# Chapter 2. Literature Survey

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CHAPTER 2
LITERATURE SURVEY

This chapter discusses different phases of wounds, assessment of wound and various types of tissues with their colours specifying the severity of the wound. Related research papers deals in the assessment of the wound by various methods like contact and noncontact, personal and remote observation were analysed. The other set of related papers which involves dependency of healing process of wound with varying types of skins were also analysed.

2.1 Phases of Wound Healing Process

The process of wound healing is a very delicate, complicate and systematic one as observed by the Wound Healing Society (WHS) and yields a function of automatic continuity. The wound healing process is a combination of events like starting with injury and ends with the formation of healthy tissue. The normal repair process and the parameters affecting were very well understood by the wound management and the wound healing process involving in a chain of overlapping phases.

There are four set of actions employed in normal wound healing process [16]. The first phase is Vascular Response (Hemostasis) in which blood vessels are helping the bleeding to stop irrespective of the blood source of injury called as vasoconstriction from which clotting of process starts and the beginning of wound formation starts within
minutes after tissue damage. The second phase is Inflammatory Response (Inflammation) in which human body’s projective system works against the damaged wounds.

In this phase, neutrophils, monocytes, leukocytes, macrophages and cell membranes are working to convert wounds into edema. The third set of action namely the active growth and proliferative phase of the healing process granulation and epithelialization constitutes overlapping of collagen deposits, granulation, wound contraction, angiogenesis and tissue development.

The fragile nature of the tissue helps in its regrowth, and the cells begin to differentiate into various layers of epidermis. The scar generally in the initial stage will be dark red in colour, thick due to pressure blanching out. The process in which the scar remolds and regains scar tissue of about 66% of its original strength and the replaced scar tissue will never be as strong as the original one is the fourth phase known as Maturation Phase or Reconstruction phase.

2.2 Wound Assessment

Age old practical method of assessing a wound looks for altogether different skills, knowledge and components. Precise wound assessment is very much required to plan appropriate realistic goals and interventions for the wounded patient. It is very much essential for a systematic consideration of various components that the assessment process posses. The process of wound assessment requires a range of skills and knowledge including, knowledge of relevant anatomy and physiology, the ability to identify factors that
may interfere with normal wound healing, the ability to collect objective and subjective data, the ability to analyse and interpret the information that has been gained, the ability to identify the patient’s problems and needs a thorough discussion.

### 2.2.1 Components of the wound assessment process

During the assessment period of a wound the following four points needs to be classified.

a. The position and aetiology of the wound.

b. Estimating wound scaling using an objective grading tool.

c. After the above estimation identification of the very first objective required in the treatment process.

d. Regimen required achieving the required treatment objectives.

The ten point guide listed below details about the appropriate wound assessment approach.

#### Classification of the wound

Even though there are number of wound types, only four are considered as main groups

a. Mechanical group such as surgical and traumatic wounds.

b. Chronic type because of pressure ulcers and leg ulcers.

c. Burns due to chemical or thermal which are further classified based on the depth of the injury.

d. Malignant like melanomas and also known as basic fundamental or primary lesions.
At the start of the wound healing process all the wounds are defined to be acute and are expected to progress normally without much of hinderence. But if the wounds get fixed in one of the major healing phases for a longer period for more than 40 days then it can be considered as chronic type of wound.

➢ **Information that assists wound assessment**

Holistic, systematic and evidence based approaches are very much required in the process of wound assessment. Laure Ritte et. al. have suggested that basic assessment on existing materials and methods can be used for nursing models [51, 67, 68, 71]. The general health, local wound environment and wound management are the three area which may delay the process of wound healing, hence this assessment framework explained in detail in this thesis should help us to identify the factors which are causing the delay. Inclusion of age, social and care environments psychological perspectives, nutrition, diagnosis medical and associated disease processes, medical interventions like drug therapy and wound history is known as the general health.

➢ **Information required to assess a wound**

It must help us in indentifying the following parameters where assessment process using a wound assessment tool is conducted.

a. The number of wounds and their location in the body.

b. By using or not using the numerical grading tools colour and scale identification of the wound.
c. The wound size in terms of length and breadth can be found out by using a plastic ruler which should be free from inflection and then approximated from a tracing paper in a proprietary measuring grid.

d. The nature of wound fluids such as exudates or serious or pus.

e. The reasons, type and severity of wound pain. The wound pain is caused due to number of reasons which can be determined by using a pain assessment scale.

