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COMPLICATIONS OF SURGERY AND THEIR PREVENTION

Introduction

Any operation, major trauma or other surgical admission may be attended by a variety of complications. These not only cause additional pain and suffering to the patient but may put the patient's life at risk.

A large proportion of complications can be prevented or minimized by appropriate prophylactic measures, careful attention to detail and by early recognition and treatment of problems as they develop. Early diagnosis and treatment is essential, as delay often leads to catastrophic, snowballing' multi-organ failure. Once three or more body systems become involved, mortality is extremely high, e.g. ARDS and renal failure, complicating an operation for obstructive jaundice.

In respect of operative surgery, complications can be divided into the general complications of any operation and the specific complications. Both groups of complications can be subdivided into immediate (during operation or within the next 24 hours), early postoperative (during the first postoperative week or so), late postoperative (up to 30 days after operation) and long-term.

The complications of surgery can be divided into four broad categories.

**Principal categories of surgical complications:**

1. Complications predisposed to by current 'medical' disorders e.g. ischemic heart disease, chronic respiratory disease or diabetes mellitus.
2. Complications of anaesthesia.
3. General complications of operations, e.g. haemorrhage or wound infection.
4. Complications of any surgical condition, e.g. pulmonary embolus, chest or urinary tract infection.

**GENERAL COMPLICATIONS OF OPERATIONS**

The main complications of any operation are haemorrhage, infection, delayed wound healing, surgical damage to related structures and inadvertent trauma to the patient in theatre.

1. **HAEMORRHAGE**

*Perioperative Haemorrhage:*

Haemorrhage occurring during an operation (primary haemorrhage) should be controlled by the surgeon before the operation is completed.

*Early Postoperative Haemorrhage:*

Haemorrhage during the immediate postoperative period usually indicates inadequate operative haemostasis or a technical mishap such as a slipped ligature or unrecognized trauma to a blood vessel. After major blood loss requiring large volume transfusion of stored blood.

*Later Postoperative Haemorrhage*

Haemorrhage occurring several days after operation is usually related to infection which erodes vessels at operation site; this is known as secondary haemorrhage. Treatment involves managing the infection, but exploratory operation is often required to legate bleeding vessels.
2. INFECTION RELATED TO THE OPERATION SITE:

*Minor Wound Infections:*

The most common operative infection is a superficial wound infection occurring within the first postoperative week. This relatively trivial infection presents as localized pain, redness and a slight discharge. The organisms are usually staphylococci or streptococci derived from the skin. The infection usually settles without treatment. The exception is the patient in whom prosthesis has been inserted, such as an arterial graft or artificial joint. For these patients, antibiotics must be given to prevent the devastating consequences of infection around the prosthesis.

*Wound Cellulitis and Abscess:*

More severe wound infections occur most commonly after bowel-related surgery. When faecal organisms are usually incriminated. The majority present in the first postoperative week but they may occur as late as the third postoperative week, often after the patient has left hospital. These infections commonly present first with pyrexia; examination of the wound reveals either a spreading cellulitis or localized abscess formation. Cellulitis is treated with appropriate antibiotics.

**LATE INFECTIVE COMPLICATIONS:**

A late infective complication of surgery is a chronically discharging wound sinus from a deep chronic abscess. It usually relates to foreign material such as a non-absorbable suture or sometimes necrotic fascia or tendon. These sinuses commonly follow wound infections where healing is delayed and incomplete.
3. IMPAIRED HEALING

Factors Retarding Wound Healing:

Wound healing in general is retarded if blood supply is poor (as in arterial insufficiency) or if the wound is under excess suture tension. Other Factors which may retard wound healing are long-term steroid therapy, immunosuppressive therapy, previous radiotherapy, severe rheumatoid disease, malnutrition and vitamin deficiency, especially of vitamin C.

Incisional Hernia:

Incisional hernia is a late complication of abdominal surgery. These hernias usually become apparent within the first postoperative year but sometimes develop as long as 5 years later; the overall incidence is about 10-15% of abdominal wounds. The hernia is caused by breakdown of the repair to the abdominal wall muscle and fascia. Predisposing factors are abdominal obesity, distension and poor muscle quality, poor choice of incision, inadequate closure technique, post-operative wound infection and multiple operations through the same incision.

An incisional hernia usually presents as a bulge in the abdominal wall near previous wound. The condition is usually asymptomatic but occasionally a narrow-necked hernia presents with pain. Once an incisional hernia has appeared, it tends to enlarge progressively and may become a trouble cosmetically or for dressing. Repair is indicated for pain or inconvenience.

4. SURGICAL INJURY:

Anatomical structures, particularly nerves, blood vessels and lymphatics, may be unavoidably damaged during operation. This is particularly true in cancer
surgery, illustrated by facial nerve damage during total parotidectomy and recurrent laryngeal nerve damage during thyroidectomy.

5. INADVERTENT OPERATING THEATRE TRAUMA:
   Apart from surgical trauma, patients are at risk of injury when being, transported in the operating theatre and during anaesthesia. Special precautions are taken by all who work in operating theaters to minimize these risks.

COMPLICATIONS OF ANY SURGICAL CONDITION

RESPIRATORY COMPLICATIONS:
   Up to 15% of patients suffer from respiratory complications associated with general anaesthesia and major operations. The most common of these are atelectasis, pneumonia and aspiration pneumonia. Pre-existing lung disease greatly increases the risk of complications. Severely ill patients including those with acute pancreatitis, and burns or trauma victims are susceptible to the development of adult respiratory distress syndrome.

Effects of Anaesthesia and Surgery on Respiratory Function:
   Anaesthesia and surgery predispose to post-operative complications by altering lung function and compromising normal defence mechanisms as follows:
   - Lung tidal volume may be reduced by as much as 50%, depending on the incision site. Thoracic, upper abdominal and lower abdominal incisions (in decreasing order of effect) particularly reduce lung volume.
   - Lung expansion is reduced by the supine posture during and after operation, pain, abdominal distension, abdominal constriction by bandages and the effects of sedative drugs.
- Diminished ventilation and pulmonary perfusion result in reduced gaseous exchange.
- Airway defences are compromised by loss of the cough reflex and diminished ciliary activity, which both lead to accumulation of secretions.

*Atelectasis:*

**Pathophysiology and clinical features:**

Atelectasis or alveolar collapse occurs when airways become obstructed and air is absorbed from the air spaces distal to the obstruction. Bronchial secretions are the main cause of this obstruction. Predisposing factors include shallow ventilation, loss of periodic hyperinflation, inhibition of coughing and pooling of mucus. All of these are particular problems after thoracic and upper abdominal surgery.

**Prevention and treatment of atelectasis:**

Atelectasis is best prevented by preoperative and postoperative physiotherapy for patients undergoing major surgery. This includes deep breathing exercises, regular adjustments of posture and vigorous coughing. During physiotherapy, wounds should be supported by the patient's hand. Nebulizer bronchodilators such as salbutamol may assist the patient to cough up secretions. Severe cases of diffuse atelectasis may require endotracheal incubation and positive-pressure ventilation. Lobar or whole lung collapse requires intensive physiotherapy and sometimes flexible bronchoscopy to aspirate occluding mucus plugs.

**Pneumonias:**

Bronchopneumonia is the usual form of chest infection seen in surgical patients. It occurs secondarily to chronic lung disease or following atelectasis or aspiration of gastric contents.
Infection is manifest by pyrexia, tachypnoea, tachycardia and sometimes cyanosis. The mucopurulent sputum is thick and green. Broad spectrum antibiotics are given until sputum culture and sensitivities are available. Physiotherapy and encouragement to cough are equally important for recovery.

**Adult Respiratory Distress Syndrome:**

Adult respiratory distress syndrome (ARDS) is a clinical syndrome caused by acute lung injury and characterized by severe hypoxemia and increased permeability of the alveolar capillary membrane leading to leakage of protein-rich fluid into the alveolar interstitium. These causes interstitial edema which reduces lung compliance and causes stiff lungs and reduced alveolar ventilation. Most patients require mechanical ventilation to achieve adequate oxygenation and to try to reverse alveolar edema and collapse.

**THROMBOEMBOLISM**

**Pathophysiology**

Venous thromboembolism is a major cause of complications and death after surgery or trauma. Venous blood is normally prevented from clotting within the veins by a complex series of mechanisms which include local inhibition of the clotting cascade, prompt lysis of small clots that do form, and continues flow of blood. This subtle balance can be disturbed by several local and systemic factors, many incompletely understood. Imbalance results in thrombus formation within the venous sinuses of the calf muscles and sometimes primarily in the pelvic veins.

**DEEP VEIN THROMBOSIS**

Deep vein thrombosis in the lower limbs (DVT) is often silent with the classic clinical features found in only half the cases. These include swelling of
the leg, tenderness of the calf muscles, increased warmth of the leg, and calf pain on passive dorsiflexion of the foot (Homan's sign).
Liposuction

Liposuction, also known as lipoplasty or suction-assisted lipectomy, is cosmetic surgery performed to remove unwanted deposits of fat from under the skin. The fat is permanently removed from under the skin with a suction device. The average amount of fat removed is about a liter. Sutures are removed between 7-9 days. Compression bandage provided to be worn for 4 weeks.

Post-operative complications:

1- Pain
2- Swelling may last some weeks, in joints some months.
3- Respiratory complications as the tidal volume may be reduced as much as 50% depending on incisional site.
4- Delayed Wound healing.
5- Circulatory complications.
6- Muscle weakness
7- Decreased ADL.
8- Complications of anesthesia.

Post-operative Physiotherapy:

Phase I: Acute stage

1. Bed supports
   These include special cushions to support a patient’s back supports and cushions under the sacrum and under the heels, to prevent pressure sores in bed. Pillows can also be used under the legs to elevate the feet or to keep the knee flexed after a hip operation.

2. Elevation of the limb on pillows for at least 3 days post-operatively.
3. **Pain control**

   A- Relaxation.
   
   B- Thermotherapy as hot packs
   
   C- Electro therapy as TENS, Laser, Ultrasound.

(1) **TENS**

Placement of electrodes: Paraincisional and increase

The intensity: Slowly in both channels until paraincisional area is numb also the intensity should be below the contractile threshold.

Time: 20 min

Pulse duration: 80 us

Pulse rate: 140 HZ

Amplitude: submotor

Frequency: 3-6 times/day

(2) **Laser**

The probe of Laser should be perpendicular on the area of pain

Dosage: 90 sec/cm²

Mode: continuous mode.

(3) **Ultrasound**

   LUS (low dose ultrasound 0.5 W/cm², pulsed mode, 1 MHz, 5 minutes) or HUS( high dose ultrasound 1.5 W/cm², continuous mode, 1 MHz, 5 minutes)for approximately 1 week to enhance wound breaking strength in an acute incisional wound. However, if the goal is to continue to facilitate collagen deposition and wound strength, then a low dose of ultrasound should be used when treatment is continued for 2 weeks.

(4) **Pulmonary physiotherapy**

   As breathing exercises (Diaphragmatic & segmental emphasis on collapsed areas).
(5) Circulatory exercises

**Phase II: Subacute stage:**

Adequate early physiotherapy will minimize late stiffness of joints and weakness of muscles.

1- Active exercises, either at home or in a physiotherapy department, is essential.

2- Swimming is particularly valuable for mobilizing joints and strengthening muscles.

