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Pressure ulcers: Current understanding and newer modalities of treatment

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ABSTRACT

This article reviews the mechanism, symptoms, causes, severity, diagnosis, prevention and present recommendations for surgical as well as non-surgical management of pressure ulcers. Particular focus has been placed on the current understandings and the newer modalities for the treatment of pressure ulcers. The paper also covers the role of nutrition and pressure-release devices such as cushions and mattresses as a part of the treatment algorithm for preventing and quick healing process of these wounds. Pressure ulcers develop primarily from pressure and shear; are progressive in nature and most frequently found in bedridden, chair bound or immobile people. They often develop in people who have been hospitalised for a long time generally for a different problem and increase the overall time as well as cost of hospitalisation that have detrimental effects on patient's quality of life. Loss of sensation compounds the problem manifold, and failure of reactive hyperaemia cycle of the pressure prone area remains the most important aetiopathology. Pressure ulcers are largely preventable in nature, and their management depends on their severity. The available literature about severity of pressure ulcers, their classification and medical care protocols have been described in this paper. The present treatment options include various approaches of cleaning the wound, debridement, optimised dressings, role of antibiotics and reconstructive surgery. The newer treatment options such as negative pressure wound therapy, hyperbaric oxygen therapy, cell therapy have been discussed, and the advantages and disadvantages of current and newer methods have also been described.

KEY WORDS

Bedsore; decubitus ulcer; pressure sore; pressure ulcer

INTRODUCTION

Pressure ulcers are a type of injury that breaks down the skin and underlying tissue when an area of skin is placed under constant pressure for certain period causing tissue ischaemia, cessation of nutrition and oxygen supply to the tissues and eventually tissue necrosis. Constant pressure resulting in 'distortion or deformation damage' is probably the most accurate description of a pressure ulcer.^[1] There is a localised, acute ischaemic damage to any tissue

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caused by the application of external force (either shear, compression or a combination of the two).

“Pressure sores” is the term used commonly in the UK but again pressure injuries that are not open wounds (such as blisters and non-blanching erythema) are not true sores, but only “pressure damage” and still belong to this family of pressure ulcers. “Pressure ulcers” is a term used widely in the USA and other countries and has been accepted as the Europe-wide term by the European Pressure Ulcer Advisory Panel (EPUAP). They are also known as ‘bedsores’, ‘decubitus ulcers’ although these names are now rarely used as it is recognised that the ulcers are not caused by lying or being in bed. The areas that are particularly prone to pressure sores are those that cover the bony areas such as occiput, trochanters, sacrum, malleoli and heel.

AETIOLOGY

There are many factors that can contribute to the development of pressure ulcers, but the final common pathway to ulceration is tissue ischaemia. The tissues are capable of sustaining pressure on the arterial side of around 30-32 mm hg for only a small duration of time. But when pressure increases even slightly above this capillary filling pressure, it causes microcirculatory occlusion and this in turn initiates a downward spiral toward ischaemia, tissue death and ulceration.^[2,3]

Pressure ulcers can develop^[1] when a large amount of pressure is applied to an area of skin over a short period. They can also occur when less pressure is applied over a longer period. The tissue distortion occurs either because the soft tissues are compressed and/or sheared between the skeleton and a support, such as a bed or chair when the person is sitting or lying, or because something is pressing into the body, such as a shoe, a prosthesis, a surgical appliance or clothing elastic. Blood vessels within the distorted tissue are compressed, angulated or stretched out of their usual shape and blood is unable to pass through them.^[4] The tissues supplied by these blood vessels become ischaemic. Besides occluding the blood flow, tissue distortion also obstructs lymphatic flow, which in turn leads to accumulation of metabolic waste products, proteins and enzymes in the affected tissue. This too can compound the tissue damage.^[5,6]

The majority of people affected with pressure sores are those having health conditions (mental or physical) that

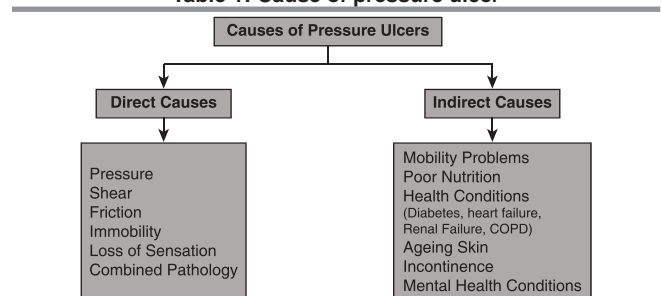
encourage immobility, especially those who are confined to bed or chair for prolonged periods of time. Several other health conditions that influence blood supply and capillary perfusion, such as type-2 diabetes, can make a person more vulnerable to pressure ulcers. Age is also a factor that the majority (approximately two-third) of pressure ulcers occur in old age people (60-80 years of age).^[7] To put it more simply, any individual, with or without a medical condition, who is incapable of avoiding prolonged periods of an uninterrupted compression, is at a risk of pressure ulcers. Majority of the patients affected with pressure ulcers frequently develop it over a bony prominence. Majority of the cases reportedly are affected over the area where skin covers bones such as sacral, ischial and trochanteric pressure ulcers^[8] and the lower extremities these are seen in the malleolar, heel, patellar and pretibial locations — account for approximately 25% of all pressure sores.^[9] Table 1 describes the various direct and indirect causes of pressure ulcers.

