DETERMINATION OF VARIOUS BANDAGE CONSTRUCTS SUB-BANDAGE PRESSURES IN HORSES

by

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Abstract

Determination of Sub-Bandage Pressures Associated with Various Bandage Constructs in Horses

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Objectives: To quantify sub-bandage pressures associated with various bandage constructs applied to the abdomen, distal limb, carpus, and tarsus. To assess the effect of time and /or post-bandaging manipulations on sub-bandage pressures.

Study design: Randomized clinical trial

Methods: Each bandage's sub-bandage pressures were measured with the Picopress® compression measuring system at various time points determined by the study protocol. Nine horses were randomly assigned to a treatment regimen consisting of placement of three abdominal bandage types. Bandages were maintained for 24 hours. 8 horses had two types of distal limb bandages (DLC and DLP) applied and maintained for 24 hours. 8 horses had a DLC bandage applied for 96 hours. 8 horses had both carpal and tarsal bandages applied and pressures monitored after application and post walking. A generalized linear model evaluating associations of pressure with location of the sensor, bandage type, time of measurement, and the potential interaction between all variables was performed ($P< 0.05$).

Results: For abdominal bandages, no time and treatment interactions were observed, and bandage pressures were maintained within each treatment group over the 24 hour period. For distal limb bandages, bandage type, sensor location, and time had a significant effect on sub-bandage pressures. For joint bandages, bandage type, sensor location, and post-bandaging manipulations had significant effects on sub-bandage pressures associated with compression bandages. Ambulation did not have a significant effect sub-bandage pressures generated by the carpal elastic bandages.

Conclusions: Abdominal sub-bandage pressures do not significantly decrease over a 24 hour period, but generate low sub-bandage pressures. In contrast, limb bandages apply high sub-bandage pressures, but these pressures degrade over the initial 24 hours.

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Acknowledgements

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Chapter 1 - Introduction

Compression bandages are frequently applied in equine practice for a wide range of problems and are the cornerstone of treatment when dealing with wounds, trauma, and cellulitis. Bandages also protect surgical incisions and prevent edema, seroma, and hematoma formation within the surgical site. Despite the frequency of use, there is little scientific evidence in veterinary literature dealing with compression bandaging except for its post-operative use in dogs undergoing cranial cruciate repair [1; 2]. Most recommendations in the literature associated with bandaging arise from text book guidelines based on author experience. In the clinical setting, frequency of bandage changes is dictated by the injury, but clinician's preference plays an important role as well. Having objective data involving assessment of sub-bandage pressures of various bandaging techniques and the determination of the longevity of bandage effectiveness would help shape clinician preferences.

Over the past 30 years, increased survival rates due to advances in equine gastrointestinal surgical techniques and post-operative management have resulted in a greater focus on non-fatal complications associated with colic surgery. The increased medical costs and convalescent time associated with incisional complications (i.e. peri-incisional edema, drainage, infection, and herniation) warrants investigation into risk reduction [3]. Multiple retrospective studies have identified risk factors for the development of incisional complications, but findings of these studies vary and are often contradictory. Reported complication rates range from 14% to 74.1% with differences in definitions and inclusion criteria explaining some of the variation between reports [4-9]. However, the published complication rates are higher than that of other domestic species, especially small animals (2.5-5%); thus calling for further investigation into treatments aimed at reducing incisional complications[10; 11].

Clinical trials investigating surgical methods and post-operative strategies with the potential to reduce incisional complications, especially incisional infections, have been performed. One randomized clinical trial determined the use of an abdominal bandage resulted in an absolute risk reduction of 45% when compared to horses not receiving an abdominal bandage [9]. The authors suggest the reduction in complication rates occurred due to incisional protection, support, and creation of an optimal environment for healing. A more recent retrospective study demonstrated a reduced incisional infection rate of 2.7% in horses with a stent bandage compared to 21.8% in horses not bandaged; suggesting that incisional protection rather than support reduces incisional infections [12]. However, a study by Mair and Smith associated placement of a stent bandage with an increase in wound complication rates [13].

Human studies aimed at quantifying sub-bandage pressures of various compression bandages and identifying adequate pressure ranges for the treatment of various diseases have been published[14]. One study concluded that placement of an abdominal binder after a laparotomy enhanced walk performance tests, helped control pain and distress, and improved patients overall post-operative experience [15]. To the authors' knowledge, no investigation into an abdominal bandage's ability to apply pressure to laparotomy incisions exists for horses.

Due to the prevalence of lymphedema in human patients, the volume of information in the human literature is staggering compared to the veterinary literature. Human studies aimed at quantifying sub-bandage pressures of various compression bandages and identifying adequate pressure ranges for the treatment of various diseases have been published[16]. Recommended sub-bandage pressures for edematous limbs vary within the literature with pressures being as low as 15 mmHg to as high as 120 mmHg [17; 18]. More recently research in this area has demonstrated that pressures within 40 mmHg to 60 mmHg have the greatest efficacy in edema reduction in human legs[14].

Numerous variations to the standard distal limb compression bandage (DLC) construct are performed to suit a perceived clinical need. One variations to the standard DLC construct includes adding additional layers to the bandage either to absorb discharge from a wound or to increase the stiffness of the bandage to help support soft tissue injuries. When surgery is performed on the lateral or medial aspect of the proximal cannon, concern of increased dead space due to limb contour has some clinicians promote application of an inner sanctum (IS) prior to placing the standard DLC bandage. The rationale is that this inner layer will place more pressure in the lateral or medial indentation between the splint bones and flexor tendons thus collapsing any dead space and preventing fluid accumulation. Even more variation exists when bandages are applied to the carpus or the tarsus due to bandage sore formation over the accessory carpal bone, the plantar aspect of the common gastrocnemius tendon, and calcaneal tuber. Various ways to prevent sore formation include not incorporating these prominences in the bandage, creating a slit in the outer bandage layers over the area of concern, and placement of an adhesive elastic bandage in substitution for a compression bandage.

The current study aims to determine sub-bandage pressures generated by various bandage constructs at various anatomical locations on the horse. Therefore, this project was divided into 3 main studies looking at pressures associated with abdominal bandages, distal limb bandages and joint bandages. The objective of the abdominal bandage study is quantifying the sub-bandage pressure achieved by three abdominal bandaging techniques over 24 hour period. The objectives of the distal limb study include quantifying the sub-bandage pressure exerted by each compression layer of the bandage, assessing distribution of pressure over the limb, quantifying the sub-bandage pressures exerted by a distal limb compression bandage (DLC), an inner sactum bandage (IS), a double layer bandage (DL) and a distal limb polo wrap (DLP), and identifying the effect of time on sub-bandage pressure for both the DLC and the DLP. The aim of joint bandage study included quantifying sub-bandage pressures associated with both a carpal compression bandage (CC) and a tarsal compression bandage (TC); comparing CC and an adhesive elastic carpal bandage (C-ELA) pressures before and after walking; and comparing TC pressures at application, after creating a slit over the calcaneus, and after walking.

Chapter 2 - Materials and Methods

Abdominal Bandage Study

Nine healthy, 2-3 year old horses consisting of 8 Quarter horses and 1 American Paint horse (4 females and 5 geldings) from the Kansas State University Department of Animal Sciences and Industry horse unit were selected for the study. All horses were housed individually in stalls, fed hay ad libitum, and had free access to water. Horses were randomly assigned to treatment blocks consisting of three horses. A table of random numbers allocated horses to treatment schedules that determined the order of abdominal bandage placement. Each horse wore each of the three bandage types for 24 hours in a consecutive manner over a three day period. Horse behavior was recorded in order to identify activity or agitation that could affect treatment efficacy (stall pacing, pawing, bucking, and lying down). Prior to beginning each treatment period, investigators performed a physical examination and recorded rectal temperature, heart rate, and respiratory rate. Horses with physical examination findings outside normal parameters or who were deemed to be non-compliant were excluded from the study prior to day 1.

Abdominal Bandaging Techniques

Bandages were placed over the abdomen spanning from just caudal to the withers to a few centimeters caudal to the umbilicus. Three different bandaging techniques were employed and placed as tightly as possible by the primary investigator (NCC). An elastic, adhesive bandage (ELA) was placed in a similar fashion as previously described[9; 19]. Briefly, an elastic wrap[1] (Sta-Put Abdominal Support Wrap) was placed without tension followed by 5-6 rolls of an elastic, adhesive tape[2] (Elastikon) with 50% overlap as tightly as possible (Figure 2-1). A commercially available abdominal belt[3] (CM) was used with the manipulating element and foam pad removed from the ventral pocket. A quilted pad was placed over the dorsum prior to placement of the belt. The belt was initially placed with minimal pressure, and the Velcro straps were subsequently tightened in a cranial to caudal direction two additional times. Following application of the belt, a breast collar was placed to prevent caudal movement of the bandage (Figure 2-2). The third type of bandage consisted of a nylon binder[4] (NYL) that closed with Velcro and was held in place with a breast collar (Figure 2-3). Removal of bandages occurred if the bandage slipped caudally enough to expose the ventral midline at a point 40 cm cranial to the umbilicus.

