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Surgical Management of Wounds

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Abstract

In surgical speciality, understanding of the wound healing is absolutely necessary. There are different kinds of wounds that require treatment which is most appropriate to them. In this chapter, we have discussed treatment for different types of wounds in four main types according to WHO Classification. Pros and cons of different types of materials used for cleaning and dressing are discussed. Dressing materials are discussed in detail. We have described the process of wound healing. There are various factors that influence wound healing and we have specifically described how they differ in primary and secondary wound healing. Usage of various kinds of dressing materials and their mechanism of action is described in detail. We have specifically highlighted the role of community nurses and tissue viability nurses. Since the availability and the recognition of tissue viability nurses, the cost of wound treatment has come down considerably and it is also very popular with the patients. Vacuum-assisted closure (VAC) therapy is very helpful in large wounds that are producing a lot of exudates. The VAC pulls the skin edges together and removes the exudate. Other adjunctive therapies are also mentioned but they are not available in most hospitals and therefore detailed descriptions are not provided.

Keywords: wound, closer, techniques, infection, surgical

1. Introduction

Wound management is considered one of the main pillars of patients' care at all levels of health service. The financial burden on the health service and the community in relation to wound management are due to prolonged stay, the cost of different materials required for wound care, delayed discharge, loss of earnings, continuous input and follow up at primary care level. No

reliable data are available for the cost of treating the wound which do not close with primary intention. A report by Lewis et al. [1] has carried out a comprehensive review of the literature and has found that the cost of dressings and other material alone could be as high as £37 million per year in England. Data for primary care are easily available as they purchase on Form 10 but the data for secondary care are difficult to find as most hospitals buy directly from manufacturers at specially negotiated price, therefore factoring this in is quite difficult and no reliable study has been found on literature search. If patient stays in hospital the cost of stay in hospital could be as high as £400–500 per day depending upon the geographic location of hospital. Additionally, the cost of staffing, local or general anaesthetic, has to be factored in as well.

Significant developments have taken place with regards to wound management over the course of the years. Thanks to the evolving technology, better understanding of the healing process and relevant contributing factors we are now able to address the problem in a timely, cost-effective and efficient manner. It is a developing area and therefore the means of management will only improve with time.

2. Understanding tissue healing

Understanding tissue healing is fundamental in wound management. Such a complex physiological process is proven to be dependent on multiple inter-related factors [2].

Wound healing can be defined as the process by which the body restores and replaces function to damaged tissues [3]. Following tissue trauma, healing can be initiated through one of the two mechanisms:

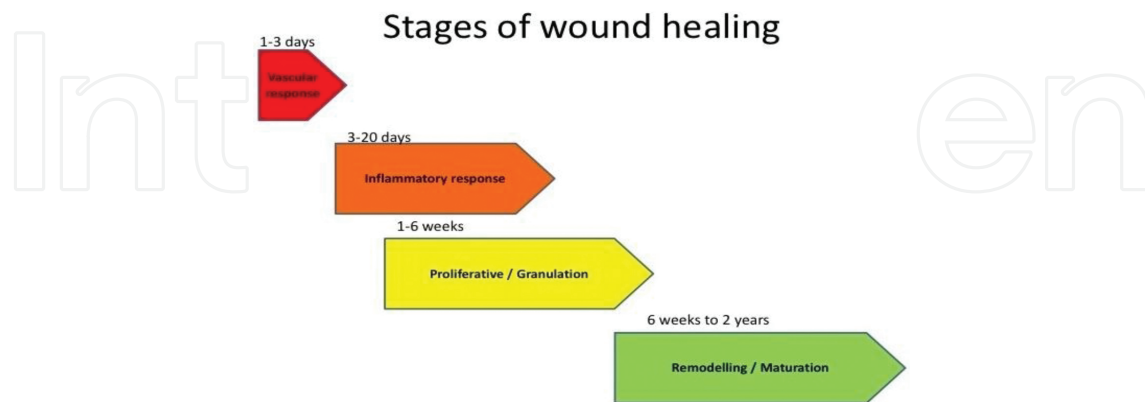
1. Regeneration, which means replacement of damaged tissue by an identical type of tissue. This process is only confined to a few types of cells, for example epithelial, liver and nerve cells [2].
2. Repair, where damaged tissues are replaced by connective tissue to form a scar. This mechanism occurs in vast majority of cases [2].