➢ **Additional techniques that can inform the assessment process**

The aetiology and extent of the wound under assessment which are invisible often will be known clearly by adapting suitable technology. During the process of differential diagnosis for the leg ulcers, Doppler ultrasound, Duplex scanning, Photo Plethysmography (PPG) activities may be performed.

In the assessment of the pressure ulcers, sinuses and dehisced wounds, the Doppler ultrasound, Sinography, and any other investigations such as computerized tomography (CT) or magnetic resonance imaging (MRI) may be utilized. The computer based assessment system which a non invasive tool can be used to a greater extent in the objective measurement of all types of wounds since they are capable of assessing the maximum dimension wound, its depth and volume of the wound.
Assessment of the surrounding skin

The different types of skin such as macerated, erythematous, excoriated, and indurated should be identified by the following assessment process.

a. Erythema – the change in the quality or nature of wound fluid because of infection, redness of the skin as a result of hyperaemic response due to the presence of micro-organisms which are either non multiplying (colonisation), or micro-organisms present in the local tissue leads to added host reaction.

b. Excoriation – whenever more wound fluid in the upper layer of the epidermis gets removed due to the prolonged exposure of the skin to toxins.

c. Induration is a texture change rather than the skin colour and makes it to be hard and less supple.

d. Maceration- this type of skin occurs due to the excess moisture present in the skin caused due to water logging.

Identify primary treatment objectives

The primary treatment objectives are identified based on the signs and symptoms. The practically possible goals are as listed below.

a. Wound cleansing – it is required to find whether the wounds needs cleansing and if yes then using what? In general the wounds should be cleaned with normal saline,
except some chronic wounds periodic cleansing is not essential for wounds which are already clean.

b. The objective Debridement or desloughing can be carried out using various methods which includes mechanical by a sharp debridement, autolytic, because of rehydration of the tissues, enzymatic, or biosurgery known as larval therapy.

c. Keeping exudates under control.

d. Oozing of blood i.e., the bleeding control.

e. Reduction of effects caused by infection.

More than one objective listed above are involved but optimization of the patients potential is the primary objective.

➢ Achievement of the planned outcome Interventions

The below uses are included in the interventions.

a. The alginates, enzymes, foams, films, hydrocolloids, hydrofibres and hydrogels are known as interactive wound management materials are aiding for development and maintenance of the optimum healing environment.

b. Active wound management materials are the phenomenon which includes growth factors like epidermal growth factor (EGF) or platelet-derived growth factor (PDGF) responsible for the stimulation of the healing environment.

c. Latest technologies like hyperbaric oxygen therapy, low level laser therapy and topical negative pressure.
d. Complementary therapies are used for the better understanding of rationale.

As soon as the primary objective is achieved, it is required to repeat the assessment to identify the next immediate objective and so on till the wound is clean.

➢ Documentation

This is very much required as a record of the best practice during its writing, and as a most important communication tool which can be accessed by all professionals involved in the patient’s wound management. Using unambiguous terms, documents are required to be done for all the components of the assessment process. Since the formal assessment charts focus the assessment process it can be used and there are many examples available to substantiate.

➢ Photographic records

Before any photographic record is received, it is important to set its goal. If ‘no’ is the answer for all the following questions then the necessity of the photography could be debated.

a. Is it for record maintenance and gathering information for the assessment of anticipated progress of wound healing?

b. Is it essential just to add in a case report file since the patient has been appointed into a clinical evaluation or trial in the research?

c. Is it to recall the history of the healing process in future since the wound is unique or rare in type?
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➢ **Patient information**

This should be in an easily available form since all the patients or any individual will be in need of various information during and post processing of the wound management.

**2.3 Classification of Tissues Based on Colour**

Once the various factors involved in the analysis of the wound healing process are considered, there is a requirement to analyse various types of tissues present in a wound formation. Damage of tissues in various layers of skin forms a wound can be identified in a wound by analysing the severity of the wound through non-contact methods using colour image processing techniques and filtering, segmentation, and classification of wounds based on various parametric issues like area of the wound by measure framework. Table 2.1 shows the types of tissues present in the wound Images [15, 27, 28] and table 2.2 shows the colour description of tissues seen in wound images. Table 2.3 presents the various items to assess the wound and its degeneration strategies [18].

