

# **Wound Bed Assessment Using Calibrated Images and Representation in OpenEHR**

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A dissertation submitted to the University of Dublin in partial fulfilment of the requirements for the degree of Master of Science in Health Informatics

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## **Author Declaration**

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university

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## Summary

Wound bed Red-Yellow-Black-Pink (RYBP) assessment is used by clinicians to classify tissue types by colour. Calibrated digital wound images can be data mined for wound bed RYBP tissue classification.

Representation of wound bed RYBP assessment in the wound care electronic health record (EHR) is needed to enable standardization in wound care. The OpenEHR archetype is a computable representation of clinical information which can be bound to terminologies to maintain interoperability between systems. The OpenEHR draft archetype *inspection of an open wound* does represent wound bed tissue types, but does not assign proportion or colour to these tissue types. This research aimed to evaluate wound bed RYBP assessment, using calibrated wound images and to present a research based proposal to develop the draft archetype *inspection of an open wound*.

Wound assessment forms from 17 wound care centres, were surveyed. 65% used wound bed RYBP assessment in their clinical practice.

19 wound care clinicians were surveyed regarding suitability of calibrated wound images for treatment recommendations using a Likert type scale. 41% believed that the images were probably suitable for treatment recommendations. A further 39% thought that they were definitely suitable.

A study was conducted to measure inter-rater agreement on wound bed RYBP assessment between 14 wound care clinicians, using calibrated wound images and the Medical Reference Standard. Moderate to good agreement was found using weighted kappa statistic,  $k_w = 0.58 - 0.80$ .

The result of this research, along with wound care knowledge was used to present a proposal to develop the OpenEHR draft *archetype inspection of an open wound*. The OpenEHR Foundation has accepted the proposal for inclusion into the archetype development process.

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## List of Abbreviations

ADL	Archetype Definition Language
ADP	Archetype Development Process
ANA	American Nurses Association
ANSI	American National Standards
AWM	Applied Wound Management
CCC	Clinical Care Classification (previously Home Health Care Classification)
CDSS	Clinical Decision Support System
CEN	Comité Européen de Normalisation
CH	Connected Health
CHOBIC	Canadian Health Outcomes for Better Information and Care
CIE	Commission Internationale de l'Eclairage
CKM	Clinical Knowledge Manager
CSP	Computer Retrieval of Information on Scientific Projects (Source vocabulary in UMLS)
EHR	Electronic Health Record
EHRCOM	Electronic Health Record Communication
EPR	Electronic Patient Record
GO	GO Gene Ontology (source vocabulary in UMLS)
GP	General Practitioner
HL7	Health Level 7
HSI	Hue Saturation Intensity
ICD	International Classification of Diseases
ICNP	International Classification Nursing Practice
ICT	Information Communications Technology
IHI	Individual Health Identifier
ISO	International Standards Organization
IT	IT Information Technology
JPEG	Joint Photographic Experts Group
LOINC	Logical Observation Identifier Names and Codes
LUT	Look Up Table
MCCC	Macbeth Color Checker Chart

MH MeSH	MeSH Heading (medical subject heading)
MSH	Medical Subject Headings (in UMLS)
NANDA	North American Nursing Diagnoses Association
NHS	National Health Service
NIC	National Cancer Institute (Source vocabulary in UMLS)
NIC	Nursing Interventions Classification
NIC-GLOSSPT	National Cancer Institute dictionary of cancer preferred terms
NLM	NLM National Library of Medicine
OMAHA	Omaha nursing classification system
OP	Obsolete Preferred Name ( In UMLS)
OWL	Web Ontology Language
PT	Preferred Name ( designated preferred name in UMLS)
RCT	Randomized Controlled Trial
RGB	Red Green Blue colour model
RM	Reference Model
ROI	ROI Region of Interest
RYB	Red Yellow Black
RYBP	Red Yellow Black Pink
SNOMED CT	Systematized Nomenclature of Medicine Clinical Terms
sRGB	Standard Red Green Blue colour model
UMLS	UMLS Unified Medical Language System
WBP	Wound Bed Preparation
WHC	Wound Healing Continuum
TVN	Tissue Viability Nurse

## Glossary of key terms and phrases

<b>Debridement</b>	Removal of unhealthy necrotic and slough tissue from the wound bed to promote healing
<b>Direct wound assessment</b>	Direct visual assessment, looking at the wound
<b>Epithelialization / Epithelial tissue</b>	<i>Pink</i> wound bed tissue that advances from the wound edge over granulation tissue
<b>Granulation tissue</b>	<i>Red</i> wound bed tissue formed from red blood vessels, with granular appearance
<b>Indirect wound assessment</b>	Indirect visual assessment, looking at a digital image of the wound
<b>Medical Reference Standard (MRS)</b>	The approximated true value for wound bed tissue colour characteristics based on algorithm in Figure 3-2
<b>Necrosis / Necrotic tissue</b>	<i>Black</i> dead wound bed tissue
<b>RYBP assessment</b>	Red Yellow Black Pink wound bed tissue colour classification
<b>Slough / Sloughy tissue</b>	<i>Yellow</i> wound bed fibrous tissue that impairs healing



**Tissue Viability Nurse (TVN)**

Clinical nurse specialist in tissue viability (CNS)

**Wound care clinician**

Health care professional involved in wound care, usually nurses and doctors

**Wound Healing Continuum (WHC) scale**

Wound healing continuum tissue colour classification scale

## **Chapter 1      Introduction**

## **1.1 Introduction**

Wound care encompasses all aspects of clinical care provided to patients with wounds. It involves shared care between the community and the hospital. Wound care is prevalent and resource consuming.

The accurate visual assessment of the wound is an essential component of this care. An understanding of the pathophysiology of wound healing has informed clinical assessment tools. Wound bed tissue colour classification and its clinical interpretation guide best practice in wound care. The Red-Yellow-Black-Pink (RYBP) tissue colour classification is widely practiced.

Colour is common to the visual assessment of both wounds and wound images. The calibrated digital wound image provides permanent accurate and reproducible wound documentation, suitable for evaluation (Van Poucke et al., 2010a). It can be data mined for size, volume and tissue classification. Automated tissue colour classification of calibrated digital wound images, using artificial intelligence has been developed (Oduncu et al., 2004, Belem, 2004, Wannous et al., 2011).

The wound bed RYBP assessment needs to be represented in the wound care electronic health record (EHR). This is a requirement irrespective of whether the assessment is performed directly with the patient or indirectly using a calibrated digital wound image. This representation in the EHR enables standardized wound care.

The OpenEHR Foundation (Beale and Heard) is developing archetypes with clinical domain specialists using the archetype development process (Madsen et al., 2010). The archetype is a computable representation of clinical information which can be bound to terminologies to maintain interoperability between systems. The draft archetype *inspection of an open wound* does represent wound bed tissue types, but not colour or proportion.

## **1.2 Aims and objectives of this dissertation**

### **Aims of dissertation**

There are two aims to this dissertation:

- 1.** To explore calibrated digital wound images in wound bed assessment

2. To present a research based proposal to OpenEHR to develop the draft archetype *inspection of an open wound*

### **Objectives of dissertation**

The objectives that need to be met in order to fulfil the aims of this dissertation are:

1. To identify current wound bed assessment clinical practice in Ireland
2. To identify opinion on the suitability of calibrated digital wound images in wound care
3. To identify the level of agreement among clinicians in the assessment of the wound bed using calibrated digital wound images.
4. To apply the research findings to the archetype development process

### **1.3 Research questions**

By answering the following questions the aims and objectives of this dissertation will be met:

1. What is current wound bed assessment clinical practice in Ireland?
2. Calibrated digital wound images -
  - a. Are calibrated digital images of wounds suitable for wound bed RYBP assessment and treatment options?
  - b. What is the level of agreement between wound care clinicians when completing wound bed RYBP assessment, using calibrated wound images?
3. Open draft archetype development -
  - a. Should the data values for wound bed tissue in the OpenEHR draft archetype *inspection of an open wound* be converted to proportion?
  - b. Should wound bed tissue types be mapped to colour in the OpenEHR draft archetype *inspection of an open wound*?

## 1.4 Research methodology

The research methods used in this dissertation are:

1. Survey of wound care centres to measure current wound bed assessment clinical practice in Ireland.
  - Results will be presented with descriptive statistics
2. Survey of wound care clinicians to measure suitability of calibrated digital wound images for wound bed RYBP assessment and treatment options
  - Results will be presented with descriptive statistics
3. Inter-rater agreement study to measure the level of agreement between wound care clinicians when completing wound bed RYBP assessment using calibrated wound images
  - Results will be presented with Cohen's weighted kappa statistic (section 2.6.3)

## 1.5 Overview of the dissertation

Following this introduction:

Chapter 2 presents the literature review and background.

Chapter 3 presents the design and implementation of the research.

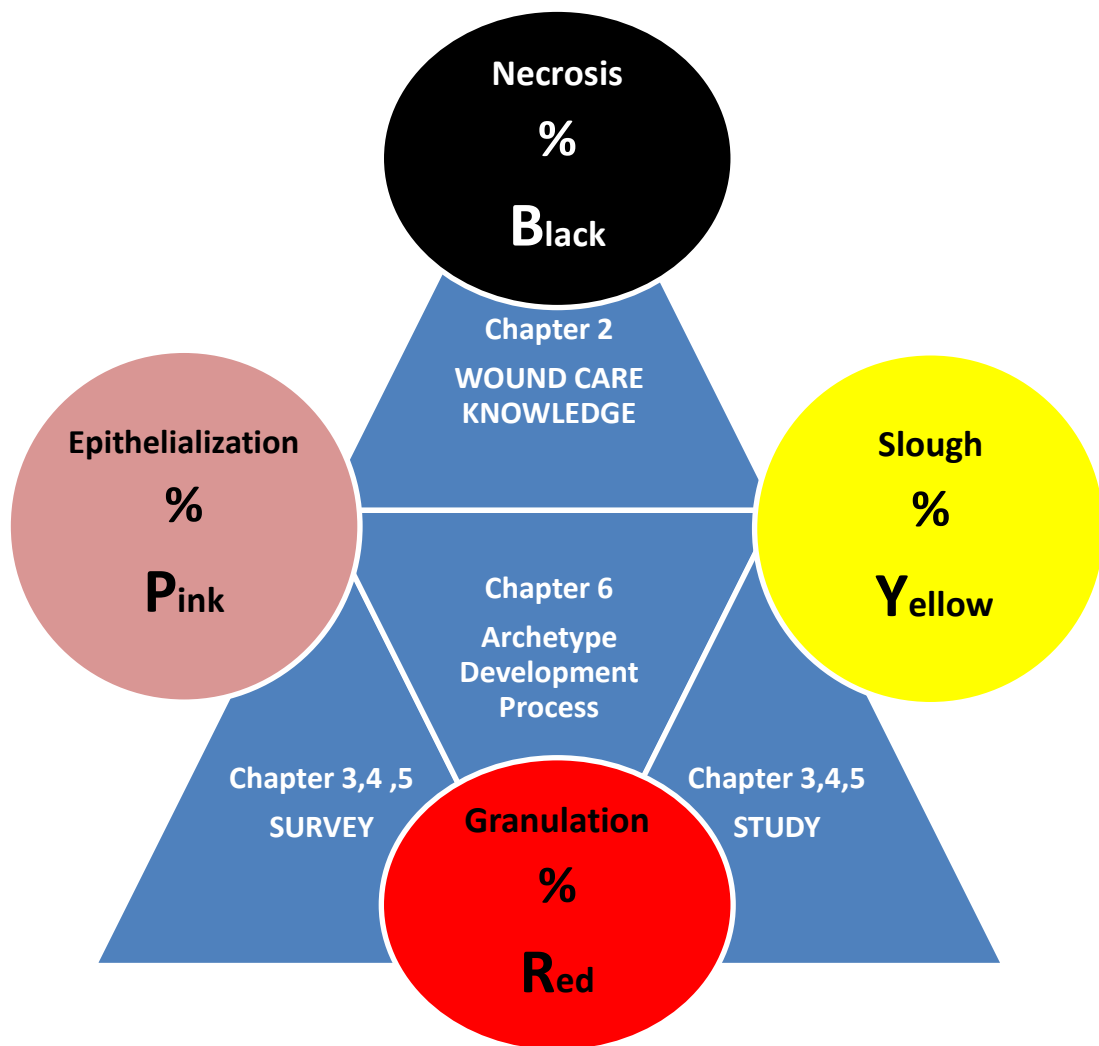
Chapter 4 presents the results of the research.

Chapter 5 presents an analysis and evaluation of the research results.

Chapter 6 presents a research based proposal to develop the OpenEHR draft archetype *inspection of an open wound*.

Chapter 7 concludes the dissertation

This overview is illustrated in Figure 1-1.



**Figure 1-1** Overview of dissertation illustrated

- Wound care knowledge – Clinical; digital imaging; health informatics; statistical methods(Chapter 2)
- Survey of wound bed RYPB assessment clinical practice (Chapters 3,4,5)
- Survey of calibrated digital wound image suitability for RYBP assessment and treatment recommendations (Chapters 3,4,5)
- Study on wound bed RYBP assessment using calibrated digital wound images (Chapter 3,4,5)
- Archetype development process to develop draft archetype *inspection of an open wound* to represent wound bed RYBP assessment (Chapter 6)

## **Chapter 2      Literature Review**

## **2.1 Introduction to literature review**

The purpose of this literature review is to identify and critically appraise state of the art research in relation to the application of digital imaging and health informatics to clinical wound care. In addition, research methodology employed by experts in these scientific domains is analyzed. Where appropriate, background knowledge is provided to contextualize state of the art research.

This literature review encompasses four scientific disciplines. These are:

- Clinical wound care
- Colour and imaging science in wound care
- Health informatics in wound care
- Quantitative statistical analysis in wound care studies

## **2.2 Search strategy**

The following resources have been utilized to obtain a comprehensive review of literature in the scientific disciplines that inform this dissertation:

- On-line searching; Google Scholar, IEEE, websites
- Journals
- Reference Texts, see bibliography
- Personal communications with experts in the related scientific disciplines

## **2.3 Clinical wound care**

### **2.3.1 Introduction to clinical wound care**

The skin is the largest organ in the body. It provides a protective barrier against the surrounding environment. A wound to the skin compromises its protective ability. Wound care encompasses all aspects of clinical care provided to patients with wounds. Wound care has advanced from the practice of cover and conceal to active wound management in the last 25 years (Harding et al., 2007).

Clinical skin assessment is a visual and descriptive process. It is necessary to have an understanding of current clinical wound care, to appreciate the role of digital imaging and health informatics in this clinical domain.



Wound care is reviewed in the context of definition; incidence; classification; clinicians; guidelines; documentation; pathophysiology and assessment tools.

### **2.3.2 Definition**

A wound is a cut or break in the continuity of the skin(Schultz et al., 2003).

### **2.3.3 Incidence, prevalence and burden of disease**

1.5% of the population is affected by a wound at any one time(Gottrup, 2004). Studies in the UK estimate that wound management accounts for up to 4% of total health care expenditure (Bennett et al., 2004, HSE, 2009). This is anticipated to rise with increasing life expectancy and chronic co-morbidity such as diabetes mellitus. The clinical domain of wound care has significant social, psychological and economic consequences for the individual and society. Wounds significantly affect the quality of life of the individual. In severe cases, they can result in loss of limb or death. Wounds result in loss of productivity and increased economic costs (Zhan and Miller, 2003). In Ireland, it is estimated that 67% of community nursing time is spent on the provision of wound care (HSE, 2009).

### **2.3.4 Wound classification**

Wounds are commonly classified according to their aetiology. They may have a single or mixed aetiology. More than one wound can be present at any given time. The aetiology of wounds impacts on their management. Causes of wounds are:

- Venous disease
- Arterial disease
- Diabetes mellitus
- Pressure
- Trauma
- Surgery
- Neoplasm
- Infection

Wounds are also classified as acute or chronic, based on the expected timeframe of healing.

- Acute wound healing progresses in accordance with the phases of healing over 21 days.
- Chronic wound healing can take months or years, characterized by impaired healing and recurrent infections.

A more in-depth description of wound healing is outlined below in the sections on *pathophysiology of wound healing* and *clinical wound assessment tools* (section 2.3.8 and 2.3.9).

Leg ulcers are an important subclass of wounds because of their prevalence, varied aetiologies and tendency towards chronicity.

### **2.3.5 Clinicians**

Wound care involves interdisciplinary collaborative shared care between clinicians. It is predominately a nursing domain. In Ireland the primary care management of wounds is provided by the community nursing service. This is delivered at the wound clinic in the local HSE Health Centre and through domiciliary visits, to those unable to attend the clinic. Others involved are the Family Practice Nurse, General Practitioner, Clinical Nurse Specialist (CNS) in Tissue Viability, Vascular Surgeon, Plastic Surgeon, General Surgeon, Dermatologist, Diabetologist and Podiatrist. This makes wound care a good domain for implementing connected health initiatives. Specialist referral is sought for complicated wounds and for patients with complicating co-morbidities.

### **2.3.6 Clinical guidelines**

Clinical guidelines are designed to support standardisation of care, in line with evidence based practice. Specific HSE guidelines are limited to the management of venous ulcers, arterial ulcers, diabetic ulcers and pressure ulcers. Guidelines provide a framework to facilitate clinical decision support in the management of leg ulcers (HSE, 2009).

Clinical guidelines, for best practice in wound care, give high priority to the accurate assessment of wounds. This assessment of wounds informs wound management decisions, such as dressing choice and specialist referral.

### **2.3.7 Wound assessment documentation**

Clinical documentation in wound care is required for:

- Recording clinical information
- Communicating clinical information
- Treatment planning
- Standardizing care, compliant with clinical guidelines
- Quality assurance
- Accreditation
- Billing
- Medico-legal reasons

Current wound assessment practice, in compliance with HSE Guidelines, uses a paper chart. This chart records details on wound size, wound bed, exudate, and infection, surrounding skin, oedema and pain severity. The wound surface area is measured by marking a trace on a sterile contact. Surface area is sometimes calculated using a Visitrack System (Nephew).

There is no national standardised wound assessment form in use in Ireland. The HSE Guidelines contain a sample wound assessment form (HSE, 2009).

### **2.3.8 Pathophysiology of wound healing**

State of the art scientific research into the pathophysiology of wound healing has altered understanding of this process. It has informed assessment and management. Physiology applies to acute wound healing and pathology applies to chronic wound healing.

#### **Acute wound healing**

Acute wound healing is the normal physiological response of the body to skin injury (Cherry et al., 2001). The three phases of acute wound healing are inflammation, proliferation and maturation. These phases may overlap. A general description of the phases of acute wound healing is an important prelude to the discussion on visual wound assessment. An understanding of this molecular and cellular pathophysiology has been utilised in the development of clinical assessment tools and treatment planning.

### *Inflammation (duration <5 days):*

Following skin injury, there is blood vessel constriction and clot formation. Once bleeding has ceased blood vessels dilate, to allow inflammatory cells, chemical mediators and nutrients to reach the wound bed. This produces exudate in the wound bed, which is necessary for moist acute wound healing (Romanelli et al., 2010). The inflammatory response brings together chemical mediators and inflammatory cells that will stimulate the proliferation of the three wound healing cells (epithelial cells, vascular endothelial cells and fibroblasts) in the proliferative phase of healing.

### *Proliferation (duration 21 days):*

Three types of proliferation occur in this phase of acute wound healing.

- Vascular endothelial cells proliferate to form new blood vessels (angiogenesis). These give the visual appearance of *red* granules and the clinical description of granulation.
- Epithelial cells proliferate to form the new surface layer of cells (epithelialization). Epithelial cells grow into the centre of the wound. Epithelial tissue is *pink*.
- Fibroblasts proliferate and form the new collagen-fibrin extracellular matrix to support the new blood vessels and epithelium.

### *Maturation and remodeling (duration 2 years):*

Contraction of the scar occurs during the maturation phase of acute wound healing. Remodeling of the scar continues for up to two years (Dealey, 2007).

## **Chronic wound healing**

Chronic wound healing does not follow the progression described above. In chronic wounds, inflammatory cells and chemical mediators are defective and incapable of orchestrating wound repair. This results in chronic hard to heal wounds with defective re-modelling of extra cellular matrix, failure of re-epithelialization and chronic inflammation. If a wound becomes infected during the proliferation phase of wound healing, chronic inflammation and tissue damage occur. This results in *black* necrosis and *yellow* slough tissue in the wound bed.

Older people are particularly vulnerable to chronic wounds. In addition, co-morbidities can delay healing, resulting in wound chronicity (Ashcroft et al., 1998).

Wound exudate has a significant role to play in the rate of wound healing. A moist wound environment promotes healing. However, chronic wounds contain excess exudate, with altered composition, that retards healing.

### **2.3.9 Clinical assessment tools**

Clinicians use assessment tools to assist them in describing the status of the wound. These provide a rationale for decision making regarding the clinical care of the wound. Clinical tools are an accepted part of wound management. They assess where a wound is on the spectrum of wound healing, at a point in time. These assessment tools have evolved over time to current state of the art wound assessment. Four such assessment tools are described below:

- The Red-Yellow-Black colour classification
- Applied Wound Management
- Wound Bed Preparation assessment tools
- ConvaTec Solutions

#### **Red-Yellow-Black (RYB) classification** (Cuzzell, 1988, Krasner, 1995)

Hellgren, a Danish dermatologist, developed the RYB wound colour classification in 1983 (Hellgren and Vincent, 1986). Cuzzell introduced it to the US in 1988, as a simple practical method of assessing wounds. The colours are descriptive of tissue types in the wound bed:

- Red wounds are usually granulating and healing.
- Yellow wounds have sloughy tissue adherent to the wound bed.
- Black wounds have necrotic devitalised tissue.

However, Cuzzell recognised the limitations of this colour classification of tissue. Red wounds can be healing (granulated), over-granulated or infected. Yellow wounds can contain slough or infected discharge. Cuzzell described the healing wound progressing from black to red over time with appropriate management.

Good to moderate inter observer agreement has been found using RYB wound bed assessment in clinical practice (Lorentzen et al., 1999, Vermeulen et al., 2007).

Pink epithelialization was subsequently added to the colour classification (Hellgren and Vincent, 1986)

The wound bed RYBP assessment is central to the research presented in chapters 3, 4 and 5 of this dissertation

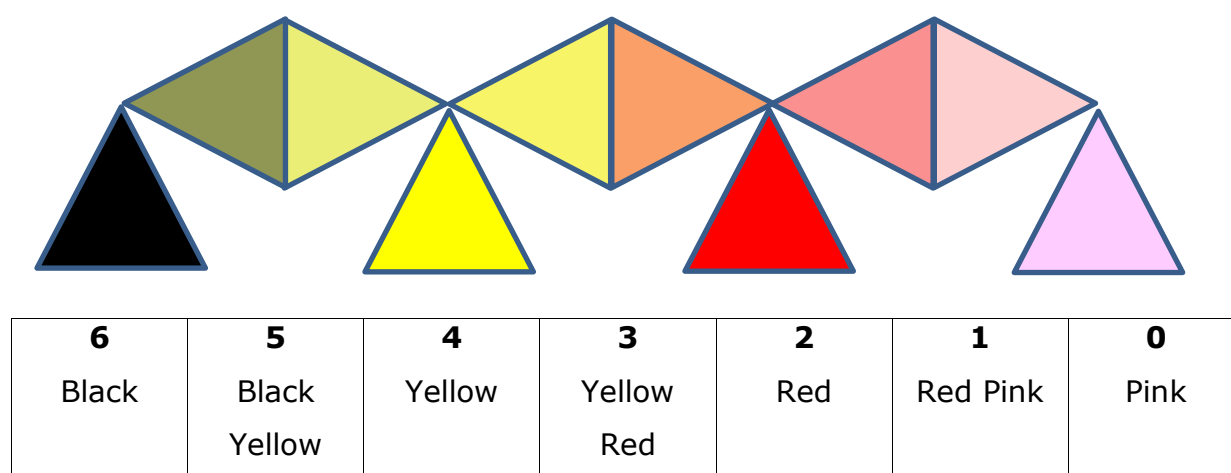
## Applied Wound Management

Applied Wound Management describes three continuums, relating to wounds. These are:

- The wound healing continuum
- The infection continuum
- The exudate continuum

The Wound Healing Continuum (WHC) has been developed using the principles of RYBP classification (Gray et al., 2005). This is a more in-depth colour classification of tissue within the wound bed, recognising 7 colour types. Colour moves, from left to right along a continuum. To the left is the unhealthy black necrotic wound and to the right is the pink healthy epithelialized wound.

The infection continuum and the exudate continuum complete Applied Wound Management. When the WHC is complimented by the infection and exudate continuums, then more accurate interpretation of tissue colour and treatment choice is achieved. Assessment of the infection and exudate continuums also informs treatment choices. Bacterial bioburden is controlled. Exudate is managed.



**Figure 2-1** Wound Healing Continuum (WHC)

**Wound Bed Preparation (WBP)** (Schultz et al., 2003, Ayello and Dowsett, 2004)

The objective of WBP is to optimize the healing environment in chronic wounds. It identifies and manages the factors that have caused wound healing to be delayed. It aims to promote healthy *red* granulation tissue, required for wound closure. It has been developed from an understanding of the cellular and molecular pathophysiology of chronic wounds, described previously. The focus is on debridement of *black* necrotic and *yellow* slough tissue, correction of bacterial imbalance and management of chronic wound exudate. Healthy red and pink tissue is protected. In addition it identifies and manages patient factors that contribute to wound chronicity.

### **ConvaTec Solutions**

These are recommendations for wound care presented in the form of 8 algorithms at the ConvaTec Web site (ConvaTec, 2012). Quantity of exudate and unhealthy (*black* necrotic and *yellow* slough) tissue in the wound bed determines management.

#### **2.3.10 Summary of clinical wound care**

Wound care is a prevalent and resource consuming clinical domain. It involves interdisciplinary collaborative shared care. Communication of wound status over time and between medical personnel is an integral part of clinical wound care. The accurate visual assessment of the wound is essential to wound management.

An understanding of the pathophysiology of wound healing has informed the clinical assessment tools that have been developed over the last decade. Wound bed tissue colour classification and its clinical interpretation guide best practice in wound bed RYBP assessment.

## **2.4 Digital Imaging in Wound Care**

### **2.4.1 Introduction to digital imaging**

Wound care requires frequent clinical assessments by interdisciplinary clinicians over time. Colour tissue classification is fundamental to accurate wound assessment, providing relevant clinical diagnostic information.

Colour digital imaging in wound care potentially offers:

- Wound documentation
- Non-invasive means of wound evaluation
- A means of communication between clinicians

Colour digital imaging in wound care has been the focus of much research in the last 25 years, but it has not found its way into daily clinical practice in Ireland. Medical photography is available in specialized centres. The advent of relatively cheap commercially available compact digital cameras has paved the way for the general adoption of digital images in routine clinical wound care. An outline of colour science and digital imaging is presented, prior to reviewing its application to wound care. Limitations of imaging technology in wound care are also addressed.

### **2.4.2 Colour perception and colour models**

Colour is represented by colour models. A colour model is a mathematical model that describes the way colour is represented by a set of numbers. The Commission Internationale de l'Eclairage (CIE) colour model is human colour perception, this is the perception used in the direct bed-side assessment of wounds. The CIE colour model is a reference model, termed the "standard colorimetric observer".

The Red Green Blue (RGB) colour model is used in the indirect assessment of wound images. Thus, the visual assessment of a wound image cannot convey the same perceptual meaning as the direct visual assessment of the same wound.

#### **Human colour perception**

Colour is the human perception of a section of the electromagnetic spectrum. Two types of photoreceptors determine what we see. Rods are achromatic and



are most responsive in dim light. Cones require more light and are chromatic (responsive to colour). Interpreting signals from these receptors in the brain is both physiological and psychological, resulting in subjective colour perception. In the context of wound bed colour classification, colour interpretation is influenced by other sensory input such as smell (Belem, 2004).

### **Red Green Blue colour model (RGB)**

The Red Green Blue (RGB) colour model is utilized in computer monitors and colour digital imaging. This facilitates the viewing and transfer of colour digital images electronically (Vander Haeghen and Naeyaert, 2006). This is an additive model, meaning that colour is represented by the addition of three primary colours (red green and blue). The RGB colour model is implemented in monitor devices with 24 (3 x 8) bits. Each of the 3 primary colours has 8 bits with 255 discrete levels per colour channel. This model represents 16 million colours.

Two colour spaces within the RGB colour model are the standard RGB (s-RGB) colour space and the Hue-Saturation-Intensity (HSI) colour space. Both these colour spaces are utilized in colour digital image calibration or standardization.

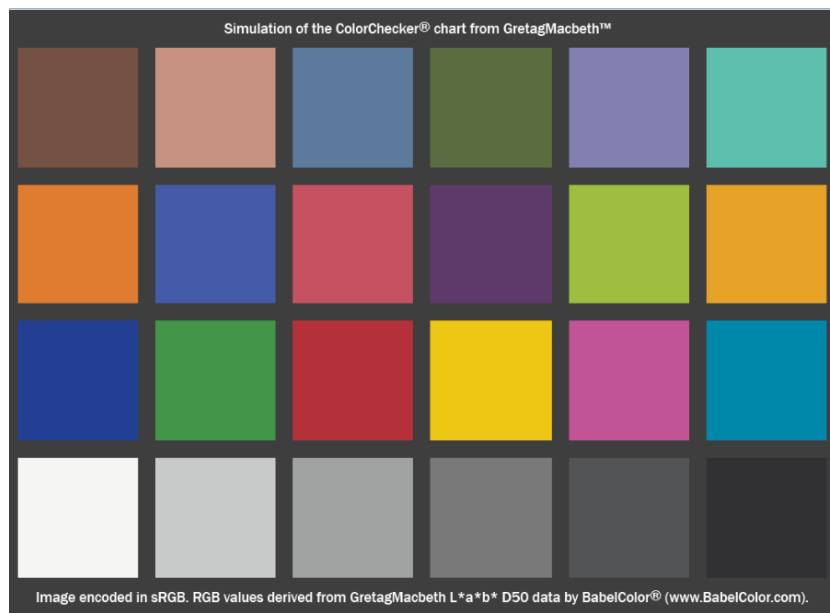
Colour calibrated digital wound images will be viewed on a laptop computer with sRGB settings in the research presented in chapters 3, 4 and 5 of this dissertation.

### **Gretag Macbeth ColorChecker Colour Rendition Chart (MCCC)**

The Gretag Macbeth ColorChecker Colour Rendition Chart (McCamy et al., 1976, Pascale, 2006) is a scientifically prepared 24 grid colour card of standardized colours Figure 2-2.

The ColorChecker chart contains:

- 12 colours representative of natural objects (skin tones, foliage, flowers, sky, fruit, etc.).
- 6 primary colours (red, green, blue, cyan, magenta and yellow)
- 6 grey scales



**Figure 2-2** Simulated Macbeth colorchecker chart (Pascale)

(Used with permission from D. Pascale)

Colour coordinates are defined for all the colour patches of the MCCC in gamma-corrected standard Red Green Blue (s-RGB) colour space (Pascale, 2006). The MCCC allows the relationship between s-RGB images and human visual perception to be mapped.

A ColorChecker chart is used in the research presented in chapters 3, 4 and 5 of this dissertation

### **2.4.3 Digital imaging technology**

#### **Image calibration**

A colour digital wound image provides a 2-D representation of the wound. The acquisition of the digital image is influenced by environmental conditions. These include illumination settings, camera distance from the wound and camera settings. This digital image is in device dependent Red Green Blue (RGB) colour space and is unsuitable for meaningful clinical evaluation (Van Poucke et al., 2010a).

In order for a wound image to be useful for clinical evaluation, it needs to be colour calibrated and standardized. The resulting image is independent of

camera settings and illumination (white balance). Colour calibration is achieved using a digital camera (>3 megapixels) and a Gretag Macbeth ColorChecker Chart (MCCC). The MCCC is placed next to the wound and incorporated into the digital image with the wound. Thus, a profile of the acquisition system is determined.

The digital wound image, which includes the MCCC, is calibrated using a calibration algorithm. This algorithm (a java plugin) scales the image using a multi-point Look-up Table (LUT) (gray-balance). Calculations are used to transform the tristimulus colour data in the image to the well-defined gamma corrected Standard Red Green Blue (s-RGB) colour space, with known primaries and white-point (Haeghen et al., 1999).

Reproducibility and accuracy of automatic colorimetric calibrated skin images, for evaluation, has been validated (Haeghen and Naeyaert, 2006, Van Poucke et al., 2010a)

- Reproducibility precision has been confirmed with repeated colour measurement, taken under different calibration profiles.
- Accuracy has been confirmed by comparing colour measurements of the imaging system to measurements made with a reference spectrophotometer.

A new improved colour calibration chart and a more sophisticated calibration algorithm is currently being prototyped (see Appendix E Vander Haeghen personal communication).

Calibration of digital wound images is performed in the research presented in chapters 3, 4 and 5 of this dissertation.

#### **2.4.4 Applications of digital imaging in wound care**

Digital imaging in wound care has found practical clinical applications in the context of telemedicine, education and research. It has not been adopted routinely in clinical care. This is despite the fact that planimetry (size of wound measurements) and tissue analysis have proven accuracy (Oduncu et al., 2004, Van Poucke et al., 2010b). Developments in health informatics and digital imaging, combined with clinical assessment tools, have the potential to develop electronic wound care.

Imaging application studies in wound care are critically reviewed in the context of telemedicine, education and research, planimetric / volumetric analysis and tissue classification.

### **Telemedicine using digital imaging**

Research relating to wound bed RYBP assessment using calibrated digital images, is presented in chapters 3, 4 and 5 of this dissertation.

Telemedicine refers to the use of ICT to facilitate health care (Coiera, 2003, Taylor, 2006). Connected health is a further development where care is centred on the patient in the community preventing disease progression and acute care episodes. ICT can facilitate changes in care models from centralised acute care to distributed networks of care. In this context, wound digital images have a role to play in telemedicine. 'Store and forward' is the method employed when using images. Images are captured and forwarded to the clinician for viewing at their convenience. Sometimes live video conferencing is necessary for urgent specialist consultation. Telemedicine and wound care is developed where geographic distance prevents access to specialist consultation.

Nurse to nurse wound care telephone consultations are common practice. The addition of a digital wound image, to a verbal report, has been evaluated.

The conclusion of one study was that expert clinicians were at risk of over-treating or under-treating wounds, in the absence of indirect digital image visual assessment (Buckley, 2009).

The provision of an image in addition to clinical data was found to be sufficient for a correct diagnosis in the care of leg ulcers. This was found to reduce the need for patients to travel long distances for medical consultation (Salmhofer et al., 2005).

These two studies have identified the benefit of a digital wound image, in addition to clinical information, in a telemedicine consultation.

Telemedicine can ensure quality of care and more efficient use of healthcare resources. The Alfred Medseed Wound Imaging System (AMWIS) in Kimberly, Western Australia (WA) is a successful implementation of telemedicine wound

care with evidence of improvements in clinical outcomes and cost effectiveness (Santamaria et al., 2004, Flowers et al., 2008).

Another example of resource management using telemedicine and digital images concerns the initial treatment of burns. This resulted in more appropriate emergency referral, with 10% more patients being diverted to day surgery. (Wallace et al., 2008).

More studies are required to justify the use of telemedicine to reduce costs (Bergmo, 2009).

The importance of information technology project management is crucial when introducing new systems. This applies to telemedicine in wound care not all implementations are successful (Barrett et al., 2010).

### **Digital imaging in education and research**

Research using calibrated wound images is presented in chapters 3, 4 and 5 of this dissertation.

Published studies relating to education and research in wound care commonly use digital images to represent wounds. In this context, the image for clinical assessment is not the primary endpoint being measured. Studies that validate the use of digital images for education or research cannot be presumed to endorse their use for the clinical assessment of wounds. Most of the studies that use digital images have no mention of digital image colorimetric calibration, prior to use in education and research.

The use of digital wound images in education and research facilitates:

- Adequate sample size (image collection over time and image rotation)
- Distribution to observers / raters / students (on-line, slide show, hard copy)
- Intra-rater assessment (rotated images in random order over time)
- Elimination of bias (isolation of the wound from the clinical environment)
- Anonymization of wounds

#### *Digital imaging in wound care education*

Researchers in Canada used digital images as a pictorial guide, portraying wound characteristics, to educate nurses prior to the use of the Bates Wound

Assessment Tool (BWAT) (Harris et al., 2010). Similarly, wound images have been used to validate the ConvaTec Solutions algorithms referred to in section 2.3.9 (Beitz and van Rijswijk, 1999). Both these studies demonstrated the advantages of using digital images in wound care education.

#### *Digital imaging in wound care research*

Digital imaging facilitates blinded assessment in randomized controlled trials (RCT's). The elimination of bias strengthens research (Baumgarten et al., 2009). This is particularly important when assessing treatment modalities. The use of imaging in research assists blinded trials in wound product evaluation. The effect of Vacutex dressing on wound progress was assessed using direct wound assessment and indirect wound image assessment. Image assessment was concluded to be best because of the elimination of bias, despite losing some finer detail of wound progress (Reynolds and Russell, 2004).

#### **Digital imaging in planimetric and volumetric analysis**

The wound boundary demarcates the wound bed and therefore the content of the wound bed. Research relating to wound bed RYBP assessment using calibrated digital images, is presented in chapters 3, 4 and 5 of this dissertation. Consequently, studies relating to planimetric and volumetric analysis in digital wound images are relevant to this dissertation.

The size of a wound and its progress over time gives an indication of the status of wound healing. Digital image planimetry utilizes software to calculate wound area from digital images. This helps to determine the extent of the wound bed. Planimetric measurement of wound images has been validated in a number of studies and was found to be superior to manual delineation in most cases (Jones and Plassmann, 2000, Van Poucke et al., 2010b, Wendelken et al., 2011). A limiting factor in two of the studies was identifying the wound boundary. Planimetric measurement gives no indication of wound depth or volume.

Digital images can also be used for volumetric measurement.

MAVIS and MAVIS 11 have been developed using the principle of colour coded structured light (Plassmann et al., 1995).

In other research 3D wound models have been obtained from a series of 2D images in different planes, using computational algorithms. Good volumetric accuracy has been recorded. (Wannous et al., 2011).

### **Digital imaging in tissue classification / segmentation analysis**

Research relating to wound bed RYBP assessment using calibrated digital images, is presented in chapters 3, 4 and 5 of this dissertation.

The clinical wound care literature review has outlined the importance of wound bed tissue classification (section 2.3.9). It gives an indication of the status of wound healing. Digital images can be used to classify tissue in the wound bed, by clinicians. More recently, automated classification has been developed using support vector machines. Wound bed tissue colour classification of digital wound images has been validated in a number of studies.

Clinicians used images to evaluate the Red-Yellow-Black (RYB) tissue colour classification system and exudate. Good to moderate inter-rater agreement was found and RYB was found to be accurate and reliable. Three limitations of this study were absence of direct wound assessment, absence of pink epithelial tissue classification and the use of uncalibrated images (Vermeulen et al., 2007).

Support vector machines have been used in 3 studies and demonstrated good results. They all assessed the wound bed in calibrated digital wound images. One study assessed inflammation. (Belem, 2004). Another study assessed slough (Oduncu et al., 2004). Yet another study assessed RYB (Wannous et al., 2011). Wannous asserts that this technological advance provides inexpensive, robust and accurate tissue classification. It has potential use in serial wound assessment over time.

The widespread use of automatic wound bed tissue classification into routine clinical practice is dependent on costs, wound EHR and clinician acceptance. In the research presented in chapters 3, 4 and 5 of this dissertation, wound care clinicians use calibrated wound images. This is an important first step in the introduction of automated tissue classifiers into clinical practice.

