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Graduated colour tape measure: Development and demonstration of this tool in a case series of neonatal skin injuries

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ABSTRACT

Aim: This study proposed to (1) develop a metric graduated colour tool and (2) demonstrate the effectiveness of the tool for use in the assessment of neonatal skin injuries.
Materials/methods: Findings from wound literature informed the metric graduated colour tool's development. Tool development included consideration of colours, size (comparative to neonatal skin injuries), cost, materials, feasibility and suitability for the neonatal clinical setting. Assessment of the tool's applicability with clinical images was then tested using digital cameras with specific evaluation of image sharpness and colour. Further evaluation was conducted within a case series of neonatal skin injuries.
Results: The metric graduated colour tool comprised of 15 colours, measures 60 mm, displays metric dimensions, and offers a discernible reference for clinical images and injury/wound bed comparison. Images collected appeared enhanced with clear wound edges compared to previous methods. Four neonates who acquired skin injuries were included in the case series for which the tool provided reliable metric and colour comparison of epidermal stripping, extravasation, birth injury, and pressure injury. When used to compare injury assessments for series subjects measurements of both increased and decreased severity were obtained.
Conclusion: A metric and colour tool can be used in conjunction with digital photographs to enhance objective assessment of neonatal skin injuries/wounds. The metric and colour tool provides the foundation for vital skin injury assessment and documentation essentials including injury bed colour, size and consideration of depth of damage.

1. Background

Neonatal skin injuries are increasingly recognized as they feature in the most common complications for hospitalized neonates [1,2]. Yet, it remains difficult to assess injury severity (specifically depth) with the naked eye given that neonatal skin tissue thickness is between 0.9 and 1.2 mm at birth and tissue depth becomes thinner with descending gestational age [3,4]. The frequency of neonatal skin injury is currently estimated between 9.25 and 43.1%, representing one-third to one-quarter of the hospitalized neonatal population [2]. Distinctions between broken and unbroken neonatal skin for those born prematurely, may involve only a few millimeters of skin tissue. In addition consistency of neonatal skin injury assessments between clinicians is often difficult [5]. Thus objective assessments of neonatal skin injuries present challenges considering injury size in conjunction with a gap for neonatal assessment standardization [2]. The Australian Commission for Safety and Quality in Health Care has directed the reduction of hospital acquired complications prioritizing specifically skin injuries [6]; further creating the need for feasible, clinician-friendly, and neonatal specific tools to improve skin injury assessment and comparison.

Within the context of previous adult and paediatric studies, the presence or absence of skin injury is established by a change in skin colour [7]. The assessment of colours within wound beds is a universally accepted practice, which assists clinicians to describe and evaluate the phase of wound healing [8]. For example, the reddening of the skin is associated with erythema or vascular tissue, yellow indicates

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the presence of slough and infected tissue, and black suggests necrosis or dead tissue [8,9]. Similar colour assessments are assumed for neonatal wound healing and may be observed in clinical practice. However, neonatal skin colour and tone changes dramatically in the first few weeks of life, from a generalised red colour indicative of polycythaemia, to a yellow-golden hue symptomatic of jaundice, further complicating objective assessment [10–12]. These changes in colour and tone can occur within days and so comparisons of the injury/wound bed to surrounding skin are more difficult. Therefore, we propose that a graduated colour tape measure (also known as a colour reference tool) would enhance objective wound bed colour assessment.

Digital images have been used to capture injuries/wounds in the adult population for many years, however is a relatively new application for the neonatal population. This research team previously investigated four commercial 'wound' cameras marketed in Australia, against an application available for iPads/iPhones. In short, the trial found the iPad/iPhone application was the most intuitive and provided the sharpest images of neonatal injuries/wounds (unpublished data).

The use of digital images of skin injuries/wounds enrich descriptions and enable more objective assessment of adult skin injuries [7,13–15]. The identification, assessment and healing for adult melanomas and diabetic foot ulcers have been improved by adjunct clinical imagery within wound treatment practices [16,17]. Furthermore, clinical images have been used to test comparison and agreement of skin injury types and stages in a number of studies [5,18]. The popularity of clinical images continues to increase within the Australian HealthCare context, to the extent that the Australian Medical Association and the Medical Indemnity Industry released a guideline for clinicians for the collection of clinical images [19].