Data Collection

Sub-bandage pressure was measured using the previously validated Picopress® Compression Measurement System[5] consisting of a portable, electronic manometer that connects to a thin walled, circular, plastic bladder with a 5 cm diameter [20] (Figure 2-4). Prior to placement of the bandage, the bladder was placed 10 cm cranial to the umbilicus on the ventral midline and secured with adhesive tape placed over the conduction tubing. A 12.7 cm wide by 40.6 cm long strip of cotton combine padding[6] was placed on ventral midline with the caudal edge located at the level of the umbilicus to ensure the bladder remained flat against the ventral abdomen. Sub-bandage pressure measurements were recorded at 0, 2, 4, 6, 8, 12, 16, 20, and 24 hours post bandage placement by inflating the bladder with 2 ml of air. At each time point, triplicate measurements were obtained during peak inspiration in order calculate a mean pressure and reduce variability due to respiration. Investigators assessed bandage location and integrity during each time point and recorded any caudal movement.

Distal Limb Bandage Study

In order to meet project objectives, 4 separate studies were performed as described below.

Distal Limb Compression Bandage (DLC) Application Pressure Study

To assess distribution of pressure on the limb and the effect of bandage components on overall sub-bandage pressure at the time of application, a DLC was applied to eight healthy horses. Horses consisted of 6 Quarter Horses, 1 Thoroughbred, and 1 American Paint horse (6 females and 2 geldings) from the Kansas State University Department of Clinical Science teaching herd were selected for the study. Bandages were randomly assigned to the right or left forelimb using a table of random numbers.

24 Hour Study

To assess the effect of time, bandage type, and anatomical location of the sensor on sub-bandage pressure, nine healthy, 2-3 year old horses consisting of 8 Quarter Horses and 1 American Paint horse (4 females and 5 geldings) from the Kansas State University Department of Animal Sciences and Industry horse unit were selected for the study.

Prior to beginning the treatment period, investigators performed a physical examination and recorded rectal temperature, heart rate, and respiratory rate. Horses with abnormal findings on physical examination or deemed to be non-compliant were excluded from the study prior to beginning the study. All horses were housed individually in stalls, fed hay ad libitum, and had free access to water. Bandage types were randomly assigned to a forelimb so that each horse wore a DLC and pillow pad/polo wrap (DLP) simultaneously for 24 hours. Horse behavior was recorded in order to identify activity or agitation that could affect treatment efficacy (stall pacing, pawing, bucking, and lying down). At the end of the treatment period, the bandage limbs were assessed for any signs of edema, tendonitis, or lameness.

DLC 96 Hour Study

To assess sub-bandage pressure exerted by a DLC bandage over a 96 hour period, 8 healthy horses from the Kansas State University Department of Animal Sciences and Industry horse unit were selected for the study. Horses consisted of 8 Quarter Horse mares, ranging in age from 5 to 14 years. Allocation of the DLC to the forelimbs was determined via coin toss. Each horse wore a DLC for 96 hours. Horse management, behavior monitoring, and pretrial examination were conducted as previously described.

Techniques Study

To assess the effect of bandage type and sensor location on sub-bandage pressure, eight healthy horses consisting of 6 Quarter Horses, 1 Thoroughbred, and 1 American Paint Horse (6 females and 2 geldings) from the Kansas State University Department of Clinical Science teaching herd were randomly selected for the study. Circumferences of the mid-cannon region was measured with a measuring tape. All horses were placed in stocks during the bandage application process. A table of random numbers allocated horses to a treatment schedule that determined the horse order, limb assignment, and order in which bandages were applied. Each horse had a DLC, DL and IS applied in consecutive order according to the treatment schedule.

Bandage Application

All bandages were applied to the forelimbs with the horse bearing weight on the limb and spanned from the coronary band to immediately distal to the carpus. For the 24 hour study, both a DLC and DLP were applied and placed as tightly as possible with even tension by the primary investigator. All bandages were applied by starting on the dorsomedial aspect of the metacarpus and wrapping across the dorsum to the palmar surface. A DLC bandage consisted of an approximately 64.5 cm long by 40.6 cm wide strip of cotton combine padding[1] compressed by a

15.24 cm wide by 5.5 m long roll of brown gauze[2] and followed by a 10.16 cm wide by 4.57 m long elastic self-adherent wrap[3] (Figure 2-5) . Each compression layer was wrapped with 50% overlap of the width of the material to prevent uneven distribution of pressure. Compression layers were started at the mid-metacarpus and wrapped distally to the bottom of the bandage before moving proximally to the top of the bandage. The layer was ended by wrapping distally until the remaining material was expended in the area of the mid-metacarpus. The distal limb polo wrap (DLP) consisted of a 30.5 cm wide by 76.2 cm long polyester lined foam pad[4] that was compressed using 14 cm wide by 40.6 cm long standing wrap[5] (Figure 2-5). Application was similar to that of the DLC bandage with the exception that the wrap material was ended at the top of the bandage. A double layer bandage (DL) consisted of cotton combine padding[1] compressed by a roll of brown gauze[2] followed by an addition role of cotton combine padding[1] compressed by a roll of brown gauze[2] and an elastic self adherent wrap[3]. An inner sanctum bandage (IS) included placement of three 10 x 10 cm gauze sponges rolled to create a cylinder that was placed in the indention of the lateral aspect of the leg associated with the suspensory ligament. This cylinder was secured using Kling gauze[4] wrapped around the leg three times without tension. A 10.2 cm wide by 2.2 m long adhesive elastic tape[5] was applied circumferentially over the cling gauze with minimal tension. The tape was applied with 50% overlap of the layers until the area of interest was covered. A DLC was then placed as previously described to complete the IS bandage.

Data Collection

Sub-bandage pressure was measured using the previously validated Picopress® Compression Measurement System[6] consisting of a portable, electronic manometer that connects to a thin walled, circular, 5 cm diameter plastic bladder [20]. Prior to placement of the bandage, a bladder was placed over the dorsum of the cannon and a second bladder was placed over the lateral aspect of the cannon centered over the suspensory ligament and secured with adhesive tape (Figure 2-6). Care was taken to ensure the adhesive tape was applied without tension so that the bladder could be fully inflated without the tape applying pressure to the bladder. Both sensors were placed at the height of the mid-metacarpus. Sub-bandage pressure was recorded after application of each compression layer by inflating the bladder with 2 ml of air. At each pressure measurement, triplicate measurements were obtained in order calculate a mean pressure. The Picopress® Compression Measurement System[6] measures pressures up to 189 mmHg. If the measured pressure exceeded the 189 mmHg threshold, it was recorded as 189 mmHg. For the 24 hour study, sub-bandage pressure measurements were recorded at 0, 2, 4, 6, 8, 12, 16, 20, and 24 hours post bandage application. For the 96 hour study, sub-bandage pressures were recorded at 0, 12, 24, 36, 48, 60, 72, 84, and 96 hours post bandage application. For the techniques study, pressures were obtained at application only. Investigators assessed bandage location and integrity during each time point and recorded any bandage movement.

Joint Bandage Study

To assess the effect of bandage type and sensor location on sub-bandage pressure, eight healthy horses consisting of 6 Quarter Horses, 1 Thoroughbred, and 1 American Paint Horse (6 females and 2 geldings) from Kansas State University Department of Clinical Science teaching herd were randomly selected for the study. Circumferences of the mid-carpus and mid-tarsus were measured with a measuring tape. All horses were placed in stocks during the bandage application process. A table of random numbers allocated horses to a treatment schedule that determined the horse order, limb assignment, and order in which bandages were applied. Each horse wore all bandage types in a consecutive order according to the treatment schedule.

Bandage Application

All bandages were applied with the horse bearing weight on the limb. A carpus compression bandage (CC) and the tarsus compression bandage (TC) consisted of the same materials and application principles as the DLC bandage with the bandage material centered over the respective joint. The carpus elastic bandage (C-ELA) consisted of cling gauze[4] applied without tension over the distal- radius and continued distally until just proximal to the accessory carpal bone where a figure of eight pattern was used to incorporate the carpus without covering the palmar aspect of the accessory carpal bone. Adhesive elastic tape[5] was then applied in a similar fashion with minimal tension.

Data Collection

Sub-bandage pressure was measured using the previously validated Picopress® Compression Measurement System[6] consisting of a portable, electronic manometer that connects to a thin walled, circular, plastic bladder with a 5 cm diameter that can measure pressures up to 189 mmHg[20]. For carpal bandages, a bladder was placed on the dorsum of the carpus at the level of the proximal row of carpal bones and at the same level on the lateral aspect in line with the lateral styloid process. For the tarsal bandage, a bladder was placed over the dorsum at the level of the mid-tarsocrural joint, over the lateral aspect of the joint in line with the lateral malleolus, and on the proximoplantar aspect of the calcaneus. Bladders were secured with adhesive tape to prevent movement. Sub-bandage pressure measurements were recorded after placement of each compression layer by inflating the bladder with 2 ml of air. At each time point, triplicate measurements were obtained in order calculate a mean pressure. For carpal bandages, an additional measurement was taken after the horse was walked approximately 50 m. For hock bandages two additional measurements were performed. The first was obtained after a 2 cm slit was made in the outer layer of the bandage over the proximal calcaneus, and the second was obtained after the horse walked approximately 50 m.

Data Analysis

Outcomes of interest included treatment, sensor location, time, and/or post-bandaging manipulation effect on sub-bandage pressure. Raw data were assessed visually and determined to be distributed normally. Mean and 95% confidence intervals (95% CI) of sub-bandage pressures were calculated for each treatment at application and after any post-bandaging manipulation. To assess sub-bandage pressure changes after application for the distal limb and joint bandages, sensor location measurements were averaged and identified as "combined sub-bandage pressure". A generalized linear model evaluating associations of pressure with bandage type, sensor location, post-bandaging manipulations, time, and the potential interaction between all variables was performed. All analyses were conducted at a significance level of $P < 0.05$, using commercial statistical software package[7].