### **Limitations with digital imaging of the skin**

There are limitations to the use of images in wound care. Digital imaging of circumferential wounds (leg, heel, toe, elbow and ankle) can be problematic. Deep sinus wounds do not illuminate properly. In the home, lighting conditions are variable and may challenge the calibration process. Some therapeutic dressings affect the appearance of the wound bed. Iodine can produce a brown stain. Silver dressings can produce a black stain. Some alginates also discolour the wound bed.

### **2.4.5 Summary of digital imaging**

An un-calibrated digital wound image is documentation without definition in colour space. It is inaccurate and not reproducible. As such, it is unsuitable for interpretation. The calibrated digital wound image provides permanent accurate and reproducible wound documentation, suitable for evaluation. It can be data mined for planimetric analysis, volumetric analysis and tissue classification. It facilitates wound comparison over time and communication between clinicians. It is used in telemedicine, education and research. It facilitates audit of wound care interventions and outcomes.



## **2.5 Health Informatics in wound care**

### **2.5.1 Introduction to health informatics**

Health informatics literature review looks at wound care terminology, ontology, archetype, template, electronic health record (EHR) and messaging standards. Background information is given, where required, to contextualize the current published literature. In addition, relevant aspects of health informatics in Ireland are discussed.

### **2.5.2 Terminology**

The pathophysiology in the wound bed is described using clinical terms. These include slough, necrosis, granulation and epithelialisation. The ability of this data to retain its integrity depends on the standards used to express these clinical terms and concepts. Controlled vocabulary facilitates integration of computerised clinical information. A recurring theme in the literature is the need for definitions of wound bed tissue characteristics (Flowers et al., 2008, Van Poucke et al., 2009). It has been identified in the literature that colour is a core concept in the wound bed.

#### **Nursing terminology**

Wound care is primarily a nursing clinical domain. Consequently, the representation of wound bed terms in nursing terminologies is relevant to their representation in an EHR. Representation of wound bed terms in nursing terminologies is shown in Table 2-1. There is a lack of term definitions in the nursing terminologies

	<b>Necrosis</b>	<b>Slough</b>	<b>Granulation</b>	<b>Epithelial -ization</b>	<b>Other</b>
<b>ICNP</b>	definition 10012482	no definition	no definition	no definition	
<b>OMAHA</b>	no definition	no definition	no definition	no definition	wound care
<b>NANDA</b>	no definition	no definition	no definition	no definition	skin tissue integrity 44 and 47
<b>NIC</b>	no definition	no definition	no definition	no definition	wound care 3660
<b>CCC</b>	no definition	no definition	no definition	no definition	wound care R55.0
<b>C-HOBIC</b>	no definition	no definition	no definition	no definition	pressure ulcer

**Table 2-1** Nursing terminology representation of wound bed tissue

The *International Classification of Nursing Practice* (ICNP) Version 1.0 is a classification of nursing practice. It is designed to be machine readable and is maintained in the Web Ontology Language (OWL).

One research study looked at ICNP coverage for nursing assessment documentation (Dykes et al., 2009). Within the domain of wound care, wound bed characteristics and wound bed planimetry were not represented as concepts.

The *Canadian Health Outcomes for Better Information and Care* (C-HOBIC) project introduced systematic use of standardized clinical nursing terminology for patient assessment, to be incorporated into electronic health records (Hannah et al., 2009). C-HOBIC identifies eight clinical outcomes with associated assessment data elements. One such outcome is pressure ulcers with the associated assessment data elements being 'number by stage'. Staging refers to the most dominant tissue affected by the pressure ulcer; epidermis, dermis, subcutaneous fat, muscle or bone (Defloor and Schoonhoven, 2004). Staging only applies to ulcers caused by pressure. This assessment does not provide

information on the wound bed characteristics. Nursing assessment and outcomes concepts in C-HOBIC have been mapped to the ICNP.

Nursing terminologies, such as ICNP and C-HOBIC, provide little granularity relating to wound bed assessment. They do not meet the atomic level of data capture required.

### **SNOMED CT**

SNOMED CT (UMLS) is a comprehensive clinical terminology. It represents the four wound bed tissue types, but does not define them. It provides preferred terms and synonyms for these four wound bed tissue types Table 2-2.

<b>Tissue Type</b>	<b>Wound bed terminology in SNOMED CT Browser</b>
Necrosis 6574001	Not defined PT: Necrosis Synonyms :Cellular necrosis, tissue devitalisation
Slough 449746002	Not defined
Granulation 225541009	Not defined PT: Granulation of Tissue Synonym: Tissue Granulation
Epithelialization 449743005	Not defined

**Table 2-2** Wound bed tissue types represented in SNOMED CT Browser

### **UMLS Metathesaurus**

The UMLS Metathesaurus (UMLS) is a collection of over 100 source vocabularies. The UMLS has the American Nursing Association (ANA) recognised terminologies integrated into their system. SNOMED CT is also integrated into UMLS.

The UMLS represents all four tissue types Table 2-3

It defines the terms necrosis and granulation (see Appendix B). Definitions are needed for unambiguous recording of wound bed characteristics in a wound care EHR.

<b>Tissue type</b>	<b>Semantic type in UMLS Metathesaurus</b>
Necrosis	<i>Organ or tissue function</i>
Slough	<i>Finding</i>
Granulation	<i>Tissue</i>
Epithelialization	<i>Finding</i>

**Table 2-3** Wound bed tissue semantic types in UMLS Metathesaurus Browser

There is a need to develop the concept of wound bed assessment within the UMLS.

### **2.5.3 Ontology**

An ontology is an explicit formal specification of terms and concepts in a domain and the relationships between them (Gruber, 1995). It is terminology with reasoning capability.

Open EHR has used formal ontology engineering to design a logical record architecture for a universal EHR (Madsen et al., 2010). The OpenEHR ontology is core ontology of health care data. The Clinical Knowledge Manager (CKM) is a web application which contains a repository of archetypes. It has an ontological structure and it enables ontological based searching. The draft archetype *inspection of an open wound* is contained within this repository. The proposal to develop this draft archetype is presented in chapter 6 of this dissertation.

## **The Woundontology Consortium**

The Woundontology Consortium is a community of working groups interested in advancing the practice of wound assessment by digital image feature analysis, ontology, semantic interpretation and knowledge extraction. It is a semi-open international virtual community, collaborating through discussion groups and wiki web site. A Woundontology is currently under construction using OWL, the web ontology language. It proposes the development of a library of wound images with associated data. This library will be available for research, education and clinical decision support (Van Poucke, 2008). Members of this consortium have contributed to the study concept and implementation presented in chapters 3, 4 and 5 of this dissertation.

### **2.5.4 Open EHR archetype**

The OpenEHR is an international not for profit foundation, founded by University of London UK and Ocean Informatics Australia. It is an open community dedicated to the realisation of the EHR. Open source software, specifications and tools are devised to create an information model to achieve semantic and technical interoperability. There are two levels in the structure of the openEHR. These are the reference information model and the archetype model. Reusable clinical models, the archetypes, are developed by domain experts. Archetypes and templates are defined using the Archetype Definition Language (ADL), and mapped to terminologies.

The openEHR draft archetype *inspection of an open wound* represents the four wound bed tissue types - necrosis, slough, granulation and epithelialization. However, it does not map colour to tissue type. Furthermore, the values are not proportion (Table 2-4)

There is current development activity on the draft wound archetype. This is represented as August 2012 in column (c) of the table. These developments do not appear in the draft archetype on the CKM web application. One such development is a proposal to assign proportion to the four wound bed tissue types.

<b>Wound bed Tissue type</b>	<b>Maximal wound bed assessment in clinical practice (a)</b>	<b>OpenEHR Draft Archetype (b)</b>	<b>Archetype (August 2012) (c)</b>
<b>Necrosis</b>	Tissue type present + colour + Percentage	Tissue type present  (ordinal)	Tissue type present  (proportion)
<b>Slough</b>	Tissue type present + Colour + Percentage	Tissue type present  (ordinal)	Tissue type present  (proportion)
<b>Granulation</b>	Tissue type present + colour + Percentage	Tissue type present  (text)	Tissue type present  (proportion)
<b>Epithelialization</b>	Tissue type present + colour + Percentage	Tissue type present  (Boolean)	Tissue type present  (proportion)

**Table 2-4** OpenEHR draft archetype *inspection of an open wound*

Table 2-4 describes:

- a.** Maximal wound bed assessment in clinical practice.
- b.** OpenEHR draft archetype as documented on the openEHR archetype repository
- c.** OpenEHR archetype August 2012 not yet on the CKM obtained from Dr. Ian McNicoll (see Appendix H personal communication).

The proposal to develop this draft archetype is presented in chapter 6 of this dissertation.

### **2.5.5 Clinical template**

A clinical template is a collection of data items that facilitates a specific healthcare application. It is modelled on the information content of a clinical form. It is designed to facilitate the recording of standardized clinical information, along with the maintenance of clinical and interoperability standards.

The NHS in Scotland commissioned a feasibility study into a national library of electronic clinical templates for community nursing. One such collaboration was with Clinical Nurse Specialists in Tissue Viability, resulting in the development of a wound assessment template (Hoy, 2007, Hoy et al., 2009) . The NHS in Scotland did not implement the clinical templates and they were finally withdrawn in January 2012. A new open source collaborative framework, ClinicalTemplates.org, has been launched. This promotes the development of clinical templates using OpenEHR (Hoy)

In Freiburg University Hospital researchers converted 2 clinical forms, with approximately 200 data items, to an electronic clinical template (Schuler et al., 2007). This template was developed to implement a generic web-based clinical information system architecture in a wound care clinic. This will be described further in the section on EHR's (2.5.6).

The proposal to develop of the OpenEHR draft archetype *inspection of an open wound* is presented in chapter 6 of this dissertation. This draft archetype will be a component of an electronic wound template that will record wound assessment.

### **2.5.6 Electronic health record (EHR)**

The Electronic Health Record (EHR) is the sum of all the useful clinical information that has been collected and stored by different people in different locations about a patient over their lifetime. It is a patient centred record of all relevant information that can be accessed from one place, independent of the location of that information.

The EHR aims to produce and maintain a common record architecture to:

- Record the clinical process (history, examination, assessment and plan)
- Document communication about this care process.

- Facilitate the safe and unambiguous recording, viewing and communication of current and planned care.
- Provide a record structure with consistent unambiguous semantics, which enables the provision of consistent clinical decision support.
- Improve quality of data for secondary use purposes (Sato, 2007).

Information and communication standards are required for the development of a wound EHR. Shared care involves sharing patient records. This requires technical, semantic and process interoperability (Gibbons et al., 2007):

- Technical interoperability - The transmission of data, including access and security. The transmission of data from image files requires effective internet services (Lowery et al., 2002).
- Semantic interoperability - The ability of information to be understood by and shared between systems. This facilitates clinical decision support.
- Process interoperability - The implementation of information systems within work settings

A generic clinical information system architecture was designed and implemented in the wound care outpatient department at Freiburg University Hospital (Schuler et al., 2007). A hospital information system (HIS) was already in place. Communication between distributed components was with HL7 V2. The authors described the stages in the iterative development of the system. Interviews were conducted with wound care clinicians. Two forms with 200 data items were identified. This in-house development was successfully implemented and established a proof of concept.

The proposal to develop of the OpenEHR draft archetype *inspection of an open wound* is presented in chapter 6 of this dissertation. This draft archetype will be a component of a wound care EHR that will fulfil the aims described above (Sato, 2007).

## **EHR and wound care in the United States of America**

In the United States of America proprietary electronic wound care management systems, incorporating digital wound images, are prevalent. These are well developed and expensive to procure. It is important to analyse the reason for



their prevalence, as it has relevance to the adoption of a wound care EHR in Ireland. Billing of health insurance providers has been a major driving force in their development. Medical insurance companies require wound planimetric data to determine the amount to pay for specialized advanced treatments. Reimbursement for wound debridement is based on the total surface area and not on the number of wounds debrided. Documentation and coding of clinical wound care is central to the billing process. Medical organisations must be compliant with International Classification of Disease (ICD) 10 by 2013.

### **2.5.7 Messaging standards**

A wound care EHR, incorporating digital wound images, will have telemedicine and clinical decision support applications. Messaging standards are relevant to this dissertation.

The ISO standards, HL7 CDA and EHRcom / EN13606, are designed to structure and code the clinical content of the EHR. Standards are required to transfer data between health information systems. Standards preserve the context information and provide comprehensive semantic definition of information.

#### **EHRcom / EN13606**

The Technical Committee 251 of the European Committee for Standardization (CEN 251) developed EN 13606 for EHR communication (EHRcom). EN 13606 has also been published as an ISO standard under the name ISO 13606. It seeks to provide a common platform between EN13606 compliant EHR systems. This is a dual model approach, which differentiates between information (Reference Model) and knowledge (Archetype Model). The CEN/TC251 EN 13606 is in five parts:

- Part 1: Reference Model – Information statements about specific entities. It reflects the stable characteristics of an EHR and the context information. It is made up of clinical data (composition, entry, element) and organizational data (folder, section, cluster)
- Part 2: Archetype Model – Knowledge statements which apply to all entities of a class. This is a formal framework to define semantically rich definitions of health concepts. An archetype is expressed in the form of constraints on the Reference Model
- Part 3: Reference archetypes and term lists

- Part 4: Security
- Part 5: Interface specification

### **Health Level Seven International (HL7)**

HL7 is another standards organization. It is accredited by the American National Standards Institute (ANSI). It aims to provide standards for all aspects of electronic health information within health services. HL7 v3 Clinical Document Architecture (CDA) is an XML-based messaging standard that is used to exchange clinical documents.

### **2.5.8 Health Informatics in Ireland**

The research presented in chapters 3, 4 and 5 of this dissertation relates to wound care clinicians in Ireland. It uses calibrated wound images in wound bed RYBP assessment. It is in this context that the EHRland project, HIQA and Data Protection are described.

#### **The EHRland project**

The EHRland project in Ireland is evaluating EN 13606. It is analysing user archetypes. These allow domain experts to agree on the information to be exchanged and the context of that information. It also aims to integrate EHRcom into existing electronic patient record (EPR) systems. The EHRland project will facilitate the development and implementation of wound care archetypes, templates and EHR.

The PARTNERS Project is one component of the EHRland project, focusing on shared community care (EHRland). The project developed and evaluated a shared electronic assessment tool, focusing on care of older people in the community. It is anticipated that this tool will be further developed for use by multi-disciplinary teams engaged in primary care, acute care and continuing care as a shared summary assessment record. This will facilitate wound care in the community.

#### **Health Information Quality Authority (HIQA)**

Established in 2007, HIQA has responsibility for standards on safety and quality in health and social care services in Ireland (with the exception of mental health services). HIQA are developing health information technical standards to support

consistency in recording health information, interoperability between systems and meaningful communication between systems. These standards include data definitions, clinical concepts and terminologies, coding and classifications, messaging specifications, the EHR and security (HIQA). The development of an Individual Health Identifier (IHI) and the proposed Health Information Bill are intrinsic to the process of standards development. Common and consistent data definitions are required to compare and measure health information. This will facilitate patient safety and quality of wound care.

### **Data Protection**

The Data Protection Acts 1988 and 2003 set out the security and privacy obligations of data controllers. The collection, storage and transmission of wound images extend the security and privacy concerns for patients relating to their personal data. The wound image is considered personal data unless it is completely anonymised. The same obligations apply to images, as with all personal data collected.

Consent is required prior to capturing a digital image. This is informed consent outlining:

- The reason why the image is required
- Where the image will be stored in their file
- What the image will be used for

As with all stored data (hardcopy and electronic), appropriate security measures are required to protect data. Transmission of data via a wireless network connection is more vulnerable to security breaches. The use of portable devices is envisaged in wound care. Measures to protect data include:

- Encryption
- Whole disk encryption
- Strong password use
- Remote memory wipe facility (in case of theft or loss)
- Logs and Audit Trails
- Intruder detection system

Currently, consent is required for the use of personal health data, including images, for research purposes. Where possible the patient image should be irrevocably anonymised for use in research or education. This places it outside data protection requirements, as it is no longer personal data. When research

requires the linking of patient identity with the research data then a code is used, this is known as pseudonymisation (Commissioner, 2007) .

Pseudonymisation is utilized in the research presented in chapters 3, 4 and 5 of this dissertation.

### **2.5.9 Summary of health informatics**

Wound care is shared between the community and the hospital. Information and communication standards are required to provide an EHR with technical, semantic and process interoperability.

The limitation of existing wound assessment terminology has been identified in the literature review. The Woundontology Consortium is advancing the practice of wound assessment by digital image feature analysis, ontology, semantic interpretation and knowledge extraction.

A number of wound care specific health informatics initiatives have been identified in the literature. These include the OpenEHR draft archetype *inspection of an open wound*, wound assessment clinical templates and wound clinic information system.

The EHRLand project and HIQA have an important role to play in facilitating the development and implementation of an EHR, incorporating wound care, in Ireland.

## **2.6 Statistical methods in quantitative wound care research**

### **2.6.1 Introduction to statistical methods**

Research is presented in chapters 3, 4 and 5 of this dissertation. This involves a study on inter-rater agreement between wound care clinicians and the Medical Reference Standard when completing wound bed RYBP assessment, using calibrated wound images. This section presents a background and literature review to the statistical analysis related to this research. Statistical analysis is outlined with respect to the Medical Reference Standard and Cohen's Kappa statistic.

### **2.6.2 Medical Reference Standard**

A number of synonyms exist for this concept in the literature. These are biological marker; gold standard; ground truth; absolute truth; true value; identifiable true value; unequivocal correct value; reference standard; reference clinician; artificial median clinician and super-clinician.

There are no unequivocal correct values or biological markers for wound bed RYBP assessment. The wound bed assessment is subjective.

*Colour analysis of pixels* in a calibrated wound does not provide an absolute medical reference with regard to wound bed RYBP assessment. Limiting the pixel colour analysis to the wound bed within the wound image requires planimetric analysis that can only approximate the wound boundary (Jones and Plassmann, 2000, Van Poucke et al., 2010a). Furthermore, a study on Red-Yellow-Black (RYB) pixel colour analysis within the wound bed reported that 46% of the wound bed had colour other than those three. There was also 24% overlap in colour in the pixel analysis, i.e. pixels that were classified as consisting of two colours. Thus, no absolute medical reference is found in pixel analysis of colour within the wound bed. Further colour semantic descriptors are required (Van Poucke et al., 2009).

*Artificial intelligence support vector machines (SVM)* do not provide an absolute medical reference either. The SVM is trained with a set of images whose tissue colour content has been determined by subjective expert clinicians. Thus, the

SVM does not have an absolute medical reference values from which to compile its 'knowledge'. (Belem, 2004, Wannous et al., 2011, Oduncu et al., 2004).

It is common to find in medical method comparison and inter-rater studies that no absolute medical reference values are available (Oduncu et al., 2004, Belem, 2004, Wannous et al., 2011). When there are no absolute medical values, then the mean of two methods of assessment most accurately represents these values (Bland and Altman, 1986). This process is described in chapter 3 Figure 3-2.

### 2.6.3 Cohen's kappa statistic (k)

Jacob Cohen published this statistical method in the journal 'Educational and Psychological Measurement' in 1960 (Cohen, 1960). It is further described in statistics texts (Fleiss et al., 2003, Agresti, 2002, Altman, 1991). This method measures agreement between clinicians, in the absence of absolute medical reference values (i.e. when judgements are complex and no judgement is correct). It seeks to differentiate agreement from association.

It assumes that all clinicians have 'equal' competency and operate independently. There is no restriction on the distribution of judgements. All discrepancies between judgements are treated equally.

This method recognises that agreement may occur by chance. It measures the proportion of agreement between clinicians after chance agreement has been removed.

Cohen's Kappa ( $k$ ) is expressed as:

$$k = \frac{Po - Pe}{1 - Pe}$$

**Equation 2-1** Cohen's kappa statistic

- **$Po$**  = Proportion of units in which judges agree (observed agreement)
- **$Pe$**  = Proportion of units for which agreement is expected by chance (expected chance agreement)

- **1-Pe** = Absolute agreement less expected chance agreement (prediction of disagreement)
- **Po-Pe** = beyond chance agreement

Recorded values between 2 Judges are plotted on a contingency table, from which *Po* and *Pe* are calculated Table 2-5.

		JUDGE B			
		↓			
JUDGE A		Category 1	Category 2	Category 3	Category 4
↓					
Category 1	Agreement	-	-	-	Marginal sum Category 1 JUDGE A
Category 2	-	Agreement	-	-	Marginal sum Category 2 JUDGE A
Category 3	-	-	Agreement	-	Marginal sum Category 3 JUDGE A
Category 4	-	-	-	Agreement	Marginal sum Category 4 JUDGE A
	Marginal sum Category 1 JUDGE B	Marginal sum Category2 JUDGE B	Marginal sum Category 3 JUDGE B	Marginal sum Category 4 JUDGE B	N subjects

**Table 2-5** Cohen's kappa statistic contingency table

**Po** is calculated from the line of exact agreement, represented in red.

**Pe** is calculated from marginal values in each category by both judges (Category1 Judge A x Category 1 Judge B) + (Category 2 Judge A x Category 2 Judge B) etc.. This is represented in pink.

### **Weighted kappa (kw)**

Jacob Cohen originally described kappa to assess agreement for nominal unrelated scales (Cohen, 1960). He subsequently made provision for ordinal scales with the weighted kappa (Cohen, 1968). Weighted kappa is further described in statistics texts (Fleiss et al., 2003, Agresti, 2002, Altman, 1991). With ordinal scales the categories have scaled degrees of disagreement. The weighted kappa takes account of these degrees of disagreement. Disagreement between adjacent categories on a scale is less than disagreement between the further most points on the same scale. In the context of wound bed RYBP assessment, one rater may rate red at 10% and another rate it at 90%. This difference would have significance for managing the wound. A weighting is applied to each value for  $P_o$  and  $P_e$ , to reflect the degree of disagreement.

- $g$  = number of categories in an ordinal scale
- $g - 1$  = number of disagreements (degrees of difference).

Two forms of weighting of kappa are described. These are linear weighting and quadratic weighting.

#### **Linear weighting** (Cicchetti and Allison, 1971, Cicchetti, 1976):

This weighting uses the number of squares that separate a value on the contingency table from the diagonal of exact agreement.

This is expressed as:

$$W_{ij} = 1 - \frac{i - j}{g - 1}$$

#### **Equation 2-2** Linear weighting of Cohen's kappa statistic

#### **Quadratic weighting** (Fleiss and Cohen, 1973):

This weighting uses the square of the numerator and square of the denominator from the linear weighting equation.

This is expressed as:



$$W_{ij} = 1 - \frac{(i-j)(i-j)}{(g-1)(g-1)}$$

**Equation 2-3** Quadratic weighting of Cohen's kappa statistic

Cohen's weighted kappa ( $kw$ ) is expressed as:

$$kw = \frac{Po(w) - Pe(w)}{1 - Pe(w)}$$

**Equation 2-4** Weighted Cohen's kappa statistic

When all categories other than absolute agreement are rated 0, then  $kw=k$ .

Weighting kappa does not always improve measurement of agreement (Cohen, 1968).

**Weighted kappa - Comparing a judge with the Medical Reference Standard**

Weighted kappa may be calculated for an *individual judge* against the *Medical Reference Standard* (Light, 1971b).

However, a different statistic ( $G$ ) is required to measure agreement between a *group of judges collectively* and a *Medical Reference Standard*. This is because the marginal values for the Medical Reference Standard in the contingency table will remain the same. This is not allowed for in the weighted kappa statistic. These marginal values are used to calculate the expected chance agreement (Light, 1971b, Fleiss et al., 2003)

**Weighted kappa in wound bed assessment studies**

The weighted kappa has been used in wound bed tissue colour classification studies (Oduncu et al., 2004, Belem, 2004, Wannous et al., 2011). In addition, these studies used a medical reference standard.

### **Multi-rater kappa (group kappa)**

Multi-rater kappa has been described (Fleiss et al., 2003, Agresti, 2002, Landis and Koch, 1977, Light, 1971b).

This is used when more than 2 raters ( $m$ ) are judging  $n$  subjects in  $g$  categories. Not all raters are required to rate all subjects in all categories.

### **Weighted kappa in IBM SPSS statistical software.**

SPSS output produces a contingency table and an unweighted kappa value. Linear and quadratic kappa is obtained by using the unweighted contingency table output matrix as a new input matrix in SPSS. Then SPSS syntax MATRIX-END MATRIX is used to generate the linear and quadratic weighted kappa value (IBM)

### **Interpretation of kappa, weighted kappa and multi-rater kappa**

The values for  $k$  are defined thus:

- **$K = 0$**  - chance agreement
- **$K = +1.00$**  - perfect agreement
- **$K < 0$**  - less than chance agreement

Interpretation of Kappa, Weighted Kappa and Multi-rater Kappa have been defined (Landis and Koch, 1977, Altman, 1991)

- **$K = 0 - 0.4$**  – fair agreement
- **$K = >0.4 - 0.6$**  – moderate agreement
- **$K = >0.6 - 0.8$**  – good agreement
- **$K = >0.8 - 1$**  – very good agreement

### **Limitations with kappa agreement**

- Raters are required to be independent and equally experienced (Cohen, 1960, Fleiss et al., 2003). However, inter-rater agreement between a single rater and a medical reference standard is allowed (Light, 1971a)
- The information contained in a contingency table is reduced to a single value. This can result in significant reduction in information (Agresti, 2002). The complete contingency table provides more information on agreement.

- Interpretation scale for kappa is open to question. The scale is arbitrary. (Landis and Koch, 1977)
- The value of kappa is dependent on marginal values that are used to calculate chance agreement. The distribution of marginal values may significantly alter the value of kappa.
- Null hypothesis and confidence intervals are not so relevant when measuring kappa.
- Kappa range is from -1 to +1. Values  $<0$  indicate agreement less than chance agreement and are not worth analysing further (Cohen, 1960).
- Kappa values cannot be compared between studies (Altman, 1991).
- SPSS does not weight kappa. However, IBM has published the syntax MATRIX-ENDMATRIX that can be applied to a kappa contingency table to yield a weighted kappa result.

#### **2.6.4 Summary of statistical methods**

Research is presented in chapters 3, 4 and 5 of this dissertation. Study data will be obtained relating to wound bed RYBP assessment from wound care clinicians (using calibrated wound images) and the Medical Reference Standard. Weighted Kappa statistic will be used to measure inter-rater agreement. This statistical measure is used in comparable studies. Furthermore, it is identified from statistical texts that this is a suitable measure to use in this study.

#### **2.7 Conclusion to literature review**

Literature was critically appraised in relation to clinical assessment, digital imaging, health informatics and quantitative statistical analysis.

Wound care involves interdisciplinary collaborative shared care. Communication of wound status over time between medical personnel is an integral part of clinical wound care. The accurate visual assessment of the wound is essential to effective wound management. An understanding of the pathophysiology of wound healing has informed clinical assessment tools. Wound bed RYBP

assessment and its clinical interpretation guide best practice in wound management.

Colour is common to the visual assessment of both wounds and wound images. The calibrated digital wound image provides permanent accurate and reproducible wound documentation, suitable for evaluation. It can be data mined for planimetric analysis, volumetric analysis and tissue classification. It facilitates wound comparison over time and telemedicine. It facilitates audit of wound care interventions and outcomes. It facilitates wound care education and research. Automated tissue colour classification of digital images, using artificial intelligence, has been developed.

Wound care involves shared care between the community and the hospital. Information and communication standards are required to provide an EHR with technical, semantic and process interoperability. The limitation of existing wound bed terminology has been identified in the literature review. A number of wound care specific health informatics initiatives have been identified. The openEHR draft archetype *inspection of an open wound*, the wound assessment clinical template and wound clinic information system architecture are the foundation for an EHR, facilitating standardized wound care. The Woundontology Consortium aims to facilitate semantic interoperability and clinical decision support.

Cohen's kappa statistic is frequently used in wound care studies. The Medical Reference Standard is used in the absence of a biological marker for wound bed tissue quantities. This statistical method is identified in statistical texts as being appropriate for use in this type of research.

Literature review has identified that:

- Clinical wound care utilizes wound bed RYBP assessment.
- Calibrated digital wound images can be data mined for wound bed RYBP assessment
- The UMLS Metathesaurus under-represents wound bed RYBP assessment
- The OpenEHR *archetype inspection of an open wound* does not use proportion data value for wound bed RYBP assessment. It does not map colour to wound bed tissue type

- Cohen's kappa statistic is a suitable measure in an inter-rater wound bed RYBP assessment study
- The Medical Reference Standard provides the reference value in wound bed RYBP assessment

The review of wound care knowledge has informed the research presented in chapters 3, 4 and 5 of this dissertation:

- Survey of wound care centres - to identify current wound bed assessment in clinical practice
- Survey of wound care clinicians - to measure suitability of calibrated wound images for treatment recommendations
- Study using calibrated wound images - to measure wound bed RYBP assessment inter-rater agreement between fourteen Tissue Viability Nurses (TVN) and the Medical Reference Standard

Wound care knowledge presented in this chapter along with the research will combine to form the basis of a proposal to develop the Open EHR draft archetype *inspection of an open wound* presented in chapter 6.

Chapters 3, 4 and 5 will present the research. Chapter 6 will present the research based proposal.

## **Chapter 3      Research Design and Methodology**

### 3.1 Introduction to Research Design and Methodology

Chapter 2 presented the literature review relating to clinical wound bed assessment, calibrated wound image assessment and health informatics in wound bed assessment.

From the literature review the aims of this research have been developed:

- To explore the use calibrated images in wound bed assessment.
- To present a proposal to develop the OpenEHR draft archetype *inspection of an open wound* to reflect wound bed RYBP assessment.

These aims will be met through the research objectives and research questions.

This chapter describes the research design and methodology. Chapter 4 will present the results of this research. Chapter 5 will evaluate and analyze the research results.

The research design and methodology of wound bed assessment relate to:

- Survey of wound care centres - to identify current wound bed assessment in clinical practice
- Survey of wound care clinicians - to measure suitability of calibrated wound images for treatment recommendations
- Study using calibrated wound images - to measure wound bed RYBP assessment inter-rater agreement between fourteen Tissue Viability Nurses (TVN) and the Medical Reference Standard

*RYBP* is *granulation (Red)*, *slough (Yellow,)* *necrosis (Black)* and *epithelialization (Pink)* tissue types in the wound bed.

*Medical Reference Standard* is an approximated true value for the four wound bed tissue types in the 11 wounds included in the study, based on an algorithm (Figure 3-2).

*TVN* is Tissue Viability Nurse

Research design and methodology are described in terms of:

- Objective
- Participants
- Data collection procedures
- Statistical methods



## **3.2 Survey on wound assessment clinical practice**

### **3.2.1 Objective**

Sixteen wound care centres in Ireland, were surveyed to identify how they record wound bed assessment.

### **3.2.2 Participants**

Paper wound assessment forms in use at the major hospitals in the Republic of Ireland were collected.

The following criteria were used when selecting the sample of 14 hospitals for the survey:

- Regional location
- Number of inpatient beds (>300)
- Presence of a TVN

### **3.2.3 Data collection procedure**

Clinical Nurse Specialists in Tissue Viability (TVN's) were contacted at the hospitals by post. They were requested to forward the wound assessment form currently in use in their centre. At this point they were also invited to participate in a study using calibrated wound images.

In addition, two community wound assessment forms were collected. Finally the sample wound assessment contained within the HSE wound management guidelines (HSE, 2009) was included.

In total, seventeen Irish paper based wound assessment forms were collected for inclusion in the survey.

### **3.2.4 Statistical methods**

#### **Data input**

Raw data collected from the survey was recorded in a codebook, immediately following data collection. Data entry was checked twice in the presence of an independent observer. The statistical software package IBM SPSS was used for data analysis.

Subsequently, the raw data was input into SPSS input files, again being checked twice in the presence of an independent observer.

SPSS input files were screened for errors in accordance with the methods described by Pallant (Pallant, 2010).

### **SPSS input files**

*Wound bed RYBP assessment* - input file

- The variable (column) was the RYBP assessment (n=1). This comprised an ordinal variable 1-5.
- The cases (rows) were the woundcare centres (n=17). This comprised 14 hospital forms, 2 community centre forms and HSE Wound Guideline sample form.

### **Statistical analysis**

Descriptive statistics were used to analyse the data collected in the *survey*. These were generated as outputs in IBM SPSS. They included:

- frequency table
- pie chart

### **Scale**

A scale was developed to categorize wound bed RYBP assessment in the forms. This scale was ordinal and contained five items:

- 1.** No tissue type recorded
- 2.** Tissue type recorded – without colour or percentage
- 3.** Tissue type recorded – colour without percentage
- 4.** Tissue type recorded – percentage without colour
- 5.** Tissue type recorded – percentage and colour

### 3.3 Survey on suitability of calibrated wound images

#### 3.3.1 Objective

The objective of this survey was to measure the suitability of calibrated wound images for treatment recommendations.

#### 3.3.2 Participants

19 wound care clinicians were asked to rate the suitability of 12 calibrated wound images for treatment recommendations, given all relevant clinical data. They completed wound bed RYBP assessment on the wound images prior to rating them.

#### 3.3.3 Data collection procedures

Data was collected on a questionnaire on suitability of calibrated wound images for treatment recommendations using a Likert type scale Figure 3-1. This was a five point rating scale, ranging from *definitely not* to *definitely yes*. This data instrument was developed using study design methods (Pallant, 2010).

#### Data instrument

If you are supplied with all other relevant clinical details, do you believe that this wound image is suitable for **TREATMENT RECOMMENDATIONS**?

Please circle one number that reflects your opinion	1. DEFINITELY NOT	2. PROBABLY NOT	3. EQUAL PROBABILITY	4. PROBABLY	5. DEFINITELY
Suitable for treatment Recommendations	1	2	3	4	5

- 1. DEFINITELY NOT:** Clinician is certain that the wound image **is not suitable** for treatment recommendations.
- 2. PROBABLY NOT:** Clinician thinks that the wound image **is not suitable** for treatment recommendations, but is not 100% certain
- 3. EQUAL PROBABILITY:** Clinician thinks that the wound image **may or may not be suitable** for treatment recommendations.

- 4. **PROBABLY:** Clinician thinks that the wound image **is suitable** for treatment recommendations, but is not 100% certain
- 5. **DEFINITELY:** Clinician is certain that the wound image **is suitable** for treatment recommendations.

**Figure 3-1** Question on suitability for treatment recommendations

### 3.3.4 Statistical methods

#### Statistical data input

Raw data was input into SPSS input files following the same protocol described for the survey on wound bed assessment in clinical practice (section 3.2.4). SPSS input files were screened for errors in accordance with the methods described by Pallant (Pallant, 2010).

#### Statistical input file

*Calibrated wound image suitability for treatment recommendation* - input file

- The variables (columns) were the wound images (n=11). These were ordinal variables 1-5
- The cases (rows) were four wound care clinicians at Tallaght Hospital, 14 TVN's and academic wound care clinician (n=19)

#### Statistical analysis

Descriptive statistics were used to analyse the data collected. These were generated as outputs from the IBM SPSS analysis. They included:

- pie chart
- bar chart

#### Scale

Suitability of calibrated wound images for treatment recommendations Likert type scale Figure 3-1 above.

## **3.4 Study of wound bed RYBP assessment using calibrated wound images**

### **3.4.1 Objective**

The objective of this study was to measure inter-rater agreement on wound bed RYBP assessment between fourteen TVN's and the Medical Reference Standard, using calibrated wound images.

The study involved the selection of patients with wounds attending the outpatient vascular clinic at Tallaght Hospital. The wounds were assessed by four wound care clinicians and photographic images were obtained. The images were calibrated. The calibrated wound images were subsequently assessed by the same four wound care clinicians, along with fourteen TVN's and an academic wound care clinician.

### **3.4.2 Participants**

#### **Patients**

Patients with lower limb wounds attending Tallaght Hospital outpatient vascular clinic over two days were selected. Nine patients (n=9) with fifteen wounds (n=15) were included in the study. These were mainly venous, arterial, and diabetic ulcers.

Informed patient consent was obtained for:

- Participation in the study
- Wound image capture
- Use of the wound image in education and research.

#### **Clinicians**

There were four wound care clinicians in Tallaght Hospital, fourteen TVN's country-wide and one academic wound care clinician.

A vascular specialist at Tallaght Hospital agreed to conduct the study in the outpatient vascular clinic. He and three of his wound care colleagues participated

in the study. Information sheets were given to the clinicians and consent for participation in the study was obtained. They assessed both the wounds and images of the same wounds six weeks later.

Fourteen TVN's were contacted and agreed to participate in the study. As outlined previously, these were selected from hospitals countrywide. These were the same nurses that supplied the wound assessment forms. Information sheets were provided and consent for participation in the study was obtained. They assessed the calibrated wound images that were collected at Tallaght Hospital.

An academic wound care clinician also assessed the calibrated wound images. Information was provided and consent for participation in the study was obtained.

### **Imaging participants**

Wound image capture – The medical photographer at Tallaght Hospital captured the wound images in accordance with hospital protocol.

Wound image calibration – Dr. Yves Vander Haeghen, referred to in section 2.4.3, has developed wound image calibration software. He calibrated the wound images in Belgium. In addition, he provided instructions relating to camera flash, camera settings and X-rite mini colour checker chart orientation.

## **3.4.3 Data collection instruments**

There were four data collection instruments, which are described below (see Appendix D). The clinicians were asked to complete data instrument 1. Data instruments 2, 3 and 4 were completed by the researcher.

### **1. Wound bed assessment data instrument**

- This comprised four colour coded boxes linking colour with tissue type
- Clinicians were requested to assign percentage to each tissue / colour type, reflecting their opinion of each wound.
- This data instrument was developed from the wound assessment forms surveyed (see section 3.2)

## **2. Exudate assessment data instrument**

- This comprised two tables to record exudate volume and exudate viscosity
- The researcher assigned values for each of these (low, medium, high), based on wound and dressing assessment
- This data instrument was developed from the Wound Exudate Continuum referred to in the literature review see section 2.3.9(Gray et al., 2005)

## **3. Infection assessment data instrument**

- This comprised a table to record level of infection observed in the wound
- The researcher circled one of four options on an ascending scale -
  - Colonised; critically colonised; local infection; spreading infection
- This data instrument was developed from the Wound Infection Continuum referred to in the literature review see section 2.3.9(Gray et al., 2005)

## **4. Pain assessment data instrument**

- This comprised four tables:
  - Pain frequency - ascending scale
  - Pain location – ascending scale
  - Analgesia use - ascending scale
  - Pain severity - verbal rating ascending scale
- The researcher recorded information obtained from interviewing the patient.
- This data instrument was developed from the wound assessment forms surveyed in section 3.2

In addition to the data instruments described above, there was an information and instruction sheet for each patient and clinician (see Appendix C). Information and instruction was also given to patients and clinicians verbally.

A glossary of terms was compiled for the study, containing definitions of wound bed terms as appear in terminologies and textbooks. However, the wound bed tissue characteristics were so familiar to the clinicians that it was decided that

the glossary was not required. This wound bed glossary is incorporated in the dissertation glossary to inform the reader.

A 5 point Likert type scale for wound edge and surrounding skin assessment was also developed. This contained 30 items. It was decided to omit this data instrument from the study; because of the time it would take clinicians to complete the form.

### **3.4.4 Data collection procedure**

Data collection for this study was in three stages:

**STAGE 1** Direct wound assessment and wound image capture

**STAGE 2** Wound image calibration

**STAGE 3** Indirect wound image assessment using calibrated wound images.

*Direct wound assessment* refers to the assessment of the patients wound at the clinic.