Ideally images for the clinical setting should utilize a photographic reference tool to provide metric comparison, improve image focus and allow for future colour correction of images [14]. Reference tools described in the literature pertain primarily to adults. 'ColorChecker' charts, a photographic industry standard, have also been used as references and calibration targets for images taken under various lighting conditions [20]. Charts generally consist of 24 colour squares, representing colours from natural objects such as human skin or flowers. Whilst reference tools are commonly used in the adult population injury/wound assessments and clinical photography, the use in the neonatal population is limited (Table 1).

Challenges for neonatal clinical photography include varied aperture of cameras, depth of field (image sharpness), the restrictive incubator environment, incubator humidification, as well as the size and depth of neonatal skin injuries. Additionally, ambient lighting is recommended in the neonatal environment to protect neonatal development, therefore achieving ideal photographic lighting can be difficult [28]. Thus, clinical images taken in the neonatal environment are likely to need colour correction to compensate for poor photographic

Fig. 1. Standard clinical image of stage 1 injury to dorsum of right foot.

conditions. Colour correction involves using white areas on a reference tool to determine if lighting conditions have tainted the overall image tone. If image tone is affected, media or image software (e.g. Adobe Photoshop) can be used to correct for white balance.

In a pilot study undertaken by this research team, a standard black and white hospital tape measure was used to provide metric reference within neonatal skin injury photos. Many of photos were poor quality and colour differentiation making injuries difficult to visualize and compare colours, thus posing issues when trying to classifying injuries. Additionally, the tape measure made of thin paper, was challenging to keep in place near the injury making injury size assessment difficult (see Fig. 1) [insert Fig. 1 approximately here]. In consultation with the hospital clinical photographer it was determined that the clarity of images was affected due to the size of the injuries coupled with the focal length of the camera which was ill-suited for small object photography (known as macro photography).

The research team hypothesized that a metric graduated colour (MGC) tool positioned near the injury would provide a colour reference for the injury bed, assist with image clarity, and allow for colour correction. Additionally, the MGC tool could improve objectivity for initial and repeated assessments of neonatal skin injuries. To the best of our knowledge neither metric nor colour reference tool has been used for assessments of neonatal skin injury. This paper describes the development and testing of the MGC tool in digital images in conjunction with a

Table 1
Injury/wound assessment tool and colour comparison charts.

Common references in adult clinical photography	• Patient identification labels [15] • Standard or commercial tape measures [18] • Colour references [14,21]
Colour scales in adult reference tools	• Standard black and white [18] • Shades of grey [21] • Red, yellow and black (to demonstrate wound stages such as graduation, slough, necrosis, etc.) [14]
Staging reference tools for adult skin injuries	• Reference tool with staging examples • Metric indicators for size o Improved assessments by non-expert wound care nurses [22,23]
Wound Camera references for adult skin injuries	• Optical target for the 3D measurements of ulcers [17]
ColorChecker charts	• Comparison of overall skin health based on colour [24] o Appearance of skin colour affects the perception of overall health • Animals photographed in uncontrolled lighting [25] o Improved clarity of images, validated and strengthened colour assessments
Application of reference tools or clinical images for neonates	• Shades of red provided frame of reference [26] o Tool assisted in assessment of erythema indicating nappy dermatitis and epidermal stripping • Endoscopic images of intra-nasal complications related to continuous positive airway devices [27]

Table 2
Colour selection and references for the MGC tool.

White	• Standard photographic reference • Macerated tissue [4] • Avascular tissue [4]	Fuchsia	• Polycythaemia, "plethora" • Erythema (blachable and non-blachable) [29]
Black	• Standard photographic reference • Tissue necrosis [8] • Unstagable injuries [29]	Red	• Erythema (blachable and non-blachable) [29] • Bleeding tissue [8] • Hypergranulation [8] • Pheomelanins pigments [30]
Peach and Blush	• Skin tone (dependant on melanin content) [30]	Tan	• Skin tone (dependant on melanin content) [30] • Scab/eschar [30]
Pink	• Skin colour (dependant on melanin content) [30] • Granulation tissue [8] • Epithelisation [8]	Brown	• Skin colour (dependant on melanin: eumelanin pigments) [30] • Scab/eschar
Yellow	• Jaundice [12] • Slough [8] • Blistered tissue • Pheomelanins pigments (melanin content) [30]	Chocolate	• Skin colour (dependant on melanin: eumelanin pigments) [30]
Mustard	• Jaundice [12] • Slough [8]	Violet	• Heamatoma • Deep Tissue Injury [29]
Orange	• Contrast between red and brown (photographic reference)	Purple	• Heamatoma • Deep Tissue Injury [13]

case series of neonatal skin injuries.