3- Walking on soft sand in bare feet is good for foot, ankle and knee joint injuries

4- Deep heat, such as short wave diathermy or ultrasound.
**POST MASTECTOMY REHABILITATION**

*Mastectomy* can be defined as it is excision of the breast. There are two types of mastectomy: (1) **Radical mastectomy**: is a removal of the breast and entire system of lymphatic glands, with excision of a part of pectoralis major and whole of pectoralis minor muscles and (2) **Modified radial mastectomy**: is excision of the breast, and retraction of the pectoralis major with or without removal of the pectoralis minor.

**Indications of Mastectomy**
1. Cancer breast.
2. Severe laceration of breast tissue

**Contra indications of Mastectomy**
1. Presence of distant metastasis.
2. Proved supraclavicular metastasis.
3. Edema of arm.
4. Extensive edema of skin of breast.

**Postmastectomy Problems:**
1. **Lymphodema**: it may result from surgical procedure, irradiation or uncontrolled progression of neoplasm.
2. **Pneumothorax**: i.e. presence of air or gas in the pleural cavity, it occurs with extended tissue dissection, the respiratory dysfunction is associated with this surgery.
3. **Restriction of shoulder ROM**: it is usually associated with axillary dissection or radiotherapy.
Evaluation

1. **Goniometric Measurements:**
   By using a standard, plastic universal goniometer to obtain goniometric measurements for shoulder flexion - extension - adduction abduction and external / internal rotation.

2. **Upper extremity circumferential measurements at five levels:** The circumferential measurements were obtained by palpating and marking the most prominent aspect of the olecranon process and then measuring and marking points 7.5 and 15.0 cm proximally and repeating the procedure 7.5 and 15.0 cm distally. Circumferential measurements were then made at these five levels to measure the amount of edema.

3. **Vital capacity assessment:**
   Electronic spirometer used to measure forced vital capacity.

4. **Hand grip strength evaluation:**
   It was used to measure hand grip an activity.

5. **Assessment of upper extremity function:**

6. **Pain Assessment:** (VAS)

Postoperative Physical Therapy Program

1. **P.T. methods to minimize pain:**
   * **Transcutaneous Electrical Nerve Stimulation (TENS):**
     It was added to P.T. program at the 2nd day postoperative for pain control (at the site of greatest pain or paraincisional) 20 min.
   * **Laser:**
     Low- power laser or cold laser has been developed with potential rehabilitative uses in pain management.
   * **Interferential current:**
2. P.T. methods to control edema:

(a) Elevation of an extremity above heart level and it must be maintained while patient is in lying or sitting position.

(b) Active Exercises

It applies to shoulder, elbow and hand muscles to increase skeletal muscle pump and improve venous lymphatic drainage.

(c) High-voltage pulsed current (HVPC)

There are several devices and protocols for providing treatment with HVPC. The resolution of edema by using HVPC is probably due to activation of the skeletal muscle pump or the negative polarity of the stimulation, which may lead to fluid shift from the region.

(d) Intermittent vasopneumatic compression

Extremity edema can be treated by using an intermittent compression device, this device used for unilateral or bilateral hand/upper extremity edema. There are two types of compression sleeves, either a single-cell sleeve that delivers equal pressure to an entire extremity or a multiunit sleeve that applies pressure sequentially from the distal to proximal parts of the limb. Pressure is delivered at a time ratio of 3:1 (three time measures on, one time measure off). The most effective pressure of the sleeve is equal to or slightly greater than patient's diastolic blood pressure.

3. P.T. methods to improve functional ROM for the upper Extremity

- Codman's pendulum exercises.
- Shoulder Wheel exercises.
- Pulley exercises.
- Finger ladder exercises.
- Hand grip dynamometer exercises.
4. **P.T. methods to improve respiratory function:**

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<td>To improve diaphragmatic muscle strength</td>
<td>To improve chest mobility</td>
<td>To improve bronchial hygiene</td>
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1. **Resisted Breathing Ex:** During the third or fourth day postoperative, the patient received resisted breathing exercise by using a sandbag on the epigastric area (1/2 Kg.) to resist diaphragm.

2. **Incentive Spirometry:** They provide low level resistive training. The visual input of balls rising in chambers colored lights reflect the degree of inspiratory effort.

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<td>2 - Postural drainage</td>
<td>3- Tracheal suction</td>
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REHABILITATION OF
UPPER ABDOMINAL SURGERY (UAS)

Definition:

Upper abdominal incision means more than 50% of the wound being above the umbilicus, on the other hand lower abdominal incision means more than 50% of the wound being below the umbilicus while extensive abdominal incision means more than one incision site.

Common upper abdominal surgery (UAS):

a) Splenic surgery:
Most surgery to the spleen is due to trauma, splenomegaly, malignancy, or hemolytic anemia. Rupture of the spleen is usually due to direct trauma to the left lower ribs, typically from a motor vehicle or bicycle accident.

b) Gastric surgery:
Gastrectomies can be either partial, subtotal, or total most are performed for gastric neoplasm or gastric ulcer.

c) Gall bladder surgery:
Cholecystectomy means removal of the gall bladder. Most gallbladder surgery is due to cholecystitis. Inflammation of the gall bladder is the result of stones, concentrated bile and secondary infection.

d) Hepatic surgery:
Common causes of liver surgery are laceration from trauma and tumor resection.
Incision placement:

Many incisions can be done in the abdominal wall. The best incision is a direct exposure on the diseased viscous; it should not cut vessels or nerves and should not follow by incisional hernia. Common placement of upper abdominal incisions is shown in fig (1) vertical or longitudinal incisions are often used in stomach, duodenal, and pancreas surgery.

Fig. (1): Abdominal incisions.

The use of laparoscopic techniques, same day surgery, improved pain relief, and the routine use of early patient mobilization has changed the face of postoperative management for upper abdominal surgery. Now, many patients are discharged home within a day of elective surgery and do not require physical
therapy. However, internal surgical sites near the diaphragm markedly decrease respiratory function, even after laparoscopy.

Pathophysiology of the postoperative stage

Patients undergoing abdominal surgery consistently develop abnormal lung function, which can be demonstrated within hours of surgery and may persist for up to two weeks. The characteristic postoperative respiratory abnormality is of a restrictive nature where vital capacity is severely reduced, particularly in patients undergoing upper abdominal surgery (UAS). There is also a clinically important reduction in functional residual capacity (FRC) of around 20% after UAS.

Rehabilitation of UAS

First 2 postoperative days:

Aims:
1- To decrease postoperative pain.
2- To accelerate wound healing.
3- To prevent respiratory complications.
4- To prevent circulatory complications.

Modalities of treatment:

1- TENS:
   Electrode placement: paraincisional
   Pulse duration: 80 us
   Pulse rate: 40 Hz
   Amplitude: comfort (submotor).
   Duration and frequency of treatment: 60-min/4 hour.
2- Laser:
   Purpose of application: wound healing.
   Dosage: 90 sec/cm²
   Distance from the skin: 2-3 mm.
   Mode: continuous mode.

3- Pulmonary physical therapy:
   It should be noted that diaphragmatic breathing is extremely shallow on the 1st postoperative day.

Incentive spirometry training:

Methods of application

1- First method:
   The patient should be instructed to exhale normally and then insert the mouthpiece and take slow, deep inspiration. Occasionally, a nose clip may be necessary if the patient has difficulty with proper inhalation technique.

2- Second method:
   Is the inhalation hold method. The patient takes a maximal inhalation and momentarily holds the inspiration for a count of 3 to 5 sec. This technique helps to ventilate airways that are collapsed distal to an obstruction such as a mucous plug.
   - Frequency: 10 consecutive breaths /hour.
   - Benefits:
     * Prevention of atelectasis.
     * Improve coughing mechanism due to improved inspiratory capacity.
     * Strengthening of the diaphragm.
4- Foot and leg exercise (circulatory exercise)

5- Sitting out of bed:

Provided that there are no respiratory complications, sitting out in a chair for about 10-20 min. is generally allowed on the 1st postoperative day. Supervised walking round the bed is usually allowed on the 2nd day.

3rd and 4th postoperative days:

Aims:

1- To prevent postoperative respiratory complications.
2- To prevent postoperative circulatory complications.
3- To maintain and improve the strength of the abdominal muscles.

Modalities of treatment:

1- Pulmonary physical therapy by incentive spirometry.
2- Circulatory exercise.
3- Exercise therapy:
   - Crook lying: hand on abdomen; abdominal contractions.
   - Lying: head bending forwards with single high knee rising.
   - Lying: slight chest raising then full chest rising.
   - Crook-lying; pelvis rising.
   - Lying: single or double ankle bending.
   - Lying: single or double foot turning inwards.

Exercise period:

20 minutes, twice daily, in addition, the pt. will practice some of the exercises on 'little and often' throughout the day.

5th to 10th postoperative day:

Usually the stitches are removed on the 10th postoperative day, depending on the patient's condition and the surgeon's opinion (absorbable cutaneous sutures
are sometimes used) the patient spends an increasing amount of time sitting in a chair. The amount of walking is also increased.

**Aims:**
1- To improve posture.
2- To improve muscle power of the trunk muscle.
3- To prevent pulmonary complications.

**Modalities of treatment:**

1- **Trunk exercise:**
   
   * Patient lying in bed:
     - Lying; single high knee rising, leg stretching forwards to 45 and slow lowering.
     - Lying: chest rising.
   
   * Patient sitting in chair:
     - Sitting; trunk bending sideways.
     - Sitting (hands on thigh); trunk bending forwards and downwards.
   
   * Patient standing:
     - General correction of posture in standing and walking.
     - Walking practice.

2- **Pulmonary physical therapy:**
   Resisted breathing exercise either manual or by using mechanical weight.
   - Placement of resistance; at epigastric area.
   - Weight graduation:
     * For manual resistance mild, moderate, and maximal.
     * For mechanical weight → 1/2, 1, 11/2, 2 Kg.
     - It must be noted that the patient must gain full diaphragm excursion before increasing the load offered weather manually by the therapist hand or mechanically by external weight.
INGUINAL HERNIA

Definition

A hernia is a lump that occurs when part of the small bowel or other abdominal tissue protrudes through an area of weakness in the wall of the abdomen which occurs in the groin and named as an “inguinal” hernia.

Cause of inguinal hernias:

They may be present at birth or develop later in life, when straining, heavy lifting, coughing or obesity increases the pressure within the abdomen, applying strain on the muscles in the groin area.

Hernia repair:

The operation is routinely performed as “open” surgery, involving an incision to the lower abdomen. Alternatively, the operation may be performed as “keyhole” surgery (laparoscopic), through small incisions in the skin using special instruments.

Postoperative Patient’s problems:

[1] Pain:

Pain is a common compliant with point prevalence from 10% to 18%. In many cases symptoms persist, causing server discomfort and inability to work.

Common treatment consists of drugs; massage other manual treatments, physiotherapy and exercise, local and epidural injections, and patient education. Current treatment increasingly includes complementary methods of which acupuncture and laser are the most common.
2- **Decrease in muscle strength:**

There is decrease in the strength of abdominal oblique muscles and hip flexors.

**The following protocol was made after surgery:**

1\(^{st}\) **week:** Isometric abdominals and hip exercises, walk increased by 5 minutes / day and ascending and descending stairs.