*Indirect wound image assessment* refers to the assessment of the calibrated wound image of the wound.

#### **STAGE 1 – Direct wound assessment and wound image capture**

Study design and methodology was discussed at meetings with the four wound care clinicians and the medical photographer, prior to data collection.

Data collection took place at the outpatient vascular clinic at Tallaght Hospital, over two days. Hospital infection control policy was adhered to during data collection.

#### **Day One**

Patients were selected from attendees at the clinic, with lower leg wounds suitable for imaging. Written and verbal information was given to these patients by the researcher. All patients who were approached agreed to participate in the study. Informed consent for the capture of the images and for participation in the study was obtained by the researcher. Each patient was assigned a folder and a unique identifier. In patients with more than one wound, each wound had



a unique identifier. Each data instrument was labeled for that patient at this time, with the exception of the wound assessment data instrument.

The researcher recorded information regarding exudate, infection and pain. This was obtained from patient interview and clinical assessment.

The *exudate assessment* was informed by discussion with the patient and attending nurse regarding the frequency of dressing changes and strike through on the dressings.

In the *infection assessment* spreading infection was based on inflammation more than two centimetres from the wound edge.

The *pain assessment* was based on a Verbal Rating Scale of 1-10, indicating the patients' subjective rating of pain severity. In addition, pain frequency, pain location and analgesia use were recorded.

Each of the four wound care clinicians involved in the study was given a clipboard containing information sheet, instruction sheet and wound bed assessment data instruments. Each clinician assessed the wounds independently. They were given a label to apply to the patient folder when their assessment was completed. There was no clinician identifier on the wound bed assessment data instrument. In doing so, anonymity of their assessment was maintained.

The unique identifier assigned to the wound was incorporated into the wound image. This was to link the image with its associated data instruments. The signed photography consent form was photographed immediately preceding capture of the wound image. This facilitated additional tracking of the images with the data sets, during the data collection process.

The medical photographer adapted to imaging in the clinic environment, rather than in the photographic studio. The workflow in the clinic required that patients remain onsite for removal of dressings, treatment of wounds and application of complex dressings. Furthermore, the profile of the patients attending the clinic was such that their mobility was impaired.

A temporary photographic studio was set up in one of the treatment rooms in the clinic. Patients were brought to this room, where black background material and step up were placed on the floor. It proved to be impractical for patients to

stand posing for image capture. Most patients were not well enough to stand on the step up. Subsequent patients were imaged in the room where they were receiving their treatment. The researcher assisted the photographer by holding the X-rite mini colour checker chart in a perpendicular plane to the wound. The mini colour checker chart was incorporated into the wound image.

The usual protocol in wound care at the clinic was adhered to. Wound dressings were removed and wounds were cleaned prior to assessment and imaging. The routine clinical practice of applying paraffin gel to the legs was deferred until imaging had been completed. This was necessary to avoid problems with reflectance in the image.

## **Day Two**

Based on the data collection procedure experience on day one, two changes were made on day two.

Firstly, an *anatomical drawing* of the human body was attached to the wound bed assessment data instruments. This was to prevent mislabeling, particularly in the case of multiple wounds on a single patient.

Secondly, an *assistant* accompanied the researcher. The assistant ensured that each patient dataset was complete.

In every other respect the data collection procedure was the same as on day one.

## **STAGE 2 - Wound image calibration**

As described above, the medical photographer captured fifteen wound images at the outpatient clinic at Tallaght Hospital. The camera was the NIKON D3X (24.5 mega pixels). The flash was the NIKON RING FLASH SPEED LIGHT SBR 200. The lens was a NIKOR 105 mm macro lens. The camera settings were ISO 800. The aperture was adjusted between f8- f16 to suit the wound. The camera setting was neutral, manual focus, RAW images, RGB colour space white balance.

It was originally planned to calibrate the images using C4Real, a software application developed by Dr. Yves Vander Haeghen for this purpose. C4Real is available on the internet. This software application was developed for use with the Gretag Mini Macbeth Color Checker Chart (Mini MCCC). However, the Mini

MCCC is no longer available, since the company Gretag merged with X-rite. Consequently, Dr. Vander Haeghen agreed to calibrate the images in Belgium, using his latest calibration software that is compatible with the X-rite chart. The anonymised wound images were sent to him via Dropbox. This method of transfer was required because of the size of the wound image files.

The calibration process as described in section 2.4.3 of the literature review was applied to fifteen wound images. The calibration was automated. Following a batch run nine images were successfully calibrated. A further three images were successfully calibrated manually (see Appendix E detailed calibration report). Three of the images were unsuitable for calibration. This was because the calibration colour checker chart was incorrectly positioned in the image capture process or the image was overexposed. Twelve calibrated images were returned via Dropbox. These were suitable for inclusion in the study.

### **STAGE 3 – Indirect wound image assessment using calibrated wound images**

The calibrated wound image assessment data was collected from:

- *Fourteen TVN's* countrywide. These were the same nurses that provided the wound assessment forms for the survey described in section 3.2
- *Four wound care clinicians* in Tallaght Hospital. These were the same four clinicians that performed the direct wound assessment at the time of image capture
- *One academic wound care clinician.*

### **Clinical Nurse Specialists in Tissue Viability - TVN's (n=14)**

The researcher met with the fourteen TVN's around the country, so that they could view and assess the calibrated wound images. Other options for viewing the images, such as postal and electronic transfer, were considered. However, the approach taken was superior for the purpose of this research study. It resulted in:

- Maximum participation in the study.
- Integrity of the data collected. Each wound bed assessment data set was linked to its related calibrated wound image, at the time of recording.

- Standardized calibrated image viewing conditions. The images were all viewed on the same Sony VAIO Laptop computer, with the same sRGB settings, to reduce bias. The viewing room environment in the different centres remained a variable. This was minimized by ensuring that all viewing took place under similar lighting and reflection conditions.
- Assistance with calibrated wound image viewing. The magnification facility on the Laptop proved to be very beneficial for visualization of the wound bed.
- Immediate response to unforeseen queries presented by the TVN's, while doing the image assessment.

Calibrated wound image assessment was done on a one to one basis, with the exception of one hospital where 2 TVN's assessed the images together, simultaneously. In this case there was no collaboration with regard to their assessments.

The data collection process took between 20-45 minutes. The time was divided between:

- Obtaining consent
- Providing information and instruction
- Recording responses to the 11 calibrated wound image assessments
- Recording responses to questionnaire on calibrated wound image suitability for treatment recommendations
- Recording responses to demographic questionnaire

### **Wound care clinicians at Tallaght Hospital (n=4)**

The researcher returned to Tallaght Hospital and presented the calibrated wound images to the four wound care clinicians, who had performed the direct wound assessments (section3.4).

More than six weeks had elapsed since their direct wound assessments had been performed. Despite the time interval between the assessments, the clinicians remembered some of the patients and described their wound progress in the interim. This introduced potential bias to their indirect wound image assessments.

These four clinicians performed their indirect wound image assessments individually. The same protocol as described for the TVN's above was used.

#### **Academic wound care clinician (n=1)**

An academic wound care clinician viewed and assessed the calibrated wound images. The researcher followed the same protocol as described for the TVN's, when collecting the data.

### **3.4.5 Data loss**

#### **Stage 1 - Direct wound assessment and wound image capture**

One wound was assessed by three clinicians prior to image capture. There was eschar (scab) on this wound, which separated from the wound bed before assessment by the fourth clinician. Consequently, the fourth direct wound assessment data set was deemed to be invalid.

One wound was assessed by four clinicians, but the wound was debrided prior to the image capture. This image was successfully calibrated, but was deemed unsuitable for inclusion in the wound image study.

On day one, there were two wounds that had mislabeled data sets. Consequently, one direct wound assessment data set from each of these wounds was rendered invalid and omitted from the study.

All data sets were inspected on the day of their completion. The data was checked twice and recorded in a study codebook in the presence of an independent observer.

#### **Stage 2 - Wound image calibration**

Three of the wound images were unsuitable for calibration, either automatically or manually. This resulted from misplacing of the colour checker chart or overexposure of the image (see Appendix E for detailed calibration report). These three wound images were not included in the study.

### **Stage 3 - Indirect calibrated wound image assessment**

Eleven calibrated wound images (n=11) were suitable for inclusion in this part of the study. A complete set of data was obtained from wound bed assessment of these eleven calibrated images. All data sets were inspected immediately following their completion. The data was checked twice and recorded in a study codebook in the presence of an independent observer.

#### **3.4.6 Statistical methods**

##### **Data input**

Raw data collected from the study was recorded in a codebook immediately following data collection. Data entry was checked twice in the presence of an independent observer.

Subsequently, the raw data was input into IBM SPSS input files, again being checked twice in the presence of an independent observer.

SPSS input files were screened for errors in accordance with the methods described by Pallant (Pallant, 2010).

##### **Data SPSS input file**

*Clinician inter-rater agreement wound bed RYBP assessment* - input file

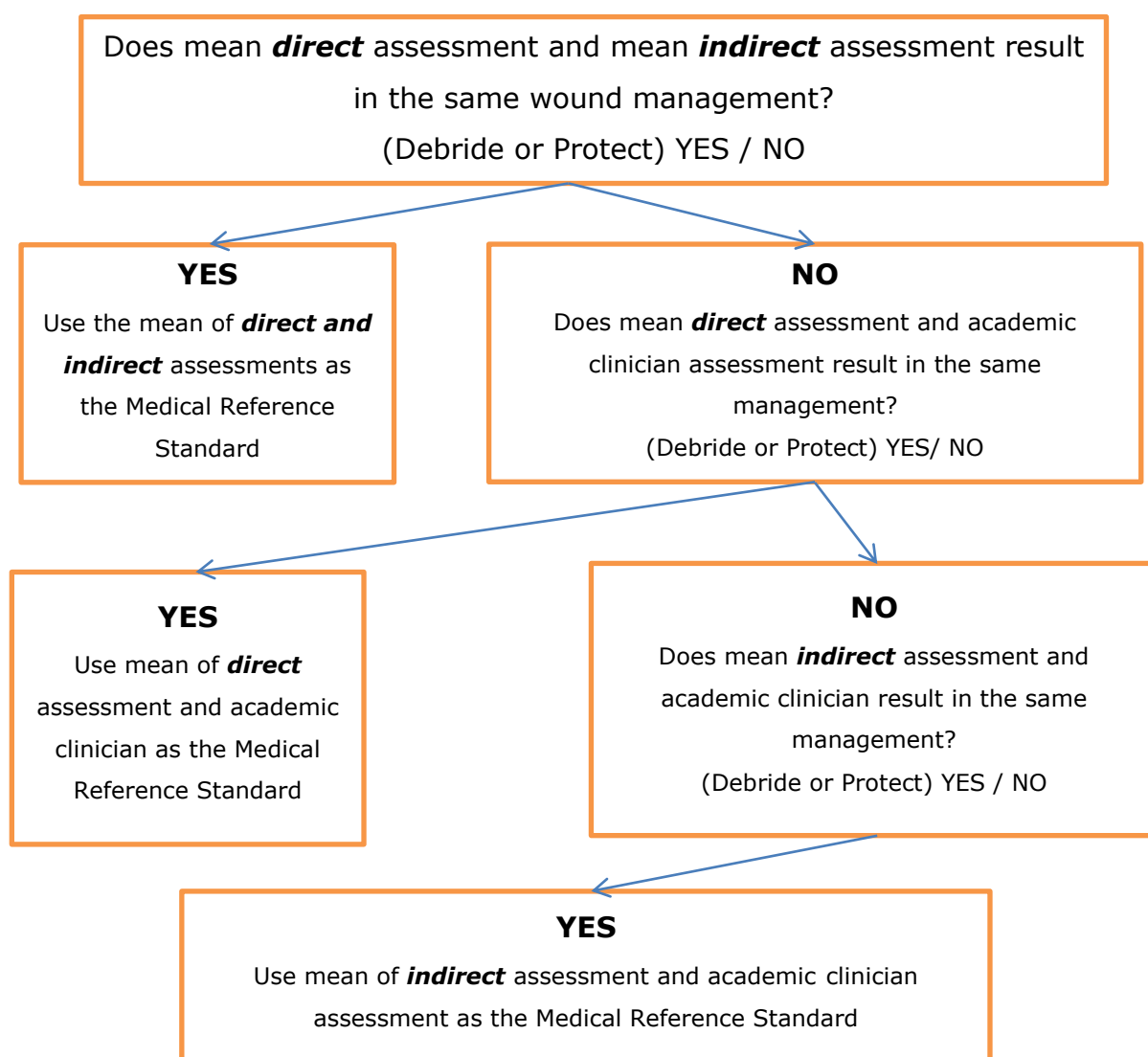
- The variables (columns) were the clinicians assessments (n=23). This comprised four wound care clinicians (direct and indirect assessments), fourteen TVN's and one academic wound care clinician. These were continuous scale variables 0-100%
- The cases (rows) were the wound tissue types. This comprised 11 images with 4 tissue types in each image (n=44)

##### **Statistical analysis methods**

The research study involved the quantitative analysis of data obtained from wound bed RYBP assessment. Cohen's weighted kappa statistic was used to measure *inter-rater agreement* between TVN's and the Medical Reference Standard, with respect to wound bed RYBP assessment.

Kappa inter-rater agreement measurement required categorical ordinal variables. The wound bed RYBP data was input as continuous variables

(percentages) in SPSS. These continuous variables were *collapsed* into 10 ordinal percentage categories, using *visual binning* in SPSS (Pallant, 2010). There were no absolute medical reference values for the wound bed RYBP assessments. The *Medical Reference Standard* was obtained from the wound care clinicians at Tallaght Hospital, who assessed both the wounds and the wound images.



**Figure 3-2** Algorithm for Medical Reference Standard

The mean value from both of their methods of assessments was assigned as the Medical Reference Standard. The academic wound care clinician assessment was used to adjudicate in the event of divergent assessments from the four wound care clinicians. Wound infection continuum data, wound exudate continuum data

and pain assessment data were also used in the adjudication process. Divergent assessment meant that the mean values for each method of assessment would result in a significant change in wound management (Figure 3-2).

Adjudication was required for three of the wounds. The method of assessment by the four wound care clinicians that was in disagreement with the academic wound care clinician and the related clinical data was not accepted. For these three wounds, the Medical Reference Standard was determined from the more consistent method of assessment by the four wound care clinicians and academic wound care clinician.

Inter-rater agreement was analyzed using weighted Kappa statistic. Four tissue types for eleven wounds were analyzed together.

A two-way contingency table was prepared, comprising the Medical Reference Standard in the rows and each TVN in the columns. Firstly unweighted kappa was calculated in IBM SPSS. Then the contingency table matrix output in IBM SPSS was weighted using the MATRIX-ENDMATRIX syntax in the syntax editor (IBM). Linear and quadratic weighting was applied to the categorical ordinal variable scales, representing degrees of difference (Fleiss and Cohen, 1973), (Cicchetti, 1976) see section 2.6.3 and Table 3-1.



## Scale

Wound bed RYBP assessment ordinal scale.

This scale had 10 categorical variables between 0% and 100%

### TVN

↓

Medical Reference Standard ↓	0- 9%	10- 19%	20- 29%	30- 39%	40- 49%	50- 59%	60- 69%	70- 79%	80- 89%	90- 100%
0-9%	1									0
10-19%		1								
20-29%			1							
30-39%				1						
40-49%					1					
50-59%						1				
60-69%							1			
70-79%								1		
80-89%									1	
90-100%	0									1

**Table 3-1** Wound bed RYBP assessment contingency table with weighting

1. *Red cells* represent the diagonal of exact agreement and its weighting is 1
2. *Blue cells* represent weighted distance from the diagonal of exact agreement (different shades represent degrees of difference)
3. *Black cells* represent maximum distance from the diagonal of exact agreement. This is disagreement and its weighting is 0

Interpretation of weighted kappa result (see section 2.6.3)

Value of K	Strength of agreement
<0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Very good

**Table 3-2** Interpretation of Kappa

### 3.5 Ethical considerations

Tallaght and St. James's Hospitals' research ethics committee use a common application form for academic and investigator led research studies that do not involve medicinal products, covered by the statutory instrument 190. This conforms to the World Medical Association Declaration of Helsinki 2008 (Association, 2008). The participation of patients and inclusion of patient data in this research study required ethical approval. Ethical approval was obtained from this joint hospitals ethics committee. In addition ethical approval was obtained from Trinity College Dublin ethics committee. This study conformed to the conditions of the ethical approvals obtained.

The Data Protection Acts (Ireland, 1988 , Ireland, 2003) provide the legislative basis for the protection of *personal data* in Ireland. The Data Commissioner Guidelines on Research in the Health Sector provide additional information on the protection of *patient data* (Commissioner, 2007).

The nature of this study involved sensitive patient data in the form of images. The Data Commissioner was contacted for specific advice (see Appendix I).

Publication level patient consent was obtained from patient participants:

- Consent to capture the image
- Consent for use of the image in education and research
- Consent to publish the image

The study did not involve access to patient healthcare records. The clinical assessments needed to be linked to the wound image. The clinical assessments and images were pseudonymised, using a code. This assigned the assessments and images a code which did not identify the patient. The code linking the images to the clinical data was held by the researcher. The electronically stored images were irrevocably anonymised. The images were not linked to an individual and could not be considered *personal data*. Consequently the images were outside the remit of data protection requirements.

The assessment forms obtained for the survey remain the property of the hospitals and centres from where they originated. The purpose of the survey was to identify how wound bed is assessed. There was no intention to publish the forms and consent to do so was not sought. (See Appendix A for sample form). No patient information was recorded in these forms. Hence there were no ethical issues in this regard.

### **3.6 Conclusion to Research Design and Methodology**

This chapter presented research design and methodology relating to wound bed assessment:

- Survey of wound care centres to identify wound bed assessment clinical practice
- Survey of wound care clinicians on suitability of calibrated wound images for treatment recommendations.
- Study measuring inter-rater agreement between TVN's completing wound bed RYBP assessment using calibrated wound images and the Medical Reference Standard.

The research was described in terms of participants, data collection procedure and statistical methods

The statistical methods used were:

- Descriptive statistics for survey of wound bed assessment clinical practice and suitability of calibrated image for treatment recommendations

- Cohen's weighted kappa statistic to measure inter rater agreement between the TVN's and the Medical Reference Standard

The ethical considerations, including ethical approval and data protection requirements, were discussed.

Research and analysis are presented in chapter 4 and chapter 5, respectively.

## **Chapter 4      Results**

## **4.1 Introduction to Results**

Chapter 3 described the methodology and implementation of the research relating to wound bed assessment. This chapter will now present the results of this research.

### **1. Survey results**

- Current wound bed assessment clinical practice
- Suitability of calibrated wound images for wound bed assessment and treatment recommendations

### **2. Study results**

- Wound care clinician agreement on wound bed assessment, using calibrated wound images

The research results are presented in terms of:

- Motivation
- Objective
- Methodology
- Results
- Analysis

## **4.2 Wound bed assessment clinical practice**

### **Motivation**

This research aims to present a rationale for developing the openEHR wound archetype. A fundamental reason for doing so is to reflect current clinical practice. It is in this regard, that a survey is undertaken to investigate current clinical practice.

### **Objective**

To measure wound bed assessment clinical practice

### **Question**

What is wound bed assessment clinical practice in the survey sample?

### **Methodology**

A sample of wound assessment forms from 14 major hospitals, 2 community based centres and HSE wound care guidelines is selected.

Recording of wound bed tissue type with associated colour and percentage is measured.

Descriptive statistic is used to analyze the data.

### **Results**

Of the 17 forms surveyed:

- One recorded tissue type without reference to colour or quantity.
- Two forms recorded tissue type and colour e.g. Necrosis (black)
- Three forms recorded tissue type and quantity e.g. Necrosis (%)
- Eleven forms recorded tissue type with colour and percentage e.g. Necrosis (black / %)

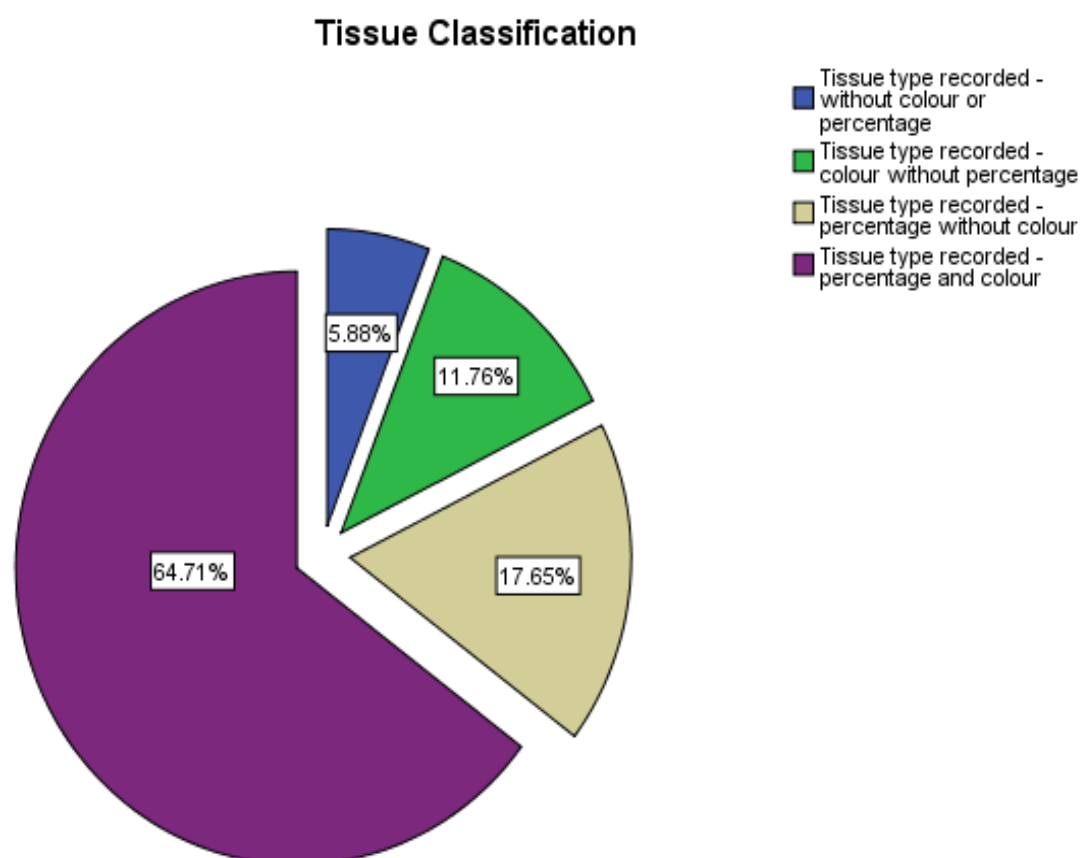
Table 4-1 presents wound bed assessment clinical practice in the sample surveyed. The data is displayed in an ascending hierarchy.

<b>Wound bed assessment documentation</b>	<b>Frequency</b>	<b>%</b>
<b>1</b> Tissue type not recorded	0	0
<b>2</b> Tissue type recorded – without colour or percentage	1	5.9
<b>3</b> Tissue type recorded - colour without percentage	2	11.8
<b>4</b> Tissue type recorded - percentage without colour	3	17.6
<b>5</b> Tissue type recorded - percentage and colour	11	64.7
<b>Total (n=17)</b>	<b>17</b>	<b>100.0</b>

**Table 4-1** Wound bed assessment clinical practice



Figure 4-1 illustrates the distribution of wound bed assessment clinical practice. Tissue classification referred to in the Pie chart is wound bed RYBP assessment.



**Figure 4-1** Wound bed assessment clinical practice - Pie chart

### Analysis

This survey demonstrates that all participating centres record wound bed tissue type. In 65% of centres, colour and percentage are also included in their wound assessment forms. Consequently, necrosis (Black), slough (Yellow), granulation (Red) and epithelialization (Pink) are important components of wound bed assessment. These are referred to as wound bed RYBP assessment. Furthermore, wound bed RYBP assessment needs to be represented in the OpenEHR draft wound archetype and related terminology.

## **4.3 Wound bed RYBP assessment and treatment recommendations using calibrated wound images**

### **Motivation**

This research aims to develop the openEHR draft wound archetype and to introduce calibrated wound images to wound care in Ireland.

The survey on clinical practice has identified that wound bed RYBP assessment is prevalent (section 4.2). Literature review has identified that wound images are used in telemedicine. Furthermore, automated wound bed tissue classification, using calibrated wound images, has been developed. Hence, wound bed RYBP assessment can be obtained either by clinicians or automatically, using calibrated wound images. The OpenEHR draft archetype inspection of an open wound needs to represent the calibrated wound image wound bed RYBP assessment to facilitate telemedicine, connected health and clinical decision support in a wound care EHR.

It is in this context that this research into wound care clinicians' opinions regarding the suitability of calibrated wound images for treatment recommendations has been undertaken.

### **Objective**

- Measurement of suitability of calibrated wound images for treatment recommendation.

### **Questions**

- Do wound care clinicians believe that calibrated wound images are suitable for treatment recommendations?

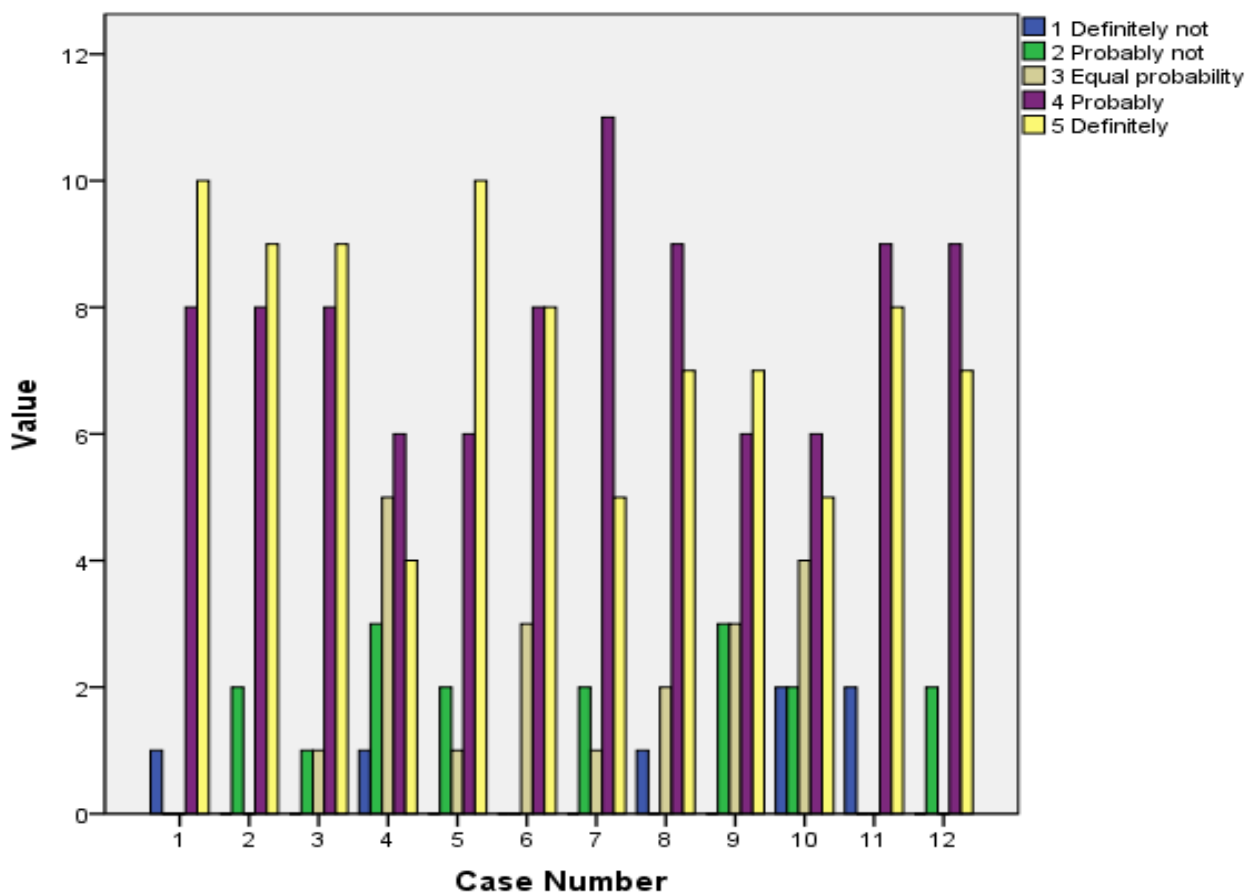
### **Methodology**

- 19 wound care clinicians were asked to score the suitability of each calibrated wound image, using a five point Likert type scale (Figure 3-1). These clinicians were asked to perform wound bed RYBP assessment before being asked about image suitability. Thus, they had given consideration to the content of the image prior to making their decision.

## Results

Of the 19 wound care clinicians surveyed:

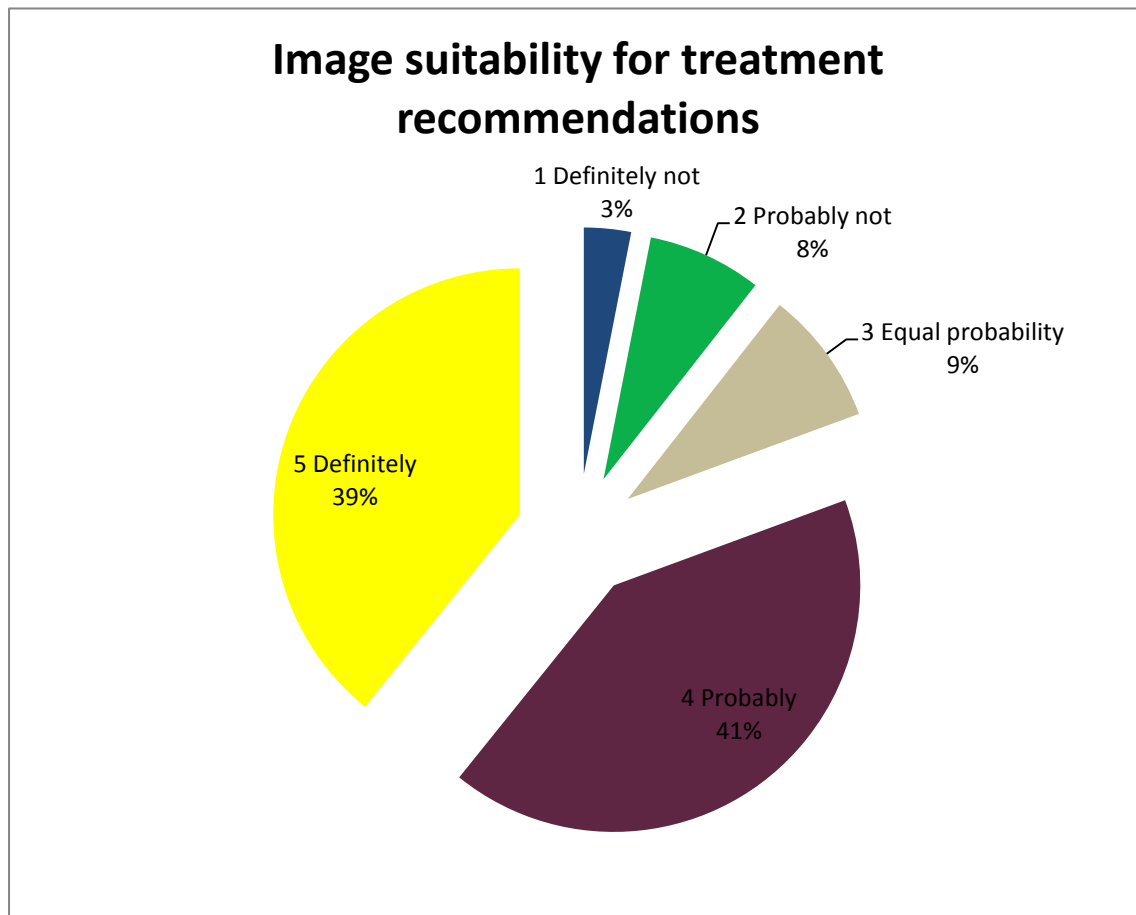
- The mode (most frequent) response was that 41% of the calibrated wound images were *probably suitable* for treatment recommendations, if the clinician was given all other relevant clinical information.
- 39% of clinicians believed that the calibrated wound images were *definitely suitable* for treatment recommendations



**Figure 4-2** Calibrated image suitability – bar chart

Likert type scale applied to 12 wounds by 19 wound care clinicians

- The x-axis represents the 12 wounds (case numbers).
- The y-axis represents the frequency of responses by the 19 wound care clinicians (values).
- The colour coded bars represent the Likert scale for each wound ranging from blue (definitely not suitable) to yellow (definitely suitable)



**Figure 4-3** Calibrated image suitability – Pie chart

The cumulative image suitability (12 wounds together), by the 19 clinicians is represented in the pie chart. The same chart colour coding is used to represent the Likert scale ranging from blue (definitely not suitable) to yellow (definitely suitable).

### Analysis

The wound images used in this study have been calibrated using a software application that is newly developed. Consequently, these calibrated wound images have never before been used for assessment by Irish wound care clinicians. This survey indicates that this important group of clinicians are positively disposed to using these images. They have the knowledge, skills and experience to decide on the quality of a calibrated wound image in order to make a treatment recommendation and deliver telemedicine in wound care.

This survey on calibrated wound images has identified that wound care clinicians believe they are probably or definitely suitable for treatment recommendations, if the clinician was given all other relevant clinical information.

The survey on clinical practice has identified that wound bed RYBP assessment is prevalent (see section 4.2). The question then arises:

What is the inter-rater agreement between wound care clinicians, when completing wound bed RYBP assessment, using calibrated wound images? This is the focus of the research study presented in the next section (see section 4.4).

## **4.4 Inter-rater agreement on wound bed RYBP assessment using calibrated wound images**

### **Motivation**

This research aims to develop the openEHR draft archetype *inspection of an open wound* and to introduce calibrated wound images to wound care in Ireland.

The surveys and literature review have identified that:

- Wound bed RYBP assessment is integral to clinical practice (section 4.2).
- The majority of clinicians who were surveyed are of the opinion that calibrated wound images are either probably or definitely suitable for treatment recommendations (section 4.3).
- Wound bed RYBP is underrepresented in the openEHR draft archetype *inspection of an open wound* and related terminology.
- Wound images are used in telemedicine. Calibrated wound images have been automatically classified, using SVM tissue classifiers (Oduncu et al., 2004, Belem, 2004, Wannous et al., 2011).

Thus, it is important to see the level of agreement between clinicians and the Medical Reference Standard on wound bed RYBP assessment, when using calibrated wound images.

### **Objective**

Measurement of inter-rater agreement between TVN's and the Medical Reference Standard, using calibrated wound images for wound bed RYBP assessment

### **Question**

What is the inter-rater agreement between TVN's and the Medical Reference Standard, using calibrated wound images for wound bed RYBP assessment?

### **Methodology**

Wound bed RYBP Medical Reference Standard has been obtained for the 11 wounds that are included in this study. There are four tissue types in each wound. Consequently, the Medical Reference Standard for the 11 wounds comprises 44 measurements. There are no absolute true values for these wound bed RYBP assessments. This is a common difficulty encountered in medical

studies (see section 2.6.2). An algorithm has been developed to establish the Medical Reference Standard (see Figure 3-2). This has been calculated from the mean of direct and indirect wound bed RYBP assessment by four wound care clinicians at Tallaght Hospital. The additional assessment of an academic wound clinician and ancillary clinical information has been utilized for three of the wounds, when establishing the Medical Reference Standard.

Cohen's weighted kappa statistic is used to measure inter-rater agreement in this study, because of its use in similar wound studies (Oduncu et al., 2004, Belem, 2004). It is well described in statistic texts (Altman, 1991, Fleiss et al., 2003, Agresti, 2002) as being suitable for assessing inter-rater agreement. The continuous percentage scale for wound bed RYBP assessment has been transformed into ten categories between 0% and 100%, using SPSS. Degrees of difference from the Medical Reference Standard are taken into account. These are represented by degrees of difference from the diagonal of exact agreement. These degrees of difference are used to calculate the weighting.

A multi-rater kappa value has not been calculated because The Medical Reference Standard has been used. Hence, a range of kappa values is reported, rather than a single multi-rater or group kappa. This approach is described in the literature (Light, 1971a).

The kappa value is interpreted according to the scale of Landis and Koch (see section 2.6.3).

## **Results**

Quadratic weighted kappa ranged from moderately good (0.56) to good (0.80). The lowest and highest agreements are highlighted (Table 4-2).

<b>Tissue Viability Nurses (TVN's)</b>	<b>Unweighted Kappa (a)</b>	<b>Linear weighted Kappa (b)</b>	<b>Quadratic weighted Kappa (c)</b>
<b>TVN A</b>	0.20	0.54	0.71
<b>TVN B</b>	0.29	0.55	0.72
<b>TVN C</b>	0.24	0.52	0.69
<b>TVN D</b>	0.37	0.65	0.80
<b>TVN E</b>	0.22	0.53	0.70
<b>TVN F</b>	0.11	0.39	<b>0.56</b>
<b>TVN G</b>	0.19	0.39	0.58
<b>TVN H</b>	0.30	0.53	0.70
<b>TVN I</b>	0.23	0.45	0.58
<b>TVN J</b>	0.17	0.43	0.50
<b>TVN K</b>	0.22	0.51	0.72
<b>TVN L</b>	0.09	0.44	0.60
<b>TVN M</b>	0.29	0.55	0.73
<b>TVN N</b>	0.42	0.64	<b>0.80</b>

**Table 4-2** Kappa inter-rater agreement – wound bed RYBP assessment

Table 4-2 reports unweighted kappa, linear weighted kappa and quadratic weighted kappa for the 14 TVN's when rated with the Medical Reference Standard. 4 tissue types in 11 wounds are compared in 14 different contingency tables.

- a.** Unweighted kappa – This measurement only takes account of values on the diagonal of exact agreement between the TVN's and the Medical Reference Standard in the contingency table. Values that are not in diagonal of exact agreement are given a zero value.
- b.** Linear weighted kappa – This measurement takes account of the number of squares from the diagonal of exact agreement in the contingency table (Cicchetti, 1976).



- c. Quadratic weighted kappa – This applies a quadratic weighting to the degrees of difference from the diagonal of exact agreement in the contingency table (Fleiss and Cohen, 1973).

## Analysis

The quadratic weighted kappa represents agreement between individual TVN's and the Medical Reference Standard, when chance agreement has been removed. The inter-rater agreement between a TVN and the Medical Reference Standard for 4 tissue types in 11 wounds is presented on a contingency table. The matrix of values is condensed to a single kappa measurement.

This study indicates moderate to good agreement between this cohort of TVN's and the Medical Reference Standard, when performing wound bed RYBP assessment in 11 calibrated wound images.

The data shows differences in the recording of red (granulation) and pink (epithelialization) by clinicians. Some clinicians described wounds as predominantly red, while others described the same wounds as predominantly pink. This may reflect difficulty distinguishing between these two colours in calibrated wound images. Alternatively, it may reflect differences in definition of the area covered in the wound bed applied by these clinicians. It is interesting to note that the same difference in recording red and pink in the wound bed occurred with direct wound assessment. Thus indicating that this is not an issue related to the images but relates to clinical interpretation. These colours are adjacent on the continuum of wound healing. Furthermore, management of red and pink wounds is the same, in that they are both protected.

This study indicates that wound bed RYBP assessment using calibrated wound images shows moderate to good agreement when compared to the Medical Reference Standard, measured with quadratic weighted kappa. Consequently, the OpenEHR draft archetype *inspection of an open wound* should be developed to represent wound bed RYBP assessment and facilitate telemedicine, connected health and clinical decision support in a wound care EHR.