Figure 2-1 Completed ELA Bandage

Completed ELA bandage consisting of an elastic wrap[1] (Sta-Put Abdominal Support Wrap) placed without tension followed by 5-6 rolls of an elastic, adhesive tape[2] (Elastikon) applied as tightly as possible by the primary investigator.

Figure 2-2 Completed CM Bandage

Completed CM bandage consisting of a quilted dorsal blanket, breast collar, and the bandage applied as tightly as possible with the ventral manipulating element and foam pad removed.

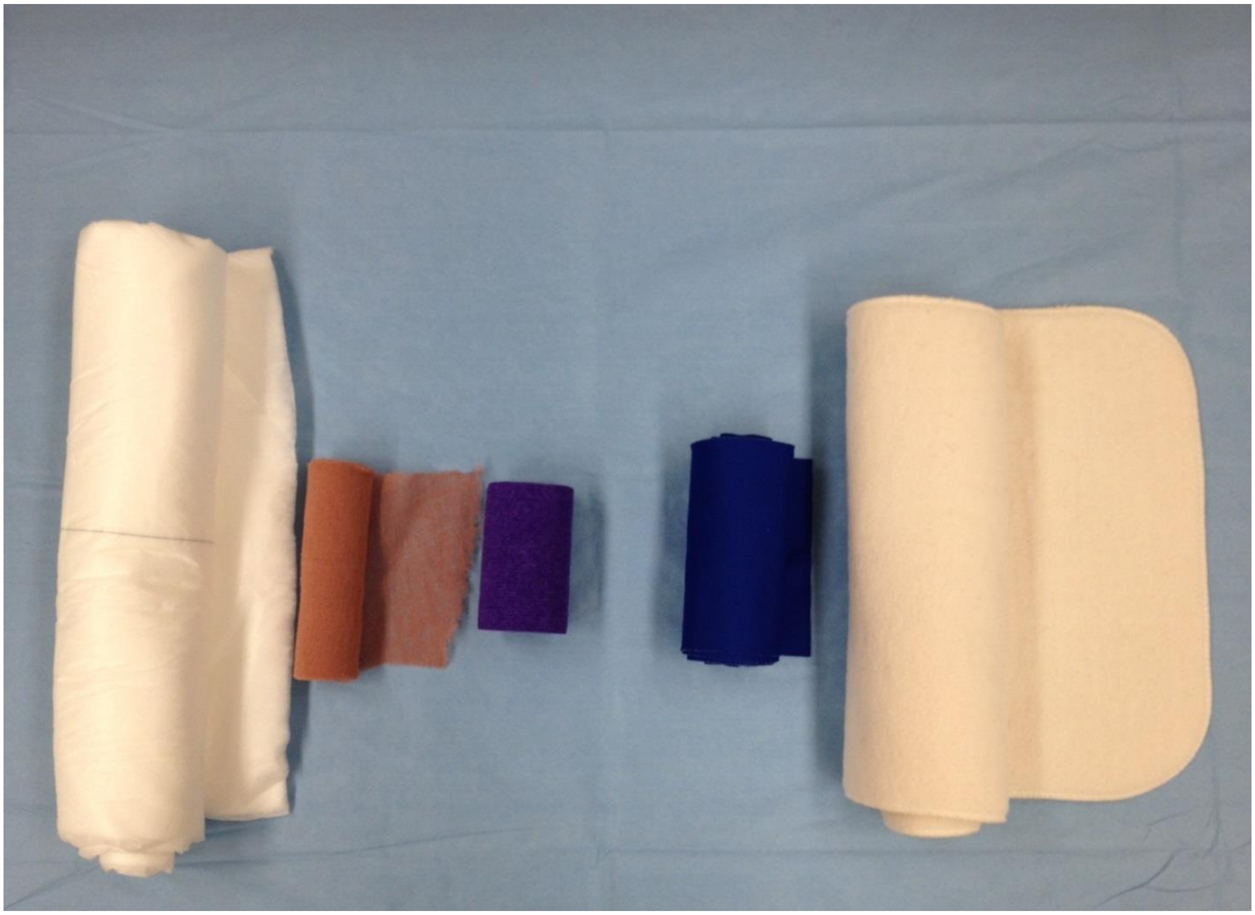
Figure 2-3 Completed NYL Bandage

Completed NYL bandage with breast collar attached.

Figure 2-4 Picopress® Compression Measurement System

Picopress® Compression Measurement System[5] consisting of a portable, electronic manometer that connects to a thin walled, circular, plastic bladder with a 5 cm diameter.

Figure 2-5 DLC and DLP Construct Components



DLC bandage components consisting of cotton combine padding[1] compressed by a roll of brown gauze[2] and followed by elastic self-adherent wrap[3] (left). DLP bandage components consisting of standing wrap[5] used to compress a polyester lined foam pad[4] (right).

Figure 2-6 Distal Limb Sensor Placement

Image depicting location of sensor placement.

Chapter 3 - Results

Abdominal Bandage Study

Mean body weight was 461 kg (range 425-495 kg) with an average abdominal circumference measured at a point 10 cm cranial to the umbilicus of 201 cm (range 192-213 cm). Physical examination deemed all horses clinically normal upon entry into the study and revealed no signs of adverse effects (i.e. distress or colicky behavior) associated with abdominal bandaging. Application of abdominal bandages was well tolerated except for horses 2, 3 and 8 who bucked during or immediately after placement of the CM bandage. Horse 1's bandage slipped caudally enough to expose the ventral abdomen within 40 cm of the umbilicus at 6 hours post application of the CM bandage. All other horses completed the 24 hour period for all three treatments. Caudal movement of bandages was recorded in 3/9 CM bandages, 9/9 ELA bandages, and 6/9 NYL bandages; caudal displacement varied between horses and ranged from 2 cm to 10 cm.

No time and treatment interactions were found so main effects are reported. Mean ± SE sub-bandage pressures were different between all treatment groups ($p < 0.001$) at 39 ± 2 mmHg, 25 ± 2 mmHg , and 5 ± 2 mmHg for CM, ELA, and NYL bandages, respectively (Figure 3-1). All treatment groups maintained their initial sub-bandage pressures over a 24 hour period; however, ELA pressures demonstrated a trend to decrease over time ($P = 0.12$) (Figure 3-2). No significant interaction between sub-bandage pressure and treatment date or treatment block was determined. Assessment of behavior recordings demonstrated lying down was recorded in 7/9 CM, 9/9 ELA, and 3/9 NYL horses at various time points. Horses were more likely to lie down when the CM ($P=0.02$) and ELA ($P= 0.0002$) bandages were applied compared to the NYL treatment. No significant effect of time or horse on the occurrence of lying down was determined.

Distal Limb Bandage Study

All horses were clinically normal upon entry into the study and no clinical signs of adverse effects (i.e. tendonitis, lameness, or generalized swelling) associated with distal limb bandaging were observed. Application of bandages was well tolerated in all horses.

Application Pressure

The mean circumference of the mid-cannon region was 18.1 cm (range 17-19 cm). When assessing sub-bandage pressure at the time of application, bandage layer had a significant effect on total sub-bandage pressure ($p < .0001$). For DLC bandages, mean combined sub-bandage pressure after compression of the Combiroll[1] with brown gauze[2] was 80 mmHg (95% CI 75 – 85 mmHg). After application of the elastic wrap[3], the mean combined sub-bandage pressure rose to 165 mmHg (95% CI 160 - 170 mmHg). Anatomical location of the sensor was also significant ($p< .0001$) with mean sub-bandage pressure at the dorsal and lateral sensor measuring 187 mmHg (95% CI 185 – 189 mmHg) and 142 mmHg (95% CI 133 – 151 mmHg)respectively (Figure 3). The majority of dorsal sensor measurements exceeded 189 mmHg after elastic wrap application.

24 Hour Study

The mean mid-cannon region circumference was 18.3 cm (range 17-19 cm). For the DLC bandage, time ($p < .0106$) and location ($p< .0001$) had a significant effect on total sub-bandage pressure. Following application, combined sub-bandage pressures were maintained for the first 6 hours with the exception of the 4 hour measurement. After the 6 hour measurement, a significant decrease in total sub-bandage pressure occurred followed by a stabilization of pressure for the remaining 24 hour period with the exception of measurements at time 20 hours (figure 3-3). Combined sub-bandage pressure measured at time 0 was 148 mmHg (95% CI 129 – 167 mmHg) and decreased to 129 mmHg (95% CI 111 – 147 mmHg) at 24 hours. The lowest pressure recorded was 123 mmHg (95% CI 105 – 141 mmHg) and occurred at the 20 hour time point. For the DLP bandage, location ($p < .001$) but not time ($p = 0.8174$) had a significant effect on total sub-bandage pressure. Combined sub-bandage pressure means ranged between 75 mmHg (95% CI 53 – 97 mmHg) and 85 mmHg (95% CI 63 – 107 mmHg) over the 24 hour period (Figure 3-4). Sub-bandage pressures measured by the dorsal and lateral sensors were 117 mmHg (95% CI 95 – 139 mmHg) and 45 mmHg (95% CI 37 – 53 mmHg).

96 Hour Study

The mean mid-cannon region circumference was 17.5 cm (range 17-18 cm). Time ($p < .0001$) had a significant effect on total sub-bandage pressure. There was a significant decrease in combined sub-bandage pressure between time 0 and 12 hours post application. Following this decrease, pressures stabilized with the exception of pressures recorded at 72 hours post application. Total sub-bandage pressure measured at time 0 was 170 mmHg (95% CI 158 – 182 mmHg) and decreased to 135 mmHg (95% CI 123 – 147 mmHg) at 96 hours (figure 3-5).

