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Robert Jones bandage pressure range assessment using a pressure mapping system and application to band calibration

M. Taroni[a], J. Molimard[b], T. Cachon[a], E. Viguier[a] and C. Carozzo[a]*

[a] UPSP ICE 2011.03.101, Université de Lyon, VetAgro Sup, Lyon, France; [b]LGF, UMR 5307, CNRS, École Nationale Supérieure des Mines, CIS-EMSE, Saint-Etienne, France.

1. Introduction

The Robert Jones bandage (RJ) is a widely used bandage among veterinary surgeons to maintain physiological position of the limbs. It is a 3-layer composite bandage, which realization involves the use of several types of bands in a specific arrangement to give the bandage all its properties. Its proper making is difficult and requires experience, as the bandage needs to be not too tight or not too loose. This issue is a recurrent matter with every type of compression bandage (Rimaud et al. 2014). For the realization of a RJ, various types of bands can be used, depending on the surgeon but each layer has its own function that cannot be changed.

The purpose of this study is to measure the pressure under a RJ bandage with a pressure mapping system and to evaluate the properties of some commonly used bands. The final application of these results is to propose a band calibration system to apply the correct pressure as a function of the band's deformation.

2. Methods

2.1 Part 1 – Interface pressure assessment in RJ

In the first part, interface pressure under whole RJ is measured with a ''FSA'' pressure mapping system (Vista Medical, Winnipeg, Manitoba, Canada) (Figure 1). It is composed of 12 x 32 piezoresistive sensors. Each sensor is a square with sides measuring 7.9 mm. The active area is 382 x 142 mm. The pressure-mapping device was installed around a 63 mm-diameter PVC tube covered with a 50 mm-diameter tubular jersey. RJ bandages with four types of cotton wool layer were applied to this structure. Type 1 had a single Soffban © (BSN Medical, Vibraye, France) layer, type 2 had a double Soffban © layer, type 3 had a "Gamgee" tissue layer and type 4 had a carded cotton layer. All types had a Velpeau bandage layer and an elastic adhesive band (Tensoplast ©, BSN Medical, Vibraye, France) layer on top of the cotton. A modified type 2 bandage with a CoFlex © (Andover Healthcare, Salisbury, MA, USA) cohesive band replacing Tensoplast © was tested in parallel. Each type was made 5 times by a single experimented operator and pressure was recorded at each step of the realization. The active area was virtually split in 4 equal parts in length. The mean pressure (mmHg) under each type of bandage for the whole area and the 4 virtual parts were calculated along with the relative standard deviation (%RSD).
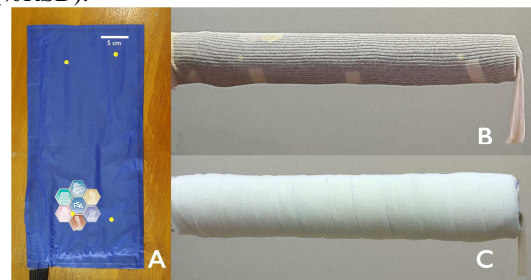

Figure 1 A: FSA Pressure mapping device. B: Installation on the PVC tube. C: Final RJ.

2.2 Part 2 – Interface pressure for single band

In the second part, physical properties of Tensoplast © band and CoFlex © cohesive band were evaluated on the same pressure-measuring device. They were strapped alone with an imposed deformation (ΔL) applied by the operator using a cross-shaped calibration system stamped on the band (Figure 2). When it was stretched at the appropriate strain, the cross becomes perfectly symmetrical to its center (the two branches of the cross were of the same length). The deformation was chosen according to the empirical value used for a RJ and the physical properties of the band. The Tensoplast © band was tested for a 30% and 60% deformation, the CoFlex © band was tested for 50% and 100% deformation. The Laplace equation was used to calculate the linear rigidity (κ in N/m) for each band from the 2 different strains experiences (Rimaud et al. 2014, Thomas 2003, Thomas 2014). This equation states that the pressure (P in Pa) of a compression applied to a curved surface is proportional to the linear rigidity (κ in N/m) and the strain ($\varepsilon = \frac{\Delta L}{L}$, d.u.) of the compression material and inversely proportional to the radius of curvature (R in m) of the surface to which it is applied: $P = \frac{\kappa \cdot \varepsilon}{R}$