The strength of inter-rater agreement with the Medical Reference Standard indicates that the method of using calibrated wound images for wound bed RYBP

assessment is reliable (Light, 1971a). The use of calibrated wound images in wound care in Ireland would also contribute to telemedicine, connected health and clinical decision support.

## **4.5 Conclusion to Results**

This chapter presents the results related to research on wound bed RYBP assessment.

The survey on wound care clinical practice indicates that 65% of wound assessment forms record tissue type with percentage and colour.

In the survey on the suitability of calibrated wound images for treatment recommendations, 41% of clinicians stated that the calibrated wound images were suitable for treatment recommendations. A further 39% of clinicians stated that they were definitely suitable for treatment recommendations.

The study on wound bed RYBP assessment inter-rater agreement between TVN's and the Medical Reference Standard indicates moderate to good agreement, using calibrated wound images.

The OpenEHR draft archetype *inspection of an open wound* needs to represent wound bed RYBP assessment and facilitate telemedicine, connected health and clinical decision support in a wound care EHR.

Calibrated wound image assessment will also contribute to these innovations in wound care.

Chapter 5 will present an analysis and evaluation of the research in the context of current knowledge

## **Chapter 5      Evaluation and Analysis**

## 5.1 Introduction to Evaluation and Analysis

This dissertation has two aims. These are to explore calibrated wound image assessment in wound care and to present a proposal to OpenEHR to develop the draft archetype *inspection of an open wound*.

The design, methodology and results of research into wound bed assessment and calibrated wound image assessment have been presented in Chapter 3 and Chapter 4, respectively.

This chapter presents an evaluation and analysis of the research. The evaluation will form the rationale of a research based proposal to develop the OpenEHR draft archetype *inspection of an open wound*. The details of this proposal will be presented in chapter 6.

The research results are evaluated and analysed, in the context of current knowledge. These are described in terms of:

- Survey of wound bed RYBP assessment in clinical practice, OpenEHR draft archetype and related terminology
- Survey on the suitability of calibrated wound images for treatment recommendations
- Study of wound bed RYBP assessment, using calibrated wound images

## **5.2 Wound bed assessment: clinical practice, existing OpenEHR draft archetype and related terminology**

### **Survey of wound bed assessment in clinical practice**

A representative sample of wound care centres has been surveyed to identify current wound bed assessment in clinical practice. This survey demonstrates that all participating centres record wound bed tissue type. In 65% of centres colour and percentage are also included in their wound assessment forms.

Wound bed RYBP assessment has been used in clinical practice since the 1980's (Cuzzell, 1988, Krasner, 1995). Other studies have validated its use (Lorentzen et al., 1999, Vermeulen et al., 2007) as an assessment tool. The wound bed RYBP assessment maps four colours to four tissue types. This is a simplification in so far as red can represent inflammation as well as granulation. Furthermore, slough may be yellow or green. However, the simplicity and is of use of this assessment is also its strength. When used in conjunction with other clinical information it identifies where the wound is on the continuum of healing and guides appropriate management.

### **The openEHR draft archetype – *inspection of an open wound***

The existing openEHR draft archetype *inspection of an open wound* is contained in the archetype repository on the Clinical Knowledge Manager (CKM) online web application.

The archetype represents the four wound bed RYBP tissue types identified in the survey as being used to clinical practice. These are necrosis, slough, granulation and epithelialization.

- *Granulation* data value is *Text*. Free text does not convey the progress of the wound on a continuum of healing in a quantifiable way
- *Necrosis and slough* data values are expressed on a graded *ordinal* scale 1-4. This scale, while attempting to quantify pathology within the wound bed, lacks internal consistency. The scale is arbitrary.
- *Epithelialization* data value is *Boolean*. This does not convey enough information to identify healing progress

Choosing the most appropriate data type maximizes precision in recording and retrieval of wound bed assessment. In this case assigning proportion to wound

bed tissue will achieve this result. Furthermore, it is required to support comparisons in wound assessment.

There is no mapping of colour to these tissue types within the archetype. Thus, the OpenEHR draft archetype *inspection of an open wound* on the CKM provides no means for recording wound bed RYBP assessment.

### **Wound bed assessment in terminology systems**

The National Library of Medicine UMLS Metathesaurus incorporates 137 vocabularies, including SNOMED CT. The American Nursing Association terminologies are also included. Nursing terminologies focus on intervention and diagnosis. They do not have the atomic level of detail required to cover wound bed assessment (Henry and Mead, 1997, Dykes et al., 2009).

The UMLS contains definitions for two of the wound bed tissue types contained in the wound bed RYBP assessment. These are granulation and necrosis. Slough and epithelialization require further development.

Binding from the OpenEHR archetype to terminology at the development stage facilitates coding of clinical assessment. This standardised clinical content enables semantic interoperability. The four wound bed tissue terms need to be defined in the UMLS and nursing terminologies. Definitions and further expansion are required for precision in recording and retrieval of wound care assessment. Furthermore, wound care is a multidisciplinary clinical domain. Consequently, wound bed RYBP assessment needs to be accessible in terminologies used by all participating clinicians.

Colour is central to wound bed RYBP assessment. Colour is a non-clinical concept. Thus, it presents a particular challenge for the terminologist (Hardiker et al., 2002). In the survey of clinical practice it has been identified that clinicians map colour to tissue type. This same process of mapping the wound bed colour to its related tissue type, in formal terminology systems, is required to properly represent wound bed RYBP assessment electronically.

Binding of the OpenEHR draft archetype *inspection of an open wound* to terminology that represents wound bed RYBP assessment is required to develop

a wound care EHR, with semantic interoperability and standardisation. This will enable telemedicine, connected health and clinical decision support.

### **5.3 Suitability of calibrated wound images for treatment recommendations**

All wound care clinicians who participated in this research were asked to comment on the suitability of the calibrated wound images for treatment recommendations. These clinicians were asked to complete wound bed RYBP assessment before commenting on image suitability. Thus, they had given consideration to the content of the image prior to making their decision. They were asked to score the suitability of each calibrated wound image, using a five point Likert type scale (Figure 3-1). The most frequent response (41%) was that the calibrated wound images were *probably suitable* for treatment recommendations. A further 39% of clinicians believed that they were *definitely suitable*.

Calibrated wound images offer accuracy and reproducibility (Haeghen and Naeyaert, 2006, Van Poucke et al., 2010a). Standardisation of these images is not primarily to improve image quality, but to facilitate evaluation of the healing wound over time. A longitudinal study with the same clinicians would yield more information on the value of calibrated wound images.

The wound care clinicians who participated in this research are in prime position to utilise calibrated wound images in their clinical practice and to deliver telemedicine in wound care in Ireland. Indeed, they are currently providing clinical decision support and education to non-expert clinicians. The positive response obtained in this calibrated wound image survey reinforces the need to include these images and related wound image data in a wound care EHR.

## **5.4 Study of wound bed RYBP assessment using calibrated wound images**

The survey on wound care clinical practice has identified that the majority of clinicians use wound bed RYBP assessment. Furthermore, the majority believe that the same assessment can be applied to calibrated wound images.

The study compares the wound bed RYBP assessments of these clinicians, using calibrated wound images, with the Medical Reference Standard. Measurement of inter-rater agreement with the Medical Reference Standard using Cohen's weighted kappa has been discussed in the literature review (section 2.6.2) and when presenting study results (section 4.4). This study indicates that these clinicians have moderate to good agreement with the Medical Reference Standard when completing wound bed RYBP assessment on calibrated wound images.

Limitations of this study are the small sample size and range of wounds represented. Originally 15 wound images were captured for the study, but data loss occurred as described in section 3.4.5.

Differences recording red (granulation) and pink (epithelialization) in the wound bed have been commented on (section 4.4). This may relate to difficulty with distinguishing these two colours in calibrated wound images. Alternatively, it may reflect differences in interpretation of the area covered within the wound bed. The same difference in recording red and pink in the wound bed occurred with direct wound assessment. Planimetric studies have identified differences in recording the wound border by clinicians (Van Poucke et al., 2010b, Jones and Plassmann, 2000). Further study is required to establish if clinicians accept pink epithelialization tissue as being a component of the wound bed or new surrounding skin.

The wound care clinicians who participated in this research are poised to use calibrated wound images in their clinical practice and record their findings in a wound care EHR. All clinicians who were approached participated in this research. This is encouraging because user engagement is a key component to the adoption of health informatics initiatives.



The literature review has identified that calibrated wound images are suitable for clinical assessment (Vander Haeghen and Naeyaert, 2006, Van Poucke et al., 2010a). Automated wound bed tissue colour classification in calibrated wound images using support vector machines (SVM) has been described (Wannous et al., 2011) (Oduncu et al., 2004) (Belem, 2004). Thus, the evidence from this research and related literature indicates that wound bed RYBP assessment, needs to be represented in the OpenEHR draft archetype *inspection of an open wound* and related terminology. This is the case irrespective of whether the assessment is performed directly or indirectly, clinically or automatically. The development of the OpenEHR draft archetype *inspection of an open wound* to represent wound bed RYBP assessment will provide a framework for telemedicine, connected health and clinical decision support in a wound care EHR. Furthermore, calibrated wound images in their own right will contribute to the advancement of wound care.

## **5.5 Conclusion to analysis and evaluation**

The research results have been evaluated and analyzed in the context of current knowledge as presented in the literature review.

Wound bed RYBP assessment is integral to clinical practice for wound management. It is accessible in calibrated wound images, either by clinicians or automated tissue classifiers. It is not represented in the existing OpenEHR draft archetype *inspection of an open wound* and related terminology.

The research results, along with existing knowledge in wound care, present a justification for developing the OpenEHR draft archetype *inspection of an open wound*. This will facilitate telemedicine, connected health and clinical decision support in a wound care EHR.

Calibrated wound images will also contribute to the advancement of wound care.

Chapter 6 will outline a research based proposal presented to the OpenEHR Foundation. This is a proposal to develop the OpenEHR draft archetype *inspection of an open wound* in order to represent wound bed RYBP assessment.

## **Chapter 6      Proposal to develop the OpenEHR draft archetype *inspection of an open wound***

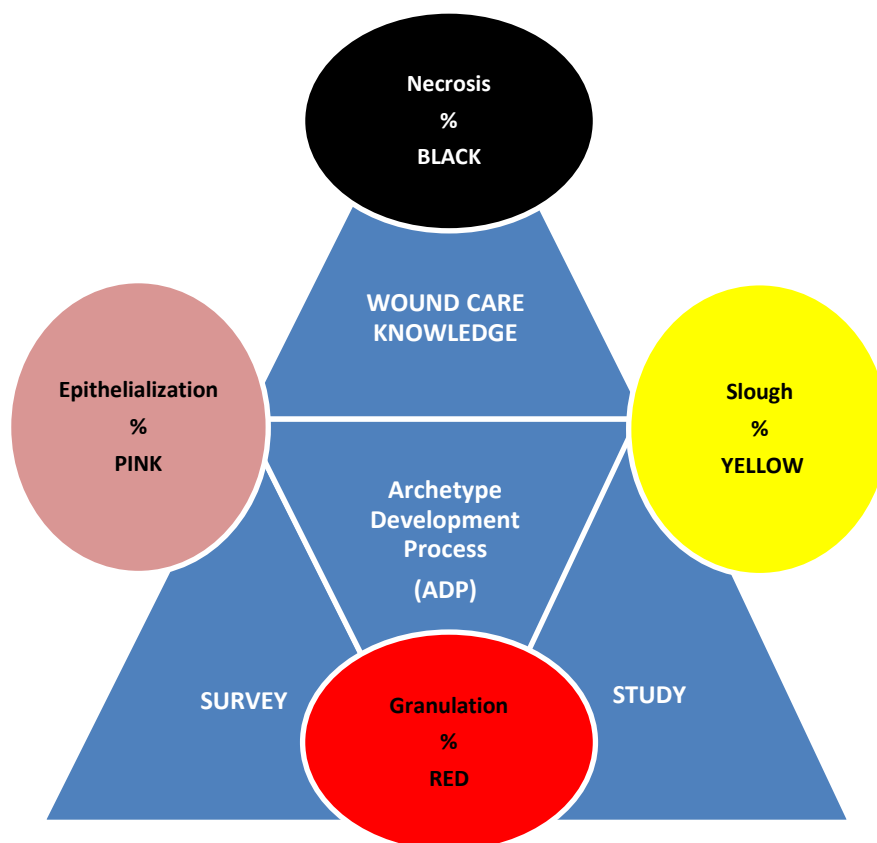
## 6.1 Introduction to the proposal

Chapter 5 has evaluated and analyzed research results on wound bed assessment in the context of current knowledge. This evaluation and analysis formed the basis of a research based proposal to develop the openEHR draft archetype *inspection of an open wound* in the archetype repository on the Clinical Knowledge Manager (CKM) online web application (Figure 6-1).

Based on the research findings in this dissertation and current knowledge it was proposed to incorporate wound bed RYBP assessment in the draft archetype.

The changes proposed were:

- To quantify the four wound bed tissue types, using proportion in the draft archetype
- To map colour with the four wound bed tissue types in the draft archetype



**Figure 6-1** Archetype development

This chapter describes the proposal:

1. The justification for and benefits of developing the archetype are restated
2. Existing OpenEHR draft archetype *inspection of an open wound* is described
3. Outline of proposal
4. Submission of proposal to OpenEHR is described
5. Response from OpenEHR is documented

## **6.2 Justification for developing the openEHR draft archetype *inspection of an open wound***

The proposal to develop the openEHR draft archetype *inspection of an open wound* has arisen from:

- *The survey of clinical practice in wound bed assessment*
  - In the sample of wound care centres surveyed, it was identified that the majority of wound care clinicians complete wound bed RYBP assessment.
- *The survey on suitability of calibrated wound bed images for treatment recommendations*
  - In the survey on suitability of wound images, it was identified that the majority of wound care clinicians are of the opinion that calibrated wound images are probably or definitely suitable for treatment recommendations
- *The study on wound bed RYBP assessment, using calibrated wound images*
  - The study indicated moderate to good agreement between TVN's and the Medical Reference Standard, when completing wound bed RYBP assessment using calibrated wound images.
- *Literature review on wound care clinical practice*
  - Wound bed assessment is used to evaluate the progress of wounds on the continuum of healing and informs wound management.
- *Literature review on the use of wound images in wound care*
  - Wound images are used for clinical assessment, education and research. Automated tissue classification using calibrated wound images has been developed.
- *Literature review on the existing representation of wound bed assessment in OpenEHR draft archetype inspection of an open wound and related terminology*
  - The openEHR draft archetype *inspection of an open wound*, as presented in the archetype repository on the Clinical Knowledge Manager (CKM), represents the four wound bed tissue types. The values are not proportion. Colour is not mapped to these tissue types. Two of the tissue types are defined in UMLS Metathesaurus.

## **Benefits of developing the openEHR draft archetype *inspection of an open wound***

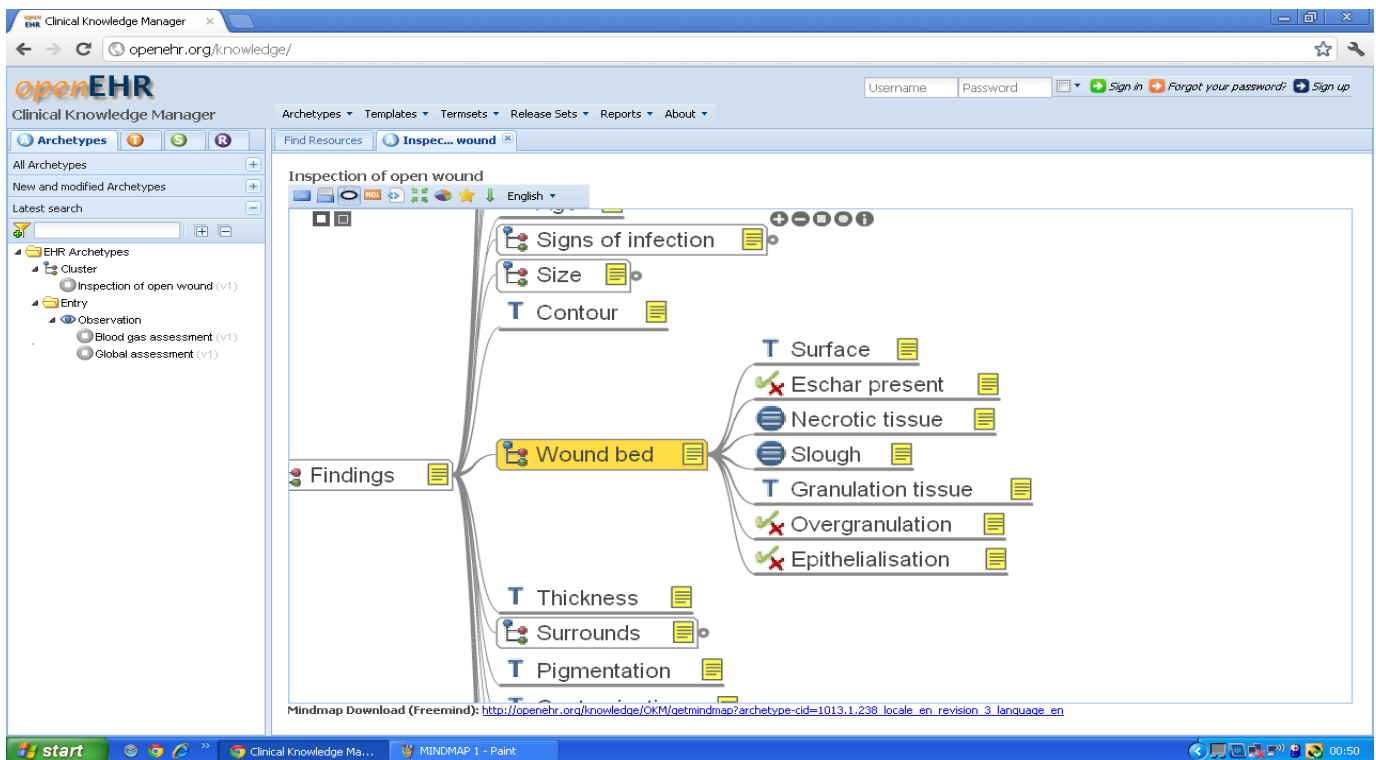
Matching wound bed data values with the most appropriate data type is required to:

- Plot the wound on the continuum of healing
- Communicate wound information between clinicians over time – continuity of care.
- Monitor response of the wound to therapeutic interventions – sequential wound assessments.
- Research advanced therapeutic interventions - use of EHR for data extraction
- Facilitate automated tissue classification of wounds.
- Facilitate clinical decision support (e g. Applied Wound Management and ConvaTec Solutions)
- Conform to the standards of best clinical practice
- Medico legal protection.

### 6.3 Existing OpenEHR draft archetype *inspection of an open wound*

The openEHR draft archetype *inspection of an open wound*, in the archetype repository on the CKM, is presented below.

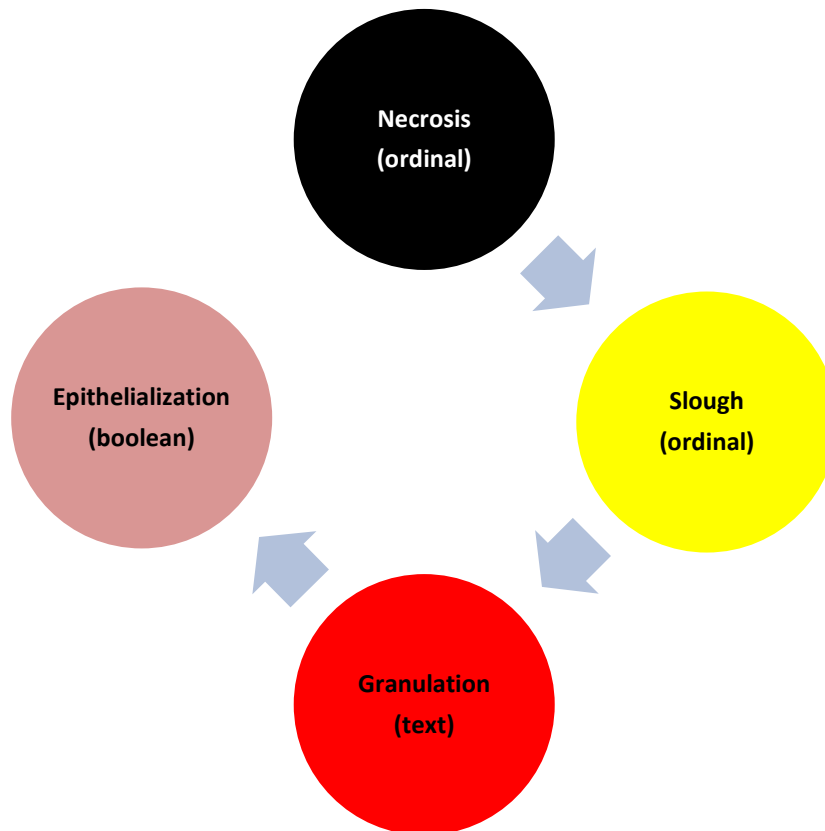
Necrosis, slough, granulation and epithelialization are represented in the archetype. However, these four tissue types are not mapped to colour and the associated data values are not proportion.



**Figure 6-2** Existing OpenEHR cluster archetype *inspection of an open wound* – mindmap

The existing values for the four wound bed tissue types are (Figure 6-3):

- Granulation is **TEXT**
- Necrosis is **ORDINAL** – graded 0 – 3
- Slough is **ORDINAL** – graded 0 – 3
- Epithelialization is **BOOLEAN** – present or absent



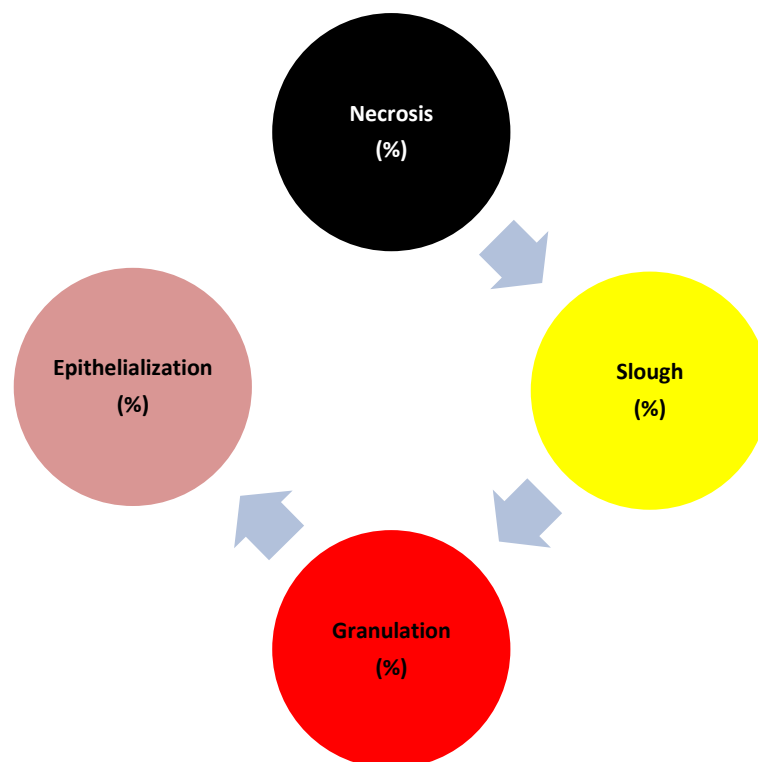
**Figure 6-3** Existing OpenEHR draft archetype inspection of an open wound



## 6.4 Proposal to develop the OpenEHR draft archetype *inspection of an open wound*

### 1. Assign proportion data values to the four wound bed tissue types in openEHR draft archetype *inspection of an open wound*

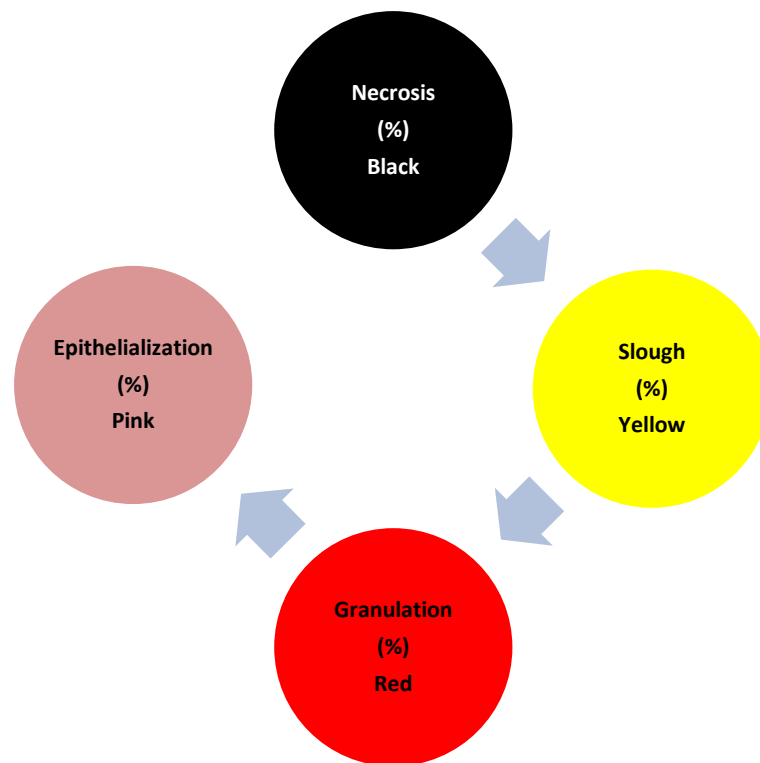
It was proposed to assign proportion / percentage data values to the four wound bed tissue types, within the draft archetype, on a scale **0% → 100%** (Figure 6-4).



**Figure 6-4** Change data value to proportion

## 2. Map of RYBP colour to the four wound bed tissue types in the openEHR draft archetype inspection of an open wound

It was proposed to map the four colours in RYBP to the four wound bed tissue types, within the draft archetype (Figure 6-5)



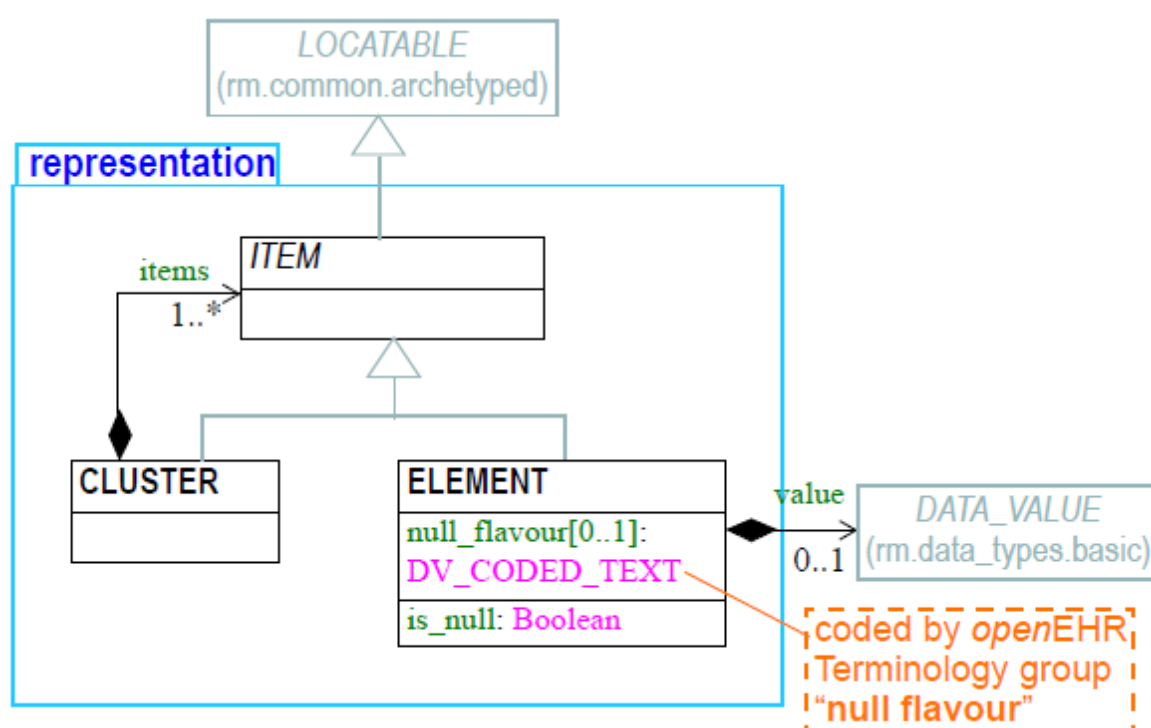
**Figure 6-5** Map colour to wound bed tissue type

### 6.4.1 Submitting the proposals to change the archetype

The CKM is used to manage developments in the archetype. The archetype is downloaded using CKM online web application. Suggested changes in the archetype are made in response to clinical knowledge. These suggested changes are made using LinkEHR or another archetype editor. LinkEHR is an open source software platform. It allows the clinical domain specialist to model their subject knowledge. The revised archetype, incorporating the suggested changes, is resubmitted for other contributors to comment. Thus, the archetype evolves iteratively. This is the archetype development process (Madsen et al., 2010). In theory, no technical ability is required, when submitting proposals to develop the archetype. However, it has been the experience in this research that some informatics guidance is necessary.

The hierarchical levels of the proposed cluster for changes were as follows:

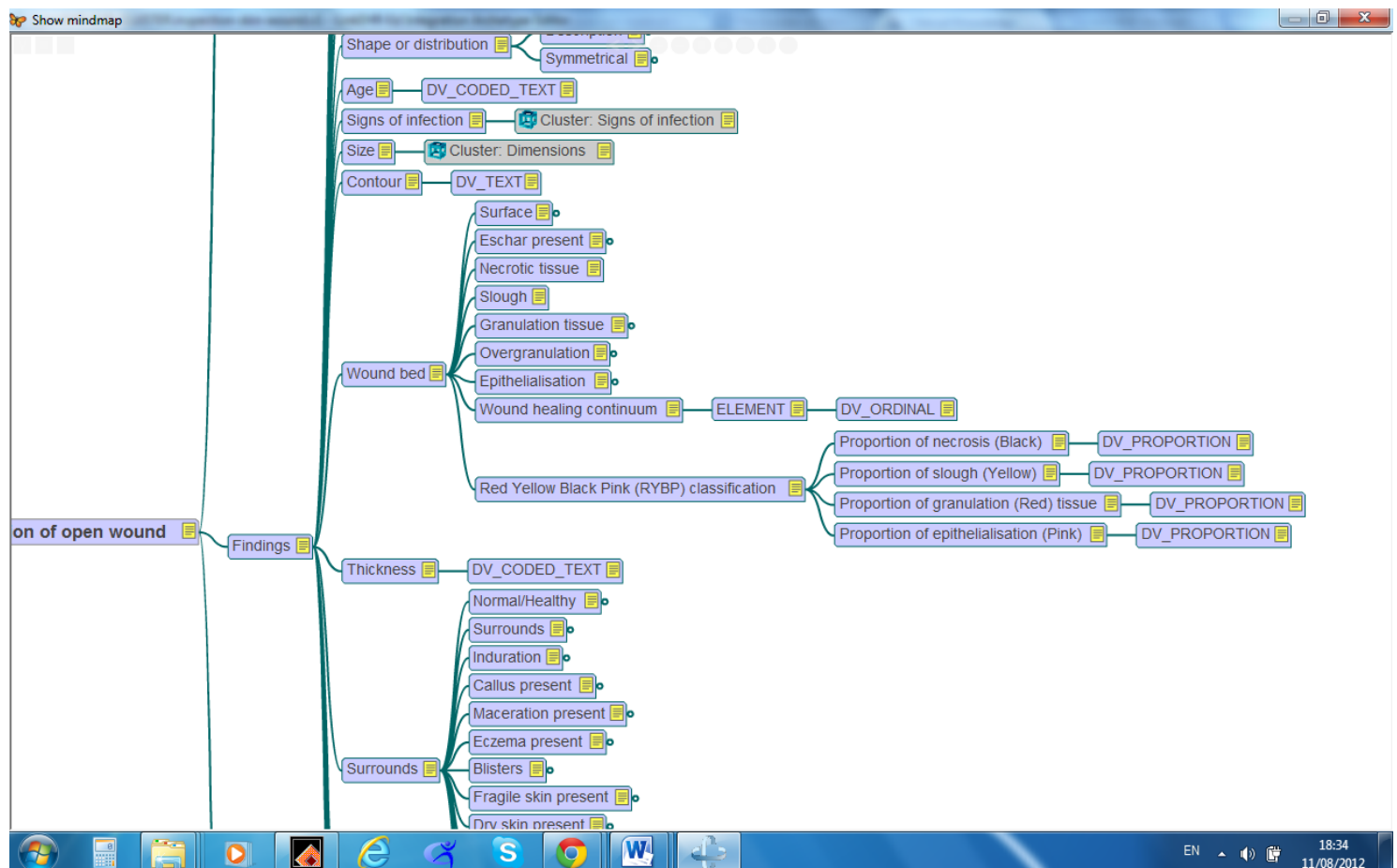
*OpenEHR cluster-inspection of an open skin wound-item-findings-wound bed-item-data value-proportion* (Figure 6-6)



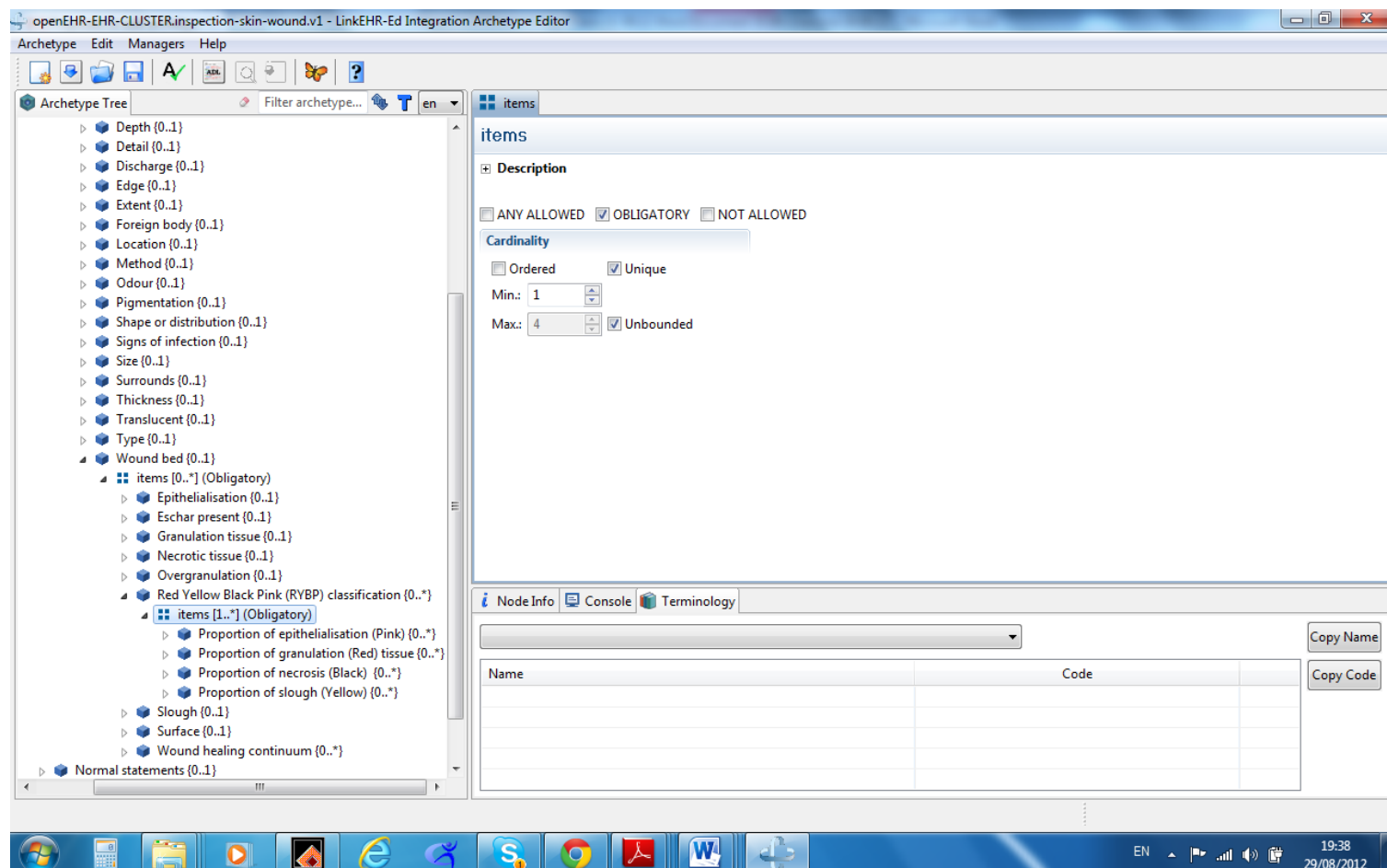
**Figure 6-6** Existing hierarchical levels for proposed cluster

(Beale, 2012)

Following the protocol described above, this proposal was submitted to the OpenEHR Foundation including an archetype that had been remodelled using LinkEHR (Figure 6-7 and Figure 6-8).



**Figure 6-7** Proposal to change OpenEHR draft archetype *inspection of an open wound* – mindmap



**Figure 6-8** OpenEHR-EHR-CLUSTER-Inspection-skin-wound.v1

## 6.5 Response from OpenEHR to the proposal

Dr. Ian McNicoll from the OpenEHR Foundation has responded positively to the proposal to develop the OpenEHR draft archetype *inspection of an open wound* (see Appendix H). Independently, two other domain experts have submitted proposals to develop the OpenEHR draft archetype. They have also proposed changing data value of wound bed tissue types to proportion. In this way collaboration between domain experts means that the proposal is more likely to be adopted. Active participation as an archetype editor and contributor is ongoing.

## 6.6 Conclusion

Justification for and the benefits of developing the OpenEHR draft archetype *inspection of an open wound* have been outlined.

The existing draft archetype wound bed *findings* have been described.

A research based proposal was submitted, via LinkEHR, to develop the openEHR draft archetype. Health informatics guidance was found to be necessary. This proposal was to map colour to the four tissue types in the wound bed and change the data values to proportion. Other domain experts are also proposing to develop the wound bed *finding* in the archetype. The proposal presented in this dissertation is being actively considered and engagement with the archetype development process is ongoing.

## **Chapter 7      Conclusion and Future Work**

### **7.1 Introduction**

This dissertation defined two aims. These aims related to wound bed RYBP assessment. One aim was to explore this assessment through the medium of calibrated wound images. A complementary aim was to represent RYBP assessment in the OpenEHR draft archetype inspection of an open wound. Research objectives and questions were formulated to fulfil these aims. The next section analyses how these aims were achieved.

### **7.2 Calibrated wound image RYBP assessment**

The results of this research indicate that wound care clinicians are positively disposed to the use of calibrated wound images for assessment and treatment recommendations. They had moderate to good agreement compared with a Medical Reference Standard, when using these images for assessment. The design and implementation of a survey and a study using calibrated wound images for wound bed RYBP assessment was successfully achieved.

### **7.3 Research based proposal to develop wound bed findings in the OpenEHR archetype**

This research indicated that the majority of wound care clinicians complete wound bed RYBP assessment in their clinical practice. The majority of them believed that calibrated wound images were suitable for assessment and treatment recommendations. Inter rater agreement with Medical Reference Standard was moderate to good, indicating that their opinion was justified. These research conclusions along with wound care knowledge presented in the literature review form the basis of a proposal to develop the OpenEHR draft archetype *inspection of an open wound* to include wound bed RYBP assessment. The positive response obtained from the OpenEHR Foundation and invitation to become an archetype editor or contributor, indicates that this aim was achieved.