2\(^{nd}\) **week:** Active exercises for hips, transverse and oblique abdominals exercise and bike riding.

3\(^{rd}\) **week:** Active exercises for hips, transverse and oblique abdominals exercise, jogging and swimming.

4\(^{th}\) **week:** running and low weight lifting,

5\(^{th}\) **week:** sprinting, running in all direction, light ball skills and kicking.

3- **Returning to work after hernia repair:**

Herniorrhaphy is a problem because patients are being advised to limit their physical activity for six to eight weeks postoperatively to prevent recurrence. Also, for early return to work advice patient to avoid heavy lifting for four weeks and resume full activity by eight weeks. Depending upon patient occupation, the expected recovery period lasting from one to six weeks.
Normal Skin:

The skin is the largest organ of the body, comprising approximately 15 percent of body weight, contains the nerve endings of sensory nerves. Averaging over 2 m² in surface area and yet in most places is less than 2 mm in thickness. The skin is the organ which envelops and covers the body. The skin with its associated glands and specialized derivatives.

Anatomically, the skin consists of two distinct layers of tissues: the epidermis, which is the outermost layer and the deeper layer, termed the dermis, a third layer involved in the anatomic consideration of the skin is the subcutaneous fat cell layer directly under the dermis and above muscle facial layer (Fig. 2).

Fig. (2): Cross Section of the Skin.
**Functions of the Skin:**

a. Transmits sensory feedback from environment.
b. Functions as part of the immune system to prevent organisms from gaining exposure to internal organs.
c. Serves as a water barrier.
d. Serve as a barrier to prevent the penetration of foreign objects, material and radiation.
e. Regulates heat exchange and assist in body temperature homeostasis.
f. Provides a cosmetic covering for personal identity.
g. Excretions of some waste products.
h. Resists mechanical stresses and formation of vitamin D3.

**PATHOPHYSIOLOGICAL CONSIDERATIONS OF THE SKIN**

Burn injuries vary in severity, depending on the amount of the total body surface area “TBSA” that has been damaged. Even the smallest burn causes discomfort that can be relieved by rapid first aid. The severe or dangerous burn involving more than 30 % of the (TBSA) may be life threatening.

Burn injury primarily results in disruption and destruction of the normal protective functions of the skin. Disruption and destruction of the skin as a result of burn injury, affects all skin functions.

**Burn types and causes:**

Burns are caused by exposure to excessive heat as flame, hot surfaces (Contact burns), scalding liquids (Scald burns) friction, electricity and chemical burns, heat destroys tissues by coagulation, thermolysis and evaporation of proteins. Exposure to irradiation may also result in skin destruction.
Burns classification according to the depth of the injury:

Burns are classified into four degrees:

* **First degree:** In which burns are superficial injuries, involving only the outer layers of epithelium. The wound is red, erythematous, hypersensitive and painful, but there is no tissue destruction, spontaneous healing occurs in about 3 weeks.

* **Second degree:** In which burns are erythematous, oedematous, hypersensitive and painful. Second degree burn can be subdivided into a superficial second degree in which there is blistering and destruction of the superficial layers of the epidermis, and a deep second degree burn affecting and destroying the deep epidermal layers until the basement membrane. In the superficial second degree regeneration and healing is possible, but the deep second degree burn with complete epidermal destruction and partially dermal destruction is in need of skin grafting like the third degree burn.

* **Third degree:** In which there is complete epidermal and dermal destruction, burn wound is dry and insensitive to pain and is in need of skin grafting.

* **Fourth degree (Char degree):** In which burn destroys and involves the underlying tissues, subcutaneous fat, muscles, nerves, bones and joints.

Burns classification according to the extent or the percentage of TBSA:

Burns may be classified into 3 groups according to the percentage of TBSA, minor burns involve less than 10% of the TBSA, major burns involve more than 10% of the TBSA, and dangerous burns involve more than 30% of the TBSA the estimation of the TBSA percentage is implemented by the application of the rule of nines, which is the most common clinical method, in which the body is divided into areas, each one representing approximately 9% or 18% of the TBSA, as follows: head and neck represent 9%, each upper limb represents 9%, each lower limb represents 18%, anterior trunk represents 18% posterior trunk represents 18% and the perineum represents only 1%.
**Pathophysiological changes of burns:**

The basic pathophysiological consequence of the burn injury is the loss of the capillary integrity, localized increase in the micro vascular permeability, generalized impairment in the cell membrane resulting in cell swelling and increase osmotic pressure of the burned tissues leading to further fluid accumulation and edema formation, which is a result of the outpouring of the intravascular fluid into the interstitial spaces. This process occurs at all areas of partial skin thickness burns and at the areas which are adjacent to the full skin thickness burns.

As the patient frequently splints the injured part because of pain and as a result of the direct damage to the lymphatic system, fluids of oedema accumulates and persists in tissue spaces around tendons, ligaments and joints, leading to the formation of new collagen fibres in this protein – rich oedema fluids and eventually leading to adhesions and loss of the normal elasticity of the supporting structures. In addition the prolonged immobilization fixes the structures and produce joints morbidity.

**Metabolic changes of burns:**

During the immediate post-burn period nutrient flow and oxygen delivery to cells is decreased, leading to a decrease in the basal metabolic rate (B.M.R.). There is massive catecholamine release from the adrenal medulla and from the nerve endings of the sympathetic division of the autonomic nervous system, leading to systematic vasoconstriction, increased vascular resistance and poor peripheral circulation affecting skin, muscle and nerve, resulting in nerve function alterations.

**Mechanisms of pain in burned patients:**

Pain in victims of burn has frequent and wide fluctuations in intensity, and its control presents a formidable challenge to those responsible for patient care.
It has been postulated that, the pain mechanisms in the burned patients are the result of stimulation of the three pain receptors, thermosensitive, chemosensitive and the mechanosensitive pain receptors. The direct effect of the thermal injury on the thermosensitive pain receptors will lead to pain, then the chemical mediators (Prostaglandins histamine and bradykinin) via inflammation will stimulate the chemosensitive pain receptors and produce pain, and finally with the metabolic stress and the predominant sympathetic tone plus edema and swelling will lead to compression and ischemic pain, exaggerated by muscle spasm via stimulation of the chemosensitive pain receptors.
WOUND HEALING AND THE BIOLOGY OF SCAR (SCAR FORMATION)

Repair of wounds

The healing of skin wound requires 2 processes:
1- Regeneration of the epidermis
2- Fibrosis in the dermis

There are 2 types of wound healing:
1. Primary union of wound = healing by first intention:
   As the surgical incision healing where no epithelial loss. This occurs in clean surgical wounds with closely approximated in edges, incision and sutures induce inflammation in both edges. Within 24 hours the basal cell layer of the epidermis regenerate and cover (bridge) the wound surface, subsequently other epidermal layers (superficial ones) regenerate with more covering of the wound surface. Fibroblasts on both sides of the wound proliferate (they received blood & nutrients from the endothelial capillaries = Neovascularization = capillary sprouting) Fibroblasts proliferate & from granulation tissues, which close the wound within 4-5 days, but union, still weak.
   Fibroblasts lay down collagen (glue), capillaries become obliterated and the granulation tissue (weak) changed into solid fibrous Tissue (Scar=cicatrix). The wound edges are now firmly united; the covering epidermis is pale and has no hair follicles, sweat or sebaceous glands.

2. Secondary union of wounds = healing by 2nd intention:
   Where there is epithelial loss. This Occurs in septic or open wounds with separated edges. Formation of new capillaries (Neovascularization) proliferation of Fibroblasts → granulation weak tissue takes place all around the cavity of the
wound. Infection of wound causes emigration of a large number of neutrophils to the wound area leading to exudation of fluid from the septic granulation tissue (pyogenic membrane = pus), once the infection is overcome, the granulation tissue becomes healthy and resist further infection. Then capillary loops will be formed at the bottom of the wound cavity → granulation tissue which is red, moist, insensitive to touch and bleeds easily, and gradually these granulation tissues will fill up the cavity. When the cavity is completely filled up with granulation tissue → the epidermis will grow from the edges.

Finally granulation weak tissue will be changed into solid fibrous tissue (big scar devoid of hair & glands).

Complications of 2nd union:
1. Chronic ulcer.
2. Sinus or Fistula.
3. Massive outward growth of granulation tissue.
4. Keloid formation: Keloid = Excessive formation of solid fibrous Tissue in the dermis leading to projecting swelling covered by thin epidermis, recurrence of Keloid after surgical removal is common. Keloid develops during the healing of burn or smallpox vaccination vesicles.
Phases of wound healing

There are 3 phases of wound healing:

1. Inflammatory phase: This prepares the area for healing.
2. Fibroblastic phase: This rebuilds the structure.
3. Remodeling phase: This is the final from.

**Inflammatory phase:**

Inflammatory is normal and necessary for the healing process, any blood vessels that traversed the wound will be cut at the time of injury. These cut vessels will pour blood into the wound, then blood will be coagulated with sealing off the injured vessels and lymphatic channels leading to temporary closing of the wound. Injured vessels as well as mast cells in the injured tissue will release histamine, which will lead to vasodilatation of the neighboring non-injured vessels also there is a release prostaglandins with more vasodilatation & edema creating a red, hot swollen and painful condition.

This inflammation (V.D & swelling) is needed for healing but balance of this inflammation is also needed because: If there is no inflammation → there is no healing, too little inflammation → slow healing, Balanced inflammation → proper & good healing, Too much inflammation → excessive scar formation, So excessive swelling & inflammation must be prevented Via:

**Medically:** by repairing & cauterization of all blood vessels **therapeutically:** by the classic (RICE) regime of rest, Ice, compression and elevation.

**Pharmacologically:** by using steroids & Aspirin which inhibits the prostaglandin release.

**Under the umbrella of the inflammatory phase, there are 2 processes:**

a. Phagocytosis
b. Neorvascularization.
**A) Phagocytosis = wound decontamination:**

The main purpose of the process is to prevent wound infection. The first W.B cells that reach the wound are the polymorphonuclear leukocytes, which start the phagocytosis process by fixing bacteria & digesting the invaders. Then macrophages will reach the wound to engulf bacteria and neurotic tissue, even in poorly nourished tissues with low O₂ level.

**B) Neovascularization = capillary canalization or vascular sprouting:**

Healing will not take place; unless new blood vessels are present to supply O₂ and nourishment to the injured tissue (injured tissues till now have no blood due to sealing off blood vessels & lymphatic). Patent vessels in the wound periphery develop small buds or sprouts that grow into the wound area. These outgrowths will eventually come in contact with other arteriolar or venular buds to form a capillary loop. These new capillary loops will fill the wound & erecting a red color throughout the wound. Immobilization is essential during this phase to permit vascular regrowth and prevent new micro-hemorrhages. So early mobilization during this phase is contraindicated as well as heat application as heat application during this phase will increase bleeding from these fragile vessels. The use of antibiotics, Debridement techniques (debris removing, proper positioning, RICE regimen, Low-dosage, pulsed ultrasonic in water baths will decrease infection and whirlpool cleaning.

2) **Fibroblastic phase: rebuilding phase:**

With the inflammatory phase completed, rebuilding can commence (start or begin). The name of this phase is acquired from the repair cells or the cells of scar production (fibroblasts).

