute burns are not a contraindication to the use of succinylcholine as the preferred neuromuscular blocking agent. Conversely, succinylcholine should be avoided in subacute burns (i.e., ≥ 72 hours old) to avoid drug-induced hyperkalemia. When upper-airway burn edema threatens the success of laryngoscopy, alternative techniques should be considered as the primary approach, or immediately available as part of a "double set-up."

Use of the Parkland formula (*see Table 8*), which has not been validated in the pregnant patient, is controversial. Pacheco and colleagues[35] argue that predictable physiologic changes occurring during pregnancy create an inherent risk of under-resuscitation if the Parkland formula is used: pregnancy is a hyperdynamic state with an increase in cardiac output, a drop in systemic vascular resistance, and increased overall metabolic demands; intravascular volume requirements increase by 50% at term; decreases in colloid osmotic pressure increase tissue fluid extravasation; and total body surface area is increased, promoting burn-surface fluid loss. Without outcome data or guidance to the contrary, the Parkland formula seems like a logical starting point. To ensure adequate resuscitation, ongoing monitoring of vital signs, urine output, cardiotocographic monitoring, and objective measures of tissue perfusion (e.g., serial serum lactate or base deficit) is important.

Burn cleansing and debridement should be done in standard fashion. Topical antibiotics, such as bacitracin and silver sulfadiazine, and biosynthetic dressings (e.g., Biobrane®, TransCyte®, Aquacel®) are not associated with fetal malformations and are considered safe in pregnancy.[36]

Victims of major burns, and all those burned in an enclosed space, should be assessed for carbon monoxide (CO) poisoning. Because fetal hemoglobin avidly binds CO, hyperbaric oxygen is recommended for all symptomatic pregnant patients and asymptomatic patients with a venous CO level greater than 15%.[37]

Electrical Injury. Traditional teaching emphasizes that even low-voltage electrical injuries are

Table 8. Parkland Formula[26,34]

- **Fluid requirement = TBSA burned (%) × Weight (kg) × 4 mL**
- **Half given in the first 8 hours and half over the next 16 hours**
- **Normal saline or lactated Ringer's solution**

associated with a significant risk of poor fetal outcomes and fetal demise.[38-40] Pathophysiologically, this is attributable to the high conductivity of amniotic fluid, putting the fetus at risk when the offending current "crosses" the uterus. There is no debate that major electrical injuries, lightning strikes, and Taser-gun injuries pose a major risk.[41,42]

A review of 31 patients by Einarson and colleagues points out that most electric injuries in pregnancy are due to 110 V household current, with no proven difference in outcomes.[43] Given the lack of certainty on this issue, it seems reasonable to assess fetal well-being immediately in all pregnant patients suffering electric injury. In the absence of fetal distress and maternal indications for admission (loss of consciousness, persistent neurological symptoms, history of cardiac disease, abnormal maternal ECG), a 4-hour period of fetal monitoring is reasonable. With most significant maternal injuries or any signs of fetal distress, immediate obstetric consultation and a longer period of maternal and fetal monitoring are indicated.

Conclusion

Management of the injured pregnant patient presents unique challenges to the emergency physician. A thorough knowledge of the differences between a pregnant and a nonpregnant trauma patient is imperative to adequately care for the pregnant trauma patient. Ultimately, maternal stabilization should be the primary focus to ensure the best possible outcome for both mother and fetus.

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CME/CNE Questions

1. Which findings on fetal monitoring indicate fetal distress?

   A. bradycardia (HR < 120)
   B. tachycardia (HR > 160)
   C. reduced variability
   D. all of the above

2. Which of the following is one of the physiologic changes of pregnancy?

   A. decreased heart rate
   B. increased cardiac output

C. decreased respiratory rate
D. increased lung capacity

3. Which of the following statements is true regarding Rh immune globulin (RhoGAM)?
   A. It must be administered within 24 hours of trauma.
   B. It should be administered after even minor abdominal trauma.
   C. It is effective up to 72 hours following trauma.
   D. B and C are true.

