

Sub-Bandage Pressure in the Canine Forelimb after Rigid Splint Application by Surgeons and Veterinary Students

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Abstract

Objective The aim of this study was to measure and compare sub-bandage pressures after a rigid splint was applied to the forelimb of a dog by surgeons and veterinary students.

Animals One, adult, Labrador Retriever.

Methods Sub-bandage pressure was measured at five locations on the limb of a dog using a previously validated pneumatic compression measurement system over a 4-hour period after splint application. All participants received the same instructions and the same dog was used for each splint application.

Results Across time and location, mean sub-bandage pressures from the experienced group were significantly greater than those from the inexperienced group at all transducer locations and at all time points. People from the inexperienced group recorded the greatest range in sub-bandage pressures and had significantly higher-pressure differences across the five locations sub-bandage pressure was measured.

Conclusions and Clinical Relevance Surgeons applied their splint bandages with approximately 50% greater pressure and 50% less variability between locations. The large range in sub-bandage pressures found may suggest that decreased and/or increased sub-bandage pressure may predispose to bandage complications.


Keywords

- ▶ bandage
- ▶ dogs
- ▶ splint

Introduction

Rigid splints and bandages are routinely used in veterinary medicine. When applied and managed appropriately, splints and bandages can provide an effective means of immobilization, stabilization, wound protection, minimization of oedema, elimination of dead space and a clean environment.^{1,2} Application of bandages is not without risk. Complications arising from suboptimal bandage application include vascular compromise, ischaemia, oedema, rub sores

or necrosis and ineffective treatment of the underlying problem.^{2–4} Meeson and colleagues reported that 63% of patients with a cast for a distal limb orthopaedic injury developed a soft tissue injury; 40% of patients required continued care because of the complication.⁵ Identifying predisposing factors is critical to reducing iatrogenic soft tissue injuries. It has been suggested that dermal sores or lesions usually develop at areas of high pressure.⁶ Empirically, soft tissue wounds secondary to bandages and casts occur adjacent to elevated areas of the limb such as the calcanei, styloids, malleoli or pads. It has been reported that less soft tissue coverage (e.g. muscle and subcutaneous tissue) results in reduced compressibility, thinner skin over bone prominences or elevated pressure.^{6–8}

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In people receiving a bandage for chronic venous insufficiency, an ideal bandage pressure range has been identified as 35 to 45 mm Hg with suboptimal pressures < 20 mm Hg and 0 mm Hg.^{9,10} Translation of these data must be performed carefully because of differences in reason for bandage application, method of pressure measurement, species anatomy, activity level with the bandage and the ability of the patient to report a potential problem. While sub-bandage pressures have been reported for the hindlimb of the dog⁶ and equine abdomen,¹¹ we are unaware sub-bandage pressure ranges have been reported for the forelimb in the dog, a common bandage application site. Lack of these data may lead to nondescript instruction when training staff and students and ultimately suboptimal bandage application. It is difficult to teach inexperienced individuals the appropriate amount of pressure to apply during application of a bandage because subjective and objective cues are limited. While our somatosensory system allows us to perceive and understand the amount of pressure being applied to our own skin, we lack the innate ability to accurately perceive the amount of pressure we apply to a patient.¹² Furthermore, veterinary patients are unable to verbally communicate the pressures sensed by their receptors adding to the difficulty of applying a bandage with the appropriate sub-bandage pressure.

Use of a sub-bandage pressure measurement system in conjunction with lectures and hands-on laboratories has been shown to be effective in improving bandaging technique and pressure application in human medicine.^{13–15} Nelson and colleagues reported that ‘Training, consisting of feedback from the pressure monitor and advice from an experienced bandager, resulted in a significantly improved sub-bandage pressure.’¹³ We found no evidence that these methods are utilized routinely during instruction of bandage application within a veterinary curriculum. Creating and implementing an instruction programme using a defined pressure range, pressure measurement system, lecture instruction and hands-on laboratory instruction may improve bandage application technique amongst veterinary students. Documenting sub-bandage pressure ranges and distribution of pressures over various anatomic regions of the limb, via sub-bandage pressure sensors is an important step toward understanding how to improve teaching methods. The objective of this study was to measure and compare sub-bandage pressures after a rigid splint was applied to the forelimb of a dog by surgeons and veterinary students. Our null hypothesis was that group assignment would not influence sub-bandage pressure.

Materials and Methods

The study protocol was reviewed and approved by the University of Minnesota Institutional Animal Care and Use Committee and informed client consent was collected from the owner for the dog used in this study. Seven faculty surgeons (Diplomates of the American College of Veterinary Surgeons) that performed orthopaedic surgery and ten 4th year veterinary students from the University of Minnesota College of Veterinary Medicine were selected to place a rigid splint on the right forelimb of the same neutered male, 6 years old, Labrador

Retriever dog. As part of their veterinary medicine curriculum, the students that participated in this study received a 1-hour lecture addressing bandaging and two, 2-hour laboratories where they practiced (with supervision) bandaging technique on artificial limbs.