**Table 2.1: Types of tissues**

<table>
<thead>
<tr>
<th>Sl.NO.</th>
<th>Tissue</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Necrotic tissue</td>
<td>Non-viable tissue without the flow of blood. Ex: Slough(Yellow, green, gray, lighter, thin wet, stringy), Eschar (black, brown, grey, darker, thicker, harder)</td>
</tr>
<tr>
<td>2</td>
<td>Epithelial Tissue</td>
<td>Outer most layer of the skin, deep pink to pearly pink, close the wound</td>
</tr>
<tr>
<td>3</td>
<td>Granulation</td>
<td>New tissue that replaces the dead tissue.</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Tissue</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4</td>
<td>Hyper Granulation tissue</td>
<td>Forms above the surface and delays the process of epitheliazation</td>
</tr>
<tr>
<td>5</td>
<td>Muscle tissue</td>
<td>Pink to dark red. Highly vascularised (richly supplied with blood), Striated (striped, grooved or ridged)</td>
</tr>
<tr>
<td>6</td>
<td>Tendon</td>
<td>Attaches muscle to bone. Shiny when healthy</td>
</tr>
<tr>
<td>7</td>
<td>Fascia</td>
<td>Covering over muscles. Shiny, white</td>
</tr>
<tr>
<td>8</td>
<td>Bone</td>
<td>Shiny, smooth</td>
</tr>
</tbody>
</table>

Table 2.2: Colour Description of tissues

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Wound Base Colour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beefy red</td>
<td>Healthy tissue, good blood flow</td>
</tr>
<tr>
<td>2</td>
<td>Pale pink</td>
<td>Poor blood flow, anemia</td>
</tr>
<tr>
<td>3</td>
<td>Purple</td>
<td>Engorged, swelling, high bacteria levels, trauma</td>
</tr>
<tr>
<td>4</td>
<td>Black</td>
<td>Non viable necrotic tissue</td>
</tr>
<tr>
<td>5</td>
<td>Brown</td>
<td>Non viable necrotic tissue</td>
</tr>
<tr>
<td>6</td>
<td>Yellow</td>
<td>Non viable tissue, slough</td>
</tr>
<tr>
<td>7</td>
<td>Green</td>
<td>Infection, non viable tissue</td>
</tr>
<tr>
<td>8</td>
<td>White</td>
<td>Macerated, poor blood flow</td>
</tr>
</tbody>
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Table 2.3: List of items and their assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Assessment</th>
</tr>
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| 1. Size | 1 = Length x width <4 sq cm  
      | 2 = Length x width 4<16 sq cm  
      | 3 = Length x width 16.1<36 sq cm  
      | 4 = Length x width 36.1<80 sq cm  
      | 5 = Length x width >80 sq cm |
| 2. Depth | 1 = Non-blanchable erythema on intact skin  
      | 2 = Partial thickness skin loss involving epidermis  
      | &/or dermis  
      | 3 = Full thickness skin loss involving damage or  
      | necrosis of subcutaneous tissue; may extend down to  
      | but not through underlying fascia; &/or mixed partial  
      | & full thickness &/or tissue layers obscured by  
      | granulation tissue  
      | 4 = Obscured by necrosis  
      | 5 = Full thickness skin loss with extensive  
      | destruction, tissue necrosis or damage to muscle,  
      | bone or supporting structures |
| 3. Edges | 1 = Indistinct, diffuse, none clearly visible  
      | 2 = Distinct, outline clearly visible, attached, even  
      | with wound base  
      | 3 = Well-defined, not attached to wound base  
      | 4 = Well-defined, not attached to base, rolled under,  
      | thickened  
      | 5 = Well-defined, fibrotic, scarred or hyperkeratotic |
| 4. Under-mining | 1 = None present  
|                | 2 = Undermining < 2 cm in any area  
|                | 3 = Undermining 2-4 cm involving < 50% wound margins  
|                | 4 = Undermining 2-4 cm involving > 50% wound margins  
|                | 5 = Undermining > 4 cm or Tunneling in any area  
| 5. Necrotic Tissue Type | 1 = None visible  
|                    | 2 = White/grey non-viable tissue &/or non-adherent yellow slough  
|                    | 3 = Loosely adherent yellow slough  
|                    | 4 = Adherent, soft, black eschar  
|                    | 5 = Firmly adherent, hard, black eschar  
| 6. Necrotic Tissue Amount | 1 = None visible  
|                  | 2 = < 25% of wound bed covered  
|                  | 3 = 25% to 50% of wound covered  
|                  | 4 = > 50% and < 75% of wound covered  
|                  | 5 = 75% to 100% of wound covered  
| 7. Exudate Type | 1 = None  