Techniques Study

The mean circumferences of the mid-cannon region was 18.3 cm (range 19-17 cm). Sensor location ($p < .0001$) and bandage type ($p = .0166$) had significant effects on sub-bandage pressure. Pressures exerted at the lateral sensors were significantly less than that of the dorsal sensors for all bandage types. The placement of the inner sanctum layer applied a mean sensor sub-bandage pressure of 75 mmHg (95% CI 62-89 mmHg) at the lateral sensor. After completion of each bandage type mean sub-bandage pressures recorded at the lateral sensors were 141 mmHg (95% CI 118-163 mmHg), 146 mmHg (95% CI 123-171 mmHg), and 108 mmHg (95% CI 88-128 mmHg) for the DLC, IS, and DL bandages. The majority of sub-bandage pressures recorded by the dorsal sensor exceeded 189 mmHg for all bandage types. Combined sub-bandage pressure measurements for both the DLC and IS were significantly higher than that of the DL. Mean combined sub-bandage pressures were 165 mmHg (95% CI 153-177 mmHg), 167 mmHg (95% CI 155-179 mmHg), and 146 mmHg (95% CI 134-157 mmHg) for the DLC, IS, and DL bandages (Figure 3-6).

Joint Bandage Study

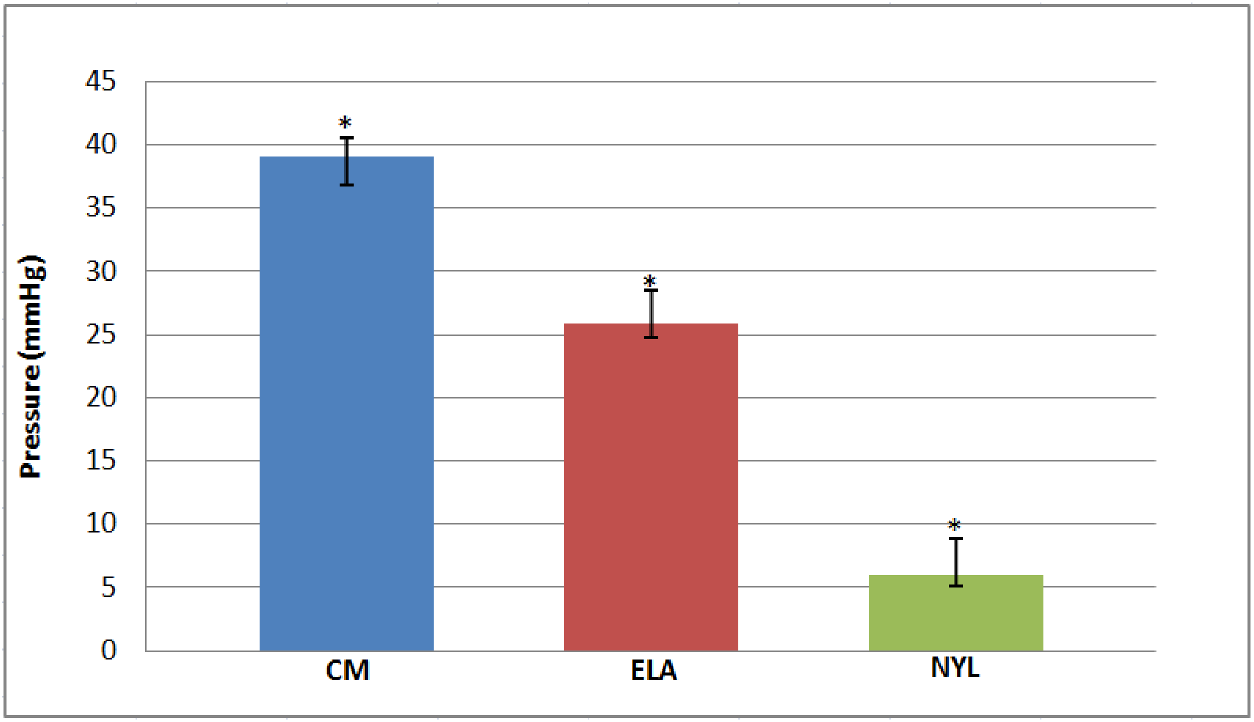
Carpal Bandages

The mean circumferences of the mid-carpus was 28.5 cm (range 27-29 cm). For carpal bandages, sensor location ($p < .0001$), bandage type ($p < .0001$), effect of walking ($p < .0001$), and walking/treatment interaction ($p = .0055$) had significant effects on sub-bandage pressure. At application, mean sub-bandage pressures for the CC bandage were 139 mmHg (95% CI 119-159 mmHg) and 169 mmHg (95% CI 150-188 mmHg) for the dorsal and lateral sensors. For the C-ELA bandage, mean application pressures were 54 mmHg (95% CI 41 – 67 mmHg) and 86 mmHg (95% CI 67 – 105 mmHg) for the dorsal and lateral sensors. CC combined sub-bandage pressure at the time of application, 154 mmHg (95% CI 148 – 160 mmHg), was significantly higher than the pressure recorded after walking, 118 mmHg (95% CI 112 – 124 mmHg). For the C-ELA bandage there was no difference in pre-walking and post-walking combined sub-bandage pressure, 70 mmHg (95% CI 64 – 76 mmHg) and 64 mmHg (95% CI 58 – 70 mmHg) respectively. Both pre-walking and post-walking CC combined sub-bandage pressures were significantly higher than the C-ELA pressures (Figure 3-7).

Tarsal Bandage

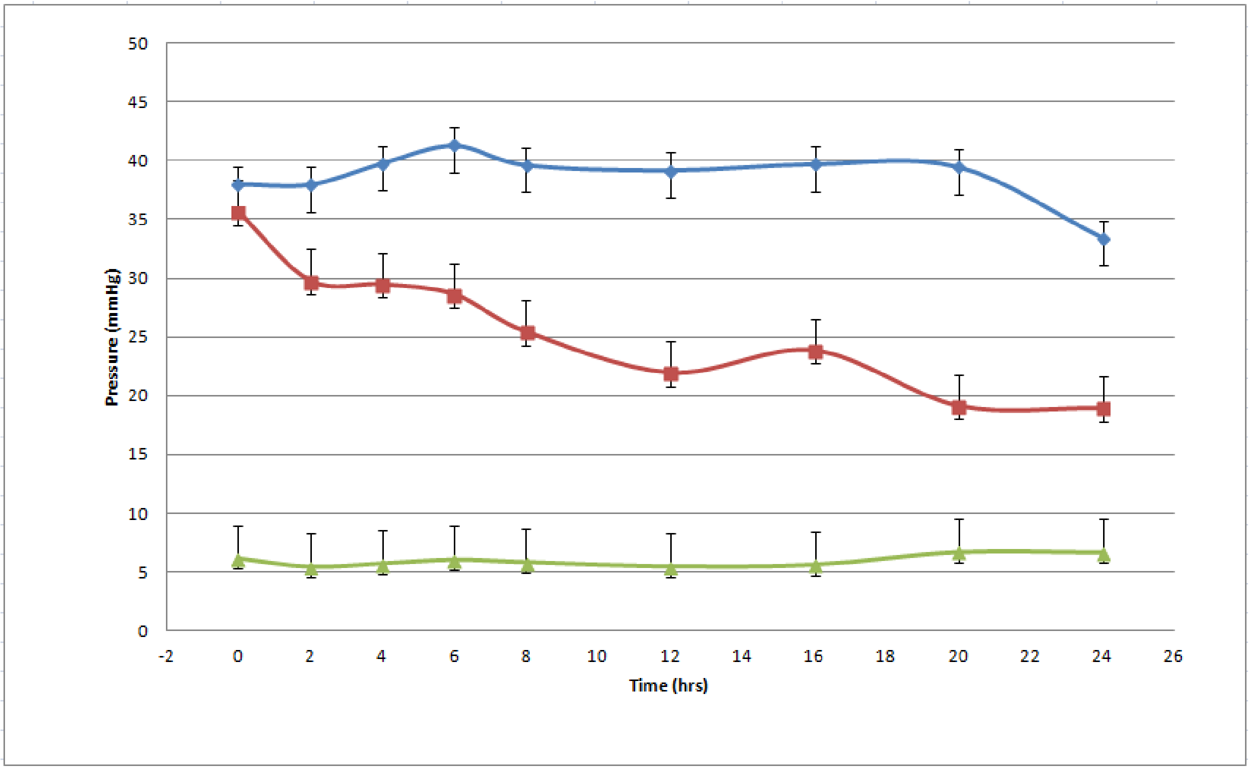
The mean circumferences of the mid-tarsus was 34.5 cm (range 33-37cm). For the TC, sensor location ($p = .0084$), creating a slit ($p < .0001$), and the effect of walking ($p < .0001$) had significant effects on sub-bandage pressure. At application, mean sub-bandage pressures at the dorsal, lateral, and calcaneal locations were 151 mmHg (95% CI 123-179 mmHg), 91 mmHg (95% CI 59 -123 mmHg), and 156 mmHg (95% CI 120-192 mmHg). At time of application, combined sub-bandage pressure was 132 mmHg (95% CI 122 – 142 mmHg) which was significantly higher than the 114 mmHg (95% CI 104 – 124 mmHg) achieved after a slit was created over the calcaneus. After walking, the combine sub-bandage pressure fell to 47 mmHg (95% CI 37 – 57 mmHg) which was significantly lower than both previous measurements (Figure 3-7). Propagation of the slit and disruption of compression layers was noted in all horses over the calcaneal tuber.