## **7.4 Limitations of the study**

The sample size of wound images was smaller than planned. This resulted from data loss during data collection and image calibration. However, the sample size was at the lower limit of requirements for Cohen's kappa statistical measurement.

The range of wounds was limited by the attendees at the wound care clinic. Inclusion of a completely necrotic wound would have been interesting to evaluate. However mixed tissue / colour wounds are probably the most challenging for clinicians.

Longitudinal study to evaluate wound progress over time, using calibrated wound images would reveal more information about their role in wound care.

## **7.5 Implications for clinical wound care**

Calibrated wound images were presented to nineteen wound care clinicians for evaluation. These clinicians are well positioned to incorporate calibrated wound images in their clinical practice. In doing so, telemedicine and connected health in wound care would be enhanced.

Calibrated wound images can be data mined for wound bed RYBP assessment, using automated tissue classifiers. In doing so, clinical decision support for non-expert clinicians would be enhanced.

Representation of wound bed RYBP assessment in the draft archetype *inspection of an open wound* would provide the means of recording an assessment that is integral to wound care clinical practice. It would allow this assessment to be communicated between wound care clinicians in this multidisciplinary clinical domain. It would make available data for secondary use in research to enhance wound care knowledge.

## **7.6 Recommendations for Future Work**

Longitudinal research, using calibrated wound images, would further explore their properties of accuracy and reproducibility.

Research into the Wound Healing Continuum colour classification of wounds, would explore it as a potential source of new colour semantic terms.



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## Appendix A Sample wound assessment form

**THE ADELAIDE & MEATH  
HOSPITAL, DUBLIN  
INCORPORATING  
THE NATIONAL CHILDREN'S HOSPITAL  
WOUND ASSESSMENT CHART**

To be completed at each dressing change/measure weekly

\*VRS= Verbal Rating Scale

Surname: .....

Forenames: .....

Address: .....

.....

Hospital No.: ..... D.O.B.: .....

Consultant: .....

Date

**WOUND DIMENSIONS**

Max. length mm.

Max. width mm.

Depth mm.

Undermining mm.

**WOUND BED ESTIMATE IN %**

Necrotic (black)

Sloughy (yellow)

Granulating (red)

Epithelialising (pink)

Other

**Exudate—Content:**

**High/Moderate/Low**

**Condition of  
surrounding skin**

Intact

Blisters

Erythema

Macerated/Excoriated

Eczema

Odema

**Odour:**

**Pain in wound:**

Intermittent

Continuous

At Dressing

\*VRS:1-10

**Infection:**

Yes/No

Wound swab taken

**Signature:**

**Ward:**

## Appendix B Wound bed terminology in UMLS Metathesaurus Browser

Tissue type	Wound bed terminology in UMLS Metathesaurus Browser
<b>Necrosis</b> <b>Concept</b> <b>C0027540</b>	<p><b>Semantic type:</b> Organ or tissue function</p> <p><b>Definition:</b></p> <p><b>CSP/PT</b>   sum of the morphological changes indicative of cell death and caused by the progressive degradation action of enzymes; may affect groups of cells or part of a structure or an organ.</p> <p><b>GO/PT</b>   A permanent cessation of all vital functions of a tissue. [GOC:dph]</p> <p><b>GO/PT</b>   A cell death process that is morphologically characterized by a gain in cell volume (oncosis), swelling of organelles, plasma membrane rupture and subsequent loss of intracellular contents. [PMID:18846107]</p> <p><b>GO/OP</b>   OBSOLETE. The processes that cause necrosis, the death of tissues, in another organism. [GOC:ma]</p> <p><b>MSH/MH</b>   The pathological process occurring in cells that are dying from irreparable injuries. It is caused by the progressive, uncontrolled action of degradative ENZYMES, leading to MITOCHONDRIAL SWELLING, nuclear flocculation, and cell lysis. Distinguish it from APOPTOSIS which is a normal, regulated cellular process.</p> <p><b>NCI/PT</b> Relating to or affected by necrosis</p> <p><b>NCI/PT</b>   A cell death process that is morphologically characterized by a gain in cell volume (oncosis), swelling of organelles, plasma membrane rupture and subsequent loss of intracellular contents.</p> <p><b>NCI/PT</b>   Relating to or affected by necrosis.</p> <p><b>NCI/NCI-GLOSSPT</b>   Refers to the death of tissues.</p>
<b>Wound Slough</b> <b>Concept</b> <b>C3266040</b>	<p><b>Semantic Type:</b> Finding</p> <p>Not defined</p>
<b>Granulation</b> <b>Tissue</b> <b>Concept</b> <b>C0018180</b>	<p><b>Semantic Type: Tissue</b></p> <p><b>Definition:</b></p> <p><b>MSH/MH</b>   A vascular connective tissue formed on the surface of a healing wound, ulcer, or inflamed tissue. It consists of new capillaries and an infiltrate containing lymphoid cells, macrophages, and plasma cells.</p>
<b>Wound</b> <b>Epithelial</b> <b>-ization</b> <b>Concept</b> <b>C3266038</b> <b>(finding)</b>	<p><b>Semantic Type:</b> Finding</p> <p>Not defined</p>

## **Appendix C Information and consent forms**

### **TRINITY COLLEGE DUBLIN and AMNCH**

#### **PATIENT INFORMATION SHEET**

**LEAD RESEARCHERS:** Bernie Gallagher; Professor Sean Tierney; Helen Strapp; Thomas Walsh.

**BACKGROUND OF RESEARCH:** This research seeks to identify the correlation between wound assessment and wound image assessment, by mapping the description of the wound image to the terminology of the wound. The wound image is an artefact representation of wound. The pre-processed and calibrated wound image is valid for wound evaluation. This study will facilitate remote expert wound assessment and clinical decision support in wound care.

**PROCEDURES OF THIS STUDY:** Wounds will be assessed. Wound images will be acquired. Wound images will be assessed. The study will take 6 months. There will be no risks to participants

**PUBLICATION:** M.Sc. Thesis in Health Informatics at Trinity College Dublin.

Individual results will be aggregated anonymously and research reported on aggregate results.

**Declaration of conflicts of interest:** There is no known conflict of interest

**Voluntary nature of participation:** Participation is voluntary. You have the right to withdraw and to omit responses without penalty.

**Expected duration of participant's involvement:** 30 minutes

**Anticipated risks / benefits to participant:** There are no anticipated risks or benefits to the participant.

**The provision of debriefing after participation:** Researcher will be available to deal with any issues that might arise.

**Anonymity:** Preservation of participant and third party anonymity, in analysis, publication and presentation of resulting data and findings, will be maintained.

**Illicit activity:** Inadvertent discovery of illicit activities will be reported to authorities.

**Direct quotations:** Provision will be made for verifying direct quotations and their contextual appropriateness.

**Audio and video recordings:** No audio or video recordings will be made available to anyone other than the research / research team, nor will any such recordings be replayed in any public forum or presentation of the research.

**RESEARCHER'S CONTACT DETAILS:** Bernie Gallagher

**INVESTIGATORS SIGNATURE:**

**Date:**

# TRINITY COLLEGE DUBLIN and AMNCH

## PATIENT INFORMED CONSENT FORM

**LEAD RESEARCHERS:** Bernie Gallagher; Professor Sean Tierney; Helen Strapp; Thomas Walsh.

**BACKGROUND OF RESEARCH:** This research seeks to identify the correlation between wound assessment and wound image assessment, by mapping the description of the wound image to the terminology of the wound. The wound image is an artefact representation of wound. The pre-processed and calibrated wound image is valid for wound evaluation. This study will facilitate remote expert wound assessment and clinical decision support in wound care.

**PROCEDURES OF THIS STUDY:** Wounds will be assessed. Wound images will be acquired. Wound images will be assessed. The study will take 6 months. There will be no risks to participants

**PUBLICATION:** M.Sc. Thesis in Health Informatics at Trinity College Dublin.

Individual results will be aggregated anonymously and research reported on aggregate results.

**DECLARATION:**

- I am 18 years or older and am competent to provide consent.
- I have read, or have had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time and that I may, at any time, even subsequent to my participation have recordings destroyed (except in situations such as above).
- I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers / research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
- I have received a copy of this agreement.

**PARTICIPANT'S NAME:**

**PARTICIPANT'S SIGNATURE:**

**Date:**

**Statement of investigator's responsibility:** I have explained the nature and purpose of this research study, the procedures to be undertaken and the risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent

**RESEARCHER'S CONTACT DETAILS:** Bernie Gallagher

**INVESTIGATORS SIGNATURE:**

**Date:**

## **TRINITY COLLEGE DUBLIN and AMNCH CLINICIAN INFORMATION SHEET**

**LEAD RESEARCHERS:** Bernie Gallagher; Professor Sean Tierney; Helen Strapp; Thomas Walsh.

**BACKGROUND OF RESEARCH:** This research seeks to identify the correlation between wound assessment and wound image assessment, with respect to wound bed tissue colour characteristics. This study will facilitate remote expert wound assessment and clinical decision support in wound care.

**PROCEDURES OF THIS STUDY:** Wounds will be assessed. Wound images will be acquired and calibrated. Wound images will be assessed. The study will take 6 months. There will be no risks to participants

**PUBLICATION:** M.Sc. Thesis in Health Informatics at Trinity College Dublin.

Individual results will be aggregated anonymously and research reported on aggregate results.

**Declaration of conflicts of interest:** There is no known conflict of interest.

**Voluntary nature of participation:** Participation is voluntary. You have the right to withdraw and to omit responses without penalty.

**Expected duration of participant's involvement:** 30 – 40 minutes.

**Anticipated risks / benefits to participant:** There are no anticipated risks the participant. The participant will benefit by being informed of the results of the study.

**The provision of debriefing after participation:** Researcher will be available to deal with any issues that might arise.

**Anonymity:** Preservation of participant and third party anonymity, in analysis, publication and presentation of resulting data and findings, will be maintained.

**Illicit activity:** Inadvertent discovery of illicit activities will be reported to authorities.

**Direct quotations:** Provision will be made for verifying direct quotations and their contextual appropriateness.

**Audio and video recordings:** No audio or video recordings will be made available to anyone other than the research / research team, nor will any such recordings be replayed in any public forum or presentation of the research.

**RESEARCHER'S CONTACT DETAILS:** Bernie Gallagher

**INVESTIGATORS SIGNATURE:**

**Date:**

**TRINITY COLLEGE DUBLIN and AMNCH**  
**CLINICIAN INFORMED CONSENT FORM**

**LEAD RESEARCHERS:** Bernie Gallagher; Professor Sean Tierney; Helen Strapp; Thomas Walsh.

**BACKGROUND OF RESEARCH:** This research seeks to identify the correlation between wound assessment and wound image assessment, with respect to wound bed tissue colour characteristics. This study will facilitate remote expert wound assessment and clinical decision support in wound care.

**PROCEDURES OF THIS STUDY:** Wounds will be assessed. Wound images will be acquired and calibrated. Wound images will be assessed. The study will take 6 months. There will be no risks to participants

**PUBLICATION:** M.Sc. Thesis in Health Informatics at Trinity College Dublin.

Individual results will be aggregated anonymously and research reported on aggregate results.

**DECLARATION:**

- I am 18 years or older and am competent to provide consent.
- I have read, or have had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
- I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
- I understand that if I make illicit activities known, these will be reported to appropriate authorities.
- I understand that I may stop electronic recordings at any time and that I may, at any time, even subsequent to my participation have recordings destroyed (except in situations such as above).
- I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers / research team.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
- I have received a copy of this agreement.

**PARTICIPANT'S NAME:**

**PARTICIPANT'S SIGNATURE:**

**Date:**

**Statement of investigator's responsibility:** I have explained the nature and purpose of this research study, the procedures to be undertaken and the risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent

**RESEARCHER'S CONTACT DETAILS:** Bernie Gallagher

**INVESTIGATORS SIGNATURE:**

**Date:**

**TRINITY COLLEGE DUBLIN and AMNCH**  
**CLINICIAN INSTRUCTION SHEET – WOUND IMAGE ASSESSMENT**

**WOUND BED TISSUE COLOUR CLASSIFICATION**

**Please record the percentage of each tissue type that reflects your opinion for each wound image**

- Black - Necrosis (%)
- Yellow - Slough (%)
- Red - Granulation (%)
- Pink - Epithelialization (%)

**WOUND IMAGE QUALITATIVE QUESTIONNAIRE**

**If you were supplied with all other relevant clinical details, do you believe that the wound image is suitable for treatment recommendations?**

**DEMOGRAPHIC INFORMATION FORM**

1. Years of wound care nursing experience.
2. Wound care patients encountered per week on average.
3. Qualification in wound care.

**RESEARCHER'S CONTACT DETAILS:** Bernie Gallagher

**INVESTIGATORS SIGNATURE:**

**Date:**

## Appendix D Data instruments

### WOUND BED ASSESSMENT

#### TISSUE TYPE / COLOUR CHARACTERISTICS

(Red / Yellow / Black / Pink)

Please assign a percentage for each tissue type that reflects your opinion

<b>Granulation (%)</b>	<b>%</b>
<b>Slough (%)</b>	<b>%</b>
<b>Necrosis (%)</b>	<b>%</b>
<b>Epithelialization (%)</b>	<b>%</b>



## WOUND IMAGE SUITABILITY QUESTIONNAIRE

If you are supplied with all other relevant clinical details, do you believe that this wound image is suitable for **TREATMENT RECOMMENDATIONS**?

Please circle one number that reflects your opinion

	1. DEFINITELY NOT	2. PROBABLY NOT	3. EQUAL PROBABILITY	4. PROBABLY	5. DEFINITELY
Suitable for treatment Recommendations	1	2	3	4	5

1. **DEFINITELY NOT:** Clinician is certain that the wound image is **not suitable** for treatment recommendations.
2. **PROBABLY NOT:** Clinician thinks that the wound image is **not suitable** for treatment recommendations, but is not 100% certain
3. **EQUAL PROBABILITY:** Clinician thinks that the wound image **may or may not be suitable** for treatment recommendations.
4. **PROBABLY:** Clinician thinks that the wound image is **suitable** for treatment recommendations, but is not 100% certain
5. **DEFINITELY:** Clinician is certain that the wound image is **suitable** for treatment recommendations.

## WOUND EXUDATE ASSESSMENT

Please circle the response that reflects your opinion

EXUDATE VOLUME		
LOW VOLUME	MEDIUM VOLUME	HIGH VOLUME

EXUDATE VISCOSITY		
LOW VISCOSITY	MEDIUM VISCOSITY	HIGH VISCOSITY

## WOUND INFECTION ASSESSMENT

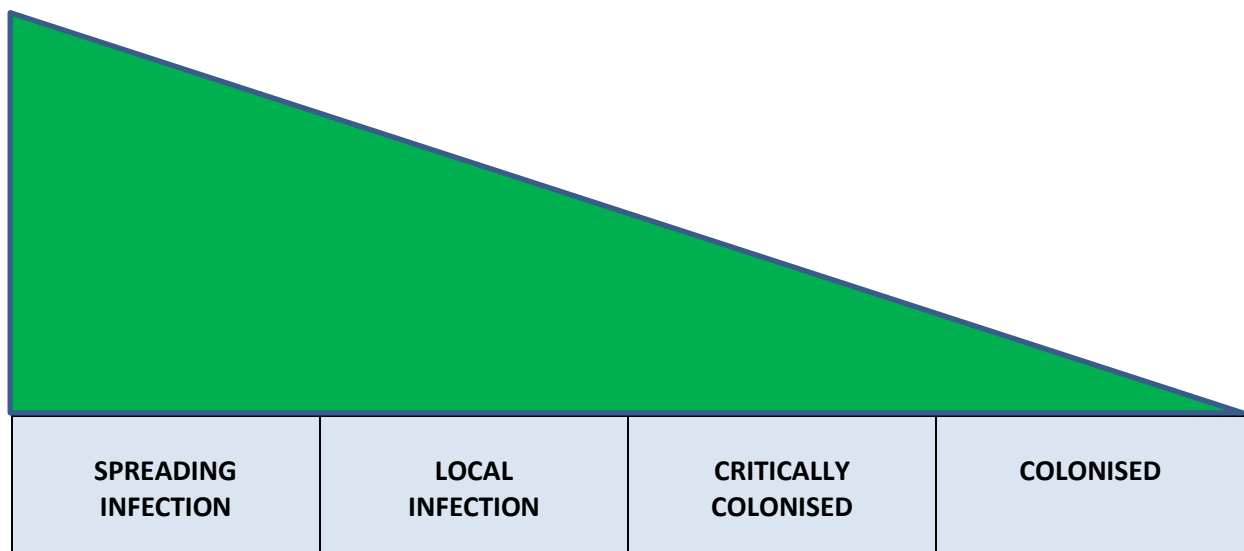
Please circle the response that reflects your opinion

INFECTION STATUS			
COLONISED	CRITICALLY COLONISED	LOCAL INFECTION	SPREADING INFECTION

## WOUND EXUDATE CONTINUUM

	HIGH VISCOSITY 5	MEDIUM VISCOSITY 3	LOW VISCOSITY 1
HIGH VOLUME 5			
MEDIUM VOLUME 3			
LOW VOLUME 1			

## 6. WOUND INFECTION CONTINUUM



## PAIN

Please circle one number that reflects patient's response

PAIN FREQUENCY	NONE	INTERMITTENT	AT DRESSING CHANGE	CONTINUOUS
Circle one number	1	2	3	4

PAIN LOCATION	NONE	AT WOUND SITE	LIMB PAIN
Circle one number	1	2	3

ANALGESIA USE	NONE	PRE DRESSING CHANGE	CONTINUOUS
Circle one number	1	2	3

PAIN SEVERITY - VERBAL RATING SCALE									
Circle one number									
1	2	3	4	5	6	7	8	9	10

## Wound care clinician demographic questionnaire

1. YEARS OF WOUNDCARE NURSING EXPERIENCE	0 – 4 YEARS	5 – 9 YEARS	10 – 14 YEARS	15 – 20 YEARS	20 – 24 YEARS	≥ 25 YEARS
Tick one box						

2. AVERAGE NUMBER OF WOUNDCARE PATIENTS ENCOUNTERED PER WEEK	0 – 19 PATIENTS	20 – 39 PATIENTS	40 – 59 PATIENTS	60 – 79 PATIENTS	80 – 99 PATIENTS	≥ 100 PATIENTS
Tick one box						

3. QUALIFICATION IN WOUND CARE	INDUSTRY SPONSORED EDUCATION IN WOUND CARE	INMO EDUCATION IN WOUND CARE	POST – GRADUATE DIPLOMA IN TISSUE VIABILITY	M.Sc. IN TISSUE VIABILITY	OTHER QUALIFICATION IN TISSUE VIABILITY (please specify)
Tick all relevant boxes					

## Appendix E Calibration Report

Calibration performed by Dr. Yves Vander Haeghen in Ghent, Belgium

### Wound No. 1 – calibration successful

23:13:35: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.1.jpg 1182x1800x24

- 23:13:38: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)

- 23:13:38: Looking for chart Color Checker Passport

- 23:13:38: Search is unrestricted

- 23:13:38: First patch search (White)

- 23:13:38: Real first patch rectangularity is 1.000

- 23:13:38: Real first patch major axis has angle -1.53433798428428 in normally oriented chart

- 23:13:38: Real first patch compactness is 0.882

- 23:13:38: Patch candidate must have an area between 532 and 106380

- 23:13:38: Patch candidate must have uniformity error < 70

- 23:13:38: Patch candidate must have rectangularity error < 50

- 23:13:38: Patch candidate must have compactness error < 50

- 23:13:38: Found 3844 first patch candidates using a threshold at 60%

- 23:13:38: There are 3844 patch candidates

- 23:13:38: Patch candidate at {X=846.0107, Y=92.92604}

is selected with fitness = 65.99

- 23:13:38: Patch candidate at {X=449.705, Y=106.7529} is selected with fitness = 69.35

- 23:13:38: Patch candidate at {X=1087.46, Y=405.3669} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.69)

- 23:13:38: Patch candidate at {X=730.8746, Y=483.5819} is selected with fitness = 64.51

- 23:13:38: Patch candidate at {X=601.0971, Y=487.4784} is selected with fitness = 70.13

- 23:13:38: Patch candidate at {X=471.2108, Y=491.2834} is selected with fitness = 79.28

- 23:13:38: Patch candidate at {X=341.0605, Y=495.7713} is selected with fitness = 80.31

- 23:13:38: Patch candidate at {X=1090.665, Y=486.4711} is rejected based on shape (rectangularity error = 99.99, compactness error = 97.75)

- 23:13:38: Patch candidate at {X=595.5252, Y=738.8889} is rejected based on shape (rectangularity error = 99.72, compactness error = 92.35)

- 23:13:38: Patch candidate at {X=568.9728, Y=770.5417} is rejected based on shape (rectangularity error = 55.60, compactness error = 92.95)

- 23:13:38: Patch candidate at {X=703.4694, Y=782.2292} is rejected based on shape (rectangularity error = 99.84, compactness error = 84.60)

- 23:13:38: Patch candidate at {X=622.5498, Y=885.3495} is rejected based on shape (rectangularity error = 99.95, compactness error = 99.38)

- 23:13:38: Patch candidate at {X=810.2283, Y=884.55} is rejected based on shape (rectangularity error = 99.98, compactness error = 84.71)

- 23:13:38: Patch candidate at {X=440.8802, Y=1189.119} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.07)

- 23:13:38: Patch candidate at {X=450.8453, Y=1355.341} is rejected based on shape (rectangularity error = 94.19, compactness error = 90.37)

- 23:13:38: There are 3829 patch(es) rejected based on area or with less than 3 points

- 23:13:38: Selected 6 first patch candidates

- 23:13:38: First patch detection took 0.35 s

- 23:13:38: Second patch search

- 23:13:38: First patch (White) at {X=341.0605, Y=495.7713}
- 23:13:38: Rough second patch located at {X=5284.896, Y=2637.431}
- 23:13:38: Optimized second patch located at {X=1006.551, Y=476.5424} in image
- 23:13:38: Image pseudo-luminance range is (0) - (242)
- 23:13:38: Image color range: (0 0 0) - (255 250 247)
- 23:13:38: Real distance between the first and second patch is 7.500 cm
- 23:13:38: Found chart at {X=329.5232, Y=96.47711} - {X=1006.55, Y=476.5423} that calibrates image
- 23:13:38: Chart detection took 0.00 s
- 23:13:38: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:13:38: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 148 36).
- 23:13:38: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (255 199 29).
- 23:13:38: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 234 16).
- 23:13:38: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:38: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 255).
- 23:13:38: Number of invalid patches: 5 < 6
- 23:13:38: Errors for valid patches prior to calibration (CIE dE\*2000): median = 11.8, IQR = 10 - 13.1, maximum = 18.1 (Purplish blue)
- 23:13:38: Errors for valid patches after calibration (CIE dE\*2000): median = 0.0831, IQR = 0.0528 - 0.136, maximum = 0.289 (Dark gray)
- 23:13:38: Errors for all patches after calibration (CIE dE\*2000): median = 0.111, IQR = 0.0573 - 0.267, maximum = 8.66 (White - Input saturated)
- 23:13:38: Image resolution is 225.473 dpi
- 23:13:38: Computation of profile took 0.00 s
- 23:13:38: Chart detection and profile computation took 3.74 s
- 23:13:38: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1182 x 1800 image
- 23:13:39: Profile application took 0.58 s
- **23:13:39: Saved calibrated image in, C:\temp\Bernie\UC Wound No.1.jpg**
- 23:13:39: Automatic calibration took 4.51 s

**Wound No. 2 image No. 1 calibration unsuccessful (second image of this wound was successfully calibrated)**

- 23:13:40: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.2 Image 1.jpg 1200x1800x24
- 23:13:47: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
  - 23:13:47: Looking for chart Color Checker Passport
  - 23:13:47: Search is unrestricted
  - 23:13:47: First patch search (White)
  - 23:13:47: Real first patch rectangularity is 1.000
  - 23:13:47: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
  - 23:13:47: Real first patch compactness is 0.882
  - 23:13:47: Patch candidate must have an area between 540 and 108000
  - 23:13:47: Patch candidate must have uniformity error < 70
  - 23:13:47: Patch candidate must have rectangularity error < 50
  - 23:13:47: Patch candidate must have compactness error < 50
  - 23:13:47: Found 4514 first patch candidates using a threshold at 60%
  - 23:13:47: There are 4514 patch candidates
  - 23:13:47: Patch candidate at {X=455.9144, Y=68.24956} is selected with fitness = 73.47

- 23:13:47: Patch candidate at {X=804.1686, Y=71.15591} is selected with fitness = 72.29
- 23:13:47: Patch candidate at {X=266.515, Y=65.19816} is rejected based on shape (rectangularity error = 100.00, compactness error = 82.23)
- 23:13:47: Patch candidate at {X=570.7422, Y=69.41626} is selected with fitness = 67.97
- 23:13:47: Patch candidate at {X=920.4199, Y=72.08287} is selected with fitness = 81.15
- 23:13:47: Patch candidate at {X=1010.652, Y=93.49119} is rejected based on shape (rectangularity error = 99.94, compactness error = 64.18)
- 23:13:47: Patch candidate at {X=1004.854, Y=339.5784} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.71)
- 23:13:47: Patch candidate at {X=803.3721, Y=299.1615} is selected with fitness = 67.76
- 23:13:47: Patch candidate at {X=348.6703, Y=402.4982} is selected with fitness = 78.94
- 23:13:47: Patch candidate at {X=462.2476, Y=404.0802} is selected with fitness = 78.13
- 23:13:47: Patch candidate at {X=576.1575, Y=405.6667} is selected with fitness = 75.57
- 23:13:47: Patch candidate at {X=689.8277, Y=407.4963} is selected with fitness = 66.78
- 23:13:47: Patch candidate at {X=532.5593, Y=608.5894} is rejected based on shape (rectangularity error = 99.99, compactness error = 94.59)
- 23:13:47: Patch candidate at {X=843.0496, Y=786.7643} is rejected based on shape (rectangularity error = 99.97, compactness error = 98.92)
- 23:13:47: Patch candidate at {X=521.3781, Y=1058.508} is rejected based on shape (rectangularity error = 99.80, compactness error = 98.44)
- 23:13:47: Patch candidate at {X=823.5904, Y=1067.748} is rejected based on shape (rectangularity error = 99.99, compactness error = 98.61)
- 23:13:47: Patch candidate at {X=318.7564, Y=1418.576} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.64)
- 23:13:47: Patch candidate at {X=249.7446, Y=1250.519} is rejected based on shape (rectangularity error = 97.03, compactness error = 97.87)
- 23:13:47: Patch candidate at {X=802.6242, Y=1251.943} is rejected based on shape (rectangularity error = 98.36, compactness error = 90.71)
- 23:13:47: Patch candidate at {X=364.4269, Y=1318.128} is rejected based on shape (rectangularity error = 100.00, compactness error = 93.66)
- 23:13:47: Patch candidate at {X=71.20789, Y=1340.711} is rejected based on shape (rectangularity error = 83.89, compactness error = 98.15)
- 23:13:47: Patch candidate at {X=596.5659, Y=1388.59} is rejected based on shape (rectangularity error = 99.39, compactness error = 98.88)
- 23:13:47: Patch candidate at {X=26.80675, Y=1417.17} is rejected based on shape (rectangularity error = 99.94, compactness error = 98.26)
- 23:13:47: Patch candidate at {X=73.54682, Y=1454.771} is rejected based on shape (rectangularity error = 47.52, compactness error = 98.03)
- 23:13:47: Patch candidate at {X=542.1575, Y=1470.118} is rejected based on shape (rectangularity error = 99.76, compactness error = 95.81)
- 23:13:47: Patch candidate at {X=614.8612, Y=1489.55} is rejected based on shape (rectangularity error = 88.43, compactness error = 93.51)
- 23:13:47: There are 4488 patch(es) rejected based on area or with less than 3 points
- 23:13:47: Selected 9 first patch candidates
- 23:13:47: First patch detection took 0.26 s
- 23:13:47: Second patch search
- 23:13:47: First patch (White) at {X=920.4199, Y=72.08287}
- 23:13:47: Rough second patch located at {X=4494.838, Y=3159.549}
- 23:13:47: No optimized second patch found in the image
- 23:13:47: First patch (White) at {X=348.6703, Y=402.4982}
- 23:13:47: Rough second patch located at {X=4407.165, Y=2616.874}



- 23:13:47: No optimized second patch found in the image
- 23:13:47: First patch (White) at {X=462.2476, Y=404.0802}
- 23:13:47: Rough second patch located at {X=4953.514, Y=2153.808}
- 23:13:47: Optimized second patch located at {X=1056.399, Y=439.2327} in image
- 23:13:47: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (68 52 46)
- 23:13:47: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (27 45 62)
- 23:13:47: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (23 31 14)
- 23:13:47: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (47 49 68)
- 23:13:47: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (39 75 75)
- 23:13:47: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (30 30 30)
- 23:13:47: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (9 17 37)
- 23:13:47: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (47 17 23)
- 23:13:47: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (19 6 30)
- 23:13:47: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (55 64 4)
- 23:13:47: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (68 59 17)
- 23:13:47: Excluded patch Orange yellow: uniformity is too low, R\*G\*B\* std (28 29 29)
- 23:13:47: Excluded patch Green: over or under-exposed, R\*G\*B\* (254 97 87).
- 23:13:47: Excluded patch Red: uniformity is too low, R\*G\*B\* std (28 32 14)
- 23:13:47: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (46 20 42)
- 23:13:47: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (9 48 58)
- 23:13:47: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:47: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 255).
- 23:13:47: Too many invalid patches  $18 > 6$
- 23:13:47: Optimized second patch does not lead to satisfactory calibration!
- 23:13:47: First patch (White) at {X=576.1575, Y=405.6667}
- 23:13:47: Rough second patch located at {X=366.3102, Y=3623.873}
- 23:13:47: Optimized second patch located at {X=102.8052, Y=809.1661} in image
- 23:13:47: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (35 34 34)
- 23:13:47: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (26 23 22)
- 23:13:47: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (43 28 29)
- 23:13:47: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:47: Excluded patch Light gray: uniformity is too low, R\*G\*B\* std (40 40 40)
- 23:13:47: Excluded patch Light medium gray: uniformity is too low, R\*G\*B\* std (39 32 30)
- 23:13:47: Number of invalid patches:  $6 < 6$
- 23:13:47: Median patch CIE dE\*2000 is too high:  $20 > 10$
- 23:13:47: Maximal patch CIE dE\*2000 error is high: 44 (Purple)
- 23:13:47: Maximal patch CIE dE\*2000 error including discarded patches is high: 61 (Blue - High non uniformity)
- 23:13:47: Optimized second patch does not lead to satisfactory calibration!
- 23:13:47: First patch (White) at {X=455.9144, Y=68.24956}
- 23:13:47: Rough second patch located at {X=647.8599, Y=2608.294}
- 23:13:47: Optimized second patch located at {X=129.4011, Y=558.1304} in image
- 23:13:47: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (76 61 73)
- 23:13:47: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (55 55 57)
- 23:13:47: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (60 62 62)
- 23:13:47: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (59 37 39)
- 23:13:47: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (35 16 36)
- 23:13:47: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (71 72 72)
- 23:13:47: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (31 31 31)
- 23:13:47: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (28 23 24)
- 23:13:47: Excluded patch Orange yellow: uniformity is too low, R\*G\*B\* std (38 26 27)

- 23:13:47: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (68 39 53)
- 23:13:47: Excluded patch Green: uniformity is too low, R\*G\*B\* std (27 50 73)
- 23:13:47: Excluded patch Red: uniformity is too low, R\*G\*B\* std (40 65 46)
- 23:13:47: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (57 58 57)
- 23:13:47: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (28 26 25)
- 23:13:47: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:47: Excluded patch White: over or under-exposed, R\*G\*B\* (255 214 199).
- 23:13:47: Excluded patch Light gray: uniformity is too low, R\*G\*B\* std (73 41 68)
- 23:13:47: Excluded patch Light medium gray: uniformity is too low, R\*G\*B\* std (24 20 67)
- 23:13:47: Excluded patch Dark gray: uniformity is too low, R\*G\*B\* std (29 29 29)
- **23:13:47: Too many invalid patches 19 > 6**
- 23:13:47: Optimized second patch does not lead to satisfactory calibration!
- 23:13:47: First patch (White) at {X=804.1686, Y=71.15591}
- 23:13:47: Rough second patch located at {X=4752.131, Y=3165.541}
- 23:13:47: No optimized second patch found in the image
- 23:13:47: First patch (White) at {X=570.7422, Y=69.41626}
- 23:13:47: Rough second patch located at {X=426.5913, Y=2174.226}
- 23:13:47: Optimized second patch located at {X=73.55844, Y=462.9194} in image
- 23:13:47: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (49 24 43)
- 23:13:47: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (47 48 49)
- 23:13:47: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (66 44 46)
- 23:13:47: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (53 35 36)
- 23:13:47: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (73 73 58)
- 23:13:47: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (70 60 50)
- 23:13:47: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (71 72 72)
- 23:13:47: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (33 32 32)
- 23:13:47: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (42 17 37)
- 23:13:47: Excluded patch Green: uniformity is too low, R\*G\*B\* std (75 24 32)
- 23:13:47: Excluded patch Red: uniformity is too low, R\*G\*B\* std (36 55 37)
- 23:13:47: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (253 253 253).
- 23:13:47: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:47: Excluded patch Light gray: uniformity is too low, R\*G\*B\* std (35 34 66)
- 23:13:47: Excluded patch Light medium gray: uniformity is too low, R\*G\*B\* std (81 42 63)
- 23:13:47: Excluded patch Medium Gray: uniformity is too low, R\*G\*B\* std (15 20 50)
- 23:13:47: Excluded patch Dark gray: uniformity is too low, R\*G\*B\* std (37 37 37)
- 23:13:47: Too many invalid patches 17 > 6
- 23:13:47: Optimized second patch does not lead to satisfactory calibration!
- 23:13:47: First patch (White) at {X=803.3721, Y=299.1615}
- 23:13:47: Rough second patch located at {X=1086.855, Y=168.6341}
- 23:13:47: Optimized second patch located at {X=215.4538, Y=45.87827} in image
- 23:13:47: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (46 31 30)
- 23:13:47: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (34 34 34)
- 23:13:47: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (70 46 49)
- 23:13:47: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (43 43 43)
- 23:13:47: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (69 70 69)
- 23:13:47: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (51 52 52)
- 23:13:47: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (31 31 29)
- 23:13:47: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (35 36 36)
- 23:13:47: Excluded patch Green: uniformity is too low, R\*G\*B\* std (62 61 60)
- 23:13:47: Excluded patch Red: uniformity is too low, R\*G\*B\* std (66 59 16)
- 23:13:47: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (28 52 66)

- 23:13:47: Excluded patch Magenta: uniformity is too low,  $R^*G^*B^*$  std (69 39 23)
- 23:13:47: Excluded patch Cyan: uniformity is too low,  $R^*G^*B^*$  std (41 41 41)
- 23:13:47: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:47: Excluded patch White: over or under-exposed,  $R^*G^*B^*$  (255 157 236).
- 23:13:47: Excluded patch Light gray: uniformity is too low,  $R^*G^*B^*$  std (67 74 55)
- 23:13:47: Excluded patch Light medium gray: uniformity is too low,  $R^*G^*B^*$  std (38 14 18)
- 23:13:47: Excluded patch Medium Gray: uniformity is too low,  $R^*G^*B^*$  std (35 34 66)
- 23:13:47: Excluded patch Dark gray: uniformity is too low,  $R^*G^*B^*$  std (36 18 15)
- **23:13:47: Too many invalid patches 18 > 6**
- 23:13:47: Optimized second patch does not lead to satisfactory calibration!
- 23:13:47: First patch (White) at {X=689.8277, Y=407.4963}
- 23:13:47: Rough second patch located at {X=5241.663, Y=121.0127}
- 23:13:47: No optimized second patch found in the image
- 23:13:47: Image pseudo-luminance range is (0) - (245)
- 23:13:47: Image color range: (3 3 3) - (255 255 255)
- 23:13:47: Real distance between the first and second patch is 7.500 cm
- **23:13:47: Could not find chart!**
- 23:13:47: Chart detection took 0.00 s
- 23:13:47: Automatic calibration took 7.40 s

#### **Wound No. 2 image No. 2 – calibration successful**

- 23:13:47: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.2 Image 2.jpg 1200x1800x24
- 23:13:53: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
  - 23:13:53: Looking for chart Color Checker Passport
  - 23:13:53: Search is unrestricted
  - 23:13:53: First patch search (White)
  - 23:13:53: Real first patch rectangularity is 1.000
  - 23:13:53: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
  - 23:13:53: Real first patch compactness is 0.882
  - 23:13:53: Patch candidate must have an area between 540 and 108000
  - 23:13:53: Patch candidate must have uniformity error < 70
  - 23:13:53: Patch candidate must have rectangularity error < 50
  - 23:13:53: Patch candidate must have compactness error < 50
  - 23:13:53: Found 4470 first patch candidates using a threshold at 60%
  - 23:13:53: There are 4470 patch candidates
  - 23:13:53: Patch candidate at {X=428.6616, Y=163.8735} is selected with fitness = 72.79
  - 23:13:53: Patch candidate at {X=776.2487, Y=168.7406} is selected with fitness = 70.44
  - 23:13:53: Patch candidate at {X=892.6632, Y=170.9908} is selected with fitness = 79.65
  - 23:13:53: Patch candidate at {X=981.9692, Y=190.8893} is rejected based on shape (rectangularity error = 99.99, compactness error = 90.49)
  - 23:13:53: Patch candidate at {X=977.7936, Y=365.968} is rejected based on shape (rectangularity error = 100.00, compactness error = 84.09)
  - 23:13:53: Patch candidate at {X=774.8542, Y=394.8289} is selected with fitness = 67.31
  - 23:13:53: Patch candidate at {X=975.3326, Y=483.1427} is rejected based on shape (rectangularity error = 100.00, compactness error = 92.64)
  - 23:13:53: Patch candidate at {X=319.4078, Y=496.2495} is selected with fitness = 79.30
  - 23:13:53: Patch candidate at {X=433.0819, Y=498.2477} is selected with fitness = 79.63
  - 23:13:53: Patch candidate at {X=546.7496, Y=500.4162} is selected with fitness = 73.72