3. Stages of wound healing

In general terms, the wound healing process can be divided into four stages with some potential overlap between the stages. Identification and recognition of the wound stage enables appropriate treatment objectives for that particular stage. When treating, practitioner at times may fail to establish correct treatment objectives due to failure to correctly recognise the healing stage of that particular wound.

3.1. Stage 1 (vascular response)

Tissue trauma leads to activation of coagulation cascade resulting in formation of a fibrin mesh to fill the gap within the tissue. It usually lasts up to 3 days [3].



Scheme 1. Stages of Wound healing.

3.2. Stage 2 (inflammatory response)

At this stage, vasodilatation and increased permeability of the adjacent blood vessels are noted. This is the result of inflammatory mediators like histamine and prostaglandins released by mast cells. Clinically, this is characterised by redness, swelling, localised heat, pain and functional limitation. Clinical presentation at this stage might be confused with wound infection, as hyperaemia occurs in the first 3 weeks of healing.

Increased capillary permeability at this phase leads to exudates production containing essential growth factors, nutrients and enzymes mandatory for wound healing in addition to their anti-microbial characteristics [4].

Immuno-compromised patients might not be able to produce appropriate inflammatory response resulting in failure of activation of normal healing process [5].

3.3. Stage 3 (proliferative/granulation phase)

New connective tissue starts to fill the wound and a decrease of the wound size is noted. This occurs as a result of epithelialisation, wound contraction and granulation [2]. Collagen and other extra-cellular materials form scaffolding on which the new capillaries grow (angiogenesis) to form connective tissue. The process is referred to as granulation formation [2]. Angiogenesis is promoted by material produced by macrophages including transforming growth factor (TGF) and tumour necrosis factor (TNF) [6].

Fibroblast contraction that takes place during this stage is responsible for wound contraction and hence reducing wound size. This is considered to be a crucial part of a large and open wound healing [7].

Growth factor	Abbreviation	Main origins	Effects
Epidermal growth factor	EGF	Activated macrophages	Keratinocyte and fibroblast mitogen Keratinocyte migration Granulation tissue formation
Transforming growth factor- α	TGF- α	Activated macrophages T-lymphocytes Keratinocytes	Hepatocyte and epithelial cell proliferation Expression of anti-microbial peptides Expression of chemotactic cytokines
Hepatocyte growth factor	HGF	Mesenchymal cells	Epithelial and endothelial cell proliferation Hepatocyte motility
Vascular endothelial growth factor	VEGF	Mesenchymal cells	Vascular permeability Endothelial cell proliferation
Platelet-derived growth factor	PDGF	Platelets Macrophages Endothelial cells Smooth muscle cells Keratinocytes	Granulocyte, macrophage, fibroblast and smooth muscle cell chemotaxis Granulocyte, macrophage and fibroblast activation Fibroblast, endothelial cell and smooth muscle cell proliferation Matrix metalloproteinase, fibronectin and hyaluronan production Angiogenesis Wound remodelling Integrin expression regulation
Fibroblast growth factors 1 and 2	FGF-1, -2	Macrophages Mast cells T-lymphocytes Endothelial cells Fibroblasts	Fibroblast chemotaxis Fibroblast and keratinocyte proliferation Keratinocyte migration Angiogenesis Wound contraction Matrix (collagen fibres) deposition
Transforming growth factor- β	TGF- β	Platelets T-lymphocytes Macrophages Endothelial cells Keratinocytes Smooth muscle cells Fibroblasts	Granulocyte, macrophage, lymphocyte, fibroblast and smooth muscle cell chemotaxis TIMP synthesis Angiogenesis Fibroplasia Matrix metalloproteinase production inhibition Keratinocyte proliferation
Keratinocyte growth factor	KGF	Keratinocytes	Keratinocyte migration and differentiation

Table 1. Various growth factors involved in wound healing [10].

During the final phase of proliferation, re-epithelialisation takes place across the wound surface. This process will be delayed until the wound bed is filled with granulation tissue in cases of wound healing with secondary intention [2].

3.4. Stage 4 (remodelling/maturation phase)

This is the fourth and final stage of wound healing and it might extend up to 2 years from the time of tissue trauma. During this stage, the raised and reddish scar becomes more flat, smooth and lighter in colour. This relates to a reduction in the blood supply. Mature scars are hairless, avascular and do not contain sweat or sebaceous glands.

Collagen fibres are reorganised to maximise tensile strength, a process called remodelling and it is stimulated by macrophages [8].

Hypertrophic scar and keloid formation are two known abnormalities associated with this stage. While the former takes place after initial repair, the latter occurs sometime after healing is completed and continues to grow afterwards [9]. Keloid formation occurs 10 times more commonly in the Black Afro-Caribbean population in comparison to Caucasian population [9]

Table 1.