Different image processing methods based on digital techniques to perform the wound healing assessment have been proposed in this study in which the dragging of mouse around the wound edge in order to select the region of interest has to be carried out by a computer operator. With the help of a structural light pattern which is a non-contact wound measurement system was put forth by Thomas A
Krouskop et. al. [82] to calculate the area and debrided wound. However this system is not easily portable, more of complexities requires calibration for each set up using specialized devices. Constant effort was put to use the colour image processing for an automatic and quantitative analysis in the process of skin wound healing [68, 87].

By measuring the amount of different types of wound tissues present in the area of the wound the assessment of healing process is carried out. Alternate method of healing measurement is the measure in shift from black to yellow necrotic tissue to reddish granulation tissue. Herbin. F et. al. [31] used a method of choosing the HSI and the RGB chromatic system of colour representation to derive a colour index for the identification and analysation of wound finds its application in healthcare to monitor the healing of the wound to decide on the course of treatment. It is also used in research to study the drug efficiency or the radiation effects. The change in the surface area of the wound is used to demonstrate the effect of a new drug applied [83]. The healing process is a set of phases which can be visually assessed by an observer restricted to qualitative terms only. The wound measurement is carried out manually by tracing the boundaries of the wound an then calculating its area. This is very cumbersome and error prone activity.

Nila B Mankar et. al highlights that the commonly used area based parameters, the absolute change and the percentage change in area are biased by the differences in wound size [62]. Therefore, a
linear parameter using the area and perimeter measurements is recommended which can be applied on wounds of any shape and size. But in this article, healing is considered as a progress of wound margin along the skin surface. The possible growth of the skin within the wound region is not at all considered here. Zheng H Bradley et al. compares the various surface measurement methods in terms of accuracy, precision, ease of its use, time consumption, cost, availability and the amount of training involved [91].

The automatic and accurate measurement is very difficult due to the vast changes in colours which are normally observed in wounds. When the wound is deeper and depends on the angle of the camera position may be formed in the wound area. Hence it is very much essential to clean the wound before commencing the acquisition of the wound image. During this process of cleaning, slight bleeding is also possible. This can also change the colour of the wound area. Some wound care materials can also cause few changes in the colours of the wound tissues. These are the reasons which might cause failure of automatic methods [8, 62, 63] of evaluating the wound condition. In some cases, along with the area contraction, healing process may also involve skin growth from within the region. In such cases, measuring the area or perimeter [82, 86, 92] alone does not give the correct result.

The measurement of volumetric wounds are an important factor for deep wounds and the techniques adopted are using casts and the
computer vision based structured light and filling the lesion with saline. However the second technique is filling the lesion with saline demands constantly the wound healing and it is not acceptable technique. On the other hand the first technique i.e., the computer vision method is more acceptable but requires the state of the best setup of the wound measurement. The ratio of the wound area to volume is correlatives and precise precision in this method. Small and deep wounds can be measured with better precision than large and shallow wounds [8, 68]. This thesis is limited to design and development of a technique to measure accurately the wound size in two dimensions without including the wound depth feature. Hence the technique is useful for measurements where depth of information is not a critical parameter.

Various parameters like patients health condition, wound location, supply of blood, response of the patient to the dosage of the drug are the numerous factors of the wound healing process making it a complex process. Hence it is difficult to make a worth full comparative study of healing assessment in usual clinical practice. However for research purposes, a wound is made as a healthy subject and the course of healing is studied. In such cases, it is required to carefully choose the patient to see the parameters like the location of the wound, the health conditions and the size or shape of wound whether they are the similar among all the patients.