4. Which medication should be avoided during resuscitation in the pregnant patient?
   A. rocuronium
   B. morphine
   C. ketamine
   D. etomidate

5. A 33-year-old G1P0 pregnant patient at 30 weeks gestation presents as a belted driver in a low-speed motor vehicle crash. After assessment of the patient reveals only a knee contusion, a bedside ultrasound confirms a fetal heart rate of 143. Which of the following is correct regarding patient disposition?
   A. The patient can be safely discharged home.
   B. Further ultrasound imaging is required to evaluate for placental abruption.
   C. Continuous fetal monitoring is required for a period of 4-6 hours.
   D. The patient should be admitted to the OB service for 24-hour observation.

6. A 24-year-old G2P1 with a pregnancy of unknown gestational age presents to the emergency department intubated for respiratory distress after a motor vehicle crash. What is the quickest way to estimate gestational age in this setting?
   A. bedside ultrasound for crown-rump length
   B. calculation of biparietal diameter
   C. palpation of the fundal height
   D. rapid retrieval of records from the obstetrician

7. Which of the following should be considered when ordering imaging tests in the pregnant patient?
   A. Consult with a radiologist to ensure lowest radiation dose.
   B. High-dose ionizing radiation should not be used despite the need for maternal diagnostics.
   C. The FAST exam can rule out intra-abdominal injury.
   D. Exposure to < 5 rad has been associated with fetal anomalies.

8. A 29-year-old G3P2 at 30 weeks gestation presents to the emergency department with complaint of falling down the stairs and injuring her left arm. Which of the following should prompt concern for domestic abuse?
   A. frequent office or emergency department visits
   B. history of depression or substance abuse
   C. a history inconsistent with the injury
   D. all of the above

9. Which of the following are necessary changes of ACLS for a pregnant patient?
   A. Medication dosages must be adjusted.
   B. Defibrillation joules should be decreased.
   C. Chest compressions should be deeper and more cephalad.
   D. All of the above are necessary.

10. Which of the following is true regarding electrical injuries in pregnant patients?
   A. Most electrical injuries in pregnant patients are due to 110 V household current.
   B. Amniotic fluid has low conductivity of current.
   C. Lightning strikes to the mother pose minimal risk to the fetus.
   D. All of the above.

Answers: 1. D; 2. B; 3. D; 4. C; 5. C; 6. C; 7. A; 8. D; 9. C; 10. A

CNE/CME Objectives

Upon completing this program, the participants will be able to:

- discuss conditions that should increase suspicion for traumatic injuries;
- describe the various modalities used to identify different traumatic conditions;
- cite methods of quickly stabilizing and managing patients; and
- identify possible complications that may occur with traumatic injuries.

CNE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to evaluate their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. *After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a credit letter.* When your evaluation is received, a credit letter will be mailed to you.

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CNE/CME Evaluation — Trauma in Pregnancy

Please take a moment to answer the following questions to let us know your thoughts on the CNE/CME program. Fill in the appropriate space and return this page in the envelope provided. **You must return this evaluation to receive your credit letter. ACEP members — Please see reverse side for option to mail in answers.** Thank you.

CORRECT ● INCORRECT ◐ ✔ ✘ ⩘

1. In which program do you participate? ◯ CNE ◯ CME
2. If you are claiming physician credits, please indicate the appropriate credential: ◯ MD ◯ DO ◯ Other _____

After completion of this program, I am able to:	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
3. Discuss conditions that should increase suspicion for traumatic injuries.	◯	◯	◯	◯	◯	◯
4. Describe the various modalities used to identify different traumatic conditions.	◯	◯	◯	◯	◯	◯
5. Cite methods of quickly stabilizing and managing patients.	◯	◯	◯	◯	◯	◯
6. Identify possible complications that may occur with traumatic injuries.	◯	◯	◯	◯	◯	◯
7. The test questions were clear and appropriate.	◯	◯	◯	◯	◯	◯
8. I am satisfied with customer service for the CNE/CME program.	◯	◯	◯	◯	◯	◯
9. I detected no commercial bias in this activity.	◯	◯	◯	◯	◯	◯
10. This activity reaffirmed my clinical practice.	◯	◯	◯	◯	◯	◯
11. This activity has changed my clinical practice.	◯	◯	◯	◯	◯	◯

If so, how? _____

12. How many minutes do you estimate it took you to complete this activity? Please include time for reading, reviewing, answering the questions, and comparing your answers with the correct ones listed. _____ minutes.