The purpose of this phase is to repair or rebuild and to provide strength to the wound. Fibroblasts begin to synthesize or produce collagen.
3 Processes are included under the umbrella of the Fibroblastic phase to achieve wound closure:

A. Epithelialization.
B. Wound contraction.
C. Collagen production.

A) Epithelialization:

Epidermis of the skin has a stratified squamous epithelium (from the cell layers to the superficial cell layers). So epithelialization means =epidermal regeneration or surface covering. Within hours after injury, the undamaged epithelial cells (cells of epidermis) at the wound margin begin to reproduce epidermal regeneration or epithelial mitosis. These undamaged epithelial cells will migratory from the periphery toward the center of the wound cavity. These migratory cells remain attached to their parent cells; therefore their movement will create a (pull) on the normal skin around the wound edge.

In case of extensive wounds or with low O\textsubscript{2}, epithelial migration cannot be implemented. Epithelialization start with one thin layer just to cover the wound, and after several weeks epithelialization become multilayered including all epidermal layers, except basal layers leading to thin epithelialization. So epithelialization closes the wound surface only not the deep.

B) Wound Contraction:

Epithelialization close the wound surface only while wound contraction is a process, which pulls the whole, wound together leading to wound shrinking or decreasing the wound area. This wound contraction = wound shrinking and its centripetal force can useful in some regions and can be harmful and detrimental in other regions. If contraction is uncontrolled as in abdomen and gluteal region where skin is loose and mobile, while the deep structures are fixed. In this condition wound contraction is useful with no contractors formation.
While in the hand region where joints, muscles, tendons and sheathes are very close to each other, so they are in need of every millimeter of skin & tissue length, so if wound contraction in hand is not controlled will create its centripetal force which pull all structures toward the wound leading to joint contractors as in cases of full-thickness hand burn.

Skin graft will decrease wound contraction, however the thickness of the graft correlate with the degree to which wound or burn contraction is inhibited:
* Split- thickness graft will decrease contraction of the wound bed by 31%
* Full- thickness graft will decrease contraction by 55%
* Full- thickness graft with splinting decrease contraction by 77%, so there is a negative correlation as increasing skin graft thickness will decrease contraction. Grafting must be applied early in the inflammatory phase before the beginning of wound contraction.

C) Collagen production = glue production:
Wound healing occurs with collagen production, if there is no collagen production, no wound healing will be occurred.

Remodeling phase:
Successful wound healing requires more than closing the wound with sufficient tensile strength. Remodeling requires the scar to change to fit the tissue. Remodeling of the scar maturation represent the final aggregation. Orientation and arrangement of the collagen fibers.
PHYSICAL THERAPY MODALITIES
TO MANAGE BURN CASES

A. MOST EFFECTIVE METHODS OF BURN PATIENTS POSITIONING AND SPLINTING

I. Proper Positioning Program

Proper positioning is one of the fundamental needs necessary for successful burn patient rehabilitation. A burn patient's positioning program is designated to minimize edema formation, prevent tissue destruction and maintain soft tissue in an elongated state to facilitate function recovery.

Burn scar contractures can be anticipated by the location, extent of the body involved, and the depth of the burn wound. Positioning the burn patient should be implemented to the extent that contractures are averted without compromising mobility and function. Total body and specific site positioning techniques are used to minimize pathophysiological effects from burn and enable optimal wound care.

Daily monitoring of the patient's medical status, range of motion, and skin condition will assist the therapist in deciding how long positions are to be maintained and what other modifications are necessary in positioning program. Specific positions are used to align individually the extremities, neck and trunk and are considered to be "anti-contracture" positions.

The proper positioning program for function is initially based upon the depth and area of the burn wound. Subsequently, the area of burn is the most indicator
for planning the function program positioning left in place 20 to 30 minutes. The involved area is maintained in the stretched position with splints. After paraffin treatments, deep massage and stretching exercises promote additional scar softening and increased range of motion.

The popular adage "the position of comfort (fetal position) is the position of contractures appears well founded. In general, the patient should be positioned in the opposite direction of comfort, that is, opposite the burn wound and impending contracture. Figure (3) and table (2) illustrate the most commonly used anti contracture positions.

**Table (2):** Burn Patient Positioning:

<table>
<thead>
<tr>
<th>Body Area</th>
<th>Contracture Predisposition</th>
<th>Preventive Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Neck</td>
<td>Flexion</td>
<td>Extension /Hyper ext.</td>
</tr>
<tr>
<td>* Anterior Axilla</td>
<td>Shoulder Adduction</td>
<td>Shoulder Adduction</td>
</tr>
<tr>
<td>* Antecubital space</td>
<td>Elbow flexion</td>
<td>Elbow Extension</td>
</tr>
<tr>
<td>* Forearm</td>
<td>Pronation</td>
<td>Supination</td>
</tr>
<tr>
<td>* Wrist</td>
<td>Flexion</td>
<td>Extension</td>
</tr>
<tr>
<td>Dorsal/hand/finger</td>
<td>MCP Hyper extension</td>
<td>MCP Flexion, IF extension, thumb palmar abduction</td>
</tr>
<tr>
<td></td>
<td>IP Flexion, thumb adduction</td>
<td>Extension, thumb radial abduction</td>
</tr>
<tr>
<td>* Palmar hand/finger</td>
<td>Finger flexion, thumb opposition</td>
<td>Finger extension thumb radial abduction</td>
</tr>
<tr>
<td>Hip</td>
<td>Flexion, adduction external rotation</td>
<td>Extension, abduction neutral rotation</td>
</tr>
<tr>
<td>* Knee</td>
<td>Flexion</td>
<td>Extension</td>
</tr>
<tr>
<td></td>
<td>Ankle</td>
<td>Planter flexion</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>* Dorsal toes</td>
<td>Hyperextension</td>
<td>Flexion</td>
</tr>
<tr>
<td>* Planter toes</td>
<td>Flexion</td>
<td>Extension</td>
</tr>
</tbody>
</table>

**Fig. (3):** General Body Positioning for Prevention of Contractures.

**a. Basic Positioning Techniques in Edema Control:**

Initially, a positioning program focuses on reducing edema through elevation of the extremities. Edema develops with 8 to 12 hours after burn injury and peaks at approximately 36 hours. Failure to reduce edema in the first 48 to 72 hours can result in organized edema components creating fixed deformity. Furthermore, improper elevation during the initial period of edema may lead to calcification and increased bone density, especially in elbow. Elevation of an extremity above heart level can be accomplished using common items such as pillows, towels and foam.
II. Splinting Techniques

Historically, splints have been used to support burned extremities, maintain joint positions following surgery and correct or prevent deformity. The design of splints can widely, but the intended results are the same. The chosen design, however, is less important than the timely application and proper fit of the splint.

The length of time a patient needs to wear a splint depends on the depth of burn, the degree of activity of the hypertrophic scar, and the patient's adherence to the self exercise program. Splinting is an extension of the therapeutic positioning program. Splinting is indicated when the patient is unable to voluntarily maintain proper positions, when voluntary positioning is ineffective in preventing contracture, or when the patient must be immobilized for an extended period such as after surgical wound closure.

Splinting may be initiated at any time in the acute burn period depending on individual patient needs and functional range of motion. Some areas, especially the hands, require splinting immediately after burn injury to aid in edema resolution and to maintain function joint position. Continuous splinting is indicated in treatment of: (1) burn wound edema in the hands; (2) exposed tendons, (3) peripheral neuropathies; and (4) uncooperative or unresponsive patients.

These splints must be removed several times daily and with the exception of exposed tendons, the involved areas should be undergoing exercise. Splints may be used with nearly every type of burn wound treatment including grafts and other biologic dressing. Frequent assessment, at least on a daily basis, is the key to effective splinting, thus insuring proper fit and function.
**Uses of the Splints:**

a. **Using of splints and protection of Joints and tendons:**

   Splints play an important role in prevention further trauma to joints and tendons or preserving anatomical structure and function. Stabilizing joints reduces external stresses, such as shearing or pressure, which can cause tissue damage.

b. **Role of splinting in edema reduction:**

   Supportive splints are used to maintain maximal limb elevation for resolution of edema. The pressure support of air splints may assist edema reduction.

c. **Splinting following skin grafting:**

   Splints are applied intraoperatively to immobilize a skin graft recipient site and prevent accidental shearing of the graft. When grafts are restricted to the upper body, splints enable the patient to be ambulatory without risk of graft disruption.

d. **Splints for uncooperative or unconscious patient:**

   Splints are used to maintain a function joint position or prevent contracture development when a patient is unable or unwilling to participate in therapy programs. Adults may develop joint stiffness following immobilization and range of motion should be assessed each the splint is removed. Children rarely develop joint stiffness as a result of prolonged immobilization. Continuous use of a splint assures proper positioning until a patient is able to actively participate in the rehabilitation program or the risk of contractors is reduced.
**Types of splints:**

1) **Primary splints:**
   During the acute phase and pre grafting period, static splints (without movable parts) are used to position the involved joints during sleep, inactivity, or periods of unresponsiveness. Whenever possible, these splints should be applied to adjacent intact skin.

2) **Postural splints:**
   During the immediate post graft phase, splints are used to immobilize joints in proper functional position, but must allow access for continued wound care. These splints are worn continuously for 5 to 14 days until the graft is secure.

3) **Follow up splints:**
   The chronic phase of burn care begins with wound closure and continues until full maturation of the wound (one to two years). Dynamic splints (movable parts) are used to increase function. They can provide support to the joint without restricting antagonistic movements, provide slow steady force to stretch a skin contracture, or provide resistive force for exercise.
APPLICATION OF THE MOST EFFECTIVE METHODS FOR BURN
PATIENT POSITIONING ON
SPECIFIC AREAS OF THE BODY

1. Head and Neck:

Patients who have sustained head burns that include the ears should not be allowed use of a pillow in order to avoid a development of chondritis of the ear. A foam gel filled donut is useful to elevate the ears from the bed. A partially filled intravenous (IV) bag is an alternate method. If a patient's head needs elevation for eating or drinking, raising the head of the bed rather than using a pillow is the preferred method.

Anterior or circumferential neck burns predispose patients to neck flexion contractures. Contracture of the anterior neck is the most common contracture requiring surgical release. Pillows which position the neck in flexion should not be when burns cover the anterior neck. Positioning is necessary to maintain neck extension or hyper extension; exercises can be used to maintain rotation.

Several options for neck positioning can be used to extension easy and quick method is a towel roll placed under the patient's shoulder or between scapula. A foam cervical collar or donut around the patient's neck is useful to prevent neck flexion when lying in bed and during upright activities. The use of hyper extension or staggered mattress also encourages neck extension. A towel roll or pillow can be placed under the head if the top of mattress is too high. Extension neck exercises should be encouraged.

If a neck burn is asymmetrical; a lateral flexion contracture toward the side of the burn can be expected. This can cause muscle imbalance and lead to a postural deformity. The neck should be positioned so that the head is held in midline. Towel rolls, wedges or sand bags placed lateral to the head, on the same side as
the burn, minimizes lateral tightness. Positioning environmental stimuli such as television; toys, bed trays, and visitors on the non-affected side will encourage the patient to turn and stretch the neck. Lying prone with the head rotated away from the side of the burn may be utilized to stretch the neck. When a neck burn is posterior and the ears are not affected, a pillow may be used to elevate the head and lengthen the posterior tissues. Various types of splints that used for the treatment of anterior neck burns, (1) Soft cervical collar is a circumferential foam neck orthosis covered with stockinet, it maintains neutral extension and prevents lateral flexion, (2) Molded neck splint or collar, it is a total contact, rigid neck support, it maintains exact position (extension) and prevents rotation and lateral flexion, (3) Halo neck splint, it is a thermoplastic orthosis that positions the neck in extension using the head and upper torso for stabilization, (4) Watusi collar, it is a series of cylindrical plastic or foam tubes fastened circumferentially around the neck. Additional tubes are added as neck extension improves (Figs. 5, 6 and 7).