*Corresponding author. Email: claude.carozzo@vetagro-sup.fr

In the third part of the study, five 2 x 5 cm bands of Tensoplast © band and CoFlex © cohesive band were submitted to a tensile test using a Instron 3343 single column tension system (Instron Corp, Norwood, MA, USA). Two ramp rates were used: 1 mm/s and 0.1 mm/s. Strain $\left(\varepsilon = \frac{\Delta L}{L}\right)$ was measured in function of the ratio of the force (F in N) to the width of the band (l in m): $\frac{F}{l} = f(\varepsilon)$. Linear regression of the curves in the deformation range used in the 2nd part of the study were made to obtain the linear rigidity (κ in N/m) of the bands: $\frac{F}{l} = \varepsilon \cdot \kappa + c$, where c is the intercept.

The linear regression was applied for $\varepsilon \, \epsilon \, [20; 40]$ for the 30% strain, [40;60] for 50%, [50;60] for 60% and [90;110] for 100%.

The linear rigidity values from the 2nd and 3rd part were compared in order to validate the applicability of the Laplace equation and, if so, provide correlation charts between the interface pressure and the band strain.
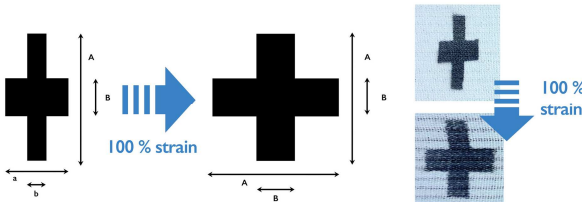

Figure 2 - Calibration system of the bands for 100% strain: when at the appropriate strain, the cross is perfectly symmetrical. a: pre-tension length, b: pre-tension width, A: final length, B: final width. $A = a.(1 + \varepsilon)$, $B = b.(1 + \varepsilon)$, where ε is the strain.

3. Results and discussion

The sensors used in the first and second part were originally designed for the measurement of low pressure applied by medical devices on the skin (Bonnaire et al., 2014). This pressure mapping system was chosen because it is thin and compliant, free from error of measurement on curved surfaces and sensitive in detecting a range of pressure as low as 0 - 100 mmHg (0 - 13.3 kPa). In the first part, the mean interface pressure (in mmHg) for each type of bandage is 22,1 ±6,9 for type 1, 28,9 ± 8,0 for type 2, 32,3 ± 8,9 for type 3, 27,4 ± 8,1 for type 4 and 27,8 ± 9,6 for modified type 2. The distribution's homogeneity is assessed by the values of the %RSD on the different parts of the pressure-mapping device. Type 2 has the lowest value for 3 out of 4 parts and thus allows the most homogenous pressure distribution. When comparing the type 2 and the modified type 2 bandages, the mean pressure is lower and %RSD is higher for the modified type 2 bandage. For the 2nd part, the linear rigidity calculated from the mean pressure was function of the strain applied to the band. For the CoFlex © cohesive band, the value for the 50% and 100% strain was respectively 301,5 ± 38,9 N/m and 516,0 ± 8,1 N/m, for the Tensoplast © with 30% and 60% strain, 675,8 ± 165,7 N/m and 2099,8 ± 250,7 N/m.

For the 3rd part, the curves were not linear, as expected, and the values of the linear rigidity were function of the strain interval. For the CoFlex © cohesive band, the value for the 50% and 100% strain was respectively 94,8 ± 11,2 N/m and 538,6 ± 46,4 N/m, for the Tensoplast © with 30% and 60% strain, 657,3 ± 14,6 N/m and 2158,1 ± 119,6 N/m.

This variation of κ for the same band at different strain can be explained by the elastic behavior of these bands due to their composition. The values for the CoFlex © band with 50% strain is different for the 2nd and 3rd part of the study. The calibration system was stenciled on the band and the gross texture of the cohesive band may have biased the operator's evaluation of the cross's deformation for this low strain.

When comparing the 1st and 2nd part interface pressure, a gross correlation chart can be proposed for the band application (Table).

Type of band	CoFlex ©	Tensoplast ©
Interface pressure	High (60 mmHg)	Low (20 mmHg)
Applied strain	100%	30%
Corresponding pattern		

Table - Calibration system characteristics for high and low pressure bandages

4. Conclusions

The application of the Laplace equation allowed providing correlation charts between the interface pressure and the band strain applicable by an original calibration system.

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