The precise assessment of wound needs lot more information than just the wound size [14, 70]. The very vital wound factors that
should be taken into account in the assessment and management of chronic wounds are dimensional measurements (length, width, depth, & area), Exudate (quantity & quality), Physical appearance (wound bed, including tissue type & amount), Suffering (pain type & level), undermining (presence or absence), repetition of evaluation (monitoring of all parameters regularly), and edge (condition of edge and surrounding skin). Hence, for more accurate results and to handle all the above mentioned conditions the user inputs are provided, so that the measurements gives accurate results.

Wound images are captured using a CCD camera, with a white piece of paper of known area placed along the wound for the purpose of size and colour. During calibration, the reference object in the image is clicked and the area of the reference object in the image is entered in the unit square millimeters. This is used to calibrate the image for size and colour. The image is median filtered to eliminate the hair on the skin, or any such noise [26, 54, 55]. For some images, a threshold can be directly applied. In some images the different tissues has to be measured separately. Therefore the operator is required to take a decision on the method suitable for wound assessment.

This decision does not call for high expertise. In direct threshold option the image is thresholded and adjusted by an operator who moves across the slider with the help of a computer mouse. As the operator moves the slider by dragging the mouse, the region which is selected by the threshold increases and gets marked in black colour,
thus giving the feedback, so that he can adjust the slider until the entire wound fully marked black. The black colour pixel can be observed as the size of the region labeled in the black colour and the operator is having liberty to choose the second option to mark individually different regions of the wound tissues.

The operator has to click on any one point of the wound tissue and label it as slough or granulation tissue or necrotic tissue by verifying the corresponding given options provided and a slider is used to increase the region. As the slider is moved, the region grows and displays by changing the growing region to red in colour.

A feedback is received from the tool by the operator regarding the type of wound tissue under observation either on the slough tissue or on the granularity tissue or on the necrotic tissue. All these three types of tissues observed in the wound region are individually labeled with the same procedure. In case of the same tissue types are scattered in the wound area provision exists to add all the regions of the same tissue types.

Macro Romanelli et. al. put forth assessment framework proposal to develop the best practice recommendations for the wound assessment [1, 3, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 23, 25, 27, 31, 32, 37, 38, 40, 41, 42, 43, 44, 45, 46, 48, 50, 51, 56, 62, 82]. The present thesis presents an artificially designed and developed vision system for the operation of segmenting skin lesion images [8]. The researchers [23, 55, 56, 57, 59, 61, 62, 63, 64, 66, 67, 68, 69, 70, 71,
75, 79, 80, 83, 84, 86, 87, 89, 90, 91, 92] have proposed various methods on wound analysis and healing process.

2.4 Summary

The present literature review deals about theoretical background needed to understand the present thesis work like wounds, wound terminology, tissue classification based on colour etc., is discussed. The first section deals about phases of wound healing in which status of the wound varies as time progresses. The phase of the wound gives the status of the wound. The subsequent sections deal about steps involved in monitoring the wound and tissue classification based on the colour. Wound healing or wound monitoring involves continuous assessment of the wound manually by either contact or noncontact methods. The wound healing measurement based on the area of the wound in noncontact method in a timely fashion and analysation of the healing status of the wound. Alternate method of measurement of healing is the shift from black to yellow necrotic tissue into real granulation tissues. The measurement of wound volume is very much required for the deeper wounds. A noncontact method of measuring depth of the wound is reviewed in next literature review. The following chapter deals about the measure of framework to analyse the healing status of a wound by calculating the area of the wound only is not enough but several other factors like intensities of various tissues present in normal skin wounds. Various techniques help in monitoring the wound remotely which is by default non contact method is reviewed and proposed a new framework WIAC.
The subsequent chapters deals about preprocessing stage of wound like denoising process with a novel approach Colourlet transform. The next subsequent chapter discusses segmentation of area of the wound in non contact manner and analysing the wound more deeply. The following section deals about digital analysis of chronic changes in wound with respect to intensity of colours. The next chapter deals about assessment of wound by tissue classification. The next section deals about a novel classifier to classify and analyse the healing status of the wound.