Pressure

As the living tissues are not static, the way they are distorted change over time. When constant pressure is maintained, soft tissues mould themselves to accommodate the external shape. This is known as tissue creep.^[10] This may reduce the external pressures but may also exaggerate internal distortions of soft tissues that further reduce the vascular supply of already compromised area due to vascular kinking. This distortion of internal conjugation of soft tissues are significantly high in paraplegic patients^[11] and particularly in these susceptible patients, If ischaemia persists for 1-2 h, necrosis takes place and pressure ulcers can occur within 1-2 h.^[12] Due to prolonged and constant pressure, the chances of atrophy of the skin with thinning of this protective barrier, making the skin more susceptible to minor compression.

The height of the available tissue cover over the bony prominence is not the only determining factor for

Table 1: Cause of pressure ulcer



developing pressure sores. Although the soles of the feet have a thin covering of soft tissue, they have a vasculature that is particularly well-adapted to withstand considerable distorting forces. On the sacrum and ischial tuberosity on the other hand, although there is a relatively thick covering of soft tissue and a wide supporting surface, the blood vessels are not adapted for weight-bearing, which means that even with fairly light compression, pressure ischaemia can develop rapidly. Hence, soles of feet do not develop pressure sores even after prolonged weight bearing in ambulatory patients unless there are underlying causes making them insensate and more prone to pressure damage.

Shear

Shearing occludes flow more easily than compression (for example, it is easier to cut off flow in a water hose by bending than by pinching it), so shear can be considered to be even more significant than pressure in the causation of pressure ulcers.^[13] Areas of the body particularly susceptible to shearing include ischial tuberosities, heels, shoulder blades and elbows. These are areas on which the body is frequently supported when in a position (such as sitting or lying semi-recumbent) which allows forward slide. Superficial pressure ulcers caused by shearing tend to have uneven appearance.

Friction

Friction, along with pressure and shear, is also frequently cited as a cause of pressure ulcers.^[14] Friction can cause pressure ulcers both indirectly and directly. In the indirect sense, friction is necessary to generate the shearing forces. Skin weakened by pressure ischaemia may be more susceptible to friction, and the two will act together to hasten skin breakdown.

Immobility

Immobility is not a primary cause of pressure ulcers but in the presence of additional factors it can initiate them. Patients with a profound immobility but intact sensation rarely develop pressure ulcers when they can still communicate. Conversely, comatose patients, even with intact sensation, can develop pressure ulcer, as they cannot communicate regarding pain of increased pressure threshold. The pain of tissue ischaemia ensures that these patients frequently ask for their position to be changed. Patients with orthopaedic casts should be encouraged to report any discomfort and pain in order to prevent iatrogenic pressure ulcers.

Failure of reactive hyperaemia cycle

It is a known fact that tissue distortion causes ischaemia that in turn stimulates protective movements to relieve pressure and circulatory activity to restore normal blood flow in the affected areas. These protective movements are often reflexes as the person is unaware of making them. However, if these prompt actions prove insufficient to relieve ischaemia, the central nervous system is stimulated by constant signals of discomfort and pain to make sure that the pressure is relieved before any permanent damage occurs. Once the pressure is relieved, and the circulation restored, local capillaries begin to dilate and increased blood flow takes place, referred to as reactive hyperaemia. As a result, a bright pink transitory patch appears on the skin, often called blanching erythema because it blanches on pressure unlike the dull red non-blanching erythema that indicates tissue damage^[15] [Figure 1a]. Reactive hyperaemia ensures a rapid restoration of oxygen and carbon dioxide balance; it also flushes out waste products. Erythema subsides as soon as tissues are restored to their resting state.

Patients who fail to produce reactive hyperaemia cannot recover from the pressure induced ischaemic episodes resulting permanent damage to the tissues. Clinically,

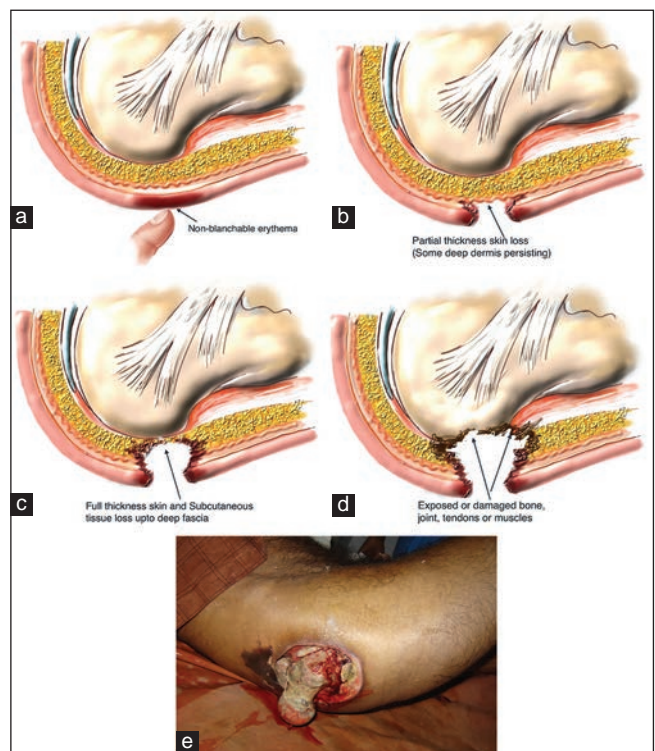


Figure 1: (a-d) Various grading of pressure ulcer [Table 2]. (e) A very severe trochanteric pressure ulcer where destruction is so severe that the femoral head dislocated and came out