2. Materials and methods

2.1. Tool development

Tool development included consideration of colours, size (comparative to neonatal skin injuries), cost, materials, feasibility and suitability for the neonatal clinical setting. The tool needed to be produced on a material that was moisture resistant, stable, and cost efficient for single patient use. A variety of materials were considered with the chosen material having a lightly adhesive underside, similar to industrial labels. Colours were chosen to represent photographic standards, wound and skin injury phases, dark and pale skin tones and colour changes specific to the neonatal population (polycythaemia and jaundice). Whilst the colour orange is not apparent in injury beds, it was chosen to provide contrast between red and brown colours. In total 15 colours were selected, each colour representing a photographic reference and multiple types of skin injury/wound tissue (Table 2).

After selection the colours were validated using an industry gold standard Pantone ColorChecker chart (Datacolour SpyderCHECKER24, 2015). The chart is approximately 8.26in x 10.6in and therefore could not be used in neonatal skin injury images due to the relative size of both the neonate and the injury. This resulted in the production of swatches of each of the 15 selected colours. These were then validated against the ColorChecker chart before each of 14 colours were resized onto a white background (total of 15 colours) producing an MGC tool measuring 60 mm long, the width of each colour band being 4.2 mm. Additionally, the MGC tool is marked at graded intervals increasing by 1 mm, to a total of 60 mm (6 cm) (Fig. 2) [insert Fig. 2 approximately here]. This size allows the MGC tool to be included in images alongside the injury/wound to provide a metric and colour assessment reference without overshadowing injuries.

2.2. Case study methods

A series of participants with skin injuries from the Neonatal skin Injury and Pressure Injury Assessment (NIPIRA) study are presented to demonstrate the performance and feasibility of the MGC tool using an iPad camera. Ethics approval was obtained for the NIPIRA study from the Townsville Health District (HREC/13/QTHS/212), the Southern Dunedin Health Board (H16/099) and James Cook University (H6400). Parental consent was obtained for all neonatal skin injury images.

3. Results

3.1. MGC tool performance and feasibility

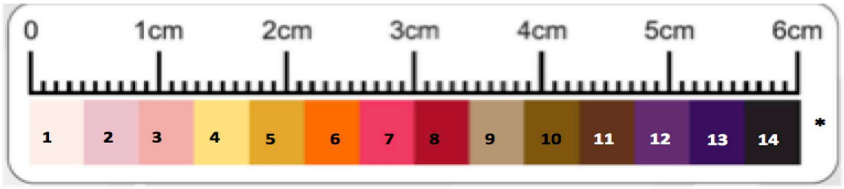
Prior to pilots with neonates, images of the MGC tool were shot under different lighting conditions to assess the clarity of the colour spectrum and metric aspect of the tool. Test images were shot in natural light, artificial light (night and day), and around the context of an incubator. The MGC tool was found to be an appropriate length and width and could be placed in the image field without overshadowing the proportionally smaller objects. The MGC tool performed well within the confined space of incubators and when examining the minimum and maximum distances from a target (injury/wound), provided clear images and allowed visualisation of the whole tool. Image 3 demonstrates a distance test. The MGC tool provided a focal point reference for images to be taken at a minimum distance of 10 cm and a maximum distance delineated by the incubator walls (approximately 25–35 cm) (Fig. 3) [insert Fig. 3 approximately here]. In keeping the entire tool in view this provided guidance to clinicians for the minimum distance 10 cm required to obtain clear images. The tool provided a robust reference for colour correction for images taken in dark lighting or that have an un-natural tint. The white content on the tool allowed the white balance to be corrected to bring the image to a normal tone through image software (Adobe Photoshop).

Each MGC tool was produced for between $0.17–0.35 AUD (($0.09–0.19 GPP)volume dependent)), making the tool cost efficient and feasible for single patient use. Additionally, the material selected was found to be stable for clinical image collection and the adhesive component provided additional benefits with the tool remaining in a fixed position or secured to another device alongside the injury/wound area.

3.2. Case series

Four neonates enrolled in the NIPIRA study, who sustained skin injuries are presented in the following case study to demonstrate how the tool provides reference for assessment of both injury/wound bed colour and measurement (Table 3).