4. Wound classification

Surgical wounds are commonly classified according to the degree of contamination and breaching of the aerodigestive tract epithelium into four categories:

A. Clean

Uncontaminated wounds without breaching of the respiratory, gastrointestinal (GI) or genitourinary (GU) tract. Examples include mastectomy, neck dissection, thyroid surgery and hernia surgery. These wounds are commonly managed with primary closure.

B. Clean-contaminated

Gastrointestinal, respiratory or Genitourinary tracts are entered in a controlled fashion. Usually no gross contamination or spillage should happen if proper precautions, i.e. minimising spillage, protecting the wound edges, etc., are taken. Examples of these types of wounds include cholecystectomy, Whipple operation, elective colonic or gastric surgery.

C. Contaminated

Any gross spillage of GI tract contents or major breach in the sterile technique either as causative agent or accidental can lead to contamination of wound. Perforated appendicitis, bile spillage, diverticular perforation or penetrating wounds come within this category. Although primary closure is still feasible in these wounds, thorough washout with copious amount of saline to remove as much contaminating agent, i.e. faeces or pus, as possible and prophylactic intra-operative antibiotics are advisable. Most randomised controlled trials (RCTs) prove the reduction in major sepsis though minor wound infection may still occur. In cases of gross

contamination of abdominal cavity with faecal matter and when one is not sure of complete removal of contaminating agent it is better to leave the abdomen open and covered with wet packs for 48 hours and then re-checking the abdomen under general anaesthetic by removing the pack. If the abdominal cavity looks clean and there is no dead tissue or bowel then the closure can be attempted. These wounds are best closed in one layer with whole thickness sutures with either nylon or prolene as tension sutures.

D. Dirty wounds

This refers to old traumatic wounds with necrotic tissue, ongoing infection or perforation and presence of known organisms in the wound prior to intervention. Primary closure is not advisable and debridement is essential. Examples include abscesses, perforated bowel and faecal peritonitis. In cases of gross contamination of abdominal cavity with faecal matter and when one is not sure of complete removal of contaminating agent it is better to leave the abdomen open and covered with wet packs for 48 hours and then re-checking the abdomen under general anaesthetic by removing the pack. If the abdominal cavity looks clean and there is no dead tissue or bowel then the closure can be attempted. These wounds are best closed in one layer with whole thickness suture with either nylon or prolene as tension sutures.

Techniques of wound closure:

A. Closure by primary intention

In this technique, approximation of wound edges and deeper tissue layers is meticulously carried out with appropriate sutures in layers. Skin is approximated by sub-cuticular sutures or staples. Steristrips™ are used to relieve tension on suture line and to give more aesthetically pleasing and functional scar. Elimination of dead space minimises new tissue formation, and careful epidermal alignment minimises scar formation [11, 12].

B. Closure by secondary intention

This is considered an adequate alternative to primary intention closure, particularly in cases where major tissue loss or gross contamination is expected. It might include closure of deeper facial planes while leaving the skin open [13].

5. Factors affecting wound healing [14]

The World Health Organisation (WHO) considers wound healing a multi-factorial process and each factor contributes to the healing process either directly or indirectly.

A. Patient-related factors

- a. Age
- b. Nutritional status
- c. Underlying co-morbidity including diabetes, anaemia and compromised immunity

d. Patients' physiological status, for instance, multi-organ dysfunction, inotropic/vasopressor support

B. Wound-related factors

a. Type of organ or tissue

b. Extent/severity of injury

c. Nature of injury, e.g. clean laceration versus crushing injury

d. Wound contamination

e. Time lapse between the injury and initiation of treatment

C. Local factors related to the surgical technique itself

a. Appropriate haemostasis to ensure viable and well vascularised wound edges is a necessity but at the same time there should be no continuous oozing

b. Decision to perform (or not to perform) wound debridement as part of the surgical wound management does affect the final outcome

c. Timing of closure can be as important as any of the above factors in determining the fate of the wound

6. Surgical approaches to wound management [14]

There are certain golden surgical principles that must be followed in order to achieve adequate wound management.

6.1. For primary repair

A. Primary closure requires clean, well approximated and tension free suturing technique.

B. Infection and delayed healing are almost inevitable when primary closure of contaminated wound takes place without proper debridement or washout.