this presents as white patches in pressure areas, which do not change colour rapidly to the red of reactive hyperaemia, as they would in a healthy person. Rather, the white patches remain for many minutes before slowly returning directly to a more normal skin colour with little or no reactive hyperaemia being observable.

Combined pathology

When the reactive hyperaemia cycle ceases to function adequately, a pressure ulcer will almost certainly develop unless preventive action is taken. There are three predisposing factors for pressure ulcers:

- Loss of movement
- Failure of reactive hyperaemia
- Loss of sensation.

The creation of a pressure ulcer can involve one or a combination of these factors. The diabetic patient with neuropathy of the feet is likely to have abnormal circulatory function in the involved area. On the other hand, the paralysed patient with a spinal injury loses sensation and the ability to move the affected areas and the ventilated patient doesn't able to feel or move due to anaesthesia while the peripheral circulation may be compromised by the administration of inotropes.

Indirect causes (associated factors)

1. Age-related physiological alterations can lower the threshold for pressure-induced injury in elderly patients. For example, an increase in the fragility of blood vessels and connective tissue and a loss of fat and muscle leading to a reduced capacity to dissipate pressure.
2. Any condition that is associated with prolonged, impaired wound healing such as diabetes mellitus, which affects 11% of adults over the age of 70 years.^[16]
3. Oxygen is required for all stages of wound healing thus any condition that is associated with a low tissue oxygen tension is a major cause of pressure ulcers. These include: Heart failure, atrial fibrillation, myocardial infarction, and chronic obstructive pulmonary disease.
4. Peripheral vascular disease, which affects 20% of older adults,^[17] has a negative impact on wound healing.
5. Contractures and spasticity can contribute by repeatedly exposing tissues to pressure through flexion of a joint.
6. Loss of sensations, the pain signal that would normally cause an immobile individual to change position is lost.

7. Paralysis and insensibility may produce atrophy of the skin leading to a thinning. This renders the skin more susceptible to the friction and shear forces a patient experiences when being moved.
8. Nutritional conditions such as malnutrition,^[18] hypoproteinemia,^[19] and anaemia^[20] can cause significant delays in wound healing and hasten the formation of pressure ulcers.^[21]
9. Moisture causes maceration, which predisposes the skin to injury. De-epithelialisation caused by trauma leads to transdermal water loss that creates maceration and adherence of the skin to clothing and any other supports in contact, resulting into further injury.^[10]
10. Mental health conditions - people with severe mental health conditions such as schizophrenia or severe depression have an increased risk of pressure ulcers for a number of reasons:
 - Their diet tends to be poor, resulting in hypoproteinemia.
 - They often have other physical health conditions, such as diabetes or incontinence.
 - They may neglect their personal hygiene, making their skin more vulnerable to injury and infection that help an ulcer to form.

SEVERITY OF PRESSURE ULCERS

Healthcare professionals use several grading systems to describe the severity of pressure ulcers; most common is the EPUAP grading system. Pressure sores are categorised into four stages [Table 2] corresponding to the depth of damage.^[22-24] It must however be emphasised that when an eschar is present, accurate staging is not possible.

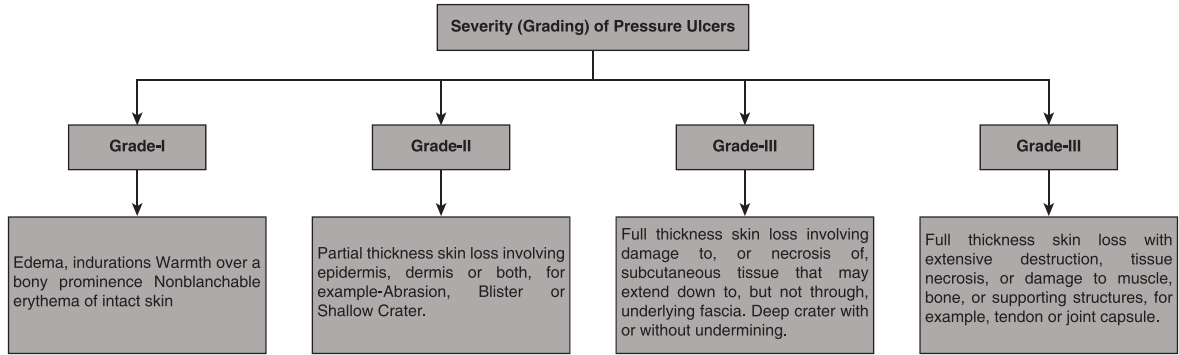
Grade 1

A grade one pressure ulcer is the most superficial type of ulcer. The affected area of skin appears discoloured and is red in white people, and purple or blue in people with darker coloured skin [Figure 1a]. One important thing to remember is that Grade 1 pressure ulcers do not turn white when pressure is placed on them. The skin remains intact, but it may hurt or itch. It may also feel either warm and spongy or hard.