- 23:13:53: Patch candidate at {X=660.2458, Y=502.9162} is selected with fitness = 66.62
- 23:13:53: Patch candidate at {X=613.046, Y=1105.083} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.84)
- 23:13:53: Patch candidate at {X=339.8384, Y=1163.047} is rejected based on shape (rectangularity error = 98.55, compactness error = 73.90)
- 23:13:53: Patch candidate at {X=272.2769, Y=1479.924} is rejected based on shape (rectangularity error = 99.25, compactness error = 99.71)
- 23:13:53: Patch candidate at {X=779.4034, Y=1347.579} is rejected based on shape (rectangularity error = 93.10, compactness error = 95.93)
- 23:13:53: Patch candidate at {X=566.6564, Y=1480.114} is rejected based on shape (rectangularity error = 77.89, compactness error = 99.08)
- 23:13:53: Patch candidate at {X=525.1141, Y=1566.398} is rejected based on shape (rectangularity error = 99.98, compactness error = 97.94)
- 23:13:53: There are 4453 patch(es) rejected based on area or with less than 3 points
- 23:13:53: Selected 8 first patch candidates
- 23:13:53: First patch detection took 0.27 s
- 23:13:53: Second patch search
- 23:13:53: First patch (White) at {X=892.6632, Y=170.9908}
- 23:13:53: Rough second patch located at {X=4331.84, Y=3565.608}
- 23:13:53: No optimized second patch found in the image
- 23:13:53: First patch (White) at {X=433.0819, Y=498.2477}
- 23:13:53: Rough second patch located at {X=4690.861, Y=2591.923}
- 23:13:53: Optimized second patch located at {X=1016.14, Y=541.3068} in image
- 23:13:53: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (58 41 36)
- 23:13:53: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (23 36 50)
- 23:13:53: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (37 39 56)
- 23:13:53: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (29 59 54)
- 23:13:53: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (9 16 35)
- 23:13:53: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (43 15 18)
- 23:13:53: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (37 43 4)
- 23:13:53: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (56 39 17)
- 23:13:53: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (10 34 42)
- 23:13:53: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:53: Too many invalid patches 10 > 6
- 23:13:53: Optimized second patch does not lead to satisfactory calibration!
- 23:13:53: First patch (White) at {X=319.4078, Y=496.2495}
- 23:13:53: Rough second patch located at {X=4062.967, Y=2415.973}
- 23:13:53: Optimized second patch located at {X=891.0929, Y=513.2395} in image
- 23:13:53: Image pseudo-luminance range is (0) - (193)
- 23:13:53: Image color range: (5 5 5) - (247 227 224)
- 23:13:53: Real distance between the first and second patch is 7.500 cm
- 23:13:53: Found chart at {X=329.6017, Y=153.2385} - {X=891.0927, Y=513.2393} that calibrates image
- 23:13:53: Chart detection took 0.00 s
- 23:13:53: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:13:53: Excluded patch Orange: over or under-exposed, R\*G\*B\* (254 160 63).
- 23:13:53: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:53: Number of invalid patches: 2 < 6
- 23:13:53: Errors for valid patches prior to calibration (CIE dE\*2000): median = 13.1, IQR = 9.69 - 15.6, maximum = 22 (Purplish blue)

- 23:13:53: Errors for valid patches after calibration (CIE dE\*2000): median = 0.124, IQR = 0.0826 - 0.165, maximum = 0.232 (Moderate red)
- 23:13:53: Errors for all patches after calibration (CIE dE\*2000): median = 0.128, IQR = 0.093 - 0.171, maximum = 3.18 (Orange - Input saturated)
- 23:13:53: Image resolution is 193.696 dpi
- 23:13:53: Computation of profile took 0.00 s
- 23:13:53: Chart detection and profile computation took 13.04 s
- 23:13:53: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image
- 23:13:53: Profile application took 0.52 s
- **23:13:53: Saved calibrated image in, C:\temp\Bernie\UC Wound No.2 Image 2.jpg**
- 23:13:53: Automatic calibration took 5.98 s

### **Wound No. 3 – calibration successful manually (see manual report below)**

23:13:54: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.3.jpg 1200x1800x24

- 23:13:56: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:13:56: Looking for chart Color Checker Passport
- 23:13:56: Search is unrestricted
- 23:13:56: First patch search (White)
- 23:13:56: Real first patch rectangularity is 1.000
- 23:13:56: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:13:56: Real first patch compactness is 0.882
- 23:13:56: Patch candidate must have an area between 540 and 108000
- 23:13:56: Patch candidate must have uniformity error < 70
- 23:13:56: Patch candidate must have rectangularity error < 50
- 23:13:56: Patch candidate must have compactness error < 50
- 23:13:56: Found 2030 first patch candidates using a threshold at 60%
- 23:13:56: There are 2030 patch candidates
- 23:13:56: Patch candidate at {X=250.8789, Y=9.581315} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.17)
- 23:13:56: Patch candidate at {X=378.0785, Y=225.7348} is selected with fitness = 68.32
- 23:13:56: Patch candidate at {X=802.3366, Y=230.9873} is selected with fitness = 62.79
- 23:13:56: Patch candidate at {X=1048.324, Y=256.6191} is rejected based on shape (rectangularity error = 99.99, compactness error = 96.68)
- 23:13:56: Patch candidate at {X=1027.008, Y=454.7838} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.00)
- 23:13:56: Patch candidate at {X=1016.191, Y=583.2977} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.71)
- 23:13:56: Patch candidate at {X=225.6644, Y=605.3251} is selected with fitness = 71.11
- 23:13:56: Patch candidate at {X=364.1632, Y=606.1771} is rejected based on shape (rectangularity error = 50.12, compactness error = 18.26)
- 23:13:56: Patch candidate at {X=501.9196, Y=607.2496} is rejected based on shape (rectangularity error = 50.49, compactness error = 18.28)
- 23:13:56: Patch candidate at {X=626.384, Y=653.6029} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.59)
- 23:13:56: Patch candidate at {X=571.1693, Y=928.3536} is rejected based on shape (rectangularity error = 98.02, compactness error = 99.70)
- 23:13:56: Patch candidate at {X=827.6218, Y=1012.913} is rejected based on shape (rectangularity error = 99.98, compactness error = 95.62)

- 23:13:56: Patch candidate at {X=749.3787, Y=1154.179} is rejected based on shape (rectangularity error = 99.96, compactness error = 98.34)
- 23:13:56: Patch candidate at {X=484.6813, Y=1519.957} is rejected based on shape (rectangularity error = 99.38, compactness error = 82.29)
- 23:13:56: There are 2016 patch(es) rejected based on area or with less than 3 points
- 23:13:56: Selected 3 first patch candidates
- 23:13:56: First patch detection took 0.20 s
- 23:13:56: Second patch search
- 23:13:56: First patch (White) at {X=225.6644, Y=605.3251}
- 23:13:56: Rough second patch located at {X=5039.755, Y=3306.982}
- 23:13:56: Optimized second patch located at {X=914.9104, Y=621.0413} in image
- 23:13:56: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (31 12 5)
- 23:13:56: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (57 41 36)
- 23:13:56: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (21 33 45)
- 23:13:56: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (31 32 46)
- 23:13:56: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (24 46 42)
- 23:13:56: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (55 24 8)
- 23:13:56: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (11 19 41)
- 23:13:56: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (36 12 16)
- 23:13:56: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:13:56: Too many invalid patches 9 > 6
- 23:13:56: Optimized second patch does not lead to satisfactory calibration!
- 23:13:56: First patch (White) at {X=378.0785, Y=225.7348}
- 23:13:56: Rough second patch located at {X=5835.718, Y=605.9098}
- 23:13:56: No optimized second patch found in the image
- 23:13:56: First patch (White) at {X=802.3366, Y=230.9873}
- 23:13:56: Rough second patch located at {X=489.9234, Y=427.3267}
- 23:13:56: No optimized second patch found in the image
- 23:13:56: Image pseudo-luminance range is (0) - (183)
- 23:13:56: Image color range: (3 3 3) - (247 222 222)
- 23:13:56: Real distance between the first and second patch is 7.500 cm
- **23:13:56: Could not find chart!**
- 23:13:56: Chart detection took 0.00 s
- 23:13:56: Automatic calibration took 2.12 s

#### Image No. 4 – calibration successful

23:13:56: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.4.jpg 1200x1800x24

- 23:14:00: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:00: Looking for chart Color Checker Passport
- 23:14:00: Search is unrestricted
- 23:14:00: First patch search (White)
- 23:14:00: Real first patch rectangularity is 1.000
- 23:14:00: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:00: Real first patch compactness is 0.882
- 23:14:00: Patch candidate must have an area between 540 and 108000
- 23:14:00: Patch candidate must have uniformity error < 70
- 23:14:00: Patch candidate must have rectangularity error < 50
- 23:14:00: Patch candidate must have compactness error < 50
- 23:14:00: Found 1914 first patch candidates using a threshold at 60%

- 23:14:00: There are 1914 patch candidates
- 23:14:00: Patch candidate at {X=994.414, Y=35.67479} is rejected based on uniformity (error = 99.24)
- 23:14:00: Patch candidate at {X=710.8983, Y=90.22197} is selected with fitness = 65.95
- 23:14:00: Patch candidate at {X=222.3634, Y=121.4733} is selected with fitness = 68.62
- 23:14:00: Patch candidate at {X=998.5634, Y=101.791} is rejected based on shape (rectangularity error = 99.99, compactness error = 84.24)
- 23:14:00: Patch candidate at {X=998.7061, Y=331.7058} is rejected based on shape (rectangularity error = 100.00, compactness error = 83.77)
- 23:14:00: Patch candidate at {X=1000.661, Y=491.5906} is rejected based on shape (rectangularity error = 100.00, compactness error = 93.11)
- 23:14:00: Patch candidate at {X=563.3188, Y=544.058} is rejected based on shape (rectangularity error = 27.36, compactness error = 99.58)
- 23:14:00: Patch candidate at {X=411.1324, Y=565.8073} is selected with fitness = 67.42
- 23:14:00: Patch candidate at {X=251.9522, Y=575.8082} is rejected based on shape (rectangularity error = 50.52, compactness error = 19.16)
- 23:14:00: Patch candidate at {X=92.22485, Y=586.4264} is selected with fitness = 69.51
- 23:14:00: Patch candidate at {X=467.3265, Y=1486.491} is rejected based on shape (rectangularity error = 98.75, compactness error = 95.63)
- 23:14:00: There are 1903 patch(es) rejected based on area or with less than 3 points
- 23:14:00: Selected 4 first patch candidates
- 23:14:00: First patch detection took 0.22 s
- 23:14:00: Second patch search
- 23:14:00: First patch (White) at {X=92.22485, Y=586.4264}
- 23:14:00: Rough second patch located at {X=5676.716, Y=3633.842}
- 23:14:00: Optimized second patch located at {X=884.8604, Y=543.2256} in image
- 23:14:00: Image pseudo-luminance range is (0) - (188)
- 23:14:00: Image color range: (0 0 0) - (250 224 224)
- 23:14:00: Real distance between the first and second patch is 7.500 cm
- 23:14:00: Found chart at {X=66.30433, Y=110.845} - {X=884.8602, Y=543.2254} that calibrates image
- 23:14:00: Chart detection took 0.00 s
- 23:14:00: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:00: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 145 45).
- 23:14:00: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:00: Number of invalid patches: 2 < 6
- 23:14:00: Errors for valid patches prior to calibration (CIE dE\*2000): median = 9.02, IQR = 6.65 - 11.1, maximum = 17.2 (Purplish blue)
- 23:14:00: Errors for valid patches after calibration (CIE dE\*2000): median = 0.0878, IQR = 0.0507 - 0.132, maximum = 0.176 (Purple)
- 23:14:00: Errors for all patches after calibration (CIE dE\*2000): median = 0.0932, IQR = 0.0587 - 0.136, maximum = 2.3 (Orange - Input saturated)
- 23:14:00: Image resolution is 268.838 dpi
- 23:14:00: Computation of profile took 0.00 s
- 23:14:00: Chart detection and profile computation took 6.14 s
- 23:14:00: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image
- 23:14:00: Profile application took 0.56 s
- **23:14:00: Saved calibrated image in, C:\temp\Bernie\UC Wound No.4.jpg**
- 23:14:01: Automatic calibration took 4.38 s

**Wound No. 5 – calibration successful manually (see manual report below)**

23:14:01: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.5.jpg 1200x1800x24

- 23:14:06: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:06: Looking for chart Color Checker Passport
- 23:14:06: Search is unrestricted
- 23:14:06: First patch search (White)
- 23:14:06: Real first patch rectangularity is 1.000
- 23:14:06: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:06: Real first patch compactness is 0.882
- 23:14:06: Patch candidate must have an area between 540 and 108000
- 23:14:06: Patch candidate must have uniformity error < 70
- 23:14:06: Patch candidate must have rectangularity error < 50
- 23:14:06: Patch candidate must have compactness error < 50
- 23:14:06: Found 1840 first patch candidates using a threshold at 60%
- 23:14:06: There are 1840 patch candidates
- 23:14:06: Patch candidate at {X=934.6898, Y=113.116} is selected with fitness = 75.31
- 23:14:06: Patch candidate at {X=791.1542, Y=115.9054} is selected with fitness = 67.63
- 23:14:06: Patch candidate at {X=1048.266, Y=114.2865} is rejected based on shape (rectangularity error = 100.00, compactness error = 81.91)
- 23:14:06: Patch candidate at {X=367.8664, Y=125.9158} is selected with fitness = 65.41
- 23:14:06: Patch candidate at {X=1065.196, Y=451.3516} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.36)
- 23:14:06: Patch candidate at {X=810.6457, Y=406.0039} is selected with fitness = 63.71
- 23:14:06: Patch candidate at {X=408.508, Y=546.1773} is selected with fitness = 73.12
- 23:14:06: Patch candidate at {X=545.3378, Y=545.6833} is selected with fitness = 67.29
- 23:14:06: Patch candidate at {X=273.3472, Y=546.7291} is selected with fitness = 74.67
- 23:14:06: Patch candidate at {X=682.8024, Y=546.3365} is selected with fitness = 62.15
- 23:14:06: Patch candidate at {X=516.5688, Y=1320.876} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.85)
- 23:14:06: There are 1829 patch(es) rejected based on area or with less than 3 points
- 23:14:06: Selected 8 first patch candidates
- 23:14:06: First patch detection took 0.22 s
- 23:14:06: Second patch search
- 23:14:06: First patch (White) at {X=934.6898, Y=113.116}
- 23:14:06: Rough second patch located at {X=1282.637, Y=118.4603}
- 23:14:06: No optimized second patch found in the image
- 23:14:06: First patch (White) at {X=273.3472, Y=546.7291}
- 23:14:06: Rough second patch located at {X=5538.95, Y=3173.047}
- 23:14:06: Optimized second patch located at {X=967.9957, Y=536.9574} in image
- 23:14:06: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (32 14 6)
- 23:14:06: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (62 45 40)
- 23:14:06: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (24 38 51)
- 23:14:06: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (31 32 45)
- 23:14:06: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (15 28 26)
- 23:14:06: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (41 21 10)
- 23:14:06: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (12 20 42)
- 23:14:06: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (43 15 19)
- 23:14:06: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (254 210 55).



- 23:14:06: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 233 38).
- 23:14:06: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:06: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 255).
- 23:14:06: Too many invalid patches 12 > 6
- 23:14:06: Optimized second patch does not lead to satisfactory calibration!
- 23:14:06: First patch (White) at {X=408.508, Y=546.1773}
- 23:14:06: Rough second patch located at {X=6403.083, Y=3688.831}
- 23:14:06: No optimized second patch found in the image
- 23:14:06: First patch (White) at {X=791.1542, Y=115.9054}
- 23:14:06: Rough second patch located at {X=175.9939, Y=1706.247}
- 23:14:06: Optimized second patch located at {X=49.07314, Y=284.252} in image
- 23:14:06: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (25 26 26)
- 23:14:06: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (41 41 42)
- 23:14:06: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (49 49 49)
- 23:14:06: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (33 27 27)
- 23:14:06: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (65 29 51)
- 23:14:06: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (77 68 31)
- 23:14:06: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (60 56 58)
- 23:14:06: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (61 61 61)
- 23:14:06: Excluded patch Yellow green: over or under-exposed, R\*G\*B\* (255 255 255).
- 23:14:06: Excluded patch Orange yellow: uniformity is too low, R\*G\*B\* std (38 37 36)
- 23:14:06: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (27 30 3)
- 23:14:06: Excluded patch Green: uniformity is too low, R\*G\*B\* std (20 12 28)
- 23:14:06: Excluded patch Red: uniformity is too low, R\*G\*B\* std (65 24 33)
- 23:14:06: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (17 50 28)
- 23:14:06: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (11 16 49)
- 23:14:06: Excluded patch Cyan: uniformity is too low, R\*G\*B\* std (36 35 34)
- 23:14:06: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:06: Excluded patch Light medium gray: uniformity is too low, R\*G\*B\* std (52 40 53)
- 23:14:06: Excluded patch Medium Gray: uniformity is too low, R\*G\*B\* std (44 39 68)
- 23:14:06: Excluded patch Dark gray: uniformity is too low, R\*G\*B\* std (83 41 24)
- 23:14:06: Excluded patch Black: uniformity is too low, R\*G\*B\* std (27 27 27)
- 23:14:06: Too many invalid patches 20 > 6
- 23:14:06: Optimized second patch does not lead to satisfactory calibration!
- 23:14:06: First patch (White) at {X=545.3378, Y=545.6833}
- 23:14:06: Rough second patch located at {X=6273.653, Y=613.6409}
- 23:14:06: No optimized second patch found in the image
- 23:14:06: First patch (White) at {X=367.8664, Y=125.9158}
- 23:14:06: Rough second patch located at {X=436.9991, Y=4485.235}
- 23:14:06: Optimized second patch located at {X=100.9835, Y=819.2738} in image
- 23:14:06: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (36 42 9)
- 23:14:06: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (70 61 62)
- 23:14:06: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (75 62 64)
- 23:14:06: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (68 56 30)
- 23:14:06: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (49 51 51)
- 23:14:06: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (28 27 27)
- 23:14:06: Excluded patch Blue: uniformity is too low, R\*G\*B\* std (47 41 54)
- 23:14:06: Excluded patch Green: uniformity is too low, R\*G\*B\* std (60 33 58)
- 23:14:06: Excluded patch Red: uniformity is too low, R\*G\*B\* std (40 54 41)
- 23:14:06: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (81 81 82)
- 23:14:06: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (36 28 28)

- 23:14:06: Excluded patch Cyan: uniformity is too low, R\*G\*B\* std (28 25 24)
- 23:14:06: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:06: Excluded patch Light gray: uniformity is too low, R\*G\*B\* std (68 34 79)
- 23:14:06: Excluded patch Medium Gray: uniformity is too low, R\*G\*B\* std (84 85 85)
- 23:14:06: Too many invalid patches 14 > 6
- 23:14:06: Optimized second patch does not lead to satisfactory calibration!
- 23:14:06: First patch (White) at {X=810.6457, Y=406.0039}
- 23:14:06: Rough second patch located at {X=598.0712, Y=575.0894}
- 23:14:06: No optimized second patch found in the image
- 23:14:06: First patch (White) at {X=682.8024, Y=546.3365}
- 23:14:06: Rough second patch located at {X=483.0432, Y=399.8847}
- 23:14:06: No optimized second patch found in the image
- 23:14:06: Image pseudo-luminance range is (0) - (224)
- 23:14:06: Image color range: (3 3 3) - (255 242 240)
- 23:14:06: Real distance between the first and second patch is 7.500 cm
- **23:14:06: Could not find chart!**
- 23:14:06: Chart detection took 0.00 s
- 23:14:06: Automatic calibration took 4.96 s

#### **Wound No. 6 calibration successful**

23:14:06: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.6.jpg 1200x1800x24

- 23:14:11: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:11: Looking for chart Color Checker Passport
- 23:14:11: Search is unrestricted
- 23:14:11: First patch search (White)
- 23:14:11: Real first patch rectangularity is 1.000
- 23:14:11: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:11: Real first patch compactness is 0.882
- 23:14:11: Patch candidate must have an area between 540 and 108000
- 23:14:11: Patch candidate must have uniformity error < 70
- 23:14:11: Patch candidate must have rectangularity error < 50
- 23:14:11: Patch candidate must have compactness error < 50
- 23:14:11: Found 5605 first patch candidates using a threshold at 60%
- 23:14:11: There are 5605 patch candidates
- 23:14:11: Patch candidate at {X=1171.17, Y=111.6411} is rejected based on shape (rectangularity error = 99.99, compactness error = 76.10)
- 23:14:11: Patch candidate at {X=883.7851, Y=210.1344} is selected with fitness = 64.08
- 23:14:11: Patch candidate at {X=411.0418, Y=225.5622} is selected with fitness = 67.51
- 23:14:11: Patch candidate at {X=1038.517, Y=264.3264} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.28)
- 23:14:11: Patch candidate at {X=1137.108, Y=423.1591} is rejected based on shape (rectangularity error = 100.00, compactness error = 89.38)
- 23:14:11: Patch candidate at {X=710.85, Y=668.306} is selected with fitness = 59.38
- 23:14:11: Patch candidate at {X=557.3022, Y=675.3088} is selected with fitness = 67.06
- 23:14:11: Patch candidate at {X=400.9406, Y=683.0539} is selected with fitness = 77.40
- 23:14:11: Patch candidate at {X=244.4332, Y=690.8813} is selected with fitness = 76.15
- 23:14:11: Patch candidate at {X=1121.195, Y=678.3497} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.98)

- 23:14:11: Patch candidate at {X=811.2833, Y=1158.246} is rejected based on shape (rectangularity error = 99.99, compactness error = 98.77)
- 23:14:11: Patch candidate at {X=705.2013, Y=1419.012} is rejected based on shape (rectangularity error = 99.81, compactness error = 99.71)
- 23:14:11: Patch candidate at {X=397.4644, Y=1229.37} is rejected based on shape (rectangularity error = 99.95, compactness error = 98.31)
- 23:14:11: Patch candidate at {X=902.9825, Y=1289.448} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.10)
- 23:14:11: Patch candidate at {X=220.4645, Y=1297.279} is rejected based on shape (rectangularity error = 99.93, compactness error = 98.47)
- 23:14:11: Patch candidate at {X=482.7776, Y=1376.518} is rejected based on shape (rectangularity error = 97.47, compactness error = 90.42)
- 23:14:11: Patch candidate at {X=323.0349, Y=1490.624} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.19)
- 23:14:11: Patch candidate at {X=625.23, Y=1586.385} is rejected based on shape (rectangularity error = 99.97, compactness error = 92.54)
- 23:14:11: There are 5587 patch(es) rejected based on area or with less than 3 points
- 23:14:11: Selected 6 first patch candidates
- 23:14:11: First patch detection took 0.30 s
- 23:14:11: Second patch search
- 23:14:11: First patch (White) at {X=400.9406, Y=683.0539}
- 23:14:11: Rough second patch located at {X=7153.867, Y=5271.518}
- 23:14:11: No optimized second patch found in the image
- 23:14:11: First patch (White) at {X=244.4332, Y=690.8813}
- 23:14:11: Rough second patch located at {X=6527.962, Y=4346.006}
- 23:14:11: Optimized second patch located at {X=1030.112, Y=668.2534} in image
- 23:14:11: Image pseudo-luminance range is (0) - (196)
- 23:14:11: Image color range: (3 3 3) - (250 227 227)
- 23:14:11: Real distance between the first and second patch is 7.500 cm
- 23:14:11: Found chart at {X=230.8565, Y=219.4741} - {X=1030.111, Y=668.2532} that calibrates image
- 23:14:11: Chart detection took 0.00 s
- 23:14:11: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:11: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (18 19 28)
- 23:14:11: Excluded patch Orange: over or under-exposed, R\*G\*B\* (254 156 53).
- 23:14:11: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:11: Number of invalid patches: 3 < 6
- 23:14:11: Errors for valid patches prior to calibration (CIE dE\*2000): median = 10.6, IQR = 7.85 - 12.6, maximum = 20.7 (Purplish blue)
- 23:14:11: Errors for valid patches after calibration (CIE dE\*2000): median = 0.0912, IQR = 0.069 - 0.113, maximum = 0.295 (Moderate red)
- 23:14:11: Errors for all patches after calibration (CIE dE\*2000): median = 0.0977, IQR = 0.0717 - 0.131, maximum = 5.14 (Orange - Input saturated)
- 23:14:11: Image resolution is 266.193 dpi
- 23:14:11: Computation of profile took 0.00 s
- 23:14:11: Chart detection and profile computation took 9.58 s
- 23:14:11: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image
- 23:14:11: Profile application took 0.59 s
- **23:14:11: Saved calibrated image in, C:\temp\Bernie\UC Wound No.6.jpg**

- 23:14:11: Automatic calibration took 4.99 s

### **Wound No. 7 – calibration successful**

23:14:12: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.7.jpg 1277x1800x24

- 23:14:16: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)

- 23:14:16: Looking for chart Color Checker Passport

- 23:14:16: Search is unrestricted

- 23:14:16: First patch search (White)

- 23:14:16: Real first patch rectangularity is 1.000

- 23:14:16: Real first patch major axis has angle -1.53433798428428 in normally oriented chart

- 23:14:16: Real first patch compactness is 0.882

- 23:14:16: Patch candidate must have an area between 575 and 114930

- 23:14:16: Patch candidate must have uniformity error < 70

- 23:14:16: Patch candidate must have rectangularity error < 50

- 23:14:16: Patch candidate must have compactness error < 50

- 23:14:16: Found 3202 first patch candidates using a threshold at 60%

- 23:14:16: There are 3202 patch candidates

- 23:14:16: Patch candidate at {X=1223.472, Y=34.75377} is rejected based on shape (rectangularity error = 99.33, compactness error = 83.25)

- 23:14:16: Patch candidate at {X=885.709, Y=121.3632} is selected with fitness = 65.71

- 23:14:16: Patch candidate at {X=360.0378, Y=144.4152} is selected with fitness = 68.51

- 23:14:16: Patch candidate at {X=1191.615, Y=136.7333} is rejected based on shape (rectangularity error = 99.99, compactness error = 95.46)

- 23:14:16: Patch candidate at {X=1184.363, Y=397.8247} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.13)

- 23:14:16: Patch candidate at {X=1184.445, Y=570.7996} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.09)

- 23:14:16: Patch candidate at {X=717.6549, Y=633.793} is selected with fitness = 62.78

- 23:14:16: Patch candidate at {X=546.1935, Y=640.8528} is selected with fitness = 68.52

- 23:14:16: Patch candidate at {X=373.5178, Y=649.7997} is selected with fitness = 73.37

- 23:14:16: Patch candidate at {X=199.3531, Y=659.3936} is selected with fitness = 68.94

- 23:14:16: Patch candidate at {X=772.6781, Y=858.6382} is rejected based on shape (rectangularity error = 99.99, compactness error = 97.08)

- 23:14:16: Patch candidate at {X=626.6689, Y=1021.931} is rejected based on shape (rectangularity error = 94.72, compactness error = 99.36)

- 23:14:16: Patch candidate at {X=1089.047, Y=1031.466} is rejected based on shape (rectangularity error = 99.81, compactness error = 89.00)

- 23:14:16: Patch candidate at {X=815.9417, Y=1029.958} is rejected based on shape (rectangularity error = 99.99, compactness error = 91.26)

- 23:14:16: Patch candidate at {X=495.1416, Y=1104.571} is rejected based on shape (rectangularity error = 98.34, compactness error = 40.23)

- 23:14:16: Patch candidate at {X=1223.963, Y=1299.521} is rejected based on shape (rectangularity error = 97.70, compactness error = 93.20)

- 23:14:16: Patch candidate at {X=444.4338, Y=1559.867} is rejected based on shape (rectangularity error = 94.99, compactness error = 93.95)

- 23:14:16: Patch candidate at {X=387.1065, Y=1591.415} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.93)

- 23:14:16: There are 3184 patch(es) rejected based on area or with less than 3 points

- 23:14:16: Selected 6 first patch candidates

- 23:14:16: First patch detection took 0.25 s
- 23:14:16: Second patch search
- 23:14:16: First patch (White) at {X=373.5178, Y=649.7997}
- 23:14:16: Rough second patch located at {X=8732.549, Y=4718.75}
- 23:14:16: No optimized second patch found in the image
- 23:14:16: First patch (White) at {X=199.3531, Y=659.3936}
- 23:14:16: Rough second patch located at {X=7763.733, Y=4376.602}
- 23:14:16: Optimized second patch located at {X=1077.491, Y=628.4594} in image
- 23:14:16: Image pseudo-luminance range is (0) - (206)
- 23:14:16: Image color range: (5 5 5) - (255 232 232)
- 23:14:16: Real distance between the first and second patch is 7.500 cm
- 23:14:16: Found chart at {X=180.7926, Y=132.5108} - {X=1077.491, Y=628.4592} that calibrates image
- 23:14:16: Chart detection took 0.00 s
- 23:14:16: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:16: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 156 55).
- 23:14:16: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (253 217 33).
- 23:14:16: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:16: Number of invalid patches: 3 < 6
- 23:14:16: Errors for valid patches prior to calibration (CIE dE\*2000): median = 11.7, IQR = 9.92 - 13.5, maximum = 20.5 (Purplish blue)
- 23:14:16: Errors for valid patches after calibration (CIE dE\*2000): median = 0.0807, IQR = 0.0521 - 0.122, maximum = 0.234 (Moderate red)
- 23:14:16: Errors for all patches after calibration (CIE dE\*2000): median = 0.0885, IQR = 0.0545 - 0.149, maximum = 4.12 (Orange - Input saturated)
- 23:14:16: Image resolution is 297.580 dpi
- 23:14:16: Computation of profile took 0.00 s
- 23:14:16: Chart detection and profile computation took 3.90 s
- 23:14:16: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1277 x 1800 image
- 23:14:16: Profile application took 0.56 s
- **23:14:16: Saved calibrated image in, C:\temp\Bernie\UC Wound No.7.jpg**
- 23:14:16: Automatic calibration took 4.64 s

#### **Wound No. 8 – calibration successful**

23:14:17: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.8.jpg 1738x1800x24

- 23:14:21: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:21: Looking for chart Color Checker Passport
- 23:14:21: Search is unrestricted
- 23:14:21: First patch search (White)
- 23:14:21: Real first patch rectangularity is 1.000
- 23:14:21: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:21: Real first patch compactness is 0.882
- 23:14:21: Patch candidate must have an area between 782 and 156420
- 23:14:21: Patch candidate must have uniformity error < 70
- 23:14:21: Patch candidate must have rectangularity error < 50
- 23:14:21: Patch candidate must have compactness error < 50
- 23:14:21: Found 8749 first patch candidates using a threshold at 60%

- 23:14:21: There are 8749 patch candidates
- 23:14:21: Patch candidate at {X=438.757, Y=166.2891} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.87)
- 23:14:21: Patch candidate at {X=821.3344, Y=160} is selected with fitness = 71.19
- 23:14:21: Patch candidate at {X=1393.251, Y=161.9142} is selected with fitness = 67.85
- 23:14:21: Patch candidate at {X=372.1932, Y=362.7148} is rejected based on shape (rectangularity error = 98.33, compactness error = 99.53)
- 23:14:21: Patch candidate at {X=1723.443, Y=446.516} is rejected based on shape (rectangularity error = 99.92, compactness error = 91.25)
- 23:14:21: Patch candidate at {X=1722.818, Y=507.0022} is rejected based on shape (rectangularity error = 99.79, compactness error = 81.72)
- 23:14:21: Patch candidate at {X=371.042, Y=561.0751} is rejected based on shape (rectangularity error = 99.98, compactness error = 99.26)
- 23:14:21: Patch candidate at {X=1722.436, Y=669.6323} is rejected based on shape (rectangularity error = 99.82, compactness error = 97.79)
- 23:14:21: Patch candidate at {X=628.6688, Y=734.8312} is selected with fitness = 84.14
- 23:14:21: Patch candidate at {X=820.6677, Y=734.6667} is selected with fitness = 82.39
- 23:14:21: Patch candidate at {X=1012.084, Y=734.9137} is selected with fitness = 72.55
- 23:14:21: Patch candidate at {X=1723.33, Y=774.4999} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.87)
- 23:14:21: Patch candidate at {X=865.3848, Y=857.4495} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.87)
- 23:14:21: Patch candidate at {X=178.0446, Y=1192.621} is rejected based on shape (rectangularity error = 99.91, compactness error = 53.69)
- 23:14:21: Patch candidate at {X=228.3554, Y=1400.744} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.45)
- 23:14:21: Patch candidate at {X=493.0349, Y=1297.321} is rejected based on shape (rectangularity error = 96.23, compactness error = 59.19)
- 23:14:21: Patch candidate at {X=364.2299, Y=1358.886} is rejected based on shape (rectangularity error = 99.99, compactness error = 54.66)
- 23:14:21: Patch candidate at {X=633.9046, Y=1375.889} is rejected based on shape (rectangularity error = 100.00, compactness error = 92.80)
- 23:14:21: Patch candidate at {X=356.3276, Y=1474.959} is rejected based on shape (rectangularity error = 97.17, compactness error = 86.27)
- 23:14:21: Patch candidate at {X=716.0032, Y=1488.219} is rejected based on shape (rectangularity error = 99.96, compactness error = 90.43)
- 23:14:21: There are 8729 patch(es) rejected based on area or with less than 3 points
- 23:14:21: Selected 5 first patch candidates
- 23:14:21: First patch detection took 0.35 s
- 23:14:21: Second patch search
- 23:14:21: First patch (White) at {X=628.6688, Y=734.8312}
- 23:14:21: Rough second patch located at {X=12690.19, Y=5742.303}
- 23:14:21: Optimized second patch located at {X=1598.873, Y=743.1994} in image
- 23:14:21: Image pseudo-luminance range is (0) - (183)
- 23:14:21: Image color range: (0 0 0) - (242 219 216)
- 23:14:21: Real distance between the first and second patch is 7.500 cm
- 23:14:21: Found chart at {X=633.6896, Y=152.7084} - {X=1598.873, Y=743.1991} that calibrates image
- 23:14:21: Chart detection took 0.00 s
- 23:14:21: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)

- 23:14:21: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:21: Number of invalid patches: 1 < 6
- 23:14:21: Errors for valid patches prior to calibration (CIE dE\*2000): median = 6.02, IQR = 4.48 - 7.72, maximum = 13.5 (Purplish blue)
- 23:14:21: Errors for valid patches after calibration (CIE dE\*2000): median = 0.118, IQR = 0.0863 - 0.154, maximum = 0.259 (Orange yellow)
- 23:14:21: Errors for all patches after calibration (CIE dE\*2000): median = 0.12, IQR = 0.0864 - 0.158, maximum = 0.282 (Cyan - Output out of gamut)
- 23:14:21: Image resolution is 328.588 dpi
- 23:14:21: Computation of profile took 0.00 s
- 23:14:21: Chart detection and profile computation took 3.92 s
- 23:14:21: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1738 x 1800 image
- 23:14:22: Profile application took 0.82 s
- **23:14:22: Saved calibrated image in, C:\temp\Bernie\UC Wound No.8.jpg**
- 23:14:22: Automatic calibration took 4.96 s

### **Wound No. 9 – calibration successful**

- 23:14:22: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.9.jpg 1344x1800x24
- 23:14:26: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
  - 23:14:26: Looking for chart Color Checker Passport
  - 23:14:26: Search is unrestricted
  - 23:14:26: First patch search (White)
  - 23:14:26: Real first patch rectangularity is 1.000
  - 23:14:26: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
  - 23:14:26: Real first patch compactness is 0.882
  - 23:14:26: Patch candidate must have an area between 605 and 120960
  - 23:14:26: Patch candidate must have uniformity error < 70
  - 23:14:26: Patch candidate must have rectangularity error < 50
  - 23:14:26: Patch candidate must have compactness error < 50
  - 23:14:26: Found 2879 first patch candidates using a threshold at 60%
  - 23:14:26: There are 2879 patch candidates
  - 23:14:26: Patch candidate at {X=1240.443, Y=55.89575} is rejected based on shape (rectangularity error = 29.23, compactness error = 90.92)
  - 23:14:26: Patch candidate at {X=355.9988, Y=114.8258} is selected with fitness = 70.47
  - 23:14:26: Patch candidate at {X=860.7446, Y=125.8949} is selected with fitness = 67.15
  - 23:14:26: Patch candidate at {X=1024.714, Y=130.7516} is rejected based on shape (rectangularity error = 19.30, compactness error = 93.92)
  - 23:14:26: Patch candidate at {X=1158.896, Y=161.4} is rejected based on shape (rectangularity error = 99.99, compactness error = 94.48)
  - 23:14:26: Patch candidate at {X=1146.32, Y=413.4458} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.50)
  - 23:14:26: Patch candidate at {X=1141.867, Y=583.8096} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.62)
  - 23:14:26: Patch candidate at {X=185.7442, Y=602.2347} is selected with fitness = 79.93
  - 23:14:26: Patch candidate at {X=351.4165, Y=605.7398} is selected with fitness = 77.13
  - 23:14:26: Patch candidate at {X=517.0831, Y=609.9082} is selected with fitness = 71.02
  - 23:14:26: Patch candidate at {X=1017.697, Y=1037.516} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.87)

- 23:14:26: Patch candidate at {X=1018.804, Y=1150.38} is rejected based on shape (rectangularity error = 99.93, compactness error = 99.01)
- 23:14:26: Patch candidate at {X=483.1459, Y=1133.768} is rejected based on shape (rectangularity error = 99.64, compactness error = 93.50)
- 23:14:26: Patch candidate at {X=261.9579, Y=1144.8} is rejected based on shape (rectangularity error = 99.89, compactness error = 66.97)
- 23:14:26: Patch candidate at {X=1031.592, Y=1377.488} is rejected based on shape (rectangularity error = 99.96, compactness error = 97.60)
- 23:14:26: Patch candidate at {X=584.5347, Y=1441.955} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.83)
- 23:14:26: Patch candidate at {X=640.0279, Y=1464.747} is rejected based on shape (rectangularity error = 97.13, compactness error = 71.87)
- 23:14:26: There are 2862 patch(es) rejected based on area or with less than 3 points
- 23:14:26: Selected 5 first patch candidates
- 23:14:26: First patch detection took 0.26 s
- 23:14:26: Second patch search
- 23:14:26: First patch (White) at {X=185.7442, Y=602.2347}
- 23:14:26: Rough second patch located at {X=6783.492, Y=4445.432}
- 23:14:26: Optimized second patch located at {X=1027.484, Y=634.3597} in image
- 23:14:26: Image pseudo-luminance range is (0) - (209)
- 23:14:26: Image color range: (0 0 0) - (252 232 232)
- 23:14:26: Real distance between the first and second patch is 7.500 cm
- 23:14:26: Found chart at {X=205.0191, Y=97.19102} - {X=1027.483, Y=634.3595} that calibrates image
- 23:14:26: Chart detection took 0.00 s
- 23:14:26: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:26: Excluded patch Blue: over or under-exposed, R\*G\*B\* (1 90 178).
- 23:14:26: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 215 0).
- 23:14:26: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:26: Number of invalid patches: 3 < 6
- 23:14:26: Errors for valid patches prior to calibration (CIE dE\*2000): median = 8.56, IQR = 6.14 - 9.86, maximum = 13.1 (Purplish blue)
- 23:14:26: Errors for valid patches after calibration (CIE dE\*2000): median = 0.0729, IQR = 0.0381 - 0.176, maximum = 0.305 (Dark gray)
- 23:14:26: Errors for all patches after calibration (CIE dE\*2000): median = 0.101, IQR = 0.0434 - 0.191, maximum = 1.66 (Blue - Input saturated)
- 23:14:26: Image resolution is 285.277 dpi
- 23:14:26: Computation of profile took 0.00 s
- 23:14:26: Chart detection and profile computation took 3.62 s
- 23:14:26: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1344 x 1800 image
- 23:14:26: Profile application took 0.60 s
- **23:14:26: Saved calibrated image in, C:\temp\Bernie\UC Wound No.9.jpg**
- 23:14:26: Automatic calibration took 4.39 s

#### **Wound No. 10 – calibration successful manually (see manual report below)**

- 23:14:27: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.10.jpg 1699x1800x24
- 23:14:29: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)