In the comparison of assessments, the tool assisted clinicians to detect that injuries/wound severity had increased in two of the cases (Cases A and D). Additionally, the MGC tool does provide metric reference for sizing, allowing for a more objective assessment of injury measurement changes (Case D). The MGC tool did provided a reference point that enhanced skin injury/wound assessment when zooming into digital images as it provided reference perspective for the size of an



1- peach
2- blush
3- pink
4- yellow
5- mustard
6- orange
7- fuchsia
8- red
9- tan
10- brown
11- chocolate
12- violet
13- purple
14- black
*- white

Fig. 2. MGC tool colour spectrum. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 3. Minimum distance test within incubator, neonatal unit and natural light.

injury area in relation to the anatomical area demonstrated by Case C Fig. 4a and b [insert Fig. 4a and b approximately here]. Lastly, colour correction for white balance was feasible for images taken with the MGC tool Fig. 5a and b [insert Fig. 5a and b approximately here].

4. Discussion

Results from this pilot study demonstrate the successful development of the MGC tool for use in the assessment of neonatal skin injuries/wounds and its contribution to enhancing digital images of these injuries. One-third to one-quarter of hospitalized neonates are at high risk of skin injuries often associated with medical devices making it impractical to leave such assessments for dermatological or wound experts. Thus, there is need for valid and available assessment tools for

Table 3
Neonatal skin injury cases and consecutive assessments using the MCG tool.

Case A-Epidermal stripping [31]	Case B-Extravasation injury [32]	Case C-Birth injury/trauma [30]	Case D-Pressure injury [29]
• Male • Birth gestation 25 + 0/40 weeks • Birth weight 820 g • Out-born, retrieved at 3 h of age	• Male • Birth gestation 32 + 1/40 weeks • Birth weight 2735 g • Inborn	• Male • Birth gestation 24 + 5/40 weeks • Birth weight 745 g • Inborn	• Male • Birth gestation 25 + 4/40 weeks • Birth weight 750 g • Inborn
Day 1 at time of injury Injury related to securement of vascular lines for retrieval with acrylate tape. Tape was NOT placed directly on skin, inadvertent attachment during retrieval. Management: Multidisciplinary review and ongoing follow-up. No specific dressings and wound management actions.	Day 3 at time of injury Injury related to parenteral nutrition and intra lipids peripherally infused for 8 h 55 min. Management: Elevation of limb, multidisciplinary review and ongoing follow-up. No treatment or injections around site.	Day 1 at time of injury Injury of uncertain origin, likely birth injury, apparent immediately after birth. Management: Dressed with a silicone contact layer alternating with silicone foam. Multidisciplinary review and ongoing follow-up.	Day 16 at time of injury Injury to bridge of nose related to positive pressure airway mask. Alternation between mask and prongs practiced before presentation. Management: Alternation continued, mask time shortened. Multidisciplinary review and ongoing follow-up.
Initial Assessment Injury bed – 'pink' erythema compared to 'blush' skin colour *Consecutive assessments:* D 3-Injury bed 'fuchsia', dry, no slough, (partial thickness injury) D 7-Injury bed 'pink', early epithelisation D 9- 'Pink', epithelisation with 'tan' and 'brown' eschar and generalised jaundice	*Initial Assessment:* 'Black' necrotic area (3 mm^2) over injury bed – Stage IV extravasation. Surrounding skin 'fuchsia' – 'red' demonstrating inflammation and secondary tracking of erythema *Consecutive assessments*: D 11- Injury bed 'fuchsia' representing granulation and epithelisation D 19- 'pink' epithelisation, 'tan' eschar covering injury bed	*Initial Assessment:* 'Violet' center 1.5 mm^2 indicative of deep tissue injury from mechanical force injury, surrounded by 'red' suggesting erythema against a 'fuchsia' skin colour known as plethora *Consecutive assessments:* D11- 'fuchsia-red' identifying granulation and 'mustard' and 'tan' eschar and thin slough	*Initial Assessment:* Thin 'red' line, non-blanchable, 1 mm wide, Stage1 compared to 'yellow' skin colour suggesting jaundice *Consecutive assessments*: D 18- 'blush' injury bed, widened to 2–3 mm, Stage 2 D 21- 'fuchsia' injury bed, 2 mm wide, representing granulation in healing Stage 2
Outcome: D 21 injury bed same as surrounding skin colour.	*Outcome:* D 27 injury bed same as surrounding skin colour, no scar tissue evident.	*Outcome*: 19 weeks, keloid scarring present.	*Outcome*: D 37 injury bed same as surrounding skin colour.