The characteristics are:

- Non-blanchable erythema of intact skin can be difficult to assess in patients with darkly pigmented skin.
- Oedema, induration.
- Warmth over a bony prominence.

Table 2: Grades of pressure ulcer [Figure 1]



- When an eschar is present, accurate staging is not possible.

Grade 2

In Grade 2 pressure ulcers, some of the outer surface of the skin (the epidermis) or the deeper layer of skin (the dermis) is damaged, leading to skin loss [Figure 1b]. The ulcer looks like an open wound or a blister. The characteristics are:

- Partial thickness skin loss involving epidermis, dermis or both, for example, abrasion, blister or shallow crater.

Grade 3

In Grade 3 pressure ulcers, skin loss occurs throughout the entire thickness of the skin. The underlying tissue is also damaged, but the underlying muscle and bone are not damaged. The ulcer appears as a deep cavity like wound [Figure 1c]. The characteristics are:

- Full thickness skins involving damage to or necrosis of, subcutaneous tissue that may extend down to, but not through, underlying fascia.
- Presents clinically as a deep crater with or without undermining.

Grade 4

A Grade 4 pressure ulcer is the most severe type of pressure ulcer. The skin is severely damaged, and the surrounding tissue begins to die (tissue necrosis). The underlying muscles, bone or joint may also be damaged [Figure 1d], sometimes very severely [Figure 1e]. People with grade four pressure ulcers have a high risk of developing a life-threatening infection. The characteristics are:

- Full thickness skin loss with extensive destruction, tissue necrosis, or damage to muscle, bone, or supporting structures, for example, tendon or

joint capsule. Undermining and sinus tracts may be associated with this stage of wound progression

- Similar to grading a burn with the addition of a stage 4 that is deeper than a stage 3 ulcer or 3rd degree burn.

TREATMENT

Where possible, treatment of ulcers is planned with an aim to reverse the factors that have originally caused the ulcer. Ulcers are often the result of combined pathology (like diabetes, pressure, loss of sensation). Careful assessment is needed before planning for treatment. In general the possible causative factor should be removed (pressure, shear, friction) and the associated general condition should be taken into the control (like treatment of associated co-morbid illness and improvement in the nutrition). The affected area requires thorough cleaning and dressing. The limb must be elevated to improve the venous and lymphatic drainage, and the part must be given some rest from the weight bearing, pressure and friction. However, since the full range of motion and active physiotherapy of joints do improve circulation, even non-weight bearing physiotherapy is desirable.

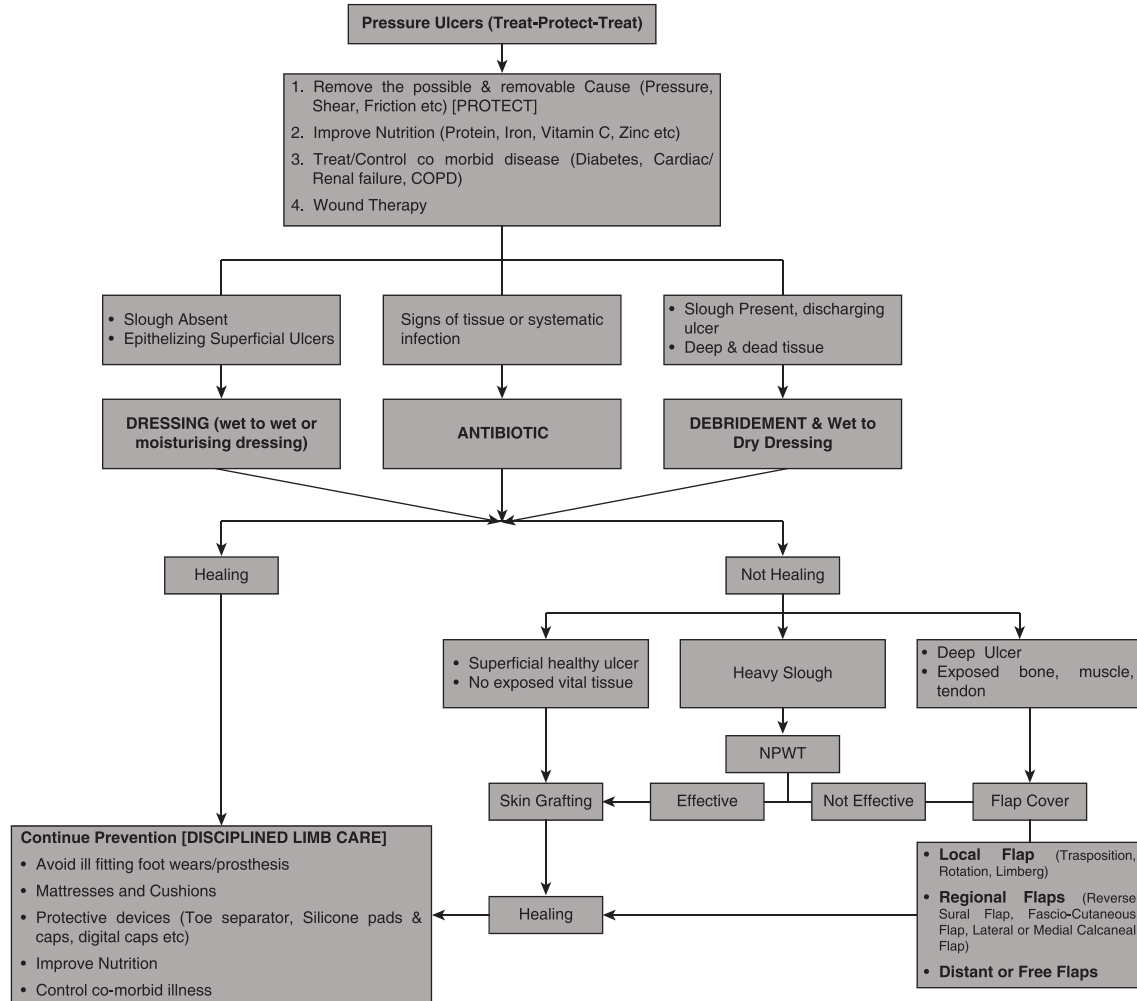
Wound healing requires adequate protein, iron, Vitamin-C and zinc. Supplements may be prescribed if they are deficient in the diet.^[25]