Figure 3-1 Mean ± SE Sub-Bandage Pressures



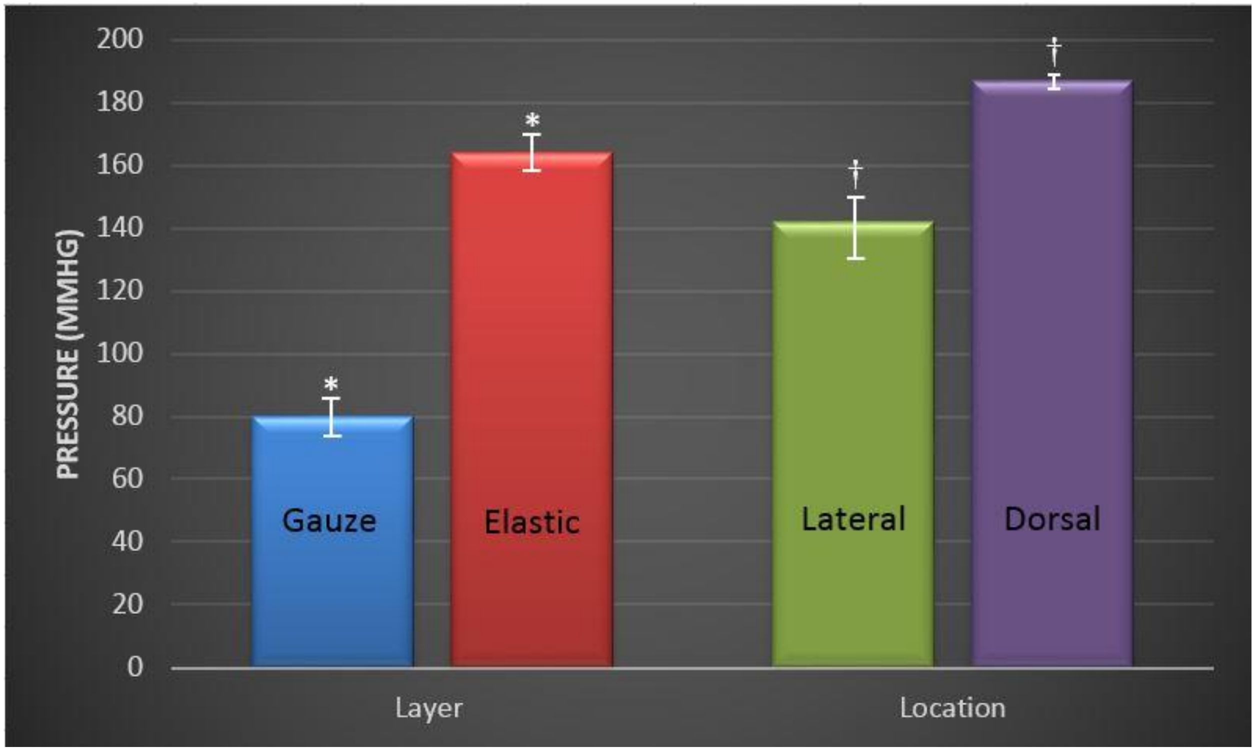
Mean ± SE sub-bandage pressures recorded (mmHg) for each treatment group; * denotes significance ($P = 0.001$).

Figure 3-2 Mean ± SE Sub-Bandage Pressures Over Time



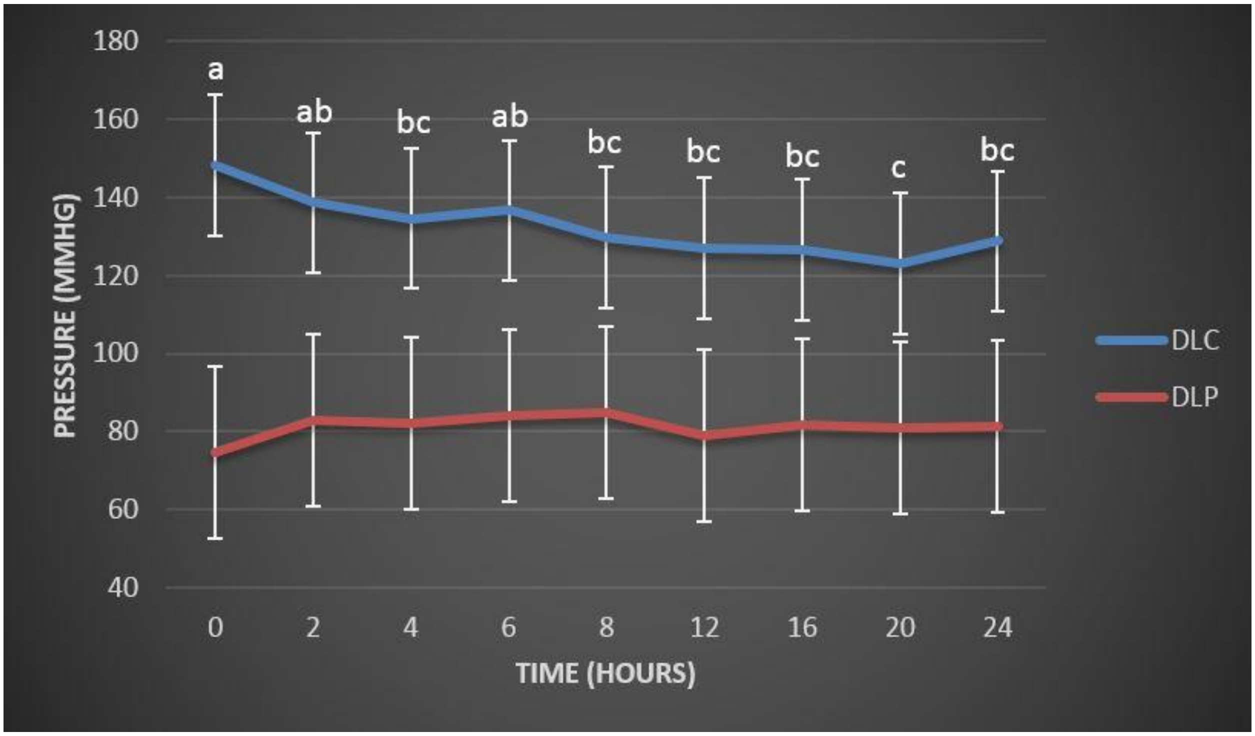
Mean ± SE sub-bandage pressures (mmHg) recorded for CM (◆), ELA (■), and NYL (▲) over time. Time 0 indicates time of application. Significance set at $P < 0.05$.

Figure 3-3 Mean ± 95% CI Combined Sub-Bandage Pressures



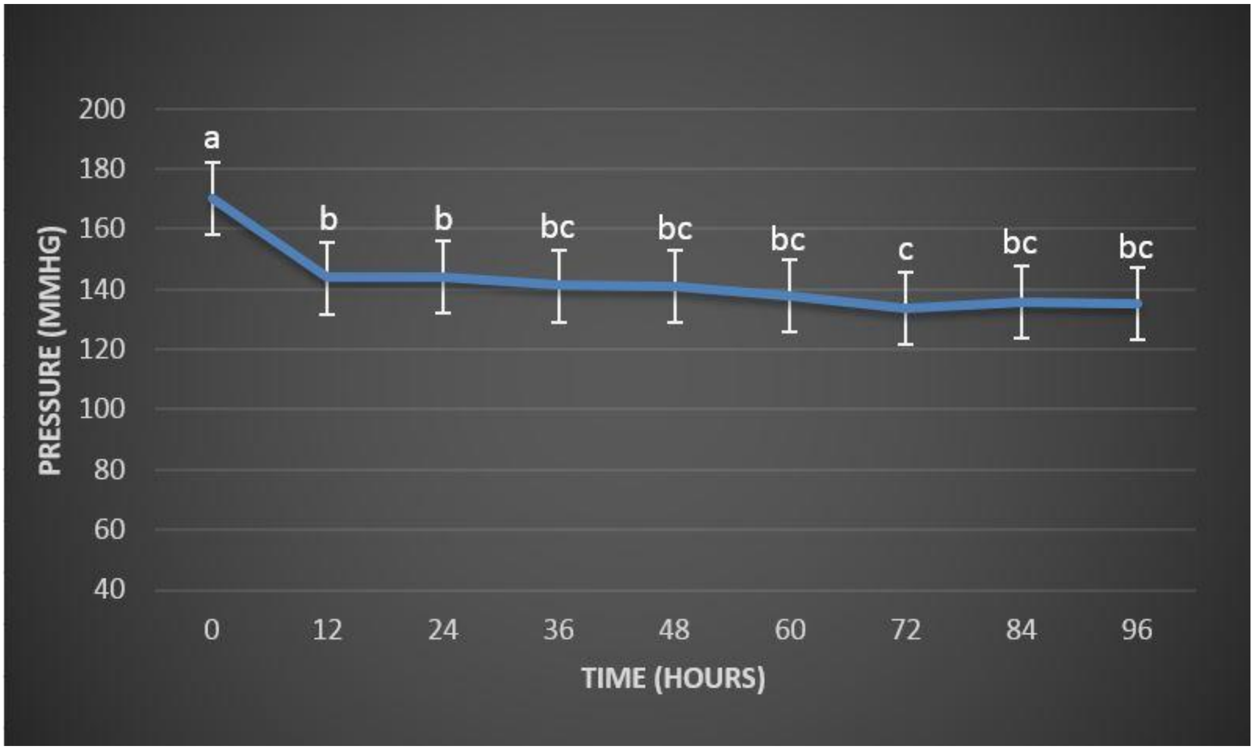
Mean ± 95% CI combined sub-bandage pressures recorded (mmHg) for each layer and mean ± 95% CI sub-bandage pressure recorded (mmHg) at each sensor location at time of application of the DLC bandage. Statistically different pressures are identified by * for layer data and by † for location data. Significance set at $P < 0.05$.