**Fig. (5):** Soft Cervical Collar.
2- Trunk:

There is a good relationship between the location and extent of burns and spinal postural deformities, i.e. burns extending from the pectoral region to an area below the umbilicus may cause a kyphosis. Burns of the lower back may lead to a lordosis, while a lateral trunk burn may cause a scoliosis with the concavity toward the burned side. In addition to these postural deformities, improper trunk alignment might impair chest expansion required for good ventilation.

When the chest is burned, the shoulder girdles should be positioned in retraction. Positioning for chest burns may include placing a square towel, or
bath blanket between the scapulae alternatively, the patient can lie supine with hands clasped behind the head with elbows resting on the bed. A figure-of-eight elastic wrap to pull the shoulders into retraction, cervical fracture braces and clavicular straps can be used when skin integrity allows. Deep breathing exercises are the only procedures that can be used to maintain maximum chest mobility. The forward tilt of the shoulders which often occurs as a result of burns of the anterior chest wall can be prevented by positioning the arms in 90 degrees of abduction. Back brace or spinal support can be applied to limit the amount of postural deviation from scar tissue tightness (Fig. 8). Lateral trunk burns require the trunk burns to be maintained straight to prevent scoliosis of the spine. Towel roll, blankets, and foam wedges can be utilized to maintain trunk alignment while in bed by placing them on the side of the trunk where the burn is located.

3- Shoulder:

The normal resting position with arms at the side is the one least likely to help maintain range of motion in the shoulder joint. The most advantageous position for maintaining range is shoulder abduction to 90 degrees. A patient with burns of the anterior axilla will tend to posture in shoulder adduction and internal rotation, therefore shoulder abduction and external rotation is the position of choice to prevent deformity.

The recommended position for the shoulder when the axilla is burned is 90° of abduction With 15° to 20° of horizontal adduction to avoid stretching and compression of the brachial plexus. When the burn involves the elbow and the shoulder, elbow extension must be maintained during shoulder positioning. Children can be motivated to move 'their arms by placing soft toys with bells on them in strategic positions on the side of the bed, many options are available to hold a patient in the positions just described. Murphy slings, made from stockinet and attached to an IV pole or an overhead ceiling tract, are especially helpful in
the early stage of positioning to achieve elevation along with shoulder abduction (Figs. 9 and 10).

Fig. (8): Spinal Support Brace.
Fig. (9): Axillary/Airplane Splint.

Fig. (10): Shoulder Abduction Splint
A soft restraint at the wrist, which is tied to the head board, maintains shoulder abduction and external rotation with the elbow flexed. Foam wedges, towel rolls, pillows and bath blankets placed between the axilla and trunk are convenient positioning devices. Several commercial shoulder abduction troughs are available as bed attachments. These troughs fasten onto the sides of the bed and are utilized not only for shoulder positioning but also may be used to elevate the upper extremity to decrease hand edema. Skin grafts of the arms or axilla require special positioning to prevent shearing tissue from contact with the bed, an arm cuff and traction bars may be used to protect upper extremity skin grafts.

4- Elbow:

The position of comfort for the patient is one of forearm pronation. Although elbow is a more functional position than extension, the tendency of the patient to withdraw into flexion in response to pain quickly produces an elbow flexion contracture. The position of choice is elbow extension with some elbow flexion exercises. Burns to the antecubital space and circumferential burns to the upper extremity can lead to elbow flexion and forearm pronation contractures.

The recommended positions for the shoulder in this case are extension elbow and supination of the forearm. Many of the devices used for shoulder positioning also can used for elbow positioning. Arm troughs allow the elbow to rest in an extended position. Elbow splints are an effective means of positioning (Fig. 11). Wrist restraints, when used in conjunction with elbow splints and attached to the head of the bed, provide a quick method for combined shoulder and elbow positioning. The use of an air splint is an alternative for positioning the upper extremity and it can be used provide pressure apply, helps control edema.
5- Forearm and Wrist:

Burns to the volar surface of the forearm will predispose the patient wrist flexion and forearm pronation contractures, while burns to the dorsal surface of the forearm may cause a wrist extension contracture. The forearm frequently assumes a pronated position with the wrist in flexion when a patient elevates the forearm and hand, or rests the segment on a pillow. Therefore, the forearm is always positioned in supination except in the case of isolated dorsal wrist burns, the wrist should be positioned in extension.

The recommended functional position of the wrist is from neutral to 30° of extension. This position can be initially or temporarily accomplished by placing a small towel or gauze roll in the palm of the hand. If the wrist range of motion becomes limited in a specific direction, splinting the wrist in the opposite direction would be indicated (Figs. 12 and 13). Circumferential forearm burns require the wrist to be positioned in neutral or slight extension due to the effects of gravity and the strength of the flexor musculature.
**Fig. (12):** Air Splint to Apply Pressure to Hand/Forearm.

**Fig. (13):** Wrist Extension Splint
6- Hand:

During early hospitalization, the hand must be elevated to minimize edema formation. Elevation can be achieved using Murphy's slings, surgical netting or pillows. Elevation must be maintained while the patient is in bed, sitting, or ambulating the antideformity or recommended position of the hand with a dorsal burn is that of "the duck-bill", "clam digger" position.

The fundamental hand positioning components are: (1) wrist extension, (2) metacarpophalangeal joint (MCP) flexion, (3) proximal interphalangeal (PIP) joint and distal interphalangeal (DIP) joint extension, and (4) thumb palmar abduction. This position can be achieved by wrapping a gauze roll or piece of foam into the palm and extending it through the thumb web space or hand splint can be used. The use of many types of splints is an alternative for positioning of the burned hand. Palmar pan splint is a thermoplastic splint that positions the joint opposite the anticipated deformity or contracture, it also to maintain tendon balance and functional position and prevents rupture of extensor mechanism. Wrist splint is wrist orthosis for immobilization and positioning (Fig. 14).

Fig. (14): Antideformity Hand Splint.
Thumb spica can be used for immobilization and positioning the thumb and wrist. Thumb web spacer is a thermoplastic splint that comforts to the index finger, thumb web space and thumb to provide positioning and/or pressure (Fig. 15).

**Fig. (15): Thumb Web Spacer**

7- Hip:

When a burn is on the anterior or posterior aspect of the hip area, the hip should be positioned in neutral rotation with slight abduction. If the patient is not positioned correctly, hip flexion, external rotation, and/or adduction contractures can result. A patient positioned with the hips in external rotation and the knees flexed for a prolonged period of time is at risk for peroneal nerve injury caused by stretch of the nerve. The results of this position can be completed the paralysis with a foot drop or some degrees of muscle weakness of the anterolateral compartments.

Towel rolls or sand bags, placed lateral to the thigh, can assist to position the hip in neutral position. A triangular foam wedge or bath blankets can be placed between the lower extremities to maintain hip abduction. Lower extremities abduction splints position the hips in abduction and neutral rotation, while knee extension splints can minimize hip flexion, by preventing knee flexion when the
patient lies supine. Prone position is an excellent position for hip extension. Anterior hip spica splint made from thermoplastic material to maintain hip extension and abduction while preventing hip flexion and adduction (Fig. 16). Hip abduction splint made from thermoplastic material and secured in place with foam straps (Fig. 17). Spreader bar fastened posteriorly to two knee extension splints to maintain abduction of the lower extremities (Fig. 18).

**Fig. (16):** Anterior Hip Spica Splint.
**Fig. (17):** Hip Abduction Splint.

**Fig. (18):** Spreader Bar Attached to Knee Gutter Extension.
8- Knee:

The tendency of the patient to withdraw into flexion in response to pain makes maintenance of hip and knee extension a vital procedure. Burns to the posterior surface of the knee cause flexion contracture, while anterior surface burns rarely cause extension contractures.

The patient with a burn to the flexor surface of the lower extremity must be positioned with the knee in extension. The extremity may be placed in bulky dressing to mechanically impede knee flexion especially after a skin graft. Pillows placed under the knees while patient is supine are not recommended as they may cause knee flexion contractures.

Positioning a patient prone with the feet over the end of a mattress is a means of achieving complete knee extension. Placing a pillow under the ankle counteracts this desired effect by producing knee flexion. For edema reduction, the foot of the bed can be elevated with pillows placed under the leg, excluding knee, to encourage knee extension. Those patients who can not maintain the position of knee extension can be supplied with splint. Knee extension splints are extremely helpful to maintain extension.

The common examples of knee splints are (1) Gutter or/through splint, can be applied to the flexor surface of the joint to maintain extension (Fig. 19), (2) knee conformer is applied to the flexor or extensor surface of a joint for immobilization and application of pressure, and (3) Air splint inflated to apply pressure, immobilization and assist with edema control.
9- Ankle and Foot:

The planter flexion contractures are the most common problem in a foot and ankle burns. One of many problems, planter-flexion puts the gastrosoleus muscle complex on slack, encouraging heel cord tightness, therefore, placing the ankle at neutral is the optimal position for posterior or circumferential burns of the ankle—methods used to maintain or achieve a neutral ankle position for circumferential or posterior burns of the ankle and foot are splints as (1) a foot-board (2) sponge booties, prefabricated splints (posterior foot splints, anterior ankle conformer and toe conformer). Figures (19) and (20) may be utilized for positioning ankle and foot burns.

If the burn is isolated across the anterior surface of the ankle and foot, positioning in planter flexion is preferred while patient is resting. If the dorsum of the foot is involved, extension contractures of toes are likely. If the patient is ambulatory and the ankle is not burned, special positioning is not indicated. The overall aims of treatment for burns are healing of the skin and restoring the patient to a normal active life as soon as possible.
Fig. (20): Anterior Ankle Conformer.
EARLY AMBULATION AND GAIT TRAINING FOR PATIENT WITH LOWER EXTREMITY BURN

The first step in gait training program for the patient with lower extremity burn is a comprehensive evaluation. This evaluation should be performed during the first ambulation session following skin "grafting and re-evaluated frequently as ambulation progress.

The history should include details of the patients pre-burn mobility level, preexisting lower extremity problems such as peripheral vascular disease, joint injuries and strength deficits should be determined. Objective measurements of passive and active ROM and strength should be completed.

Goals of Ambulation Program:

The ultimate goal of ambulation for the patient with a lower extremity burn is the ability to walk efficiently so that all daily activities can be accomplished easily. Early ambulation is an essential part of rehabilitation program whether or not the patient has burn on the lower extremities. It decreases the risk of thromboemboli formation, maintains lower extremity strength and ROM and to increase a patient's functional independence.

Initial treatment program:

This program includes positioning, exercise and ambulation, as with all burns positioning is dependent on the surface area affected. Usually, with a lower extremity burn, the anti deformity position includes hip extension with neutral rotation and approximately 20 to 30 of abduction, the knee must frequently is placed in extension and the ankle in neutral. Possible interventions to attain these positions include the use of splints, wedges, foot boards and prone position.
To enhance lower extremity circulation, ankle pump indicated while the patient is on bed rest.