13. Do you have any general comments about the effectiveness of this CME program? _____

_____

I have completed the requirements for this activity.

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Optional for ACEP members: In accordance with ACEP requirements, below we provide the option for ACEP members to submit their answers for this CME activity. If you wish to submit answers for this activity, please refer to Volume 12, Number 3 and circle the correct responses.

Trauma in Pregnancy

1. A B C D 2. A B C D 3. A B C D 4. A B C D 5. A B C D 6. A B C D 7. A B C D
8. A B C D 9. A B C D 10. A B C D

Trauma Reports

2011 Reader Survey

In an effort to learn more about the professionals who read *Trauma Reports,* we are conducting this reader survey. The results will be used to enhance the content and format of *Trauma Reports*.

Instructions: Fill in the appropriate answers. Please write in answers to the open-ended questions in the space provided. Please insert this survey in the provided envelope along with your continuing education evaluation. Return the questionnaire by **July 1, 2011.**

1. Are the articles in *Trauma Reports* written about issues of importance and concern to you?

O A. Always
O B. Most of the time
O C. Some of the time
O D. Rarely
O E. Never

2. How would you rate your overall satisfaction with your job?

O A. Very satisfied
O B. Somewhat satisfied
O C. Somewhat dissatisfied
O D. Very dissatisfied

3. What are you most dissatisfied with in your job?

O A. staffing
O B. heavy workload
O C. low morale in your department or facility
O D. impact of cost-cutting on quality of care
O E. other _____

Questions 4-9 ask about coverage of various topics in *Trauma Reports*. Please mark your answers in the following manner:

A. very useful B. fairly useful C. not very useful D. not at all useful

4. Recent Advances in Wound Care (July/Aug. 2010)	O A	O B	O C	O D
5. Organ Procurement in Trauma (Sept./ Oct. 2010)	O A	O B	O C	O D
6. Thoraco-abdominal Injury (Nov./Dec. 2010)	O A	O B	O C	O D
7. Rapid Sequence Induction (Jan./Feb. 2011)	O A	O B	O C	O D
8. Facial Trauma (March/April 2011)	O A	O B	O C	O D
9. Trauma in Pregnancy Trauma(May/June 2011)	O A	O B	O C	O D

10. How do you receive *Trauma Reports*?

O A. I am a paid subscriber (proceed to question 11)
O B. I receive it as a supplement to another publication (skip to question 12)

11. Do you plan to renew your subscription to *TR*? O A. yes O B. no

If not, why? _____

12. How would you describe your satisfaction with your subscription to *TR*?

O A. Very satisfied
O B. Somewhat satisfied
O C. Somewhat dissatisfied
O D. Very dissatisfied

13. What is your title?

O A. Practicing emergency medicine physician
O B. Trauma surgeon
O C. Emergency department or surgical nurse
O D. Physician assistant
O E. Professor/academician
O F. Emergency medicine manager/director
O G. Resident

14. On average, how much time do you spend reading each issue of *TR*?

O A. fewer than 30 minutes
O B. 30-59 minutes
O C. 1-2 hours
O D. more than 2 hours

15. On average, how many people read your copy of *TR*?

O A. 1-3
O B. 4-6
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O D. 10-15
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16. On average, how many articles do you find useful in *TR* each year?

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O C. 201-300 beds
O D. 301-500 beds
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Please rate your level of satisfaction with the following items.
A. excellent B. good C. fair D. poor

18. Quality of newsletter	○ A	○ B	○ C	○ D
19. Article selections	○ A	○ B	○ C	○ D
20. Timeliness	○ A	○ B	○ C	○ D
21. Length of newsletter	○ A	○ B	○ C	○ D
22. Overall value	○ A	○ B	○ C	○ D
23. Customer service	○ A	○ B	○ C	○ D

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28. Has reading *Trauma Reports* changed your clinical practice? If yes, how?

_____

_____

_____

29. What do you like most about *Trauma Reports*?

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_____

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