Rest of the management of ulcer depends on many factors, and Table 3 illustrates an algorithm to help formulate a treatment plan. Various treatment options are available to treat pressure ulcers, they include:

Cleaning and debridement

Cleaning of the wound and meticulous skin care are the most essential part of the treatment. The

Table 3: Algorithm for management of pressure ulcers



process involves removal of surface contamination and meticulous excision of all dead tissue. This is debridement. Besides the conventional surgical debridement other types of debridement like mechanical debridement which includes use of repeated wet to dry dressings to removes slough,^[26] enzymatic debridement using enzymes to liquefy dead tissue in the wound and remove them with the dressings,^[27] and biological debridement or maggots and larval therapy^[28,29] (in which the larvae eat all the dead tissue and make the wound clean without harming the living tissues) also find a mention in literature. Maggots also help to fight infection by releasing substances that kill bacteria and stimulate the healing process.^[29] Sharp surgical debridement using blade or scissors is the most commonly used and most effective method of debridement in able surgical hands. Dead tissue may be removed using mechanical means. Some mechanical debridement techniques include:

Cleansing and pressure irrigation

Where dead tissue is removed using high-pressure water jets. There is no evidence available to support any specific and effective cleansing techniques or solution, in particular.^[30]

Ultrasound

Dead tissue is removed using low-frequency energy waves.^[31,32]

Laser

Dead tissue is removed using focused beams of light.^[33]

Basically, debridement is done for converting the chronic wound into an acute wound so that it can progress through the normal stages of healing.

Wound dressings

The dressing used for various stages of wound healing is specialised for every stage; in fact there is a whole range

of dressings available to assist with the different stages of wound healing. These are classified as non-absorbent, absorbent, debriding, self-adhering and many others. It is vital to determine the most appropriate dressing as it ultimately depends on the site/type of ulcer, for hospital care or domiciliary management, personal preference and cost to the patient.

Dressings are usually occlusive, so the ulcers heal better in a moist environment. If the ulcer is clean and dry, occlusive dressings are usually changed weekly, and more frequent changes are avoided as dressing changes remove healthy cells along with debris. Contaminated or weeping wounds may require more frequent dressing changes, sometimes every few hours. Heavily contaminated ulcers are treated with negative pressure wound therapy (NPWT).^[34]

Specialised dressings and bandages are used to protect and speed up the healing process of the pressure ulcers. These dressings include:

Hydrocolloid dressings

These contain a special gel that encourages the growth of new skin cells in the ulcer and keeps the nearby healthy area of skin dry.^[35,36]

Alginate dressings

These are made from seaweed that contains sodium and calcium known to speed up the healing process. Honey-impregnated alginate dressings are known to accomplish total wound healing to pressure ulcers.^[37]

Nano silver dressings

These use the antibacterial property of silver to clean the ulcer.^[38,39]

Creams and ointments

To prevent further tissue damage and help speed up the healing process, topical preparations, such as cream and ointments are frequently used.

Antibiotics

All pressure sores do not require antibiotics.^[4] Antibiotics are usually only prescribed to treat an infected pressure ulcer and prevent the infection from spreading. If tissue infection exists, antibiotics are necessary to treat the infection, but effort must be made to debride the ulcer thoroughly and leave all viable tissues only, otherwise antibiotics alone will not clean up the ulcer. Antibiotics

are adjunct to surgical debridement and not an alternative to it.

Topical antibiotics should be avoided because their use may increase antibiotic resistance and allergy. Antiseptic cream may also be applied topically to pressure ulcers to clear out any bacteria that may be present.