- 23:14:29: Looking for chart Color Checker Passport
- 23:14:29: Search is unrestricted
- 23:14:29: First patch search (White)
  - 23:14:29: Real first patch rectangularity is 1.000
  - 23:14:29: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
  - 23:14:29: Real first patch compactness is 0.882
  - 23:14:29: Patch candidate must have an area between 765 and 152910
  - 23:14:29: Patch candidate must have uniformity error < 70
  - 23:14:29: Patch candidate must have rectangularity error < 50
  - 23:14:29: Patch candidate must have compactness error < 50
  - 23:14:29: Found 9440 first patch candidates using a threshold at 60%
  - 23:14:29: There are 9440 patch candidates
  - 23:14:29: Patch candidate at {X=1587.768, Y=85.86794} is rejected based on shape (rectangularity error = 99.02, compactness error = 18.96)
  - 23:14:29: Patch candidate at {X=532.4144, Y=191.4084} is selected with fitness = 67.14
  - 23:14:29: Patch candidate at {X=1515.499, Y=495.2069} is rejected based on shape (rectangularity error = 99.97, compactness error = 92.40)
  - 23:14:29: Patch candidate at {X=1516.047, Y=557.5613} is rejected based on shape (rectangularity error = 99.80, compactness error = 82.99)
  - 23:14:29: Patch candidate at {X=1522.738, Y=658.7986} is rejected based on shape (rectangularity error = 99.87, compactness error = 96.88)
  - 23:14:29: Patch candidate at {X=1520.563, Y=731.7445} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.53)
  - 23:14:29: Patch candidate at {X=318.5821, Y=797.0816} is selected with fitness = 82.87
  - 23:14:29: Patch candidate at {X=529.9159, Y=797.7498} is selected with fitness = 79.97
  - 23:14:29: Patch candidate at {X=740.7502, Y=798.4808} is selected with fitness = 71.06
  - 23:14:29: Patch candidate at {X=1523.964, Y=840.4246} is rejected based on shape (rectangularity error = 99.98, compactness error = 97.94)
  - 23:14:29: Patch candidate at {X=712.8661, Y=1157.414} is rejected based on shape (rectangularity error = 62.96, compactness error = 98.94)
  - 23:14:29: Patch candidate at {X=646.4403, Y=1272.146} is rejected based on shape (rectangularity error = 93.96, compactness error = 96.42)
  - 23:14:29: Patch candidate at {X=748.6288, Y=1317.767} is rejected based on shape (rectangularity error = 99.98, compactness error = 95.77)
  - 23:14:29: Patch candidate at {X=907.1412, Y=1406.281} is rejected based on shape (rectangularity error = 99.70, compactness error = 99.18)
  - 23:14:29: Patch candidate at {X=1101.599, Y=1588.646} is rejected based on shape (rectangularity error = 91.09, compactness error = 99.55)
  - 23:14:29: Patch candidate at {X=1370.477, Y=1466.025} is rejected based on shape (rectangularity error = 99.59, compactness error = 88.54)
  - 23:14:29: Patch candidate at {X=1400.193, Y=1585.113} is rejected based on shape (rectangularity error = 99.50, compactness error = 95.14)
  - 23:14:29: Patch candidate at {X=1600.502, Y=1559.289} is rejected based on shape (rectangularity error = 43.05, compactness error = 82.13)
  - 23:14:29: Patch candidate at {X=678.7045, Y=1596.489} is rejected based on shape (rectangularity error = 99.98, compactness error = 63.15)
  - 23:14:29: Patch candidate at {X=1235.36, Y=1756.014} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.26)
  - 23:14:29: There are 9420 patch(es) rejected based on area or with less than 3 points
  - 23:14:29: Selected 4 first patch candidates
  - 23:14:29: First patch detection took 0.33 s

- 23:14:29: Second patch search
- 23:14:29: First patch (White) at {X=318.5821, Y=797.0816}
- 23:14:29: Rough second patch located at {X=11985.34, Y=6758.834}
- 23:14:29: Optimized second patch located at {X=1377.282, Y=806.3222} in image
- 23:14:29: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (35 24 23)
- 23:14:29: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (11 18 26)
- 23:14:29: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (18 20 28)
- 23:14:29: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (20 35 33)
- 23:14:29: Excluded patch Blue: over or under-exposed, R\*G\*B\* (3 78 174).
- 23:14:29: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 213 0).
- 23:14:29: Excluded patch Cyan: over or under-exposed, R\*G\*B\* (1 157 193).
- 23:14:29: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:29: Too many invalid patches 7 > 6
- 23:14:29: Optimized second patch does not lead to satisfactory calibration!
- 23:14:29: First patch (White) at {X=529.9159, Y=797.7498}
- 23:14:29: Rough second patch located at {X=13256.36, Y=6086.064}
- 23:14:29: Optimized second patch located at {X=1611.923, Y=758.5173} in image
- 23:14:29: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (65 47 43)
- 23:14:29: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (21 42 59)
- 23:14:29: Excluded patch Blue sky: uniformity is too low, R\*G\*B\* std (25 33 11)
- 23:14:29: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (48 53 74)
- 23:14:29: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (45 82 76)
- 23:14:29: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (75 76 76)
- 23:14:29: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (10 11 27)
- 23:14:29: Excluded patch Purplish blue: uniformity is too low, R\*G\*B\* std (56 16 22)
- 23:14:29: Excluded patch Moderate red: uniformity is too low, R\*G\*B\* std (18 11 28)
- 23:14:29: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (59 71 16)
- 23:14:29: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (89 61 41)
- 23:14:29: Excluded patch Orange yellow: uniformity is too low, R\*G\*B\* std (27 26 27)
- 23:14:29: Excluded patch Red: uniformity is too low, R\*G\*B\* std (45 37 19)
- 23:14:29: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (55 21 45)
- 23:14:29: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (25 45 59)
- 23:14:29: Excluded patch Cyan: uniformity is too low, R\*G\*B\* std (28 27 28)
- 23:14:29: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:29: Excluded patch Black: uniformity is too low, R\*G\*B\* std (30 29 30)
- 23:14:29: Too many invalid patches 17 > 6
- 23:14:29: Optimized second patch does not lead to satisfactory calibration!
- 23:14:29: First patch (White) at {X=740.7502, Y=798.4808}
- 23:14:29: Rough second patch located at {X=13512.23, Y=1609.181}
- 23:14:29: No optimized second patch found in the image
- 23:14:29: First patch (White) at {X=532.4144, Y=191.4084}
- 23:14:29: No rough second patch found in the image
- 23:14:29: Image pseudo-luminance range is (0) - (209)
- 23:14:29: Image color range: (0 0 0) - (252 232 229)
- 23:14:29: Real distance between the first and second patch is 7.500 cm
- **23:14:29: Could not find chart!**
- 23:14:29: Chart detection took 0.00 s
- 23:14:29: Automatic calibration took 2.28 s

### **Wound No. 11 – calibration successful**

23:14:30: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.11.jpg 1170x1800x24

- 23:14:34: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:34: Looking for chart Color Checker Passport
- 23:14:34: Search is unrestricted
- 23:14:34: First patch search (White)
  - 23:14:34: Real first patch rectangularity is 1.000
  - 23:14:34: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
  - 23:14:34: Real first patch compactness is 0.882
  - 23:14:34: Patch candidate must have an area between 526 and 105300
  - 23:14:34: Patch candidate must have uniformity error < 70
  - 23:14:34: Patch candidate must have rectangularity error < 50
  - 23:14:34: Patch candidate must have compactness error < 50
  - 23:14:34: Found 1667 first patch candidates using a threshold at 60%
  - 23:14:34: There are 1667 patch candidates
  - 23:14:34: Patch candidate at {X=1119.589, Y=65.90418} is rejected based on shape (rectangularity error = 51.55, compactness error = 88.16)
  - 23:14:34: Patch candidate at {X=346.5843, Y=88.73196} is selected with fitness = 66.33
  - 23:14:34: Patch candidate at {X=1001.218, Y=354.0741} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.60)
  - 23:14:34: Patch candidate at {X=992.772, Y=501.2448} is rejected based on shape (rectangularity error = 100.00, compactness error = 97.21)
  - 23:14:34: Patch candidate at {X=191.0062, Y=497.9958} is selected with fitness = 76.99
  - 23:14:34: Patch candidate at {X=331.5512, Y=503.8044} is selected with fitness = 79.12
  - 23:14:34: Patch candidate at {X=471.2348, Y=509.3335} is selected with fitness = 69.60
  - 23:14:34: Patch candidate at {X=406.7768, Y=883.5862} is rejected based on shape (rectangularity error = 99.99, compactness error = 98.31)
  - 23:14:34: Patch candidate at {X=528.7827, Y=950.3026} is rejected based on shape (rectangularity error = 99.89, compactness error = 75.50)
  - 23:14:34: Patch candidate at {X=347.6523, Y=1089.578} is rejected based on shape (rectangularity error = 99.98, compactness error = 96.38)
  - 23:14:34: Patch candidate at {X=427.2825, Y=1087.412} is rejected based on shape (rectangularity error = 100.00, compactness error = 91.84)
  - 23:14:34: Patch candidate at {X=375.2761, Y=1117.338} is rejected based on shape (rectangularity error = 99.99, compactness error = 95.75)
  - 23:14:34: Patch candidate at {X=408.7492, Y=1352.188} is rejected based on shape (rectangularity error = 97.14, compactness error = 99.39)
- 23:14:34: There are 1654 patch(es) rejected based on area or with less than 3 points
- 23:14:34: Selected 4 first patch candidates
- 23:14:34: First patch detection took 0.16 s
- 23:14:34: Second patch search
  - 23:14:34: First patch (White) at {X=331.5512, Y=503.8044}
  - 23:14:34: Rough second patch located at {X=6150.001, Y=3341.69}
  - 23:14:34: Optimized second patch located at {X=1071.914, Y=559.1832} in image
  - 23:14:34: Excluded patch Dark skin: uniformity is too low, R\*G\*B\* std (54 35 30)
  - 23:14:34: Excluded patch Light skin: uniformity is too low, R\*G\*B\* std (18 30 43)
  - 23:14:34: Excluded patch Foliage: uniformity is too low, R\*G\*B\* std (40 40 61)
  - 23:14:34: Excluded patch Blue flower: uniformity is too low, R\*G\*B\* std (34 73 65)
  - 23:14:34: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (77 76 75)

- 23:14:34: Excluded patch Orange: uniformity is too low, R\*G\*B\* std (7 11 31)
- 23:14:34: Excluded patch Purple: uniformity is too low, R\*G\*B\* std (50 58 5)
- 23:14:34: Excluded patch Yellow green: uniformity is too low, R\*G\*B\* std (84 54 14)
- 23:14:34: Excluded patch Red: uniformity is too low, R\*G\*B\* std (48 38 13)
- 23:14:34: Excluded patch Yellow: uniformity is too low, R\*G\*B\* std (60 18 44)
- 23:14:34: Excluded patch Magenta: uniformity is too low, R\*G\*B\* std (6 50 64)
- 23:14:34: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:34: Too many invalid patches 12 > 6
- 23:14:34: Optimized second patch does not lead to satisfactory calibration!
- 23:14:34: First patch (White) at {X=191.0062, Y=497.9958}
- 23:14:34: Rough second patch located at {X=5051.459, Y=3110.192}
- 23:14:34: Optimized second patch located at {X=899.3132, Y=535.2155} in image
- 23:14:34: Image pseudo-luminance range is (0) - (188)
- 23:14:34: Image color range: (5 5 3) - (245 222 219)
- 23:14:34: Real distance between the first and second patch is 7.500 cm
- 23:14:34: Found chart at {X=213.338, Y=73.01161} - {X=899.3129, Y=535.2153} that calibrates image
- 23:14:34: Chart detection took 0.00 s
- 23:14:34: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:34: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:34: Number of invalid patches: 1 < 6
- 23:14:34: Errors for valid patches prior to calibration (CIE dE\*2000): median = 4.35, IQR = 2.47 - 5.18, maximum = 7.13 (Purplish blue)
- 23:14:34: Errors for valid patches after calibration (CIE dE\*2000): median = 0.079, IQR = 0.0459 - 0.135, maximum = 0.449 (Dark gray)
- 23:14:34: Errors for all patches after calibration (CIE dE\*2000): median = 0.0806, IQR = 0.0465 - 0.164, maximum = 0.449 (Dark gray)
- 23:14:34: Image resolution is 240.211 dpi
- 23:14:34: Computation of profile took 0.00 s
- 23:14:34: Chart detection and profile computation took 7.07 s
- 23:14:34: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1170 x 1800 image
- 23:14:35: Profile application took 0.55 s
- **23:14:35: Saved calibrated image in, C:\temp\Bernie\UC Wound No.11.jpg**
- 23:14:35: Automatic calibration took 5.10 s

#### **Wound No. 12 – calibration successful**

23:14:35: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.12.jpg 1800x1200x24

- 23:14:39: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:39: Looking for chart Color Checker Passport
- 23:14:39: Search is unrestricted
- 23:14:39: First patch search (White)
- 23:14:39: Real first patch rectangularity is 1.000
- 23:14:39: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:39: Real first patch compactness is 0.882
- 23:14:39: Patch candidate must have an area between 540 and 108000
- 23:14:39: Patch candidate must have uniformity error < 70
- 23:14:39: Patch candidate must have rectangularity error < 50

- 23:14:39: Patch candidate must have compactness error < 50
- 23:14:39: Found 3862 first patch candidates using a threshold at 60%
- 23:14:39: There are 3862 patch candidates
- 23:14:39: Patch candidate at {X=1617.015, Y=55.01075} is rejected based on shape (rectangularity error = 99.78, compactness error = 32.00)
- 23:14:39: Patch candidate at {X=1499.901, Y=120.004} is rejected based on shape (rectangularity error = 99.81, compactness error = 42.16)
- 23:14:39: Patch candidate at {X=776.2369, Y=123.2448} is selected with fitness = 71.36
- 23:14:39: Patch candidate at {X=552.6185, Y=114.2221} is rejected based on shape (rectangularity error = 100.00, compactness error = 94.01)
- 23:14:39: Patch candidate at {X=1186.151, Y=134.6294} is selected with fitness = 68.48
- 23:14:39: Patch candidate at {X=1321.823, Y=137.7127} is selected with fitness = 74.16
- 23:14:39: Patch candidate at {X=1415.695, Y=438.6739} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.45)
- 23:14:39: Patch candidate at {X=1178.644, Y=379.4581} is rejected based on shape (rectangularity error = 41.89, compactness error = 99.69)
- 23:14:39: Patch candidate at {X=645.6591, Y=498.4804} is selected with fitness = 76.51
- 23:14:39: Patch candidate at {X=778.6566, Y=501.8208} is selected with fitness = 76.05
- 23:14:39: Patch candidate at {X=912.16, Y=505.8222} is selected with fitness = 71.47
- 23:14:39: Patch candidate at {X=1045.825, Y=510.487} is selected with fitness = 63.44
- 23:14:39: Patch candidate at {X=1643.801, Y=491.9367} is rejected based on shape (rectangularity error = 68.09, compactness error = 99.11)
- 23:14:39: Patch candidate at {X=1637.746, Y=559.3798} is rejected based on shape (rectangularity error = 99.96, compactness error = 99.03)
- 23:14:39: Patch candidate at {X=1643.129, Y=629.375} is rejected based on shape (rectangularity error = 99.85, compactness error = 97.20)
- 23:14:39: Patch candidate at {X=518.5143, Y=690.9603} is rejected based on shape (rectangularity error = 66.17, compactness error = 98.67)
- 23:14:39: Patch candidate at {X=499.2569, Y=775.6572} is rejected based on shape (rectangularity error = 99.99, compactness error = 99.19)
- 23:14:39: Patch candidate at {X=581.9541, Y=777.0724} is rejected based on shape (rectangularity error = 100.00, compactness error = 86.62)
- 23:14:39: Patch candidate at {X=616.5437, Y=767.0988} is rejected based on shape (rectangularity error = 99.99, compactness error = 93.98)
- 23:14:39: Patch candidate at {X=36.77957, Y=824.7738} is rejected based on shape (rectangularity error = 99.69, compactness error = 49.17)
- 23:14:39: Patch candidate at {X=1049.043, Y=867.7853} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.44)
- 23:14:39: There are 3841 patch(es) rejected based on area or with less than 3 points
- 23:14:39: Selected 7 first patch candidates
- 23:14:39: First patch detection took 0.22 s
- 23:14:39: Second patch search
- 23:14:39: First patch (White) at {X=645.6591, Y=498.4804}
- 23:14:39: Rough second patch located at {X=6877.653, Y=2822.365}
- 23:14:39: Optimized second patch located at {X=1299.625, Y=523.0117} in image
- 23:14:39: Image pseudo-luminance range is (0) - (201)
- 23:14:39: Image color range: (0 0 0) - (255 229 232)
- 23:14:39: Real distance between the first and second patch is 7.500 cm
- 23:14:39: Found chart at {X=660.3777, Y=106.1006} - {X=1299.625, Y=523.0114} that calibrates image
- 23:14:39: Chart detection took 0.00 s

- 23:14:39: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:39: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 159 42).
- 23:14:39: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (255 199 10).
- 23:14:39: Excluded patch Blue: over or under-exposed, R\*G\*B\* (0 101 192).
- 23:14:39: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 224 0).
- 23:14:39: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:39: Number of invalid patches: 5 < 6
- 23:14:39: Errors for valid patches prior to calibration (CIE dE\*2000): median = 11.7, IQR = 9.59 - 14.3, maximum = 18.1 (Purplish blue)
- 23:14:39: Errors for valid patches after calibration (CIE dE\*2000): median = 0.11, IQR = 0.0748 - 0.196, maximum = 0.258 (Dark gray)
- 23:14:39: Errors for all patches after calibration (CIE dE\*2000): median = 0.164, IQR = 0.0813 - 0.241, maximum = 3.26 (Orange yellow - Input saturated)
- 23:14:39: Image resolution is 221.632 dpi
- 23:14:39: Computation of profile took 0.00 s
- 23:14:39: Chart detection and profile computation took 3.64 s
- 23:14:39: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1800 x 1200 image
- 23:14:39: Profile application took 0.53 s
- **23:14:39: Saved calibrated image in, C:\temp\Bernie\UC Wound No.12.jpg**
- 23:14:39: Automatic calibration took 4.34 s

#### **Wound No. 13 – calibration unsuccessful**

23:14:40: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.13 Image 1 upper.jpg 1200x1800x24

- 23:14:40: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:40: Looking for chart Color Checker Passport
- 23:14:40: Search is unrestricted
- 23:14:40: First patch search (White)
- 23:14:40: Real first patch rectangularity is 1.000
- 23:14:40: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:40: Real first patch compactness is 0.882
- 23:14:40: Patch candidate must have an area between 540 and 108000
- 23:14:40: Patch candidate must have uniformity error < 70
- 23:14:40: Patch candidate must have rectangularity error < 50
- 23:14:40: Patch candidate must have compactness error < 50
- 23:14:40: Found 3789 first patch candidates using a threshold at 60%
- 23:14:40: There are 3789 patch candidates
- 23:14:40: Patch candidate at {X=1169.926, Y=92.56523} is rejected based on shape (rectangularity error = 91.09, compactness error = 22.74)
- 23:14:40: Patch candidate at {X=52.26858, Y=110.5022} is rejected based on shape (rectangularity error = 100.00, compactness error = 65.03)
- 23:14:40: Patch candidate at {X=317.2918, Y=123.3636} is rejected based on shape (rectangularity error = 86.54, compactness error = 18.25)
- 23:14:40: Patch candidate at {X=802.4311, Y=140.7439} is rejected based on shape (rectangularity error = 87.45, compactness error = 18.39)
- 23:14:40: Patch candidate at {X=965.9458, Y=149.8032} is rejected based on shape (rectangularity error = 82.78, compactness error = 18.68)

- 23:14:40: Patch candidate at {X=1089.169, Y=154.9062} is rejected based on shape (rectangularity error = 100.00, compactness error = 59.68)
- 23:14:40: Patch candidate at {X=1155.688, Y=194.7298} is rejected based on shape (rectangularity error = 21.62, compactness error = 52.93)
- 23:14:40: Patch candidate at {X=157.9181, Y=166.6036} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.44)
- 23:14:40: Patch candidate at {X=474.0073, Y=174.9353} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.83)
- 23:14:40: Patch candidate at {X=640.0276, Y=183.4111} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.73)
- 23:14:40: Patch candidate at {X=471.7691, Y=293.8524} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.68)
- 23:14:40: Patch candidate at {X=1057.688, Y=421.912} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.01)
- 23:14:40: Patch candidate at {X=788.2418, Y=379.2118} is rejected based on shape (rectangularity error = 92.94, compactness error = 19.28)
- 23:14:40: Patch candidate at {X=167.6185, Y=466.5572} is rejected based on shape (rectangularity error = 93.65, compactness error = 19.92)
- 23:14:40: Patch candidate at {X=321.9008, Y=471.6732} is rejected based on shape (rectangularity error = 93.36, compactness error = 19.83)
- 23:14:40: Patch candidate at {X=475.5237, Y=477.4232} is rejected based on shape (rectangularity error = 93.00, compactness error = 19.76)
- 23:14:40: Patch candidate at {X=628.7603, Y=483.7255} is rejected based on shape (rectangularity error = 92.99, compactness error = 19.78)
- 23:14:40: Patch candidate at {X=480.8013, Y=700.1971} is rejected based on shape (rectangularity error = 98.26, compactness error = 99.14)
- 23:14:40: Patch candidate at {X=515.0536, Y=968.7656} is rejected based on shape (rectangularity error = 99.96, compactness error = 99.69)
- 23:14:40: Patch candidate at {X=437.8856, Y=1056.664} is rejected based on shape (rectangularity error = 99.99, compactness error = 97.71)
- 23:14:40: Patch candidate at {X=516.0679, Y=1248.157} is rejected based on shape (rectangularity error = 99.94, compactness error = 98.57)
- 23:14:40: Patch candidate at {X=569.632, Y=1252.461} is rejected based on shape (rectangularity error = 99.98, compactness error = 96.89)
- 23:14:40: Patch candidate at {X=828.0165, Y=1513.479} is rejected based on shape (rectangularity error = 99.71, compactness error = 81.05)
- 23:14:40: There are 3766 patch(es) rejected based on area or with less than 3 points
- 23:14:40: Selected 0 first patch candidates
- 23:14:40: Found 3048 first patch candidates using a threshold at 54%
- 23:14:40: There are 3048 patch candidates
- 23:14:40: Patch candidate at {X=1169.908, Y=92.34045} is rejected based on shape (rectangularity error = 94.82, compactness error = 22.67)
- 23:14:40: Patch candidate at {X=55.08779, Y=132.6312} is rejected based on shape (rectangularity error = 100.00, compactness error = 91.41)
- 23:14:40: Patch candidate at {X=317.4208, Y=123.2749} is rejected based on shape (rectangularity error = 87.40, compactness error = 18.90)
- 23:14:40: Patch candidate at {X=480.8132, Y=131.3047} is rejected based on shape (rectangularity error = 85.97, compactness error = 19.14)
- 23:14:40: Patch candidate at {X=802.2892, Y=141.0873} is rejected based on shape (rectangularity error = 84.50, compactness error = 18.82)

- 23:14:40: Patch candidate at {X=963.9755, Y=148.7795} is rejected based on shape (rectangularity error = 84.44, compactness error = 20.05)
- 23:14:40: Patch candidate at {X=1089.572, Y=154.123} is rejected based on shape (rectangularity error = 100.00, compactness error = 56.06)
- 23:14:40: Patch candidate at {X=1155.47, Y=195.2104} is rejected based on uniformity (error = 99.99)
- 23:14:40: Patch candidate at {X=155.0962, Y=165.9154} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.91)
- 23:14:40: Patch candidate at {X=638.126, Y=182.6111} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.26)
- 23:14:40: Patch candidate at {X=477.9681, Y=250.9076} is rejected based on shape (rectangularity error = 89.45, compactness error = 18.83)
- 23:14:40: Patch candidate at {X=633.0536, Y=300.8558} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.57)
- 23:14:40: Patch candidate at {X=773.7397, Y=306.9525} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.36)
- 23:14:40: Patch candidate at {X=1057.679, Y=420.4} is rejected based on shape (rectangularity error = 100.00, compactness error = 94.95)
- 23:14:40: Patch candidate at {X=788.5305, Y=377.5438} is rejected based on shape (rectangularity error = 91.76, compactness error = 19.60)
- 23:14:40: Patch candidate at {X=167.3714, Y=466.6189} is rejected based on shape (rectangularity error = 93.80, compactness error = 19.93)
- 23:14:40: Patch candidate at {X=321.6288, Y=471.679} is rejected based on shape (rectangularity error = 92.75, compactness error = 19.74)
- 23:14:40: Patch candidate at {X=475.2757, Y=477.3635} is rejected based on shape (rectangularity error = 93.76, compactness error = 19.89)
- 23:14:40: Patch candidate at {X=628.7672, Y=483.5988} is rejected based on shape (rectangularity error = 93.33, compactness error = 19.82)
- 23:14:40: There are 3029 patch(es) rejected based on area or with less than 3 points
- 23:14:40: Selected 0 first patch candidates
- 23:14:40: First patch detection took 0.43 s
- 23:14:40: Image pseudo-luminance range is (0) - (216)
- 23:14:40: Image color range: (0 0 0) - (255 237 240)
- 23:14:40: Real distance between the first and second patch is 7.500 cm
- 23:14:40: No first patch candidates for the chart could be found!
- 23:14:40: Could not find chart!
- 23:14:40: Chart detection took 0.00 s
- 23:14:40: Automatic calibration took 0.61 s

#### **Wound No. 14 calibration unsuccessful**

23:14:41: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.14 Image 2 lower.jpg 1200x1800x24

- 23:14:41: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:41: Looking for chart Color Checker Passport
- 23:14:41: Search is unrestricted
- 23:14:41: First patch search (White)
- 23:14:41: Real first patch rectangularity is 1.000
- 23:14:41: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:41: Real first patch compactness is 0.882



- 23:14:41: Patch candidate must have an area between 540 and 108000
- 23:14:41: Patch candidate must have uniformity error < 70
- 23:14:41: Patch candidate must have rectangularity error < 50
- 23:14:41: Patch candidate must have compactness error < 50
- 23:14:41: Found 3789 first patch candidates using a threshold at 60%
- 23:14:41: There are 3789 patch candidates
- 23:14:41: Patch candidate at {X=1169.926, Y=92.56523} is rejected based on shape (rectangularity error = 91.09, compactness error = 22.74)
- 23:14:41: Patch candidate at {X=52.26858, Y=110.5022} is rejected based on shape (rectangularity error = 100.00, compactness error = 65.03)
- 23:14:41: Patch candidate at {X=317.2918, Y=123.3636} is rejected based on shape (rectangularity error = 86.54, compactness error = 18.25)
- 23:14:41: Patch candidate at {X=802.4311, Y=140.7439} is rejected based on shape (rectangularity error = 87.45, compactness error = 18.39)
- 23:14:41: Patch candidate at {X=965.9458, Y=149.8032} is rejected based on shape (rectangularity error = 82.78, compactness error = 18.68)
- 23:14:41: Patch candidate at {X=1089.169, Y=154.9062} is rejected based on shape (rectangularity error = 100.00, compactness error = 59.68)
- 23:14:41: Patch candidate at {X=1155.688, Y=194.7298} is rejected based on shape (rectangularity error = 21.62, compactness error = 52.93)
- 23:14:41: Patch candidate at {X=157.9181, Y=166.6036} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.44)
- 23:14:41: Patch candidate at {X=474.0073, Y=174.9353} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.83)
- 23:14:41: Patch candidate at {X=640.0276, Y=183.4111} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.73)
- 23:14:41: Patch candidate at {X=471.7691, Y=293.8524} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.68)
- 23:14:41: Patch candidate at {X=1057.688, Y=421.912} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.01)
- 23:14:41: Patch candidate at {X=788.2418, Y=379.2118} is rejected based on shape (rectangularity error = 92.94, compactness error = 19.28)
- 23:14:41: Patch candidate at {X=167.6185, Y=466.5572} is rejected based on shape (rectangularity error = 93.65, compactness error = 19.92)
- 23:14:41: Patch candidate at {X=321.9008, Y=471.6732} is rejected based on shape (rectangularity error = 93.36, compactness error = 19.83)
- 23:14:41: Patch candidate at {X=475.5237, Y=477.4232} is rejected based on shape (rectangularity error = 93.00, compactness error = 19.76)
- 23:14:41: Patch candidate at {X=628.7603, Y=483.7255} is rejected based on shape (rectangularity error = 92.99, compactness error = 19.78)
- 23:14:41: Patch candidate at {X=480.8013, Y=700.1971} is rejected based on shape (rectangularity error = 98.26, compactness error = 99.14)
- 23:14:41: Patch candidate at {X=515.0536, Y=968.7656} is rejected based on shape (rectangularity error = 99.96, compactness error = 99.69)
- 23:14:41: Patch candidate at {X=437.8856, Y=1056.664} is rejected based on shape (rectangularity error = 99.99, compactness error = 97.71)
- 23:14:41: Patch candidate at {X=516.0679, Y=1248.157} is rejected based on shape (rectangularity error = 99.94, compactness error = 98.57)
- 23:14:41: Patch candidate at {X=569.632, Y=1252.461} is rejected based on shape (rectangularity error = 99.98, compactness error = 96.89)

- 23:14:41: Patch candidate at {X=828.0165, Y=1513.479} is rejected based on shape (rectangularity error = 99.71, compactness error = 81.05)
- 23:14:41: There are 3766 patch(es) rejected based on area or with less than 3 points
- 23:14:41: Selected 0 first patch candidates
- 23:14:41: Found 3048 first patch candidates using a threshold at 54%
- 23:14:41: There are 3048 patch candidates
- 23:14:41: Patch candidate at {X=1169.908, Y=92.34045} is rejected based on shape (rectangularity error = 94.82, compactness error = 22.67)
- 23:14:41: Patch candidate at {X=55.08779, Y=132.6312} is rejected based on shape (rectangularity error = 100.00, compactness error = 91.41)
- 23:14:41: Patch candidate at {X=317.4208, Y=123.2749} is rejected based on shape (rectangularity error = 87.40, compactness error = 18.90)
- 23:14:41: Patch candidate at {X=480.8132, Y=131.3047} is rejected based on shape (rectangularity error = 85.97, compactness error = 19.14)
- 23:14:41: Patch candidate at {X=802.2892, Y=141.0873} is rejected based on shape (rectangularity error = 84.50, compactness error = 18.82)
- 23:14:41: Patch candidate at {X=963.9755, Y=148.7795} is rejected based on shape (rectangularity error = 84.44, compactness error = 20.05)
- 23:14:41: Patch candidate at {X=1089.572, Y=154.123} is rejected based on shape (rectangularity error = 100.00, compactness error = 56.06)
- 23:14:41: Patch candidate at {X=1155.47, Y=195.2104} is rejected based on uniformity (error = 99.99)
- 23:14:41: Patch candidate at {X=155.0962, Y=165.9154} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.91)
- 23:14:41: Patch candidate at {X=638.126, Y=182.6111} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.26)
- 23:14:41: Patch candidate at {X=477.9681, Y=250.9076} is rejected based on shape (rectangularity error = 89.45, compactness error = 18.83)
- 23:14:41: Patch candidate at {X=633.0536, Y=300.8558} is rejected based on shape (rectangularity error = 100.00, compactness error = 96.57)
- 23:14:41: Patch candidate at {X=773.7397, Y=306.9525} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.36)
- 23:14:41: Patch candidate at {X=1057.679, Y=420.4} is rejected based on shape (rectangularity error = 100.00, compactness error = 94.95)
- 23:14:41: Patch candidate at {X=788.5305, Y=377.5438} is rejected based on shape (rectangularity error = 91.76, compactness error = 19.60)
- 23:14:41: Patch candidate at {X=167.3714, Y=466.6189} is rejected based on shape (rectangularity error = 93.80, compactness error = 19.93)
- 23:14:41: Patch candidate at {X=321.6288, Y=471.679} is rejected based on shape (rectangularity error = 92.75, compactness error = 19.74)
- 23:14:41: Patch candidate at {X=475.2757, Y=477.3635} is rejected based on shape (rectangularity error = 93.76, compactness error = 19.89)
- 23:14:41: Patch candidate at {X=628.7672, Y=483.5988} is rejected based on shape (rectangularity error = 93.33, compactness error = 19.82)
- 23:14:41: There are 3029 patch(es) rejected based on area or with less than 3 points
- 23:14:41: Selected 0 first patch candidates
- 23:14:41: First patch detection took 0.42 s
- 23:14:41: Image pseudo-luminance range is (0) - (216)
- 23:14:41: Image color range: (0 0 0) - (255 237 240)
- 23:14:41: Real distance between the first and second patch is 7.500 cm
- 23:14:41: No first patch candidates for the chart could be found!

- 23:14:41: Could not find chart!
- 23:14:41: Chart detection took 0.00 s
- 23:14:41: Automatic calibration took 0.60 s

#### Wound No. 15 - calibration unsuccessful

23:14:42: D:\Users\yvdh\Dropbox\Wound Study uncalibrated images\Uncalibrated Wound Images 20.04.2012\Un-calibrated wound images 1 - 16 April 22\UC Wound No.15.jpg 1473x1800x24

- 23:14:43: Automatic determination of profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:14:43: Looking for chart Color Checker Passport
- 23:14:43: Search is unrestricted
- 23:14:43: First patch search (White)
- 23:14:43: Real first patch rectangularity is 1.000
- 23:14:43: Real first patch major axis has angle -1.53433798428428 in normally oriented chart
- 23:14:43: Real first patch compactness is 0.882
- 23:14:43: Patch candidate must have an area between 663 and 132570
- 23:14:43: Patch candidate must have uniformity error < 70
- 23:14:43: Patch candidate must have rectangularity error < 50
- 23:14:43: Patch candidate must have compactness error < 50
- 23:14:43: Found 11096 first patch candidates using a threshold at 60%
- 23:14:43: There are 11096 patch candidates
- 23:14:43: Patch candidate at {X=1333.029, Y=67.9825} is rejected based on shape (rectangularity error = 99.33, compactness error = 43.28)
- 23:14:43: Patch candidate at {X=1344.905, Y=64.84731} is rejected based on shape (rectangularity error = 97.19, compactness error = 21.05)
- 23:14:43: Patch candidate at {X=1103.183, Y=138.6667} is selected with fitness = 74.52
- 23:14:43: Patch candidate at {X=934.9626, Y=139.6749} is selected with fitness = 66.70
- 23:14:43: Patch candidate at {X=599.2552, Y=142.5369} is selected with fitness = 65.29
- 23:14:43: Patch candidate at {X=430.652, Y=144.4682} is selected with fitness = 70.11
- 23:14:43: Patch candidate at {X=940.1066, Y=470.5376} is selected with fitness = 62.73
- 23:14:43: Patch candidate at {X=1234.568, Y=435.3085} is rejected based on shape (rectangularity error = 99.65, compactness error = 82.62)
- 23:14:43: Patch candidate at {X=1238.879, Y=580.0557} is rejected based on shape (rectangularity error = 99.99, compactness error = 97.02)
- 23:14:43: Patch candidate at {X=772.8534, Y=639.8993} is selected with fitness = 66.91
- 23:14:43: Patch candidate at {X=602.779, Y=641.5873} is selected with fitness = 74.64
- 23:14:43: Patch candidate at {X=431.968, Y=642.3525} is selected with fitness = 77.43
- 23:14:43: Patch candidate at {X=261.2174, Y=644.1118} is selected with fitness = 82.22
- 23:14:43: Patch candidate at {X=1241.687, Y=672.0793} is rejected based on shape (rectangularity error = 100.00, compactness error = 98.09)
- 23:14:43: Patch candidate at {X=851.4896, Y=747.6779} is rejected based on shape (rectangularity error = 100.00, compactness error = 99.72)
- 23:14:43: Patch candidate at {X=773.7654, Y=1042.553} is rejected based on shape (rectangularity error = 99.98, compactness error = 55.70)
- 23:14:43: Patch candidate at {X=531.4434, Y=1135.591} is rejected based on shape (rectangularity error = 99.97, compactness error = 92.11)
- 23:14:43: Patch candidate at {X=737.6412, Y=1304.937} is rejected based on shape (rectangularity error = 80.10, compactness error = 92.95)
- 23:14:43: Patch candidate at {X=318.7027, Y=1416.228} is rejected based on shape (rectangularity error = 100.00, compactness error = 95.12)

- 23:14:43: Patch candidate at {X=851.4561, Y=1420.951} is rejected based on shape (rectangularity error = 100.00, compactness error = 76.39)
- 23:14:43: There are 11076 patch(es) rejected based on area or with less than 3 points
- 23:14:43: Selected 9 first patch candidates
- 23:14:43: First patch detection took 0.27 s
- 23:14:43: Second patch search
- 23:14:43: First patch (White) at {X=261.2174, Y=644.1118}
- 23:14:43: Rough second patch located at {X=7922.34, Y=4259.733}
- 23:14:43: Optimized second patch located at {X=1123.067, Y=642.8182} in image
- 23:14:43: Image pseudo-luminance range is (0) - (242)
- 23:14:43: Image color range: (0 0 0) - (255 247 242)
- 23:14:43: Real distance between the first and second patch is 7.500 cm
- 23:14:43: Excluded patch Light skin: over or under-exposed, R\*G\*B\* (252 196 174).
- 23:14:43: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 164 23).
- 23:14:43: Excluded patch Moderate red: over or under-exposed, R\*G\*B\* (255 131 135).
- 23:14:43: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (255 213 0).
- 23:14:43: Excluded patch Red: over or under-exposed, R\*G\*B\* (255 71 70).
- 23:14:43: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 241 0).
- 23:14:43: Excluded patch Magenta: over or under-exposed, R\*G\*B\* (255 149 199).
- 23:14:43: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:14:43: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 251).
- 23:14:43: Too many invalid patches 9 > 6
- **23:14:43: Found chart at {X=260.4412, Y=127.0022} - {X=1123.066, Y=642.818}, but it does not lead to a satisfactory calibration!**
- 23:14:43: Chart detection took 0.00 s
- 23:14:43: Automatic calibration took 1.13 s

**23:14:43: Finished batch calibration, 9 out of 16 images calibrated in 67.25 s (4.20 s per image).**  
**23:14:43: 1 out of 16 are bad images (over- or underexposure) that cannot be calibrated**  
**23:14:43: 6 out of 16 are images where we could not locate the chart, but which might still be calibrated manually**

### **Wound No. 3 – manual calibration successful**

- 23:43:16: **UC%20Wound%20No.3.jpg** 1200x1800x24
- 23:43:16: Chart manually situated at {X=239.7901, Y=238.5426} - {X=938.8867, Y=624.0909}
  - 23:43:16: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
  - 23:43:16: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
  - 23:43:16: Excluded patch White: uniformity is too low, R\*G\*B\* std (79 80 79)
  - 23:43:16: Excluded patch Light gray: uniformity is too low, R\*G\*B\* std (50 51 51)
  - 23:43:16: Number of invalid patches: 3 < 6
  - 23:43:19: Errors for valid patches prior to calibration (CIE dE\*2000): median = 8.58, IQR = 6.76 - 10.4, maximum = 16.9 (Purplish blue)
  - 23:43:19: Errors for valid patches after calibration (CIE dE\*2000): median = 0.196, IQR = 0.171 - 0.31, maximum = 0.81 (Light medium gray)
  - 23:43:19: Errors for all patches after calibration (CIE dE\*2000): median = 0.213, IQR = 0.171 - 0.311, maximum = 0.81 (Light medium gray)
  - 23:43:19: Image resolution is 231.848 dpi
  - 23:43:19: Computation of profile took 0.00 s
  - 23:43:19: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image

- 23:43:19: Profile application took 0.51 s
- 23:43:19: Manual calibration took 3.28 s

23:44:13: UC%20Wound%20No.3.jpg 1200x1800x24

- 23:44:13: Chart manually situated at {X=237.932, Y=236.6846} - {X=913.8029, Y=608.2975}
- 23:44:13: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:44:13: Excluded patch Bluish flower: uniformity is too low, R\*G\*B\* std (24 48 43)
- 23:44:13: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:44:13: Number of invalid patches: 2 < 6
- 23:44:15: Errors for valid patches prior to calibration (CIE dE\*2000): median = 8.04, IQR = 6.44 - 10.4, maximum = 17 (Purplish blue)
- 23:44:15: Errors for valid patches after calibration (CIE dE\*2000): median = 0.101, IQR = 0.0913 - 0.187, maximum = 0.4 (Light medium gray)
- 23:44:15: Errors for all patches after calibration (CIE dE\*2000): median = 0.117, IQR = 0.0929 - 0.21, maximum = 0.585 (Cyan - Output out of gamut)
- 23:44:15: Image resolution is 223.988 dpi
- 23:44:15: Computation of profile took 0.00 s
- 23:44:15: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image
- 23:44:16: Profile application took 0.53 s
- **23:44:16: Manual calibration took 3.30 s**

#### **Wound No. 5 - manual calibration successful**

23:46:36: UC%20Wound%20No.5.jpg 1200x1800x24

- 23:46:36: Chart manually situated at {X=239.9814, Y=138.3711} - {X=969.2715, Y=537.8549}
- 23:46:36: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:46:36: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 163 51).
- 23:46:36: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (255 210 54).
- 23:46:36: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 233 38).
- 23:46:36: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:46:36: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 255).
- 23:46:36: Number of invalid patches: 5 < 6
- 23:46:38: Errors for valid patches prior to calibration (CIE dE\*2000): median = 16.6, IQR = 13.4 - 18.1, maximum = 24.4 (Purplish blue)
- 23:46:38: Errors for valid patches after calibration (CIE dE\*2000): median = 0.136, IQR = 0.0596 - 0.175, maximum = 0.276 (Dark gray)
- 23:46:38: Errors for all patches after calibration (CIE dE\*2000): median = 0.154, IQR = 0.0727 - 0.231, maximum = 7.04 (White - Input saturated)
- 23:46:38: Image resolution is 241.481 dpi
- 23:46:38: Computation of profile took 0.00 s
- 23:46:38: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1200 x 1800 image
- 23:46:39: Profile application took 0.51 s
- **23:46:39: Manual calibration took 2.90 s**

#### **Wound No. 10 - manual calibration successful**

23:47:36: UC%20Wound%20No.10.jpg 1699x1800x24

- 23:47:36: Chart manually situated at {X=323.9032, Y=191.8451} - {X=1366.742, Y=809.6514}
- 23:47:36: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)

- 23:47:36: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 214 0).
- 23:47:36: Excluded patch Cyan: over or under-exposed, R\*G\*B\* (1 157 193).
- 23:47:36: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:47:36: Number of invalid patches: 2 < 6
- 23:47:39: Errors for valid patches prior to calibration (CIE dE\*2000): median = 6.37, IQR = 5.34 - 8, maximum = 9.74 (Purplish blue)
- 23:47:39: Errors for valid patches after calibration (CIE dE\*2000): median = 0.101, IQR = 0.0676 - 0.184, maximum = 0.351 (Dark gray)
- 23:47:39: Errors for all patches after calibration (CIE dE\*2000): median = 0.113, IQR = 0.0724 - 0.193, maximum = 4.63 (Cyan - Output out of gamut, input saturated)
- 23:47:39: Image resolution is 352.000 dpi
- 23:47:39: Computation of profile took 0.00 s
- 23:47:39: Applying profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010) to 1699 x 1800 image
- 23:47:40: Profile application took 0.80 s
- **23:47:40: Manual calibration took 3.48 s**

#### **Image No. 15 – manual calibration unsuccessful – too many excluded patches**

23:48:51: UC%20Wound%20No.15.jpg 1473x1800x24

- 23:48:51: Chart manually situated at {X=258.8576, Y=150.066} - {X=1113.567, Y=642.453}
- 23:48:51: Computing profile Shaper and CLUT (slower, but best quality), Color Checker Passport, DSC Labs spectro dataset (28/08/2010)
- 23:48:51: Excluded patch Light skin: over or under-exposed, R\*G\*B\* (253 196 174).
- 23:48:51: Excluded patch Orange: over or under-exposed, R\*G\*B\* (255 164 23).
- 23:48:51: Excluded patch Moderate red: over or under-exposed, R\*G\*B\* (255 131 135).
- 23:48:51: Excluded patch Orange yellow: over or under-exposed, R\*G\*B\* (255 213 0).
- 23:48:51: Excluded patch Red: over or under-exposed, R\*G\*B\* (255 71 70).
- 23:48:51: Excluded patch Yellow: over or under-exposed, R\*G\*B\* (255 241 0).
- 23:48:51: Excluded patch Magenta: over or under-exposed, R\*G\*B\* (255 149 199).
- 23:48:51: Excluded patch Cyan: out of gamut in sRGB (0.0 0.2 0.4).
- 23:48:51: Excluded patch White: over or under-exposed, R\*G\*B\* (255 255 251).
- **23:48:51: Too many invalid patches 9 > 6**
- 23:48:51: Computation of profile took 0.04 s
- 23:48:51: Manual calibration took 0.23 s

Communication from Dr. Yves Vander Haeghen that accompanied the calibration report:

I had a go at the 15 images in the dropbox folder, at first without looking at the images. However, seeing that several could not be calibrated during my batch run I had a closer look at them (9 out of 16 calibrated). Unfortunately, the photographer did not follow the guidelines on every image

- 1: saturated in all channels for the white patch, i.e. over-exposed. Good composition and layout
- 2-1: completely saturated, even the light gray patch! Probably lost for calibration!
- 2-2: good image (even if it looks a bit washed out)
- 3: proper exposure, but the chart is slanted (i.e. not perpendicular to the optical axis) so it cannot be found automatically (well we even don't want to find it because the lighting falls on it at an angle that is different from the lesion)
- 4: chart is partly out of the image and not in focus, and slanted. Proper exposure. Amazingly this image was calibrated automatically!