C. Various suturing techniques mean each technique is ideal for certain types of wounds. For example, while a subcuticular skin suture is considered to be an excellent option of good alignment for the wound edges, it is not the best haemostatic technique and in wounds with oozing edges or expected oozing a continuous mattress suture might be a better option in those cases where oozing is expected.

D. Choosing the correct suture material is vital in ensuring a desirable outcome. In general, a monofilament stitch carries less risk of infection in comparison to braided (multifilament) stitches [15]. Correct tensile strength of the material used is essential in maintaining the integrity of the wound until the healing is complete [15].

E. Size of sutures and interval between stitches should be proportional to the thickness of approximated tissues.

F. Deep wounds should be closed in layers whenever possible.

G. Timing of suture removal is determined by site and vascularity. For example, while skin stitches on the face can be removed as early as in 3 days, abdominal closure, usually, necessitate keeping suture material for up to 7–10 days.

H. Some operations that leave quite a large raw area may require drains as the chances of haematoma formation are high. The most common example is mastectomy. In these cases use of human fibrin glue spray reduces the drainage and also Seroma formation is reduced to a significant degree [16]. The product ARTISS is produced by Baxter Ltd. It contains 5% fibrin and 95% prothrombin and comes loaded in syringe. The product must be connected to a pressurised air source and before using the temperature of fluid must be at 25°C. This solution is good where one may need adjusting the flaps as it takes roughly 3 minutes for it to work [16]. If immediate fixation of the surfaces is required, Tessil (Baxter) is a good product [17]. This contains 95% fibrin and 5% prothrombin and adheres immediately. This is very useful in thoracotomy where it is sprayed straight to the chest wall and pleura [17].

For delayed primary closure:

A. Delayed primary closure is a good alternative in clean contaminated wounds and whenever washout is required. Wounds can be left open with saline-soaked sterile gauze and then patient should be taken back to the theatre, the gauze is removed and if wound looks clean and free of contaminant, sutures can be applied after 48 hours.

6.2. For healing with secondary intention

A. Promote healing with secondary intention after performing surgical debridement.

B. Surgical debridement includes washout of wound edges with antiseptic solutions, thorough washout with copious amounts of saline, excising dead and necrotic tissue down to healthy bleeding edges and gentle tissue handling to minimise iatrogenic tissue trauma.

7. Post-operative wound care

Regardless of the nature of the wound, healing mechanism or the type of closure, the aims of post-operative wound care remain the same. The main goal is to promote fast, complication-free healing with the best possible functional and aesthetic outcome [18]. Special consideration is given to wound healing with primary intention. As there is minimal tensile strength at the wound edges due to lack of remodelling collagen fibres, additional support in the form of sutures, tapes or staples is usually required until epithelisation takes place [19].

8. Guidance for reducing post-operative surgical site infection (SSI) [20]

A. Dressings and wound cleaning

- a. Aim not to disturb the wound in the first 48 hours as this can damage the new delicate layer of epithelium. If necessary, use sterile saline for cleaning wound during this period and not to rub the surface.
- b. Aseptic non-touch technique is mandatory for changing/removing dressings.
- c. Advise patients that they can have a shower 48 hours post-operatively as by this time the top layer of epithelium has formed and the wound becomes water tight.
- d. Early referral to tissue viability services is preferable in cases of wounds healing by secondary intention.

B. Anti-microbial treatment

- a. Consider giving antibiotics whenever SSI (cellulites) is suspected.
- b. Antibiotic choice should be broad spectrum initially then spectrum should be narrowed to target specific organisms once the culture and sensitivity report is available [21].

C. Further debridement

- a. If debridement becomes necessary, surgical debridement in the theatre is always preferred in grossly contaminated wounds.
- b. Avoid gauze dressings as when gauze is removed it damages granulation tissue which sticks to it. Though in certain superficial pussy wounds this method is still used and statistically no difference has been found in the healing time in comparison to more costly dressings.
- c. Some non-healing wound with lot of dead tissue can be treated with sterile Green Bottle Larvae (*Lucilia sericata*) which destroy the necrotic tissue with enzyme and then ingest it. Larvae are applied directly to the wound and then held in place with an occlusive dressing. These can be applied to wound infected with MRSA (Methicillin Resistant Staphylococcus Aureus) as the larvae digest the bacteria as well and reduce the chance of continued infection. It is stipulated that the enzyme also produces growth of granulation tissue, however, some patients may find having larvae on their body unacceptable and if left too long the enzyme produced may destroy the keratinised epithelium [2].
- d. Different types of special dressings can be applied to absorb the exudates and let the wound heal quicker and with less pain when changing the dressing. There are numerous dressings available for this kind of wounds and are described in the next section.
- e. Cleaning the wound with hydrojets and by putting the patient in whirlpool has also been tried and found helpful in cleaning grossly contaminated wounds or quite large wounds. If wound is small and irrigation is required to remove exudates and debris that might interfere

with wound healing, gentle irrigation with a syringe filled with saline or sterile water is preferred [3, 22].

f. Irrigation of wounds with antiseptic solution has been tried with hypochloride (*Eusol*) solution, Aserbane™ and hydrogen peroxide as caustic agents have been tried but there are no reliable data available to prove their efficacy [3].