Fig. 4. a and 4b: Zooming capacity of MGC tool for Case C in nigh time artificial light.

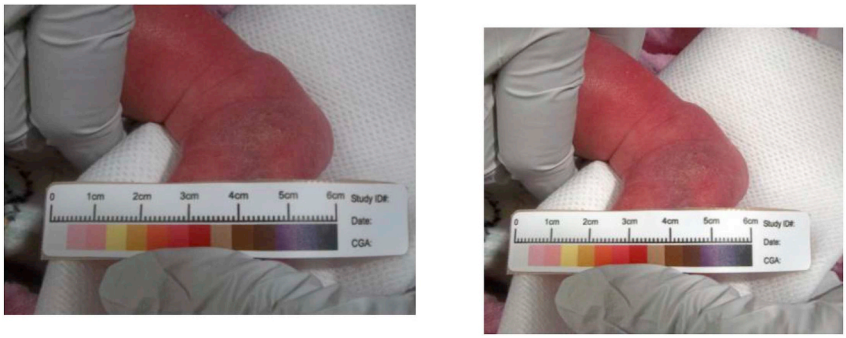


Fig. 5. A Natural light, night-time, MGC tool and image testing with camera, haematoma/bruised lateral foot. 5B: Colour correction for white balance in Adobe Photoshop (version CS6) of haematoma below ankle. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

neonatal clinicians to improve injury identification, consecutive assessments, injury staging and healing phases.

The MGC tool shows promise in the assessment and photographing of neonatal skin injuries in this case series. The colour spectrum gave clinicians specific colour references to describe injury/wound beds and surrounding skin, which provides consistency in consecutive descriptions for changes to injury depth and colour. If clear images can be taken by clinicians, then identification, assessment and classification could be retrospectively reviewed by experts when deemed necessary; a process shown to improve melanomas detection and referrals in the adult population [16]. This process could then improve the reporting of neonatal skin injury frequency, size, epidemiologic data and injury-bed progression or healing.

High-quality skin injury/wound images are becoming an adjunct expectation of effective clinical assessments [15]. Additionally, field experts suggest measurement of injury/wound healing is essential such that quantification (size and depth) is free of observer bias [17]. Skin injury/wound photography is a rapidly emerging field, and this evolving technology is currently uncommon within the neonatal specialty. The MGC tool is a simple and cheap instrument, that facilitates capturing clinical photographs on the initial assessment of an injury/wound, overcoming potential delays waiting for a Clinical Photographer, and minimizing specific lighting or complex distance parameters for image collection. The MCG tool provides a consistent reference allowing for comparison of skin injury images from various facilities facilitating benchmarking.

The use of the MGC tool within neonatal skin injury images has been nested within a large multicentre study in which over 300 images have been collected. These images and the MGC tool are under further evaluation for applicability of colour correction, colour referencing and sizing for injury/wound beds. Thus the MGC tool may have the potential to enhance clinical assessments of other neonatal skin conditions such as neonatal haemangiomas, surgical wounds and intrapartum or postpartum skin complications.

4.1. Limitations

The case series utilized 10 colours contained in the MGC tool, however the four remaining colours while not found in this case study, are likely to be helpful for neonatal skin assessments. Two of the colours (orange and white) are not expected to be seen for skin assessments and two colours (brown and chocolate) were not evident based on the participants due to lighter skin tones. It should be noted that the images with the MGC tool outlined in this paper have been captured with an IPad/IPhone camera and the findings regarding minimum and maximum distances and clarity are currently unknown with the use of other digital devices. It is plausible that injury images gained with the MGC tool taken with other digital devices, could allow neonatal clinicians and researchers to more efficiently describe and classify neonatal skin injuries, enabling objective comparison of injuries.

5. Conclusions

A metric and colour tool can be used in conjunction with digital photographs to enhance objective assessment of neonatal skin injuries/wounds. The MGC tool provides the foundation for vital skin injury assessment and documentation essentials including injury bed colour, size and consideration of depth of damage. There is an increasing expectation to provide clinical photographs as an adjunct to documentation for adult skin injuries and this should be the same for the neonatal population.

Disclosure and conflicts of interest

We have no conflicts of interests to declare. Deanne August has a registered patent (2017904788 and 2019900648) for the metric graduated colour (MGC) tool relating to assessment and measurement in human skin and tissue. Support was received in part by the Mona Kendall Nursing Development Association through a research grant and

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