Biofilm

It has been noticed that the longstanding pressure ulcers are frequently colonised by micro-organisms in a biofilm. The biofilm may be composed of bacteria, fungi or other organisms, which are embedded in and adherent to the underlying wound. The organisms are protected from the effect of conventional antibiotics; unnecessary prescription of antibiotics may, in fact, select more resistant organisms. We address the problem of biofilm by changing the pH of the wound — dressing with dilute acetic acid if it is alkaline, which it usually is and curetting out all the underminings, cracks and crevices of the ulcer or by surgical debridement.

NEGATIVE PRESSURE WOUND THERAPY

This is an invaluable tool in the management of pressure sores and involves the application of sub-atmospheric pressure to a wound using a computerised unit to intermittently or continuously convey negative pressure to promote wound healing. NPWT, is effective for deep, cavitating, infected and copiously discharging pressure ulcers, particularly with exposed bone.^[40] With growing clinical experience^[41] it can be said with certainty that it assists wound healing, and its benefits can be summarised thus:

- Assists granulation.
- Applies controlled, localised negative pressure to help uniformly draw wounds closed.
- Helps remove interstitial fluid allowing tissue decompression.
- Helps remove infectious materials and quantifies exudates loss.
- Provides a closed, moist wound healing environment
- Promotes flap and graft survival.
- Both hospital and domiciliary use.
- Reduces hospital/dressings/nursing cost (if we can discharge the patient to home).

Newer research

There are many supportive therapies to promote healing of pressure ulcers. While some are in clinical use others

are in the realm of research. Many products are available to aid wound healing but should be prescribed only under strict medical advice, as they still require further research to determine their effectiveness. These include:

1. Growth factors and cytokines.^[42]
2. Hyperbaric oxygen (HBO) to increase tissue oxygen tension.^[43]
3. Skin graft substitutes (bioengineered skin).^[44]
 - a. Connective tissue matrix.
 - b. Expanded epidermis.
 - c. Epidermal stem cells.^[45]
4. Bone marrow (BM) or adipose tissue derived stem cell (ASC) therapy.^[46]

Cytokines and growth factors

Chronic pressure ulcers display high levels of inflammation and disruption of the collagen matrix, along with increased indications of apoptosis and decreased levels of growth factors and their receptors. These characteristics can be used to comprehensively evaluate the aetiology and treatment of these ulcers.^[47] Contemporary authors had compared the healing response of sequential topically applied cytokines to that of each cytokine alone and to a placebo in pressure ulcers, and evaluated the molecular and cellular responses.^[48] Ulcers treated with cytokines had greater closure than those in placebo-treated patients. Patients treated with basic fibroblast growth factor (bFGF) alone did the best, followed by the granulocyte-macrophage colony-stimulating factor (GM-CSF)/bFGF group. Patients treated with GM-CSF or bFGF had higher levels of their respective cytokine after treatment. Patients with the greatest amount of healing showed higher levels of platelet-derived growth factor on day 10 and transforming growth-factor beta-1 on day 36. Message for the bFGF gene was upregulated after treatment with exogenous bFGF, suggesting autoinduction of the cytokine. Both cytokines and growth factors may have a big role to play in the treatment of pressure ulcers in future.

Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBO) is being used for treatment of pressure sores. Specially constructed devices equipped with controlled pressure sealings, and automatic relief valves are fitted in HBO chambers. A constant pressure of 22 mm Hg (1.03 atmospheres absolute) is maintained inside the chamber using pure oxygen at a flow-rate of 2-8 L/min with direct discharge to atmosphere.^[47] It has proven to be very successful and safe adjunctive treatment to daily wound dressing,^[49]

administration of antibiotics and surgical debridement because:

- a. It increases oxygen transport to wound area stopping further tissue damage
- b. It facilitates growth of new capillaries (angiogenesis) improving the microcirculation
- c. It speeds up wound healing by reducing inflammation and swelling
- d. It relieves pain
- e. It reduces infection by eliminating bacteria directly and increasing capacity of white blood cell to fight infection
- f. It improves microcirculation and elimination of toxins in the blood
- g. It enhances the effect of some antibiotics
- h. It stimulates the release of stem cells from the BM
- i. It decreases blood viscosity and risk of thrombosis and stroke
- j. It improves lymphatic circulation
- k. It improves bone density and mineralisation and speeds up bone healing
- l. It enhances peripheral nerve regeneration for improved sensitivity
- m. It prepares tissue and bone for grafting before surgery
- n. It speeds up healing after surgery and improves chances of graft survival.

Skin substitutes (bio-engineered skin)

Cultured keratinocytes have been used for the treatment of various types of wounds for more than a decade.^[50] Researches explain that in patients with partial/full-thickness skin defects, the most effective therapy is cultured dermal substitute (CDS), while cultured epidermal substitute, and cultured skin substitute have also been used as biological wound dressings.^[51] The artificial dermis induces angiogenesis and fibroplasia in deep, poorly vascularised tissue defects with fewer vascular invasions. However, it is difficult to apply collagen matrix to pressure ulcers, because they are usually accompanied by infection with discharge of excessive amounts of exudate or pus and generally exposed to external forces that prevent graft fixation.^[52] The allogeneic CDS effectively treats intractable ulcers while BM cell implantation combined with allogeneic CDS is used in treating severely ischaemic ulcers.^[53]