D. Structured wound care approach

a. Using flowcharts and a structured approach with clear guidance is essential to ensure continuity within the team.

b. Continuous education about recent updates in wound care.

E. Methods to avoid

a. Topical antibiotics in wounds healing by primary intention.

b. Moist cotton gauze or mercury-based antiseptic solutions.

F. Post-operative wound complications: The most common and significant post-operative wound complications are wound infection and wound dehiscence. Once suspected, active management should start and this includes swabs for culture and sensitivities, followed by empirical antibiotics administration in the first instance [21]. Debridement in some cases might be necessary to promote wound healing.

9. Dressings

a. The ideal dressing should carry certain characteristics to assist wound healing. It must maintain some moisture at the wound site, act as a barrier against fluid or bacterial contamination, potentially remove excess exudates that might lead to wound maceration and finally it should be adherent to skin but removed with no/minimal trauma [24]. Tegaderm™ and Opsite™ dressings are two such dressings. These are water resistant and allow patient to have a wash next day if the patients wish so.

b. Wound which are producing lot of debris and discharge need cleaning with aseptic technique. There are a number of different materials available, some of the commonly used ones are described below.

- Hydrocolloid dressings. These contain sodium carboxymethylcellulose which is combined to elastomers and applied to a carrier, usually polyurethane foam. The hydrocolloid absorbs the exudates and becomes gel and when dressing is removed the whole lot lifts off without disturbing the granulation tissue. Common ones are Granuflex™, Comfeel Plus™, Aquacel™ and DuoDerm Extra Thin™.
- Polysaccharide beads. This comes in powder form and swells when it comes in contact with fluid or exudates. This can be left in place for a few days and then removed with gentle wash with saline. It is available as Debrisan (Pharmacia Ltd) and Iodosorb (Perstrop).

- Alginates. These are made from the sodium salts of alginic acid. Alginic acid is produced from seaweed. When exposed to fluid it is activated and forms a gel and absorbs the exudates. It comes in different size and shape as flat squares and ribbons. It is very commonly used in UK. Flat square and ribbons are manufactured by many pharmaceuticals. Kaltostat (Convatec) is the most widely used in our institute.
- Foam dressing. These are made from polyurethane or silicon which absorbs liquid by capillary action. They can be applied to wound as a filler for the cavities. Dressings can be removed every couple of days and the foam can be washed and cut to size for re-application. Lyofoam (Seton) and Silastic (Dow Corning Ltd) are common examples.
- Silver impregnated dressings. These dressings also come as squares or ribbon. They are made of alginate, carboxymethylcellulose and silver impregnated nylon fibres. Silver is used for its anti-microbial action and at the same time the alginate absorbs the exudate to form gel. It is quite effective for the superficial wounds infected with gram positive bacteria and as ribbon for the cavities after surgery for pilonidal sinuses. Most common one is Silver-cel (Systagenix). Aquacel™ is also available with silver.
- Iodine containing dressings. These are gauze dressings impregnated with iodine which is usually good for quite superficial wounds. Iodine acts as antiseptic. Inadine (Systagenix) is readily available. The only problem with this dressing is that it sticks to the granulation tissue, so have to soak the wound in saline for 5 minutes before removing the dressing.
- Allograft and Xenograft for challenging skin loss situations [22, 23]

Skin is considered the largest organ of the human body representing about 16% of the total body weight. Skin loss is commonly encountered in problems such as burns or de-gloving injuries. The skin plays a vital role in terms of immunity, protection and thermoregulation of the human body. Consequently, skin loss can be associated with significant morbidities and even mortalities. Over decades, Research has been carried out to provide biologic skin substitutes that can take the skin function and can be readily available. Cadaveric and porcine grafts have been used for decades as a biologic skin substitutes. When cadaveric grafts are used, they are called allograft as they are originated from the same species. On the contrary, porcine grafts are called xenografts because they are taken from one species and transplanted on to another one.