- 5: chart is strongly slanted, and out of focus. Could not be calibrated
- 6: Proper exposure, slightly slanted. Nice
- 7: Proper exposure, slightly slanted and out of focus.
- 8: Very good exposure, but lesion is in front of chart (I know this is though to do with an open lesion!). The original image actually looks better than the calibrated one on my screen, but this is partly because our screens have a though time creating proper blacks!
- 9: Okay image
- 10: good exposure, but lesion is in front of chart (closer to the camera). Did not get calibrated automatically because there is a default limit to the portion the chart can take up in the image (to speed up searching for the chart). Once this limit was increased it calibrated just fine ...
- 11: Fine image
- 12: Slanted chart, slightly out of focus, but fine otherwise (scary color balance though)
- 13: very slanted chart, can never be calibrated!
- 14: the same as 13
- 15: Strongly over-exposed (8 patches are actually saturated in one or more channels!), slightly slanted but lesion in front of chart

There is a detailed calibration report of the batch run, and some individual report of images that were done manually.

In the end we got about 12 images calibrated, some with some larger maximum errors due to saturation (look at the lines with the CIE dE2000 errors in the reports).

In order to get even better results, the quality and consistency of images has to get even better. I know this is very hard to achieve with real patients and real lesions. In my case i found out that using a chart holding kit improves the quality (something like the the Cullmann FLEXX studio kit can help).

## March, 2012

If you use professional flash equipment, and with a good photographer than this should be no problem (we used studio umbrella type flashes with diffusers in the past, and it works). The main thing is to have an even lighting over the scene. My experience is just that in the hands of less experienced photographers we were better off without flash ...

## Appendix F Calibrated wound images 1 - 12

### Calibrated wound image No. 1





Calibrated wound image No. 2



**Calibrated wound image No. 3**



**Calibrated wound image No. 4**





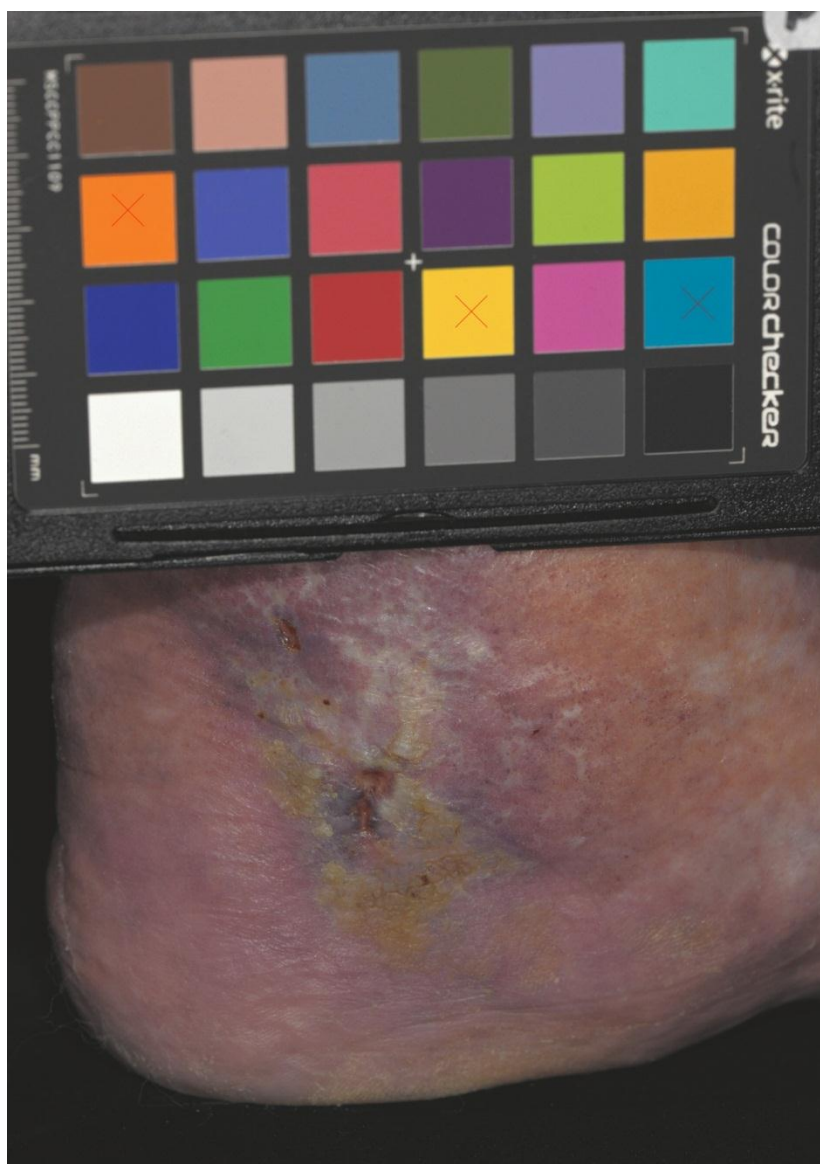
**Calibrated wound image No. 5**



**Calibrated wound image No. 6**



**Calibrated wound image No. 7**



**Calibrated wound image No. 8**





**Calibrated wound image No. 9**





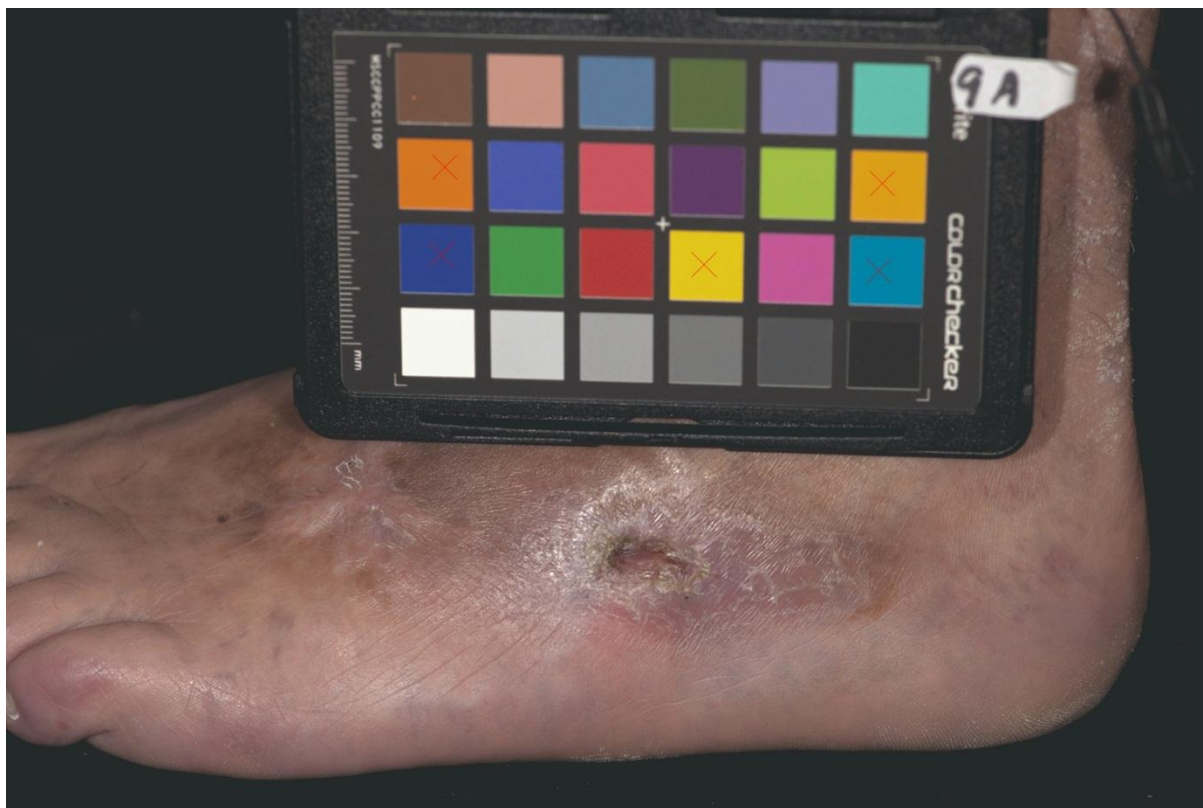
**Calibrated wound image No. 10**



**Calibrated wound image No. 11**



**Calibrated wound image No. 12**



## Appendix G Inter-rater agreement weighted kappa

Contingency table explained:

<b>MRS</b>	Medical Reference Standard
<b>TVN</b>	Tissue Viability Nurse (A – N)
<b>Binned (visual binning in SPSS)</b>	"Collapsed" continuous wound bed RYBP assessment variables into categories
<b>1 (= &lt;9%) 2 (10-19%) etc.</b>	Categories wound bed RYBP assessment
<b>N = 44</b>	4 tissue colour types in 11 wounds = 44 variables
<b>Total column and Total row</b>	Marginals – to calculate expected agreement by chance
<b>Matrix values</b>	Degrees of agreement - from exact agreement (weighting = 1) to maximum disagreement (weighting = 0)
<b>Red diagonal line</b>	Diagonal of exact agreement

## MRS (Binned) \* TVN A (Binned)

		Crosstab											
		TVN A (Binned)											
		1	2	3	4	5	6	7	8	9	10		
		<= 9	10 - 19			40 - 49	50 - 59		70 - 79	80 - 89	90+		
MRS (Binned)	1 <= 9	18	1	0	0	0	0	0	0	0	0		19
	2 10 - 19	6	1	0	0	1	0	0	0	0	0		8
	3 20 - 29	0	1	0	0	0	0	0	0	0	1		2
	4 30 - 39	0	1	0	0	0	0	0	0	0	1		2
	5 40 - 49	1	1	0	0	0	1	0	0	1	1		5
	6 50 - 59	1	0	0	0	0	0	0	0	0	0		1
	7 60 - 69	0	0	0	0	0	0	0	1	0	1		2
	8 70 - 79	0	1	0	0	0	0	0	0	1	1		3
	9 80 - 89	0	0	0	0	0	0	0	0	0	2		2
	10	0	0	0	0	0	0	0	0	0	0		0
Total		26	6	0	0	1	1	0	1	2	7		44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.203	.057	3.055	.002
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNA

WK1 .5425742574

WK2 .7063078396

----- END MATRIX -----

## MRS (Binned) \* TVN B (Binned)

		Crosstab										
		TVN B (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29		40 - 49	50 - 59	60 - 69	70 - 79	80 - 89	90+	Total
MRS	1 <= 9	13	2	2	0	1	0	1	0	0	0	19
(Binned)	2 10 - 19	1	3	3	0	0	1	0	0	0	0	8
	3 20 - 29	1	0	1	0	0	0	0	0	0	0	2
	4 30 - 39	0	0	1	0	0	1	0	0	0	0	2
	5 40 - 49	0	1	1	0	1	0	0	0	1	1	5
	6 50 - 59	0	0	1	0	0	0	0	0	0	0	1
	7 60 - 69	0	0	0	0	1	0	0	1	0	0	2
	8 70 - 79	0	0	0	0	0	0	1	0	2	0	3
	9 80 - 89	0	0	0	0	1	0	0	0	1	0	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		15	6	9	0	4	2	2	1	4	1	44

### Symmetric Measures

	Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement Kappa	.289	.074	4.555	.000
N of Valid Cases	44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNB

WK1 .5536231884

WK2 .7218750000

----- END MATRIX -----

## MRS (Binned) \* TVN C (Binned)

Crosstab												
		TVN C (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79		90+	Total
MRS	1 <= 9	16	1	0	1	0	0	0	1	0	0	19
(Binned)	2 10 - 19	4	0	1	1	0	2	0	0	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	1	0	0	0	0	0	0	1	0	0	2
	5 40 - 49	1	0	1	0	1	1	0	0	0	1	5
	6 50 - 59	0	0	0	1	0	0	0	0	0	0	1
	7 60 - 69	0	0	1	0	0	0	1	0	0	0	2
	8 70 - 79	0	0	0	0	0	0	1	1	0	1	3
	9 80 - 89	0	0	0	0	0	1	0	0	0	1	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		23	1	3	4	1	4	2	3	0	3	44

### Symmetric Measures

	Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement Kappa	.244	.069	4.020	.000
N of Valid Cases	44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNC

WK1 .5229292570

WK2 .6907395070

----- END MATRIX -----

## MRS (Binned) \* TVN D (Binned)

		Crosstab											
		TVN D (Binned)											
		1	2	3	4	5	6	7	8	9	10		
		<= 9	10 - 19	20 - 29	30 - 39		50 - 59	60 - 69	70 - 79	80 - 89	90+		
MRS (Binned)	1 <= 9	17	1	1	0	0	0	0	0	0	0	19	
	2 10 - 19	2	4	1	1	0	0	0	0	0	0	8	
	3 20 - 29	0	1	0	1	0	0	0	0	0	0	2	
	4 30 - 39	0	0	0	0	0	1	0	0	1	0	2	
	5 40 - 49	1	0	1	0	0	0	0	1	1	1	5	
	6 50 - 59	0	0	0	0	0	1	0	0	0	0	1	
	7 60 - 69	0	1	0	0	0	1	0	0	0	0	2	
	8 70 - 79	0	0	0	0	0	0	2	0	0	1	3	
	9 80 - 89	0	0	0	0	0	0	0	0	1	1	2	
	10	0	0	0	0	0	0	0	0	0	0	0	
Total		20	7	3	2	0	3	2	1	3	3	44	

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.373	.074	5.672	.000
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVND

WK1 .6450368292

WK2 .7969658660

----- END MATRIX -----



## MRS (Binned) \* TVN E (Binned)

		Crosstab										
		TVN E (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39		50 - 59	60 - 69	70 - 79	80 - 89	90+	Total
MRS	1 <= 9	12	4	2	0	0	1	0	0	0	0	19
(Binned)	2 10 - 19	2	3	2	0	0	0	0	1	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	0	1	0	0	0	0	0	0	0	1	2
	5 40 - 49	1	0	1	1	0	0	1	0	0	1	5
	6 50 - 59	0	1	0	0	0	0	0	0	0	0	1
	7 60 - 69	0	0	0	1	0	0	1	0	0	0	2
	8 70 - 79	0	0	0	0	0	1	1	0	1	0	3
	9 80 - 89	0	0	0	0	0	0	0	0	1	1	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		16	9	5	3	0	2	3	1	2	3	44

Symmetric Measures				
		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>
Measure of Agreement	Kappa	.223	.075	3.472
N of Valid Cases		44		

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNE

WK1 .5267120832

WK2 .6985491671

----- END MATRIX -----

## MRS (Binned) \* TVN F (Binned)

Crosstab												
Count		TVN F (Binned)										Total
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80 - 89	90+	
MRS (Binned)	1 <= 9	13	4	1	0	0	0	1	0	0	0	19
	2 10 - 19	3	0	3	1	1	0	0	0	0	0	8
	3 20 - 29	1	0	0	0	0	0	0	0	1	0	2
	4 30 - 39	0	0	0	0	0	1	0	0	1	0	2
	5 40 - 49	1	1	0	0	0	0	1	1	1	0	5
	6 50 - 59	1	0	0	0	0	0	0	0	0	0	1
	7 60 - 69	0	0	0	0	1	1	0	0	0	0	2
	8 70 - 79	0	1	0	0	0	0	1	1	0	0	3
	9 80 - 89	0	0	1	0	0	0	0	0	0	1	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		19	6	5	1	2	2	3	2	3	1	44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.111	.062	1.664	.096
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNF

WK1 .3924418605

WK2 .5575589459

----- END MATRIX -----

## MRS (Binned) \* TVN G (Binned)

		Crosstab										
		TVN G (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69		80 - 89	90+	Total
MRS	1 <= 9	10	4	3	1	0	1	0	0	0	0	19
(Binned)	2 10 - 19	1	3	0	1	2	1	0	0	0	0	8
	3 20 - 29	1	0	0	0	0	0	1	0	0	0	2
	4 30 - 39	0	1	0	0	1	0	0	0	0	0	2
	5 40 - 49	1	1	0	0	1	1	0	0	1	0	5
	6 50 - 59	0	0	0	0	0	0	0	0	0	1	1
	7 60 - 69	0	0	0	1	0	1	0	0	0	0	2
	8 70 - 79	0	0	1	0	0	1	0	0	0	1	3
	9 80 - 89	0	0	1	0	0	0	0	0	1	0	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		13	9	5	3	4	5	1	0	2	2	44

Symmetric Measures				
		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>
Measure of Agreement	Kappa	.187	.072	2.987
N of Valid Cases		44		

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNG

WK1 .3873004085

WK2 .5824890367

----- END MATRIX -----

## MRS (Binned) \* TVN H (Binned)

		Crosstab										
		TVN H (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49		60 - 69	70 - 79	80 - 89	90+	Total
MRS (Binned)	1 <= 9	16	1	0	0	2	0	0	0	0	0	19
	2 10 - 19	3	2	1	1	0	0	1	0	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	1	0	0	1	0	0	0	0	0	0	2
	5 40 - 49	1	0	1	0	0	0	0	1	0	2	5
	6 50 - 59	0	0	0	0	0	0	0	0	0	1	1
	7 60 - 69	1	0	0	1	0	0	0	0	0	0	2
	8 70 - 79	0	0	0	0	0	0	1	1	0	1	3
	9 80 - 89	0	0	0	0	0	0	0	0	1	1	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		23	3	2	4	2	0	2	2	1	5	44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.298	.078	4.641	.000
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNH

WK1 .5339938504

WK2 .7029158700

----- END MATRIX -----

## MRS (Binned) \* TVN I (Binned)

		Crosstab											
		TVN I (Binned)											
		1	2	3	4	5	6	7	8	9	10		
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49		60 - 69	70 - 79	80 - 89	90+	Total	
MRS (Binned)	1 <= 9	16	1	0	0	1	0	0	0	0	1	19	
	2 10 - 19	3	1	1	1	1	0	1	0	0	0	8	
	3 20 - 29	1	0	0	0	1	0	0	0	0	0	2	
	4 30 - 39	1	0	0	0	0	0	0	1	0	0	2	
	5 40 - 49	1	0	1	0	1	0	0	0	0	2	5	
	6 50 - 59	1	0	0	0	0	0	0	0	0	0	1	
	7 60 - 69	1	0	0	1	0	0	0	0	0	0	2	
	8 70 - 79	0	0	0	0	0	0	2	0	1	0	3	
	9 80 - 89	0	0	0	0	0	0	0	0	1	1	2	
	10	0	0	0	0	0	0	0	0	0	0	0	
Total		24	2	2	2	4	0	3	1	2	4	44	

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.227	.070	3.500	.000
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNI

WK1 .4479202475

WK2 .5761516956

----- END MATRIX -----

## MRS (Binned) \* TVN J (Binned)

		Crosstab											
		TVN J (Binned)											
		1	2	3	4	5	6	7	8	9	10		
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49		60 - 69	70 - 79	80 - 89	90+		
MRS	1 <= 9	14	3	0	0	0	0	0	0	0	2	19	
(Binned)	2 10 - 19	5	1	2	0	0	0	0	0	0	0	8	
	3 20 - 29	0	1	0	1	0	0	0	0	0	0	2	
	4 30 - 39	1	0	0	0	0	0	0	0	1	0	2	
	5 40 - 49	1	0	0	1	1	0	0	0	1	1	5	
	6 50 - 59	1	0	0	0	0	0	0	0	0	0	1	
	7 60 - 69	0	1	0	0	0	0	0	0	1	0	2	
	8 70 - 79	0	0	0	0	0	0	1	1	0	1	3	
	9 80 - 89	1	0	0	0	0	0	0	0	0	1	2	
	10	0	0	0	0	0	0	0	0	0	0	0	
Total		23	6	2	2	1	0	1	1	3	5	44	

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.167	.075	2.499	.012
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNJ

WK1 .4310990133

WK2 .5059880240

----- END MATRIX -----

## MRS (Binned) \* TVN K (Binned)

		Crosstab										
		TVN K (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49		60 - 69	70 - 79	80 - 89	90+	Total
MRS	1 <= 9	15	2	2	0	0	0	0	0	0	0	19
(Binned)	2 10 - 19	2	2	0	2	1	0	1	0	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	1	0	0	0	0	0	0	0	1	0	2
	5 40 - 49	1	1	0	2	0	0	0	0	1	0	5
	6 50 - 59	0	0	0	0	0	0	0	0	0	1	1
	7 60 - 69	0	1	0	0	1	0	0	0	0	0	2
	8 70 - 79	0	0	0	0	1	0	0	1	0	1	3
	9 80 - 89	0	0	0	0	0	0	0	0	0	2	2
	10	0	0	0	0	0	0	0	0	0	0	0
	Total	20	6	2	5	3	0	1	1	2	4	44

### Symmetric Measures

	Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement Kappa	.222	.069	3.309	.001
N of Valid Cases	44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNK

WK1 .5149359886

WK2 .7213750323

----- END MATRIX -----

## MRS (Binned) \* TVN L (Binned)

Crosstab												
TVN L (Binned)												
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59		70 - 79	80 - 89	90+	Total
MRS	1 <= 9	13	3	1	0	0	0	0	0	2	0	19
(Binned)	2 10 - 19	5	0	1	1	1	0	0	0	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	1	0	0	0	1	0	0	0	0	0	2
	5 40 - 49	2	0	0	0	0	1	0	0	0	2	5
	6 50 - 59	0	0	1	0	0	0	0	0	0	0	1
	7 60 - 69	1	0	0	0	0	1	0	0	0	0	2
	8 70 - 79	0	0	0	0	0	1	0	1	0	1	3
	9 80 - 89	0	0	0	0	0	0	0	0	0	2	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		23	3	3	2	2	3	0	1	2	5	44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.087	.063	1.371	.170
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNL

WK1 .4449369247

WK2 .5972420352

----- END MATRIX -----



## MRS (Binned) \* TVN M (Binned)

Crosstab												
		TVN M (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80 - 89	90+	Total
MRS (Binned)	1 <= 9	14	3	1	0	1	0	0	0	0	0	19
	2 10 - 19	3	1	0	1	1	1	1	0	0	0	8
	3 20 - 29	1	0	0	1	0	0	0	0	0	0	2
	4 30 - 39	0	0	0	1	0	0	1	0	0	0	2
	5 40 - 49	1	0	1	0	1	1	0	0	0	1	5
	6 50 - 59	1	0	0	0	0	0	0	0	0	0	1
	7 60 - 69	0	0	0	1	0	0	1	0	0	0	2
	8 70 - 79	0	0	0	0	0	1	0	1	0	1	3
	9 80 - 89	0	0	0	0	0	0	0	0	1	1	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		20	4	2	4	3	3	3	1	1	3	44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.288	.083	4.464	.000
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNM

WK1 .5535777857

WK2 .7283034148

----- END MATRIX -----

## MRS (Binned) \* TVN N (Binned)

		Crosstab										
		TVN N (Binned)										
		1	2	3	4	5	6	7	8	9	10	
		<= 9	10 - 19	20 - 29	30 - 39			60 - 69	70 - 79	80 - 89	90+	Total
MRS	1 <= 9	18	1	0	0	0	0	0	0	0	0	19
(Binned)	2 10 - 19	2	5	1	0	0	0	0	0	0	0	8
	3 20 - 29	1	0	0	0	0	0	1	0	0	0	2
	4 30 - 39	0	0	1	0	0	0	1	0	0	0	2
	5 40 - 49	1	1	0	0	0	0	0	2	0	1	5
	6 50 - 59	0	0	0	0	0	0	0	0	1	0	1
	7 60 - 69	0	0	1	0	0	0	1	0	0	0	2
	8 70 - 79	0	0	0	1	0	0	0	1	1	0	3
	9 80 - 89	0	0	0	0	0	0	0	0	0	2	2
	10	0	0	0	0	0	0	0	0	0	0	0
Total		22	7	3	1	0	0	3	3	2	3	44

### Symmetric Measures

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Measure of Agreement	Kappa	.417	.076	6.103	.000
N of Valid Cases		44			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Run MATRIX procedure: TVNN

WK1 .6432851604

WK2 .8000498008

----- END MATRIX -----

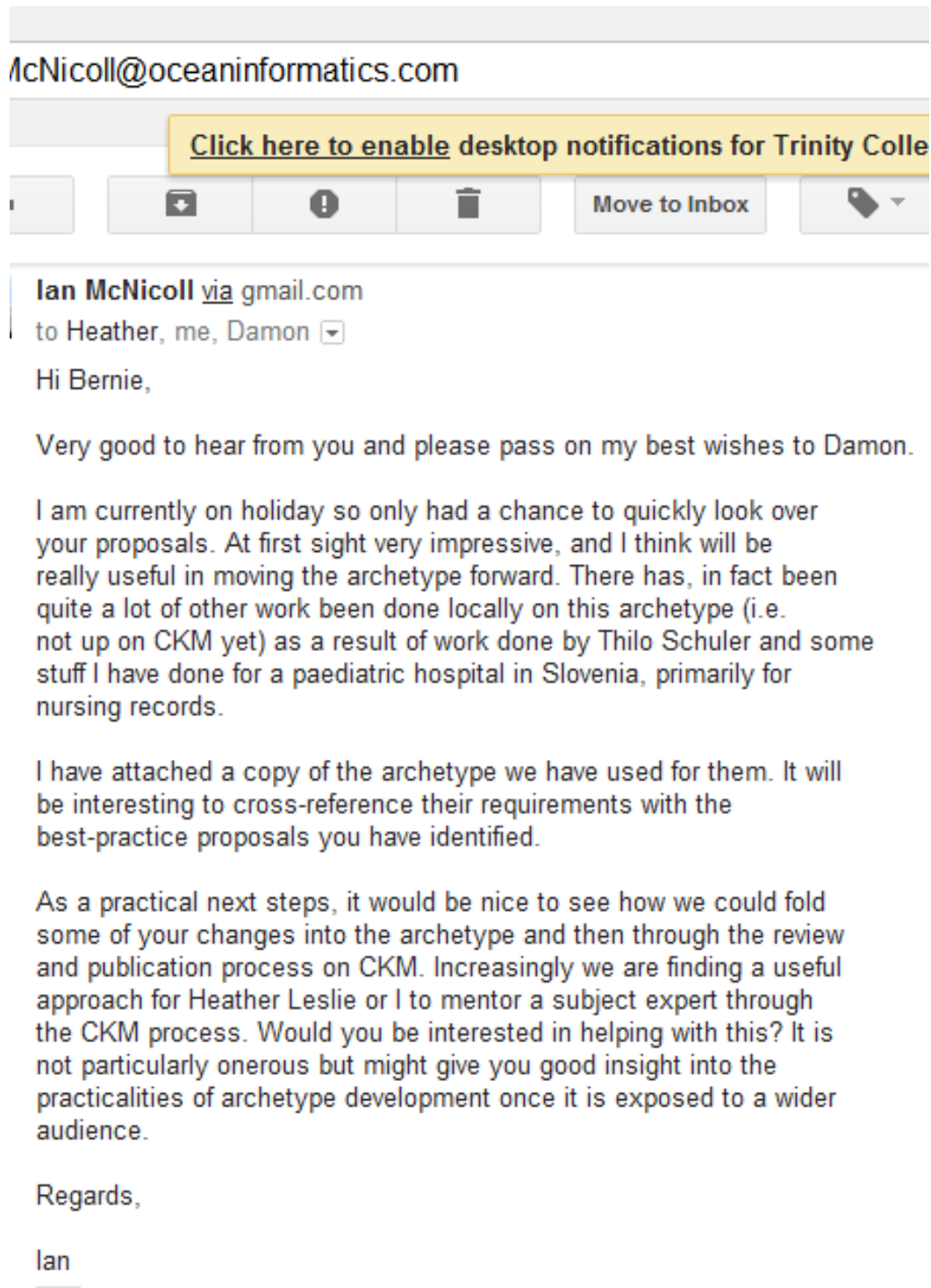
## IBM SPSS syntax MATRIX-ENDMATRIX

MATRIX-ENDMATRIX applied to the unweighted kappa contingency tables to produce linear weighted kappa (**WK1**) and quadratic weighted kappa (**WK2**).

```
* Read in the IxI matrix of counts for I-level scale.
DATA LIST LIST / x1 to x3.
BEGIN DATA
abc
lmn
xyz
END DATA.
* Commands to compute weighted Kappa .
matrix.
GET x /var=x1 to x3.
compute wt1=make(nrow(x),ncol(x),0).
compute wt2=make(nrow(x),ncol(x),0).
compute prop=x/msum(x).
loop i=1 to nrow(x).
loop j=1 to ncol(x).
compute wt1(i,j)=1-(abs(i-j)/(nrow(x)-1)).
compute wt2(i,j)=1-((i-j)/(nrow(x)-1))**2.
end loop.
end loop.
compute wk1num=msum(wt1&*prop)-
msum(mdiag(rsum(prop))*wt1*mdiag(csum(prop))).
compute wk1den=1-msum(mdiag(rsum(prop))*wt1*mdiag(csum(prop))).
compute wk1=wk1num/wk1den.
print wk1.
compute wk2num=msum(wt2&*prop)-
msum(mdiag(rsum(prop))*wt2*mdiag(csum(prop))).
compute wk2den=1-msum(mdiag(rsum(prop))*wt2*mdiag(csum(prop))).
compute wk2=wk2num/wk2den.
print wk2.
end matrix.
```

## Appendix H OpenEHR Foundation correspondence

Response from Dr. Ian McNicoll to the proposal to develop the OpenEHR draft archetype *inspection of an open wound*



## Appendix I Data Protection correspondence

### Data Protection query



The Official Google Blog - [Half a gigameter of biking navigation in 12 countries in Google Maps for Android](#) - 29/8

### Use of Wound Images in a Telemedicine Application



**Bernie Gallagher**

7 Feb ☆



to info ▾

Further to a telephone query to your office I wish to put in writing my questions regarding the use of wound images in a clinical setting.

I am a second year post graduate student in Health Informatics at TCD. I am doing a study on wound assessment and wound image assessment.

If there is a strong correlation between the assessment of wounds in vivo and the assessment of wound images then there would be potential for using this technology in a telemedicine application.

Many patients are treated in the community for chronic wounds and specialist advice can only be sought on an outpatient basis. If images could be sent in addition to any relevant clinical history then treatment could be advised to the professional in the community.

What would be the data protection issues around this?

If images are anonymised, ie if a code were assigned to a patient image, as there is currently no unique health identifier in this country, would this meet the approval of the data commissioner?

How does this differ to patient x rays being sent to specialist centres?

What are the issues around the use of smart phones, which have good camera capability?

What are the regulations on the storage of images in hospitals and outpatient clinics?

Are there different regulations regarding the storage of photographs as opposed to digital images held in software?

## Data Protection Query



Inbox x



**Data Protection** info@dataprotection.ie

to me ▾

Dear Bernie,


I refer to your recent email enquiry to this Office.

Having reviewed your query I can offer the following general guidance:

Under the Data Protection Acts, "personal data" means data relating to a living individual who is or can be identified either from the data or from the data in conjunction with other information that is in, or is likely to come into, the possession of the data controller. It covers any information that relates to an identifiable, living individual. An individual's image would be considered his/her personal data.

Where the individual is not capable of identification from the image (leg wound) and no identifiable information is included in the accompanying medical history (male, 29 etc), we would not see an issue from a data protection perspective with the disclosure of this information to another medical professional where this is taking place in the context of the patient's treatment. The seeking of opinions from other relevant health professionals in the context of a person's treatment can take place without the inclusion of identifiable information. Where identifiable information is included, it would be expected that the patient would be informed that this use of their data is taking place.

We would expect that, as with all personal data collected, the patient is informed of the reason why it is necessary to take the image where it is



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this use of their data is taking place.

We would expect that, as with all personal data collected, the patient is informed of the reason why it is necessary to take the image where it is associated with their file and what it will be used for.

We consider that there would be additional ethical considerations to take account of which would not be a matter for this Office.

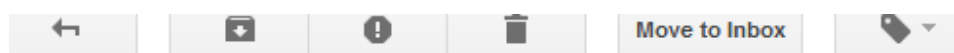
In relation to your query regarding data security, under the Data Protection Acts data controllers are required to take “appropriate security measures” against unauthorised access to or alteration, disclosure or destruction of, the data. This obligation applies to both manually and electronically stored data.

Extensive guidance on data security can be found on our website at the following link: <http://www.dataprotection.ie/viewdoc.asp?DocID=1091&ad=1>

Regarding your query on the use of patient data for research and training purposes, I can advise that in the absence of a specific legal basis to underpin the processing of personal health data for research purposes, consent needs to be part of the process in order to meet the legal obligations as set out in the Data Protection Acts as this type of processing would be subject to different requirements than the uses of data in a direct patient treatment context. Capturing an explicit and informed patient consent for further processing of a person's data for research/teaching purposes at the first opportune point a person presents to the health services and thereafter as necessary, is advocated as the optimal way forward both from a data protection and efficiency perspective.

Of course, where patient identifiable data is not required, which would likely be the case in a large number of situations, it is strongly recommended that patient data be anonymised before it is accessed for

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Of course, where patient identifiable data is not required, which would likely be the case in a large number of situations, it is strongly recommended that patient data be anonymised before it is accessed for secondary research or teaching purposes. Irrevocable anonymisation of personal data puts it outside data protection requirements as the data can no longer be linked to an individual and therefore cannot be considered to be personal data. However I would stress that the anonymisation must be irrevocable in order for it to fall outside of the scope of the data protection legislation.

Detailed guidance on research in the health sector can be found on our website at the following link:

[http://dataprotection.ie/documents/guidance/Health\\_research.pdf](http://dataprotection.ie/documents/guidance/Health_research.pdf)

I hope that this is of assistance.

Kind regards,  
Fiona

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Office of the Data Protection Commissioner  
Canal House  
Station Road  
Portllington  
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Is le haghaidh an duine nó an eintitis ar a bhfuil sí dírithe, agus le haghaidh a bheartaítear an fhaisnéis a tarchuireadh agus féadfaidh sé go bhfuil ábhar faoi Toirmiscear aon athbhreithniú, atarchur nó leathadh a dhéanamh ar an bhfais

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