Quadriceps and gluteal muscles isometrics can help to maintain strength when the patient is prohibited to move due to recent skin grafting. When movement is allowed lower extremity exercises may include hip extension, straight leg raising heel slides and squatting.

**Ambulation program and timing:**

Early ambulation is an essential part of rehabilitation program whether or not the patient has burn on the lower extremities, however there can be problems associated with early ambulation including pain, bleeding, increased edema, venous stasis and delayed or poor wound healing.

**Factors influence ambulation:**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Status</td>
<td>* Alert, able to follow directions</td>
</tr>
<tr>
<td>Vital signs</td>
<td>* BP, HR within range of criteria set for patient</td>
</tr>
<tr>
<td>Edema</td>
<td>* Mild or Moderate</td>
</tr>
<tr>
<td>Range of motion</td>
<td>* Adequate to allow gait cycle</td>
</tr>
<tr>
<td>Strength</td>
<td>* Able to bear weight on lower extremities</td>
</tr>
<tr>
<td>Pain</td>
<td>* Patient tolerance</td>
</tr>
</tbody>
</table>

**Ambulation following skin graft:**

The initiation of ambulation following lower extremity skin grafting usually is dependent upon the establishment of competent circulation to the grafted area. The graft probably remains at risk for at least 10 to 20 days after skin grafting.
For this reason ambulation protocols following skin grafting usually have not been initiated until the tenth to fourteenth postoperative day.

The graft should be inspected carefully following each ambulation trial. Prior to ambulation, the burned, lower extremity must first be provided with elastic bandage support for the vascular system and help to control edema, venous stasis and dependent pain.

Severe discomfort or pain during or after ambulation can be an indicator of potential graft problems. If discoloration, bleeding breakdown, or edema occurs, the frequency or distance the patient ambulates may need to be decreased or the vascular support to the lower extremities may need to be increased.

Following skin grafting, some patients will be unable to safely stand due to orthostatic hypotension if immobilization and bed rest has occurred. These patients may require the use of a tilting table to gradually achieve an upright position. The patient blood pressure should be monitored during this procedure.

Once patients are able to tolerate standing on the tilting table, they can ambulate from the table. Patients who have been allowed to sit out of bed prior to dangling usually don't require the use of tilting table.

Some patients may need to begin ambulation in the parallel bars while others can begin from bed side or chair.

Once ambulation has been initiated following skin grafting, the patient should be advanced to independent ambulation as rapidly as possible. Walkers, canes and crutches can be used but they should be discontinued as soon as possible to facilitate normal gait pattern. The next step is to increase the distance of ambulation and improve the quality of gait.
Emphasizing a heel to toe gait pattern with equal step lengths, reciprocal body motion and good body alignment will help to maintain the quality of gait and to prevent long term postural changes. A wide variety of physical equipment (e.g. treadmill and bicycle) can be used to enhance gait training. Several gait deviations occur frequently in the patient with a lower extremity burn although many may correct themselves once the patient's wounds heal and pain diminishes.

Common gait deviations following burn injuries:
* Forward trunk Position.
* Trunk rotation
* Pelvic mobility
* Hip flexion
* Inadequate hip abduction
* Hip external rotation.
* Knee flexion or extension maintained throughout cycle
* Ankle planter flexion with no heel strike.
* Poor weight shift.
* Weight bearing on affected lower extremity
* Stance phase on affected lower extremity
* Swing phase on non affected lower extremity.
* Improve step alteration
* Wide base of support

Some of these deviations can be minimized by proper positioning and aggressive exercise during the acute phase of burn care. Problems that remain after the initiation of ambulation often can be corrected with an appropriate exercise program. The use of mirrors will provide the patient with visual feedback about postural and gait deviations.
**STRETCHING EXERCISES**

**Definition of stretching:**
A general term used to describe any therapeutic maneuver designed to lengthen (elongate) pathologically shortened soft-tissue structures and thereby to increase range of motion. Stretching exercise is considered one of the physical therapy modalities designed to treat contracture.

**Definition of contracture:**
It means shortening of muscle or other tissues that cross a joint which results in limitation of joint motion.

**Types of contracture:**

**A. Reversible contracture:**

1. **Myostatic contracture:**
   It means significant loss of range of motion due to adaptive shortening, it occur particularly in two joint muscles such as hamstrings, rectus femoris or gastrocnemius. However there is no tissue pathology present.

2. **Scar tissue adhesions:**
   It means laying down scar tissue between normal tissues, which results in scar tissue adhesions.

3. **Fibrotic adhesions:**
   It means fibrotic changes of soft tissues as a result of chronic inflammation.

4. **Pseudomyostatic contracture:**
   It means limitation of motion due to hypertonicity caused by a central nervous system lesion.

**B. Irreversible contracture:**
It means a permanent loss of extensibility of soft tissues that cannot be released by non-surgical treatment.
In relation to burn, patients may be susceptible to different types of soft tissue tightness with varying times of onset (table 3).

**Table (3):** Timeline for development of various tissue tightness.

<table>
<thead>
<tr>
<th>Tissue type</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bum scar contracture</td>
<td>1-4</td>
</tr>
<tr>
<td>Intramuscular adhesions from bleeding</td>
<td>3-5</td>
</tr>
<tr>
<td>Tendon and sheaths</td>
<td>5-21</td>
</tr>
<tr>
<td>Muscle adaptive shortening</td>
<td>14-21</td>
</tr>
<tr>
<td>Ligaments and joint capsule</td>
<td>30-90</td>
</tr>
</tbody>
</table>

Burn patient's exercises especially stretching exercises are designed primarily to prevent the development of burn scar contracture and to avoid the deleterious effects of in-patient hospitalization. An understanding of the qualities of contractile and noncontractile tissues and their responses to immobilization and stretch will assist the therapist in selecting the safest and most effective stretching procedures for patients.
I. Passive Stretching:

While the patient is relaxed, an external force applied either manually or mechanically, lengthens the shortened tissues.

1. Manual passive stretching:
   - External force (intensity): applied by the therapist.
   - Speed: Slow.
   - Duration: Applied for at least 15, 30 sec but up till now there is no specific time has been determined to be the most effective duration for passive stretching.

   * The intensity and duration of the stretch are dependent on the patient's tolerance and the therapist's strength and endurance.
* Manual passive stretching is a rather short duration stretch. The gains achieved in range of motion are transient and are attributed to temporary sarcomere give (elastic changes in actin-myosin overlap).

2. **Mechanical passive stretching:**
- External force (intensity): 5 to 15 lb applied by pulley system cast or splint.
- Duration: from 20 to 30 min. or as long as several hours.

II. **Active inhibition:**

The patient reflexively relaxes the muscle to be elongated prior to the stretching maneuver. This type of stretching is only possible if the muscle to be elongated is normally innervated and under voluntary control.

**There are 3 variations of active inhibition techniques:**

1. **Contract - Relax (Hold - Relax):**
   * The patient performs an isometric contraction of the tight muscle before it is passively lengthened.
   * This technique depends on autogenic inhibition, the Golgi tendon organ (GTO) may fire and inhibit tension in the muscle so that it can more easily lengthened.

2. **Contract - Relax - Contract (Hold - Relax - Contract):**
   * The patient performs an isometric contraction of the tight muscle then relaxation followed by a concentric contraction of the muscle opposite the tight muscle as the muscle opposite the tight muscle shortens, the tight muscle lengthens.
   * This technique combines autogenic inhibition and reciprocal inhibition to lengthen a tight muscle.

3. **Agonist contraction:**
   * The term Agonist refers to the muscle opposite the tight muscle and antagonist therefore refers to the tight muscle.
* The patient dynamically contracts (shortens) the muscle opposite the tight muscle against resistance. This causes a reciprocal inhibition of the tight muscle, and the tight muscle lengthens more easily as the extremity moves.

### III. Self stretching:

The patient may passively stretch out his own contractures by using his body weight as the stretch force.

#### Indications of stretching:

ROM is limited due to
* Contractures
* Adhesions.
* Scar tissue formation
* Anticipated deformities.

#### Procedures for applying passive stretching:

1. **Evaluation of the patient:**
   - Detect the cause of decreased motion (joint stiffness or soft tissue contracture).
   - Evaluate muscle strength of muscle opposing tissue tightness.
   - Detect exposed tendon, dystrophic calcification, and IV lines.

2. **Preparation of patient for stretching:**
   - Detect the best type of stretching technique.
   - Explain the purpose of stretching to the patient.
   - Position the patient in comfortable and stable position that will allow the therapist to do the stretching technique properly.
   - Explain the procedure to the patient.
   - Ask the patient to avoid restrictive cloths.
   - Ask the patient to use relaxation techniques.
- Apply heat to tight soft tissue; heat will increase the extensibility of soft tissues.

3. Procedure of stretching:

   - **Hand placement:**
     * Grasp proximal and distal to the joint where motion is to occur.
     * The grasp with the palm of the hand.
     * The grasp must be firm but not to cause pain.
   - To avoid compressive force over the joint apply distraction force.
   - Move the extremity slowly through the free range to the point of restriction.
   - Then apply the stretch force in a gentle, slow and sustained maneuver, take the joint to the point of tightness and then move just beyond.
   - Hold the patient in the stretched position at least 15 to 30 sec. or longer.
   - If the tension under your hand decreases, move the joint a little further.
   - Gradually release the stretch force.
   - Ask the patient to rest then repeat the technique.

**N.B:**
* Don't attempt to gain the full range in one treatment session.
* To stretch 2 joint muscles, stretch the muscle at one joint at a time, then over all joints simultaneously until optimum length of soft tissue is achieved.

**Precautions and contraindications to stretching:**

A. **Precautions of stretching:**
1. Osteoporosis due to disease, prolonged bed rest, prolonged use of steroids and age.
2. After immobilization for long periods avoids vigorous stretching because the tissue looses its tensile strength.
3. Avoid stretching of edematous tissue, as it is more susceptible to injury than normal tissue.
4. Avoid stretching of weak m.s.
5. Avoid stretching exposed tendon because it is more susceptible to rupture.
6. Take care of IV lines during stretching.

**B. Contraindications of stretching:**

1. Bony block.
2. Recent.
3. Evidence of acute inflammatory or infectious process.
4. Sharp pain (acute stage of bum).
5. Evidence of tissue trauma.
6. When contracture is needed to develop stability.
7. Exposed joints.
8. Exposed tendon.
10. D.V.T
11. Compartment syndrome.
12. Fresh skin graft.
Evaluating a burn patient is an ongoing process requiring daily modification. This part describes the evaluation process for a patient having an acute major burn injury. A therapist should perform the initial evaluation as soon as possible following the patient's hospitalization, even though the activity surrounding the patient during this time may encumber the process.

The initial evaluation may be performed at the time of admission in the emergency room, during the initial wound care session, at bedside, or at the first wound dressing change. The first essential in treating a burn patient is to determine the severity of the injury in the individual and then to decide the level of expertise necessary to care for this patient.

**Goals of evaluation:**
1- To determine the patient's present status.
2- To identify the rehabilitation problems.
3- To anticipate the patient's potential problems by assessing all the necessary information available.