10. Role of district nurses for wound management

While the journey of wound management starts at the acute hospital, a major part of it takes place in the community. District nurses and practice nurses in the community play a role in wound care. District nurse care is usually provided to patients who cannot physically attend their general practice for various reasons. Once the patients' condition enables them to move freely outside their homes, they are strongly advised to consult the practice

nurses in the general practice and this allows appropriate resource allocation and provides a good service for the people who really need it. Moreover, it promotes recovery of the relatively fitter patient population.

11. Tissue viability services [25]

The concept of tissue viability nurses is relatively new though the idea originated in the 1980s. It covers all aspects of skin and soft tissue wounds. Although surgical wound management is a major part of their role, it is not their sole field of expertise. They also cover various soft tissue-related areas such as pressure sores and chronic leg ulceration. In addition to their bedside role, they provide education to the entire healthcare team. Across the UK, they are also working on preventing common hospital-related skin problems like pressure sores, thereby saving costs in the long term. Their role extends into the community where they provide support to district and practice nurses and help them to choose the correct dressing material and other essential tools for wound healing. The Tissue Viability Society has been established since 2014 and it is considered an excellent forum to discuss all new techniques and materials used for wound healing [26].



Figure 1. Prospective evaluation of vacuum-assisted closure in abdominal compartment syndrome and severe abdominal sepsis, *J Am Coll Surg.* 2007; **205**: 586–592 (Courtesy of KCI medical).

11.1. Vacuum-assisted closure (VAC) therapy and its role in wound healing

VAC therapy is a simple but effective method of promoting rapid healing. It is currently considered to be an effective means of managing large complex acute and chronic wounds (**Figures 1 and 2**) [27].



Figure 2. Vacuum dressing on small oozing wound (Courtesy of WWW.REHABPUB.COM).

VAC is an active wound therapy that was first described in 1997 by Morykwas and Argenta [28]. The system applies negative pressure to the wound bed via an open-cell polyurethane foam dressing [28]. The foam will be in direct contact with the wound and connects to a canister via a suction tube. An effective airtight seal is mandatory for the system to function.

Treatment objectives

- A. Removal of excessive exudate and promoting a moist rather than wet environment for wound healing [27].
- B. Increase angiogenesis which promotes granulation formation [28].
- C. Ability to promote healing in complex wounds and wounds that fail to heal with the conventional methods [27, 28].

Wounds that can be treated with VAC therapy [29]

- A. Pressure ulcers
- B. Diabetic foot ulcers
- C. Trauma wounds with tissue loss
- D. Burns
- E. Leg ulcers
- F. Skin grafts
- G. Surgical wound dehiscence

Contraindications and precautions [29]

- A. Known or suspected malignant wounds

- B. Gastrointestinal fistulation
- C. Untreated osteomyelitis
- D. Direct exposure of large blood vessels due to risk of bleeding
- E. Thick/necrotic eschar.

11.2. Adjunctive measurements contributing to wound management

1. Ultrasound waves, electrotherapy or laser therapy. These adjuncts have always been thought to contribute towards better wound management. In a recent RCT, Cullum et al. concluded that there is lack of sufficient reliable evidence to draw conclusions about the contribution of laser therapy, therapeutic ultrasound, electrotherapy and electromagnetic therapy to chronic wound healing [30].
2. Hyperbaric oxygen therapy. Tissue hypoxia is one of the characteristics of chronic wounds. Therefore, means of increasing O₂ supply to tissues could potentially improve chronic wound healing. In a recent Cochrane review of 12 randomised trials, it was concluded that hyperbaric O₂ therapy can improve the chance of healing of diabetic foot ulcers only on short term but not on long term bases [31]. It can also reduce the size of wounds caused by chronic venous insufficiency but it was found to have no effect in wounds/ulcers caused by arterial insufficiency [31].

12. Conclusion

After reading this chapter the reader would have full understanding of types of wounds (WHO Classification) and how to treat them. We have described in details how to deal with different types of wound from clean surgical wound to heavily contaminated wounds. Closure of wounds by primary intention when the wound is clean and debridement and then leaving the wound to heal by secondary intention with or without secondary closure with sutures as deemed necessary. Different types of dressings are described in details with pros and cons of each one of them. Role of all personnel involved in treating the wound is defined. More specific types of method, i.e. laser therapy, ultrasound, hyperbaric oxygen and compression used for treating the wound are enumerated but not described in details as there is not enough evidence available.

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