Figure 3-4 DLC and DLP Sub-Bandage Pressures Over Time



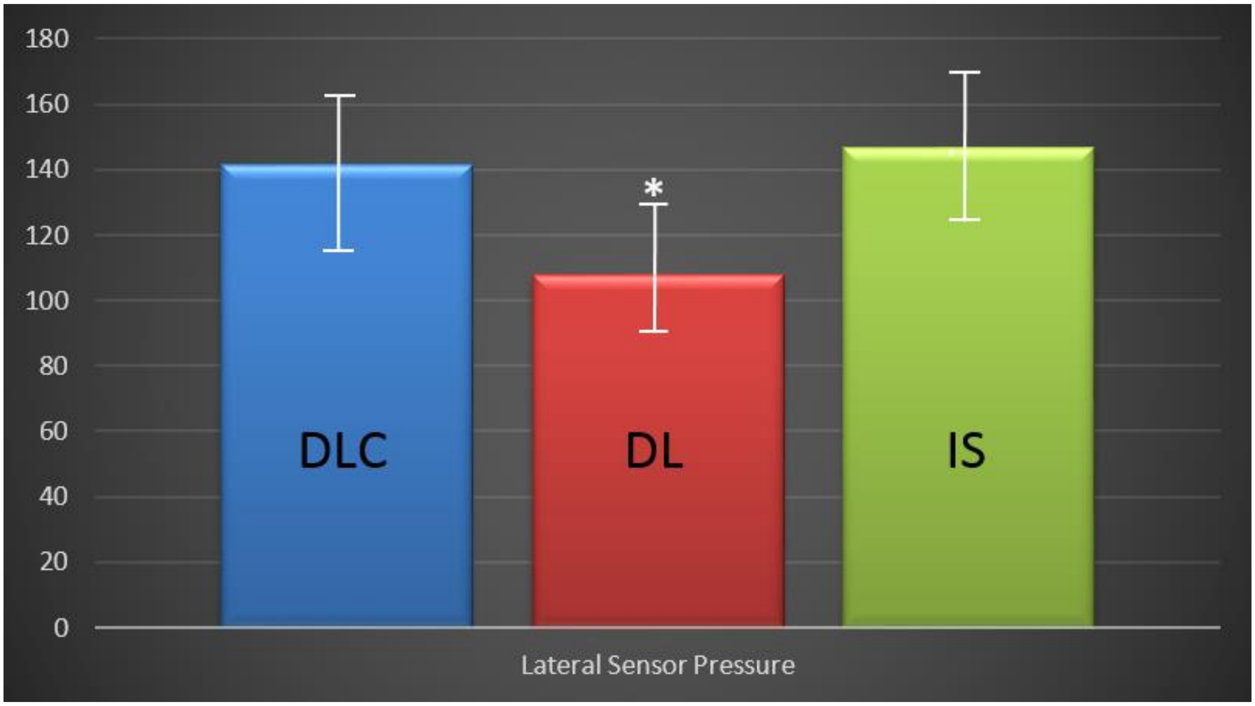
Mean ± 95% CI combined sub-bandage pressures recorded (mmHg) for DLC and DLP bandages over time. Time 0 indicates time of application. Within treatment time points with different superscripts are statistically different. Significance set at $P < 0.05$.

Figure 3-5 DLC Pressure Over 96 Hours



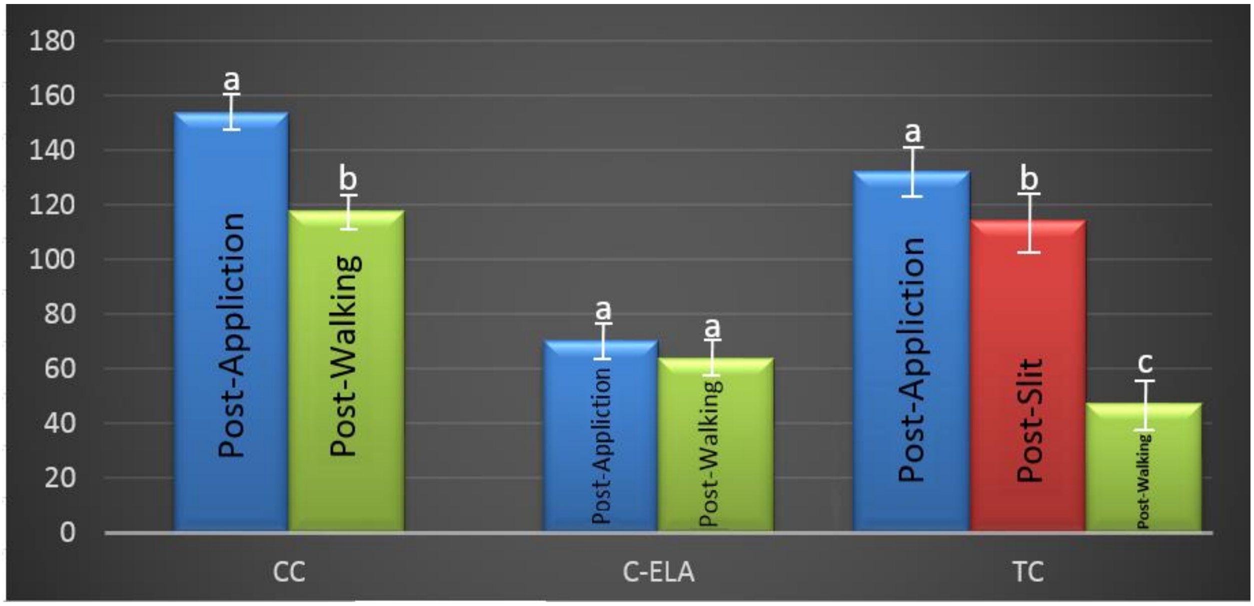
Mean ± 95% CI combined sub-bandage pressures recorded (mmHg) for the DLC bandage over time. Time 0 indicates time of application. Time points with different superscripts are statistically different. Significance set at $P < 0.05$.

Figure 3-6 DLC, DL, and IS Lateral Sensor Sub-Bandage Pressure



Mean sub-bandage pressure (mmHg) measured at the lateral sensor for each distal limb bandage construct: * denotes significance (p=0.0166).

Figure 3-7 Changes in Combined Sub-Bandage Pressures for CC, C-ELA and TC



Mean combined sub-bandage pressure (mmHg) for each joint bandage at various time points; bars within each treatment with different superscripts are significantly different ($p < 0.05$).

Chapter 4 -Discussion

Opinions of post-operative abdominal bandages vary between clinicians, but nonetheless it is a fairly common clinical practice. Proposed benefits of bandaging include incisional protection from the environment, support during the early post-operative period[9], and anecdotal reports indicate application of the CM™ Hernia Heal Belt can reduce both surgical and umbilical hernias. While the bandages ability to protect the incision is easily assessed, means of assessing incisional support are lacking in horses. Current rationale states that increasing the bandage's ability to compress the abdomen leads to greater pressures exerted on the incision thus increasing support[15; 21]. Following this rationale, the CM bandage was superior to the ELA and the NYL bandages in respect to incisional support. However, the current study cannot determine the clinical significance of the differences in sub-bandage pressures between treatments.

While the current study lacks information on post-operative patients, evaluation of the human literature allows certain comparisons to be drawn. One human study reported increased patient comfort and ambulation in the early post-operative period by application of an abdominal bandage that reduced the patients abdominal circumference by 10-20%[15]. A reduction of this magnitude is physically impossible in equine patients due to anatomical differences between bipeds and large quadrupeds; however, this lack of circumferential reduction does not equate to inadequate support. Pressures exerted by the CM bandage falls within the established ranges for reduction and prevention of edema in human patients. Partsch et al. demonstrated exertion of pressures greater than 30 mmHg but less than 70 mmHg were more effective in reduction of leg edema when compared to lower pressures[14]. A later study from the same group found that optimal pressures for edema reduction lie between 40 and 60 mmHg with higher pressures correlating to a reduced rate of volume reduction[22]. This group also concluded that pressures around 30 mmHg were nearly as effective as the recommended pressure range. The claim that abdominal bandages can reduce peri-incisional edema is supported by the ability of the CM bandage to exert pressures within the established ranges for reduction of edema in human patients and clinical data reported in one equine study involving application of abdominal bandages in post-operative patients [9].

Development of peri-incisional edema frequently occurs prior to suppuration, but it is unclear whether edema production is a precursor to or an effect of surgical site infection. Multiple studies report a far greater incidence of edema than that of laparotomy surgical site infections; with reported incidences as high as 74% [5; 9]. Coomer et al. demonstrated that horses with excessive peri-incisional edema were 3.5 times more likely to experience wound suppuration, but cause and effect was not determined[23]. Trauma leads to an influx of interstitial fluid into the subcutaneous tissues thus increasing the diffusion distance for both oxygen and nutrients. This fluid influx subsequently disrupts the normal fluid movement which can compromise associated tissues and predispose to infection[24]. Compression bandaging reduces edema by applying external pressure that translates to an increase in the interstitial pressure underneath the bandage. The pressure increase alters Starling's forces causing a reduction in the fluid filtration rate along with increased sub-fascial lymph drainage which act in concert to reduce or eliminate subcutaneous edema; creating a healthier incisional environment[25]. Therefore, methods of reducing post-operative peri-incisional edema would appear to be a way in which morbidity due to incisional infection may be reduced.