**Sources of information available to the therapist:**
1- Medical chart.
2- Physician
3- Nurse
4- Patient's family
5- Patient
6- Other member of burn team.
**Causes of deformity** (with burn cases)

1- Skin and soft tissue contractures  
2- Destruction of tendon and muscles  
3- Changes related to prolonged immobilization  
4- Orthopedic complications

**Components of an Evaluation**

1- **Patient demographic data**

These demographic data include patient's name, diagnosis, referring physician, medical record number, admission date, burn date, date of evaluation, cause of burn, date of initial physical therapy programs, and past medical history i.e. any previous or old injury or trauma or surgery or disease or deformity and or burn.

2- **Burn Severity Index:**

There are many factors that play an important role in increasing rate of mortality. These factors are the key indicators to project the amount or the level of severity of burn and the amount of therapeutic intervention that may be required for each patient. The factors are age-gender-burn wound assessment-respiratory status.

* **Age as factors of burn severity:**

There is a positive relationship between both extremes of age (young and old ages) and high rate of mortality. Children are more susceptible to scar contracture development because they are still under growth and their skin mature required a long time for healing. The older patients have decreased the ability to recover
from burn injuries when compared to adult patients due to reduction of fluids and decrease level of blood oxygenation after injury.

* Gender as index for burn severity:
  Burn injuries occur more frequently in males than in females. Males (men and boys) have a greater exposure to burn injuries due to occupational and social respects. Some studies have indicated that women are at risk to die from their burn injury than men for reasons not explained. Other studies also reported that women required more time to return to work than men for the same extent of burn. This gender difference may be due to factors associated with the burn injury such as cosmetic concerns.

* Burn wound assessment as index for burn severity:
  The primary components to assess burn wound are:
  
  a) Extent of burn injury:
  The total amount of the surface area of the burn has a significant effect on the development of scar contractures i.e. there is a linear relationship between the percent of body burn and the contractures developed, therefore the percent of total body surface is an index for severity of burn and rate of mortality.
  
  b) Depth of burn injury:
  The approaches of physical therapy interventions are based on the burn wound depth. Superficial partial-thickness burn wounds usually heal without scar contracture formation or/hypertrophic scar. These kinds of wounds heal within a few days to 2 weeks. Deep partial thickness burns represent a major challenge to the therapist due to rapid formation of scar tissue contractures. Moreover, full thickness burn injuries lead to an increased incidence of lost motion and scar contracture formation, this concept results in rate of severity and mortality.
c) Location of burn injury:

The anatomical sites and locations are important key to anticipate contracture development. Some studies found that the skin crease overlying the surface near to the joint is susceptible to development of scar tissue contracture.

* Parameters contributing to scar contracture formation:
  1- Length of hospitalization.
  2- Ventilator dependence.
  3- Intensive care length stay.
  4- Number of skin graft operations.
  5- Percent of hospitalization spent in ICU.
  6- Number of joint surface area requiring skin grafting.
  7- Amount of septic or / bacterimia.
  8- Number of anatomic area splinted.

d) Respiratory status:

The burn severity index associates inhalation injury with high mortality, i.e. patients with extensive burns and associate, with inhalation are confined to bed or are less mobile and are at greater risk to die (high mortality rate).

3- Edema and Limb Circumference Assessment:

The techniques of tissue edema evaluation are:

* Tape measure form
  The selected tape measure circumferences can be used as an objective means to record changes in edema formation.

* Water displacement method
  This method is used to assess formation of edema in patients with an acute burn injury especially hand or foot burns This measurement technique requires the patient to place the limb (hand or / foot) in a dependent position.

* Wring method techniques
  This method can be used with a notable increase in the neck size, along with some signs of circulatory compromise.
4- Sensory assessment:

It is the testing of cutaneous sensation by using pin-pricking technique.

**a. Sensory assessment for burn injury cases only**

<table>
<thead>
<tr>
<th>Second degree burns</th>
<th>Third degree burns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin pricking can be used to assess cutaneous sensation</td>
<td>Pin pricking can be used to help the depth of burns.</td>
</tr>
</tbody>
</table>

b- Sensory assessment for burn cases associated with spinal cord injury:

The spinal cord injury may be due to an auto-accident or fall while escaping the fire. These cases require an extensive sensory evaluation (complete sensory assessment).

5- Range of Motion Assessment:

The main standard indicator to assess and measure joint range of motion with burn cases is goniometer. With burn cases, the main causes of the limitation of range of motion are pain, edema, and inelastic eschar.

6- Muscle Strength Assessment:

There are two types of manual muscle testing: (1) Gross m. testing, and (2) individual (specific) m. testing. If a burn patient functioned at a normal level before the injury, the gross muscle testing may be required. On the other hand, the specific muscle testing should be considered in cases of severe edema and electrical burn injury. The main causes of nonphysiologic decrease in muscle strength are: (1) Pain. (2) Edema formation. (3) Anxiety.
7- Endurance Assessment:
A patient's aerobic capacity is directly affected by consequences of burn injury such as prolonged bed rest and immobilization, rather than as a direct result of burn injury unless an inhalation injury is present.

8- Ambulation Assessment:
Permission for a patient's ambulation after burn injury is a medical decision. Lower extremity burns are major obstacles that may interfere with ambulation, also the location of the burns may inhibit ambulation especially when the planter aspect of the foot, Achilles tendon area or popliteal space is involved. Deviations in gait patterns are related primarily to pain.

Factors that Influencing Ambulation:
1. Mental status of the burn patient should be alert and able to follow simple directions.
2. The patient's vital signs of blood pressure and pulse rate should be stable and within range of criteria.
3. Formation of massive edema can be a contraindication to ambulation due to increased compartment pressures and potential episodes of hypotension.
4. Presence of inhalation injury requires good measurable oxygenation; this case is on ventilator and may be confined to bed.
5. Patient's ability to tolerate pain with activity.

9- Functional Activities Assessment:
Technical protocols or / step to achieve functional assessment are:
* Hand dominance should be recorded for functional and patient self assistive assessment.
* Therapist should know the patient's previous daily living routine to play an important role in planning appropriate treatment and hospitalization progresses.
* Work, leisure times activities, school level and personal interests should be involved in the treatment program.
* The accomplishment of basic task such as feeding, grooming and personal hygiene adds to patient's feeling of progress and self-worth.
* Assistive devices may be required to complete these functional activities.

**Evaluation of functional activities:**

It includes the following items:

1. Brush the hair.
2. Sweater over head.
3. Wash the face.
4. Brush the teeth.
5. Nose-finger pattern.
6. Wash the upper part of the ipsilateral scapula.
7. Wash the upper part of the contralateral scapula.
8. Carry a grocery bag.
10. Feeding and grooming activities.
11. Work and leisure time activities.

**Measurement of wound Surface Area**

**Methods of Measuring WSA (Burn size)**

Methods of measuring the wound surface areas (WSA) can be divided into invasive and Non-invasive.

**A. Invasive method:** Used by doctors, it may include:

- Microbiology (micro-orgasmic analysis)
b- Serum analysis (measurement of collagen protein) (procollagen peptide 3 (ppIII))
c- Surgical method.
d- Taking of blood sample.

B. (Non-invasive method): It may include
   a- Photo instrumentation.
   b- Observation of wound contractor
   c- Doppler (laser Doppler)
   d- Physical therapy methods

Physical Therapy Methods:
Several methods of documenting wound size have been reported
a- First method that used photographs of the wound pictured in conjunction
   with some linear reference standard. Such photographs which are two
   dimensional and uniplanar, may produce considerable distortion of three
   dimensional multiplanar wound surfaces.

b- A more common method of documenting wound size is the manual
   measurement and description of the general dimensions of a wound.
   Documenting wound healing may be incomplete without such a
   measurement. Particularly when wounds are irregular.
   Some investigators have documented measuring wound surface areas. They
   used 4 methods:
   a- First method calculated surface area by multiplying the dimensions of the
      wound. The product of the two dimensions of a wound can serve as an
      accurate indicator of wound surface area only if a wound is rectangular
   b- Second method focused on practiced by physiotherapist that entailed tracing
      ulcers on transparent paper. Placing the tracing over metric graph paper and
      counting the number of square centimeters within the tracing.
   c- Third method questioned the ability of observers to delineate the edge of the
      wound particularly when transparent paper was placed over it. They preferred
to take photographs of open wounds and to use a planimeter to determine the wound area from the photographs.

d- Fourth method also used photographs as a basis for determining wound surface area. After projecting photographs onto paper, the examiner cut the wound's shape from on outline he had made on the paper. By weighing the shapes, he is able to document the extent of healing. They multiply the width maximum length $2 \times 4 = 8 \text{ cm}^2$

**Disadvantage:** This method is not accurate because the surface area may be changed.

**BOHANNON method 1983:**

This method can be achieved through the following steps.

Tracing were made by placing sterilized transparency film over the wound and tracing the wound's perimeter (wound edges the border between the wound" floss and peripheral epithelium) on the film with a fine tipped transparencies.

**N.B.:** Both the film and the marker were the type used to make overhead transparencies. The tracing of the wounds were carefully cut from the transparency film, the weighing procedure involved weighing of the tracings on gramatic balance.

The counting procedure entailed tracing the outline of the tracing on metric graph paper and counting the number of square millimeters with in the tracing

\[ W.S.A = \frac{\text{weight of tracing}}{\text{weight of } 1 \text{ cm}^2} \]

**Disadvantage:**

1- Distortion of wound surface
2- It is subjective method, there is some variations between the persons determination of wound edges.

**Wound Size Measurement**

1- **Digital analysis of slides method:**
Measurements of wound surface area (WSA) were conducted before the first treatment and after every fifth treatment for 20 days at each measurement session; three 35 mm color slides were taken at a distance of 27.9 to 30.5 cm (11-12 inch) with a metric ruler taped next to the ulcer. The WSA values for the three slides from each measurement session were averaged giving each patient one average WSA measurement for days 0.5, 10, 15 and 20 the same person conducted all WSA measurements to obtain measurements of WSA, each slide was projected on to paper and because adjusted so that the metric ruler measurements on the slide corresponded with a superimposed ruler identical to the one in the slide. At each measurement session, a tracking of ulcer on to a clear transparency was made using a permanent felt-tip pen. The tracings were used for immediate feedback to patients. Concerning ulcer size. The feedback was conducted in a standardized way to avoid bias. The ulcer perimeter was carefully traced and then transferred to a table digitizer with a stylus pen; the area (in square millimeters) was calculated using generic CAAD 3.5 software program interfaced with an IBM.

To obtain reliability of measurements obtained with this method. The investigator performs a test retest study of six pressure ulcers before the study began three slides were taken of each ulcer and the procedure was repeated often an hour. An analysis of test retest measurements was conducted using an interclass correlation (icc) coefficient with an obtained value of 0.99 to further verify consistency of procedure of tracing slides and digitizing the analysis to 11 patients slides was repeated on a subsequent days comparing measurement between the two days and (icc) was obtained therefore the wound surface over measurements to be reliable

2- Wound size was measured immediately after each treatment by using a transparent hole template with concentric circular marking. The template was placed over the wound and the circular ring nearest to the size of the wound was noted. The resolution of the template was 1.58 mm. This process was repeated a minimum of 3 times for: each measurement with the value
obtained two or more times being reported. The some persons performed all measurement and were blind with respect to the animals treatment assignment Majesick (1992).