Bone marrow/adipogenic stem cells

“Cell therapy” can be defined as a set of strategies, which use live cells for therapeutic purposes. The

aim of such therapy is to repair, replace or restore the biological function of a damaged tissue or organ. Bone Marrow (BM)-mono nuclear cells (MNCs) can be easily obtained in large numbers by aspiration without extensive manipulation or cultivation before transplant and cells can be transplanted directly without *in vitro* expansion. Using the entire mononuclear fraction, no potentially beneficial cell type is omitted and MNCs from a patient's own BM promote angiogenesis^[46] and this seems to be a key factor for optimal healing of skin wounds. Marrow stem cells (MSCs), which make up a small proportion of BM-MNCs, secrete paracrine factors that could recruit macrophages and endothelial cells to enhance wound healing.^[54] The repair functions of MSC are thought to involve the secretion of factors such as vascular endothelial growth factor^[55] or FGF^[56] which could help prevent apoptosis, promote angiogenesis, assist in matrix reorganisation, and increase the recruitment of circulating MSCs.^[57] BM harvesting is rather invasive and painful. In 2001, Zuk *et al.*^[57] identified and characterised adipose tissue derived stem cells ASCs from lipoaspirates and even a section of whole fat (biopsy). A very small percentage of the nucleated cells, which compose the BM, are actually MSCs, whereas the amount of ASCs is approximately 500-fold greater when isolated from an equivalent amount of adipose tissue.^[58,59] Even though cell therapy is a relatively new tool, several studies prove these types of cells may be used safely, and they have demonstrated their efficacy in healing wounds and sores.

RECONSTRUCTIVE SURGERY

Sometimes the severe pressure ulcer (Grade III or IV) fail to heal, in such cases, surgery is required to fill the wound and prevent any further tissue damage. This is usually done by cleaning the wound and closing it by bringing together the edges of the wound (direct closure), application of various type skin grafts or using local and regional flaps and free tissue transfer. It is prudent to remember and use the reconstructive ladder during planning of reconstructive surgery for pressure ulcers [Table 3].

There are many risks and complications that can occur after surgery, including infection, necrosis of flap, muscle weakness, blisters, recurrence of the pressure ulcers, septicaemia, infection of the bone (osteomyelitis), bleeding, abscesses, and deep vein thrombosis. Despite

the risks, surgery is often a necessity and the only option to prevent limb and life-threatening complications.

The available reconstructive options are

Split thickness skin grafting

When the ulcer is superficial and vital tissues such as bone, vessels, nerves or tendons are not exposed, and the ulcer is not copiously discharging, skin grafting is the first option for surgical treatment. The slimy layer over the surface of ulcer is sharply debrided to get a healthy vascular bed for skin grafting.

Local flaps

Variety of local flaps can be used to reconstruct the defect created by excision of pressure ulcers. Local transposition, rotation, limberg flap are the available options [Figures 2 and 3]. Biceps femoris V-Y advancement (in paraplegics only) for ischial pressure sore^[60,61] and perforator based V-Y advancement is another good options if the anatomy permits [Figure 4].

Regional flaps

Sometimes the local or limberg flap cannot close the larger defects due to their size or location resulting in need for regional flaps. For Sacral pressure sores there are many flap options such as gluteus maximus myo-cutaneous flap, Sup gluteal artery based rotation fascio-cutaneous flap, superior gluteal artery perforator flaps [Figure 5], perforator based V-Y advancement flap, lumbogluteal sensory flap. For lower extremity pressure ulcer reconstruction; Islanded Medial planter flap [Figure 6], lateral or medial calcaneal flaps, Reverse sural flap [Figure 7], varieties of fascio-cutaneous flaps may provide a huge reconstructive option.



Figure 2: Occipital pressure ulcer (a) managed by marginal debridement and coverage using Limberg's flap (b and c). A 2-week post-operative picture of flap (d)



Figure 3: Sacral pressure ulcer (a) managed by marginal debridement and cover by Limberg's flap (b). 3-months follow-up (c) and 2 years follow-up (d) shows that flap is stable without recurrence



Figure 4: Sacral pressure sore (a), debridement and cover by local perforator based V-Y advancement flaps (b and c), 1-month post-operative (d), recurrence on the flap after 11 years (e) due to loss of family support and subsequent improper care. Another patient with the same flap after 16-year of follow-up (f) with a proper weight shifting and care showing stable coverage



Figure 5: Grade four sacral pressure ulcer (a) managed by right-sided superior gluteal artery perforator flap (b), and 2-year follow-up (c)

Microvascular free flaps

Microvascular free flaps are usually reserved for some selected cases where the local and regional flap options are either not available or have failed, and the depth of the pressure ulcer demands adequate volume restoration for proper weight bearing. In fact, the latter reason is so vital that many large pressure ulcers on weight bearing soles or on tip of amputation stumps are today being primarily treated with microvascular free tissue transfer.