Selection of a bandage type for post-operative patients depends upon the clinician's reasons for bandaging the incision. All three bandages successfully protected the ventral midline with the exception of the CM bandage on horse 1. This occurred while using the manufacturer's dorsal pad which the horse used to rub against the stall wall causing it to slip. Use of the pad was discontinued, and all other horses had a quilted blanket placed with no further incidence of midline exposure. ELA bandages migrated caudally more frequently and to a greater degree than that of the other bandages, which allowed for 2 geldings to urinate in or on the bandage. Placement of a breast collar with the CM and NYL bandages successfully reduced caudal movement of the bandages. The current study included healthy horses fed ad libitum whereas in clinical cases, horses may be fasted or have reduced intake in the immediate post-operative period. Furthermore, defecation and flatus could decrease abdominal circumference and loosen the bandage in post-operative horses. These scenarios highlight how the use of an adjustable bandage would be preferred over that of the ELA bandage. While both CM and ELA exerted greater pressures on the incision, this increase in pressure is speculated to cause horses to lie down more frequently. Laying down in association with a colic episode has been thought to increase tension across the incision and cause movement of the wound edges, but the effect of laying down on a bandaged horse's incision is beyond the scope of this study [26].

While commercial bandages are expensive when compared to the ELA bandage, their reusability offsets the cost of initial purchase. Based on the price of Elastikon[1] for this study, 29 or 12 elastic bandages could be placed before surpassing the initial cost of the CM and NYL bandages, respectively. More important than cost, the ability and ease of both checking the incision and changing the contact layer on a daily basis with the commercial bandages is superior compared to replacing an elastic bandage. Several studies report changing bandages every 2-3 days to reduce the number of bandage changes prior to discharge[9; 12; 27]. However, Mair et al. associated placement of a stent bandage for 3 days with higher incisional complication rates and cited increased risk of infection as one possible cause [13].

Bandaging protocols for equine distal limbs vary due to clinician preferences and the clinical rationale for bandage application. Acute wounds or surgical incisions may require bandage changes every 24 hours in order to assess progress in wound healing, monitor for infection, or perform wound debridement. During this period, bandage changes will be performed by the veterinarian ensuring appropriate application and compression of the limb. Proper application protects the wound from the environment while at the same time reducing edema, seroma, or hematoma formation[28]. Technical skills of owners vary, making reduction in the number of bandage changes required after patient discharge beneficial for both the owner and the horse. Published recommendations for frequency of bandage changes vary and can be as long as 10 days[29]. Assessment of sub-bandage pressure in human patients demonstrated that the majority of commercially available compression bandages were unable to maintain the recommended pressure ranges over a 7 day period[30]. The current study demonstrates that DLC bandages will exert a total sub-bandage pressure higher than 120 mmHg for up to 96 hours post application. Based on this data, greater than 4 day intervals between bandage changes may be appropriate in normal horses with the absence of limb edema.

While adequate pressure ranges have not been determined for reduction of edema in equine patients, research involving human patients has established recommended pressure ranges for treatment of lymphedema. Partsch *et al.* (2011) demonstrated that pressures greater than 30 mmHg but less than 70 mmHg were more effective in reduction of leg edema when compared to lower pressures[14]. A later study from the same group found that optimal pressures for edema reduction lie between 40 and 60 mmHg with higher pressures correlating to a reduced rate of volume reduction[22]. This group also concluded that pressures around 30 mmHg were nearly as effective as the recommended pressure range. The current study demonstrates that both DLC and

DLP sub-bandage pressures exceed the pressures recommended for effective edema reduction in human patients. The concern with excessive compression in human appendages is due to the ability to collapse veins within the limb[14]. In humans, intravenous pressure is dependent upon the weight of the column of blood between the anatomical location of interest and the heart[31]. However, due to the high density of venous valves in the equine forelimb comparisons to humans may be invalid[32]. Regardless, extrapolating from digital venous pressure in the standing horse, it is presumable that venous pressures within the cannon region range from 50 - 100 mmHg[33]. Interstitial fluid pressures in human legs with and without lymphedema range between -1 and 10 mmHg[18] allowing bandage pressures of 30-60 mmHg to substantially increase interstitial pressure. Increasing the interstitial pressure reduces fluid filtration into the interstitium and increases uptake of fluid into the lymphatics thus reducing edema [24]. Interstitial pressures at the coronary dermis in horses bearing full weight on the limb ranged from 1.28 ± 7.69 mmHg at the heel to 5.01 ± 5.23 mmHg at the toe[34]. Another study found that mean interstitial pressures within the digit of healthy horses was 26 mmHg which is quite higher than the reported values in humans[35]. With the lack of information involving interstitial and venous occlusion pressures in the equine distal limb, comments on the clinical superiority of the DLC versus the DLP bandages cannot be made. However, anecdotal clinical evidence from our hospital demonstrates that both bandage types have the ability to effectively reduce distal limb edema. Further investigation is needed to establish recommended pressure ranges for edema reduction in horses.

Increased pressures produced by the DLC are a function of the bandage construct. Nelson *et al* (1997) concluded that 2 layer bandages exerted twice as much pressure as a single layer bandage when applied to human legs[36]. The results in this study concur with their findings in that 48%

of the overall sub-bandage pressure in the DLC came from brown gauze compression and the additional 52% was applied by the elastic tape. The DLC is composed of 3 layers but inner cotton layer functions to pad the limb from the pressure of the outer layers. Human literature demonstrates that adding more than 2 compressive layers offers limited benefit to the cumulative sub-bandage pressure [37].

In the equine distal limb, distribution of sub-bandage pressure is not uniform. For both the DLC and DLP the dorsal sensor recorded significantly higher pressures than that of the lateral sensor. The reason for the pressure difference is the shape of the distal limb. The dorsum of the metacarpal region is composed of the extensor tendon and the third metacarpal bone which produce a flat surface with very little soft tissue covering. The lateral and medial aspects contain a concavity associated with the suspensory ligament branches that is interposed between the splint bones and flexor tendons. It is presumed that this concavity inhibits complete compression of the cotton layer of the bandage thus leading to reduced force applied to the skin. In the current study, sensors were not applied to either the medial or palmar aspect of the limb. Pilot data revealed minimal difference in mean sub-bandage pressure when comparing medial and lateral sensor placement[38]. In order to acquire accurate measurements, the manometer must lay flat on the limb. Due to the width of the flexor tendons, the manometer curved over the palmar aspect of the limb making measurements unreliable.

The current study has several limitations. Since the Picopress® Compression Measurement System[6] cannot measure pressures in excess of 189 mmHg, the true pressure achieved on the dorsum of the cannon bone could not be quantified. The majority of horses maintained pressures in excess of 189 mmHg at the dorsal sensor for the duration of the treatment period (both 24 and 96 hours). To account for this, combined sub-bandage pressure was used in the linear model to establish a more accurate estimate of pressure changes over time. While this allows for quantifying the change in pressure, the true pressure values could be higher than that reported. Another limitation is that the bandages were applied to equine limbs absent of edema. While this study should accurately predict the pressure levels over time in horses bandaged for protection of surgical wounds, it is difficult to extrapolate these results to horses suffering from edema. It is reasonable to assume that sub-bandage pressure will decrease as the fluid is absorbed into the lymphatics requiring more frequent applications of compression bandages. Ultimately, choice of bandage type is dependent upon clinical situation and the clinician's rationale for apply compression to the limb.

Techniques for applying equine distal limb bandages vary due to clinician preferences and the clinical rationale for bandage application. Reduction of fluid accumulation is particularly important in surgical wounds associated with the lateral or medial aspect of the cannon region. In this region, a concavity is formed by the suspensory ligament and its branches as they course between the splint bones and flexor tendons. Since this indentation is associated with the surgical site for desmotomy of the accessory ligament of the deep digital flexor tendon and ostectomy of the second or fourth metacarpal/tarsal bones, clinicians worry about both seroma and hematoma formation within this space. For this reason, some clinicians advocate the use of an IS for the aforementioned procedures with the aim of the rolled gauze sponge reducing dead space. The current study demonstrates that application of a IS does not significantly increase the sub-bandage pressure at this location thus yielding no added benefit over a standard compression bandage. When a standard DLC is applied, the cotton layer of the bandage is compressed by the outer layers and conforms to the contour of the limb. Consequently, the compressed cotton material fills the lateral or medial concavity with pressures in the same magnitude as the IS.

While application of IS under greater tension could result in increased lateral sensor pressures, the complications associated with this practice (i.e. tendonitis or focal skin necrosis) outweigh the benefits of increasing the sub-bandage pressure.

Application of the DL significantly reduced the pressures applied to the lateral aspect of the limb compared to both the IS and DLC. This finding agrees with previous studies in human patients where application of more than 2 compressive layers offered limited benefit to the cumulative sub-bandage pressure [37]. Dale *et al* (2004)demonstrated that when an additional compressive layer is applied to a multilayer bandage construct, it applies only 50-60% of the pressure exerted when applied individually[39]. In regards to the DL bandage, the addition of the second Combi roll and brown gauze layer further separates the elastic layer from the bandage-skin interface. In the DL, pressure applied by the elastic layer compresses both Combi rolls leading to more dissipation of pressure within the bandage construct and reduces the pressure applied to the skin. While applying additional layers can have clinical benefits, especially in regards to increasing bandage stiffness, it is erroneous to conclude increasing the number of layers in a bandage leads to increases in the sub-bandage pressure. The relationship of sub-bandage pressure and additional compressive layers relies heavily on the construct of the bandage. The cotton within the Combi layer seems to be maximally compressed by the elastic layer in the standard DLC construct making additional layers unnecessary in regards to sub-bandage pressure. An alternative to the DL is to apply 2 DLCs over the distal limb. While this would increase the stiffness and sub-bandage pressure compared to the DL bandage, the ability of this type of construct to significantly raise the pressures above that of a single DLC bandage is questionable. Furthermore, the DLC construct provides high pressures both dorsally and laterally that are clinically effective in the reduction of distal limb edema which negates the need for higher pressures.