A) Modification of the Tracing Method:
Some observers use graph paper divided into millimeters, the wound trace is placed on the graph paper and count the squares to obtain the rewound surface area
N.B.: To avoid sliding of the transparent put the transparent then white paper then carbon paper then graph paper and determine the shape of the wound by using blind end pen which is printed on the graph paper finally count the number of suppers which is equal to the wound area.

B) Measurement of inter and intra tester reliability: by Majesick. Inter tester reliability between the tester and on there testers intra tester reliability: The same result between the test and himself,
1) Measurement of intra tester reliability:
   Computer 98%  Tape 93%  Graph 97%
2) Inter tester measurement:
   Not less than 96% tester can use 4 methods (tracing-scanner-maximum width-tap measurement)
   The 4 methods have good inter and intra tester reliability but by using ANOV A they found significance difference between tape measurement and other so its accuracy is weak.

Measurement of wound volume

During measurement of wound volume we deal with 3 dimensions width, depth and length. Aims of measurement the wound volume
a. To measure the progression of wound healing
b. To calculate the volume rather than the surface area (in chronic and deep wounds).

**Methods:**

1. **Burg technique (1990)**
   This method is performed by using saline and calculate its volume.
   **Disadvantage:** it is difficult to follow this method if the wound in a position like ischial region

2. **Condon gauge (transformer) Technique:**
   A small gauge (instrument) enters the wound and measure the 3 dimensions (depth - width - length)

3. **Dental impression material:**
   Some materials are saluted in water, silicone and rubbery material and infected into the ulcer and wait until it dries from 1 to 2 minute then remove it. It will provide negative stump. Fill the stump with wax +ve stump volume of wound.
   **Disadvantage:** This method can't be used in wound with sinus

4. **Disposable tape method:**
   The maximum depth of the wound or ulcer was recorded by placing the disposable measuring tape directly into the deepest part of the wound.

5. **Alginate method:**
   Wound volume W.S.A depth
   This method is performed by using powered material when it puts in water it change to rubber material.
SKIN GRAFTS AND FLAPS TREATMENT

Definition:
- **Skin graft**: It is nonvascular skin transfers may be divided into two groups.
  A) Split-thickness skin graft.
  B) Full-thickness skin graft.
- **Flap**: It is a portion of skin and/or subcutaneous tissue and muscle that contains its own vascular supply. Thus survival of tissue does not initially depend on the status of the vascularity of the recipient bed.

I. **Classifications of flap**:
1. According to donor site:
   a) Local       b) Distant
2. According to tissue transferred:
   Skin, subcutaneous tissue, fascia, muscle, and bone.
3. According to nature of blood supply:
   Non vascular skin -transfers
   a. Split-thickness skin graft.
   b. Full-thickness skin graft.

III. **Free Vascularized Tissue Transfer**:
   Non vascular skin transfers:
   Skin grafts
   **Definition**
   - Grafting is the closure of a burn wounds with skin tissue. The closure may be temporary or permanent depending on the tissue chosen.
   - Also defined as non vascular skin transfer may be divided into two groups.
     A) Split - thickness skin graft.
     B) Full - thickness skin graft.
**Indications for Skin Grafts:**

1) **To achieve temporary cover**
   A) To close an open wound  
   B) To prevent infection  
   C) Hasten initial healing  
   D) And prevent exposure of underlying structures  

2) **For definitive cover:**  
   A) To provide permanent skin durable replacement.  
   B) To resurface areas of scarring or contracture.  

**Types of skin graft:**

1. **Auto graft:** It is skin transferred from one area of the body to another. This should provide permanent cover.  
2. **Allograft (homograft):** It is skin from another human (possibly a cadaver) is used. This provides only temporary cover until an autograft is available.  
3. **Xenograft (heterograft):** This uses animal (e.g.) pig skin or porcine and is also only a temporary cover (donor-site).  

**N.B.**  
- The patient’s immune Response which induces the reaction of the allografts this approach solves this problem.  
- The benefit of combined use of allograft, and autograft epidermal cultures in therapy of burns lead to decrease in Hospital reduction in patients suffering more extensive burns, and increases the survival rate of extensively burned patients.  

* The most common way to close a deep burn wound after removal of eschar is with the use of **(non vascular skin transfers)**  

**A) A split-thickness skin graft (STSG):**

- Include the epidermis and any portion of the dermis.  
- The Donor sites of the split thickness skin graft are generally obtained from
the thigh, buttock, or abdomen.

**B) Full thickness skin graft (FTSG):**
- Includes the epidermis and entire dermis.
- Full - thickness skin grafts are usually taken free - hand. All subcutaneous fat is removed from the dermis to improve the survival of the graft.
- The Common donor site includes the groin and the medial aspect of the arm because the residual scar is hidden.

**Advantages of non vascular graft:**
1- Include a large supply of donor areas.
2- Ease of harvesting.
3- Reusable donor sites.
4- Decreased primary (early) contracture.
5- And the ability to cover large surface areas.

**Disadvantages of non vascular graft:**
1- Bad cosmetic appearance (to full thickness grafts).
2- Decrease durability.
3- Hyper pigmentation.
4- Increase secondary (or late) contracture.

**N.B.**
(1) The split thickness graft undergoes secondary (Late) contracture when it contracts as it heals, pulling the wound margins inward.
(2) Both Types of grafts can be held in place with sutures, staples, or tape.
(3) Meshing the graft is helpful in improving survival where moderate serous drainage is expected.
(4) Where grafts may be exposed to shear forces, “tie - voer” dressing are useful.
(5) Donor Site: Skin harvesting from the scalp in children can be recommended
as first choice. The Advantages, especially the rapid epithelialisation and the lack of visible scars, over come the problems and the risks (Gyger et al., 1996)

**Healing of skin Grafts:**

The healing skin grafts can be divided into three phases.

1. **First phase:** the phase of serum imbibition begins immediately, after placing the graft on the wound bed. Because there are no vascular connections, nutrients fluid supplied by diffusion of serum from the bed. The graft is held in place only by weak fibrin and fibronectin bonds.

2. **Second phase:** at 24-48 hours new capillaries start invading the skin graft making the phase of revascularization.

3. **Third phase:** the phase of organization starts at 4-5 days when collagen linkages are made between the wound bed and the graft to create firm attachments.

**Factors Affecting Wound Healing:**

1. **Age:** affects wound repair. The rate of healing appears to slow with increasing age.

2. **Infection:** infection lead to healing failures.

3. **Nutritional factors:** nutrition is of extreme important factor for wound healing.

4. **Vitamins:** vitamins are important for normal tissue repair as vitamin C, A, E, B, (Thiamine) and B2 (pantothenic acid).

5. **Trace elements are metals:** that are needed for enzyme function.
   - As iron, zinc, copper, manganese calcium, and magnesium.
   - Shortages in trace elements may contribute to impair healing.

6. **Oxygen:**
   - Adequate blood supply is essential for healing.
Oxygen is required to supply the energy for high metabolic needs healing wound.

-Poor vascularity essentially translates into hypoxia.

7. **Diseases causing impaired wound healing:**

- Diabetes altered healing.
- Chronic renal failure and liver failure lead to impaired healing.
- Malignancy leads to healing abnormalities.

8. **Other causes of impaired healing:**

- Steroids drugs altered healing.
- Chemotherapy agents lead to impair healing.
- Radiations
- Drug that alter immune system

**Complications of skin grafts:**

- Wound problems due to grafting on an inadequately prepared or unsuitable bed.
- Avascularity.
- Infection.

**Graft problems:**

**Early:**

- Failure of take due to inadequate contact between graft bed.
- Inadequate fixation (shearing)
- Haematoma
- Failure of take/graft lysis due to infection

**Late:**

- Avoidable scarring/contracture
- Excessively expanded mesh graft
- Graft margins crossing anatomical segment & trophic ulceration/trauma
- Graft insensate
- Graft too thin for permanent cover

**Donor Site Problems:**

- Failure to heal
- Infection

**Physical therapy treatment for skin grafting patients stages of treatment:**

1. Pre-grafting stage (pre operative stage)
2. The grafting and post-grafting stage (Immediate postoperative stage).

**A) Pre-Grafting stage:**

This stage begins as soon as the patient is admitted to the hospital until the patient is taken to the operating room for skin grafting.

**The Goals of Physical Therapy Treatment:**

1. Maintenance of a good air way.
2. Reduction of edema.
3. Prevent structural damage
4. To prevent contracture and deformity.
5. To maintain ROM, strength of good functional positions to keep patient as active and independent as possible.
6. To prevent infection.
7. To investigate understanding of emergency procedures.

**Methods of Treatment:**

1. Breathing Exercises
2. Elevation
3. Positioning
4. Splint
5. Passive exercises
6. Strengthening exercises
7. Functional ex’s, gait training exercises.

**B) The grafting and post-grafting stage:**
The Goals of physical therapy treatment)
1. To prevent structural damage of dry grafted skin/ donor site / third 4 burns that lack sensation.
2. To reduce edema.
3. To prevent infection.
4. To prevent scar formation of grafted skin.
5. To avoid contracture and deformity.
6. To decrease ROM and strength of the muscles.
7. To improve functional activities and walking.

*Physical therapy treatment post operative skin graft:*
1. For 4 or 5 days post operative the graft are usually left undisturbed.
2. The fifth post operative day when the graft is noted to be surviving dressing changes with non adherent gauze arc instituted.
3. The seventh to tenth post operative day the healing graft is will vascular gentle range of motion exercises (passively)

**N.B.:**
It may be advisable to exercise without dressings during this phase of healing because a dressing that slips or rubs may harm rather than protect the healing wound.
4. Elevation is used to control edema.
5. Usually by about 2 weeks postoperative the graft will be pink and adherent over its area and the graft appears to have taken well (compression wraps are applied).
6. The early use of pressure garments.
   a. By 2 weeks post operative with consulting the treating physician.
b. Care must be taken in application to prevent shearing forces.
c. If commercial pressure garments are used, Zippers are helpful.
d. Pressure garments should not be prescribed until edema is decreased, because a decrease in edema will decrease the garment’s ability to apply firm Pressure over the grated area.

7. Splint may be applied over the pressure garment to maintain the grafted part in its maximally lengthened position.

8. In the later stages of healing (3 to 4 weeks post operative) after the wound is closed, gentle massage is used, with a topical, lubricant. To keep the skin pliable, to mobilize the skin and underlying scar.

9. Positioning: according to the site

10. Five weeks after grafting, some recovery of Sensation may be noted and continues to improve.

11. When there is complete recovery of sensation it start
   A) Ultrasound: To improve circulation and to separate collagen fibers which from in the scar.
   B) Followed by cold application or hydrotherapy to gain relaxation.
   C) Then we apply active stretch followed by prolonged passive stretch and should be graduated until 20 minutes.

12. Functional exercises then gait training.


**N.B.**
Advices the patient should be caution against exposure of either graft donor or recipient sites to the sun for at least 6 months. Pressure garments and sun screens are helpful in protecting the graft from exposure.
Management of donor sites

1. Split thickness skin graft donor sites:
   A) Application of pressure garments to prevent hypertrophic scar.
   3) Massage with a topical lubricant after (5 - 10 days of epithelialization has occurred)

2. Full thickness skin graft donor sites
   A) Sutures are removed at (7 to days).
   B) Massage may be initiated 2 to 3 days after, suture removal to help soften
   C) Application of pressure garments.
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