Prevention: Mattresses and cushions

Protection is the best way to prevent ulcers. Patients who are at risk of developing pressure ulcers should have the skin carefully inspected for any damage or redness (particularly over bony areas) twice daily. The skin should be kept clean and dry. Any pressure causing damage to skin or tissue should be immediately eliminated. This can be done with the help of special mattresses, cushions and



Figure 6: Medial planter flap for heel sore: A long-standing deep trophic ulcer of heel (a). The islanded medial planter flap was transposed to the defect and the resultant donor site was covered by split thickness skin graft (b). The 1-week (c) and 3-month (d) post-operative pictures showing stable coverage. Patient allowed full weight bearing from 6th week along with silicone footpad protection

by many protective devices that can relieve the external pressure on vulnerable areas of body limbs. These specially designed protective devices can be very helpful in patients who thought to be at risk of developing pressure ulcers, or who have pre-existing Grade 1 or 2 pressure ulcers. Classified by their static or dynamic nature, many advanced low tech and high tech support surfaces and overlays are available for patients bound to lie on bed for long periods of time. Static surfaces (such as foam filled mattresses, air-filled mattresses,

fluid-filled mattresses) do not require electrical power, while dynamic surfaces (such as alternating air pressure mattresses or pneumatic ripple beds) require electrical power for shifting and redistributing the pressure within the surface.^[62] Other integrated electronic beds like air fluidised beds (Clinitron or KinAir bed)^[63] and electronic moving air mattresses require high technology and heavy machinery to let air and ceramic sphere particles support the object on a stream mechanically; are often costly, noisy and not easily available. Due to lack of substantial evidences and researches, it is difficult to firmly conclude about relative effects of support surfaces.

We are using pneumatic ripple beds (alternating air pressure mattresses) that consist of several air-filled chambers that are separately inflated and deflated at an alternate cycle of 5-10 min with the help of a pneumatic pump. This helps in avoiding continuous contact of any body part with bed and prevents pressure sores. Owing to unique pressure redistributing properties, affordable cost, easy availability and effectiveness; pneumatic ripple beds are now most commonly used for pressure ulcer prevention worldwide. Many nursing homes and hospitals have turned to pneumatic beds from standard beds to make the overall stay of immobile or critically ill patients more comfortable and therefore, these beds form mainstay of pressure ulcer prevention at most places. For small areas like hand, ankle and foot, we use water filled tied surgical hand gloves [Figure 8a] as pressure relieving devices at hospital setups and we advise the patients to use these at their home as a very easy to make, very low-cost pressure relieving device.



Figure 7: Reverse sural flap for posterior heel ulcer: A full thickness (Grade-4) acute pressure ulcer of posterior heel (a). The ulcer was sharply excised and covered with the reverse sural flap (b). The donor site and distal half of the island pedicle were covered with split skin graft in this one stage repair. At 36-months post-operative follow-up (c)

Pressure ulcers put a greater health risk to regular users of wheelchairs or those who are bound for prolonged sitting. The most frequently involved areas while seating are sacrum, coccyx, ischial tuberosities and greater trochanters. These sites tend to develop pressure ulcers more quickly as these are bony areas, and the fat that works as natural cushion is less in these areas. But pressure ulcers are said to be largely preventable with the help of protective devices and proper management. There are custom designed gel and pneumatic wheelchair cushions which are easily available, and they help to distribute the load more evenly and help in preventing ulcer formation. Further, patients or their caretakers are taught to conduct pressure release movements or weight shifts on regular intervals to prevent pressure concentration and tissue damage. Patients who sit for a long time need to use protective cushioning/fabricated air mattresses for protection of bony points and do periodic change of postures and offloading of pressure points by side bending, forward bending and lifting off the chair with powerful upper body muscles. Other pressure management tools include protective padding, pillows or cushions to separate body surfaces from hard seats.

Many soft silicone elastomer based commercially available devices may be effectively used to avoid the pressure from the affected or at risk area of limb. The commonly used are: Partial or full silicone sole, silicone pads and digital caps, toes separators etc., [Figure 8].



Figure 8: Variety of foot protective devices: Indigenous made (water filled and tied gloves) placed below the area needs pressure protection (a), It is inexpensive, easy to fabricate, ideal for domiciliary care. Varieties of foot protective devices are commercially available, which are made up of soft silicone elastomer to protect respective areas to protect from pressure like-adhesive pads (b), silicone sole (c) and toe separator (d). Image source: <http://www.shop.mediuk.co.uk/protect-silicone-insole.html>, <http://www.sturdyfoot.com/Silicone-Bunion-Shield-Toe-Separators>

Nutrition plays a very important role in any wound healing process so in pressure ulcers, compounding the effect of older age, diabetes and many other medical conditions hampering adequate intake of nutrition.^[64] Protein energy malnutrition is directly related to the occurrence as well as healing of the pressure ulcer. Though the serum albumin <3.5 mg/dl is traditionally considered as clinical indicator of malnutrition,^[65] recent researches relates low level of serum albumin and pre-albumin to inflammatory process or to disease rather than malnutrition directly.^[66,67] Rising level of serum albumin indicates improvement in clinical status and is desirable. Apart from biochemical data nutritional assessment should be done by other changes, such as weight changes, fluid intake, wound healing or progression. Pressure ulcer prevention and treatment guidelines should include guidelines that have nutritional recommendation too like National Pressure Ulcer Advisory Panel/EPUAP guidelines.^[68]

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