While distal limb bandages maintain high pressures over a 96 hour period, carpal and tarsal bandages behave quite differently. Compression bandages placed over both joints had rapid degradation in sub-bandage pressure after walking a short distance. Pressure degradation was more severe in the tarsal bandage with a 60% reduction in sub-bandage pressure compared to a 23% degradation in the carpus. One reason for the excessive pressure loss in the TC involves the creation of a slit over the calcaneal tuber. This technique has been advocated by some individuals in our practice to prevent sore formation over the common gastrocnemius tendon and the calcaneal tuber. Other methods for sore prevention include not incorporating the calcaneus with either of the compression layers so that the Combi roll is exposed over the point of the hock. Both methods result in disruption of the bandage after the flexion of the hock which correlates with a significant drop in sub-bandage pressure. To prevent bandage disruption, some clinicians advocate placing a strip of adhesive elastic tape over the caudal surface of the bandage[40]. While this may prevent disruption at the point of the hock, in our experience disruption of the elastic layer still occurs at various other locations over the lateral or medial aspect of the bandage thus causing a presumed decrease in the sub-bandage pressure. Due to the rapid degradation in pressure, the practice of slitting or not incorporating the point of the hock is not recommended.

The decision to place a compression bandage versus an elastic adhesive bandage over a joint depends on the rationale for application. In regards to sub-bandage pressure, a compression bandage construct will exert higher pressures initially compared to an adhesive elastic bandage, but the initial compression bandage’s pressure degrades rapidly. When looking at pressures associated with the carpus, the initial combined CC pressures were over two times greater than the combined C-ELA pressures. However, the disparity in pressures between the bandage types diminishes as the horse ambulates due to cycling of the compression bandage components. The current study demonstrated a significant decrease in combined CC sub-bandage pressures after walking horses a short distance whereas C-ELA pressure were not significantly lower. Continued degradation in compression bandage pressures is likely as horses are able to ambulate within a stall. Presumably, the CC pressures will fall below that of the C-ELA as continued flexion of the carpus will further stretch the bandage components. Therefore if prevention or resolution of edema is the goal of bandage placement, placing a C-ELA may be more efficacious as it will exert more consistent pressures for a prolonged period of time. C-ELA bandages exerted pressures above the human therapeutic pressure range for edema reduction and were able to maintain this pressure while walking. Additionally, a pillow pad with a polo wrap over the distal limb produced mean sub-bandage pressures that ranged from 75 mmHg to 85 mmHg over a 24 hour period. Anecdotal evidence observed in our hospital demonstrates polo/pillow pad wraps are efficacious in reducing distal limb edema, and it is reasonable to assume the C-ELA pressures, although slightly less than that of the polo wrap pressures, are equally efficacious for carpal edema. Since CC continue to produce high sub-bandage pressures after walking, more research is needed to determine the rate of continued pressure degradation over time. This information will help practitioners determine the best bandaging practices for the reduction of edema associated with the carpus.

Since an adhesive elastic bandage was not applied to the tarsus, comments on the superiority of one bandage type are purely speculative. However, extrapolating from the trends set by the carpal bandages, an adhesive elastic bandage placed on the tarsus may apply higher pressures for a prolonged period of time compared to a TC construct. After walking, TC mean combined pressure was 47 mmHg whereas the C-ELA maintained pressures in the 60-70 mmHg range. While this comparison favors elastic bandage application, differences in bandage application between the carpus and tarsus could make extrapolations erroneous. Since TC had slits created prior to walking the horse, the degree of pressure degradation recorded in this study could be dramatically different from what occurs in an unaltered TC. Thus drops in sub-bandage pressure could reflect that of the CC with post-walking pressures exceeding the pressure range achieved by elastic bandages. Furthermore, the any extrapolation assumes that an elastic bandage would apply similar pressures in the tarsus as it does in the carpus. However, compression bandages demonstrated differences in pressure ranges between the carpus and tarsus with mean combined CC pressures being 20 mmHg higher than that of the TC. Ultimately, further research is needed to quantify sub-bandage pressures achieved by tarsal elastic bandages and determine the effect of time on both TC and elastic sub-bandage pressures.

As with the distal limb, carpal and tarsal bandages do not uniformly distribute sub-bandage pressure at the time of application. When applied with even tension, carpal pressures are significantly higher laterally compared to dorsal pressures for both bandage types. The opposite is true for the TC bandage with lateral pressures being significantly lower than both the dorsal and calcaneal pressures. Anatomical variation in soft tissue distribution and contour of the limb likely account for the majority of the pressure difference. Areas with little soft tissue covering over bony prominences or areas with taught tendons or ligaments under the skin surface allow for greater compression of the subcutaneous tissues by the bandage construct. Interestingly, the difference in pressures exert at the lateral and dorsal sensors was the same for both carpal bandage types, about 30 mmHg. This finding demonstrates differences in sensor pressures are more likely due to anatomical conformation and not a function of the bandage construct. For both the CC and TC, differences in dorsal and lateral sensor pressures diminished after walking due to cycling of the bandage construct. For the TC bandage, calcaneal pressures fell significantly below other sensor pressures, but this was due to the deterioration of the bandage construct at the point where the slit was created. These findings demonstrate that as both CC and TC sub-bandage pressures drop, different areas of the bandage are unequally stressed causing the construct to exert more uniform pressure.

In regards to tarsal bandages, the current study cannot determine the changes in sub-bandage pressure when a slit is not created over the calcaneal tuber. With the varying application techniques, the pressures reported might not reflect the pressures achieved by other TC constructs. For both carpal and tarsal bandages pressure degradation occurs quite rapidly, it is beyond the scope of the current study to predict changes in sub-bandage pressure over a prolonged period of time. To simulate the cycling that occurs as horses ambulate in a stall, walking the horses over a short distance was employed. How this correlates to the stresses applied to the bandage during stall rest is unknown. Furthermore, horses respond differently to application of a TC with some hyperflexing the tarsus when walking is initiated thus placing large amount of tension on the bandage. For these reasons, extrapolation of the current data to that of a stall rested horse can be difficult.

The current study quantified sub-bandage pressures generated by various bandage constructs at different anatomical locations. The three abdominal bandage types maintained pressures for a 24 hour period. The CM bandage pressures measured higher than that of both the ELA and NYL bandages, but the clinical effectiveness of each bandage cannot be determined by this study. For both distal limb and joint bandages, distribution of pressure was not uniform. For distal limb bandages, sub-bandage pressures at the lateral sensor were not increased by applying additional layers to the DLC construct. The DLP pressures were maintained for a 24 hour period; however, the pressure magnitude was less than that of the DLC. In contrast, DLC pressures fell over the initial 6-12 hour range, but even with the initial pressure degradation DLC bandages maintained high pressures. DLC bandages placed on normal distal limbs can maintain high pressures over a 96 hour period. In regards to CC and TC bandages, there is rapid degradation in sub-bandage pressure after horses walked a short distance with greater decreases in pressure with the TC than CC. C-ELA bandage pressures did not significantly differ before and after walking. Due to the large drop in sub-bandage pressure associated with the TC construct, splitting the bandage over the calcaneal tuber is discouraged.

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Appendix A – Manufacturer Details

Abdominal Bandage Study

[1] Sta-Put™ Abdominal Support Wrap, Equus Therapeutics Inc., Afron, VA.

[2] Elastikon, Johnson & Johnson, New Brunswick, NJ.

[3]CM™ Hernia Heal Belt, CM™ Equine Products, Norco, CA.

[4]Glenwood Abdominal Support Bandages, Rachel's Sewing Repair, Carbondale, CO.

[5] Microlab Electonica, Nicolo, Italy.

[6] CombiRoll, Franklin-Williams Co., Lexington, KY.

[7]JMP, SAS Institute Inc., Cary, NC.

[8]SAS, SAS Institute Inc., Cary, NC.

Distal Limb Bandage Study

[1] CombiRoll, Franklin-Williams Co., Lexington, KY.

[2]Brown "Cling" Gauze, Jorgensen Laboratories Inc., Loveland, CO.

[3]Cohesive, Oasis Medical, Mettawa, IL.

[4]Jacks No Bow Wraps, Jacks Inc., Washington, OH.

[5]Jacks Standing Leg Wraps, Jacks Inc., Washington, OH.

[6] Microlab Electonica, Nicolo, Italy.

[7]JMP, SAS Institute Inc., Cary, NC.

Joint Bandage Study

[1] CombiRoll, Franklin-Williams Co., Lexington, KY.

[2]Brown "Cling" Gauze, Jorgensen Laboratories Inc., Loveland, CO.

[3]Cohesive, Oasis Medical, Mettawa, IL.

[4]Bandage Role, Dukal Corp., Ronkonkoma, NY.

[5]Elastikon, Johnson & Johnson, New Brunswick, NJ.

[6] Microlab Electonica, Nicolo, Italy.

[7]JMP, SAS Institute Inc., Cary, NC.