A standard operating procedure was written so explanation of the study protocol to the participants and study methodology (e.g. technical support, animal restraint, application of the pressure device) was reproducible. The surgeons and students were instructed that for the purposes of the study they should assume the dog presented with a chronic injury at the level of the carpus that required rigid stabilization with the carpus in 180° of extension. Participants were allowed to place the type of rigid splint they routinely applied in practice or were most comfortable applying. A variety of bandage material was available including 76.2-mm Synthetic Cast Stockinette (3M; St. Paul, Minnesota, United States), 25.4-mm Nexcare Sensitive Skin Tape (3M), 76.2-mm Scotchcast dry cast padding (3M), 76.2 VetRap (3M;), Vetcast Plus Veterinary Casting Tape (3M), 76.2-mm Sensi Wrap Cling (Jorgensen Labs; Loveland, Colorado, United States), aluminium rods, pre-formed commercially available plastic splints, a cast saw and bandage scissors. The bandage material that was used was documented but the exact thickness of the bandage was not measured. The length of the bandage was also noted. More specifically, it was documented how proximal on the limb the bandage extended (distal, middle, proximal radius/ulna or above elbow) and if any of the dog’s toes could be visually examined distally.

Prior to the onset of the study, the dog used in the study had participated in pilot work so the investigators could test the pneumatic pressure device (PicoPress Compression Measurement System; MediGroup, Melbourne, Australia) used to measure sub-bandage pressure and the dog would become familiar with the test environment and application of an antebrachial splint. The pneumatic pressure device, five PicoPress transducer bladders and conduction tubes were used in compliance with manufacturer’s previously validated instructions and similar to previous publications.^{11,15–18} Transducer bladders were positioned on the (1) palmar aspect of the foot over the top of the accessory carpal pad, (2) lateral side of the metacarpal–phalangeal joint, (3) medial side of the metacarpal–phalangeal joint, (4) cephalic vein at the middle of the radius and (5) lateral side of the middle of the radius (→ Fig. 1).

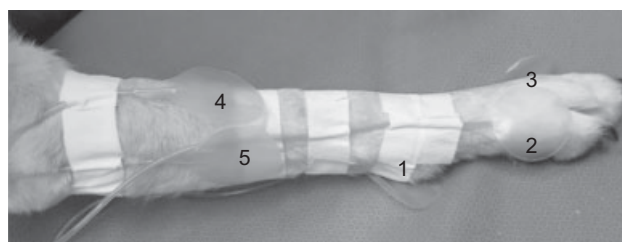


Fig. 1 Photograph demonstrating method and placement of transducers on the forelimb of the dog used in this study prior to placement of a stockinette. Transducer bladders were positioned on the (1) palmar aspect of the foot over the top of the accessory carpal pad, (2) lateral side of the metacarpal–phalangeal joint, (3) medial side of the metacarpal–phalangeal joint, (4) cephalic vein at the middle of the radius and (5) lateral side of the middle of the radius.

The limb was measured and landmarks were used so transducer bladders were consistently positioned by a single investigator. Conduction tubes were taped into position using 25.4 mm Nexcare Sensitive Skin to the fur of the dog using caution not to compress the tubing and avoiding placing tape on the bladder. The conduction tubes were stretched out completely towards the proximal aspect of the limb to prevent the tubing from coiling underneath the bandage, labelled and a 76.2-mm Synthetic Cast Stockinette was placed over the limb to the level of elbow. These steps were taken so that the motion of the transducer bladders during and after bandage application was limited, pressures could be identified after bandage application and the conduction tubes did not kink.

Bladder pressure was documented to be 0 mm Hg in each of the five PicoPress transducers and then participants were allowed to apply their splint. The bandage was removed after the hour 4 measurements were recorded. The bandage was removed earlier than the hour 4 measurements if the dog appeared painful. All splints were applied on a different day. Pressures were recorded from each of the five sensors at 0, 1, 2, 3 and 4 hours after bandage application. Pressure measurements were performed twice at each sensor and the average was used. The dog was allowed to use the forelimb and walk freely in a confined, 3 × 3 m space under supervision between measurements.

The data were checked for outliers and data distributions with summary statistics and plots. The analysis was into two stages. First, repeated measures, analysis of variance, were used to test group effect, time effect and the group by time interaction, at each location. At locations where the group by time interaction was significant, group effect was tested at each time point using Wilcoxon rank-sum test. Data are reported as mean ± standard deviation. Statistical significance was set at $p < 0.05$.

Results

All surgeons and students applied a Modified Robert Jones bandage with a splint method to provide rigidity. All surgeons and students used three rolls of Scotchcast dry cast padding and two rolls of Sensi Wrap Cling to pad the limb prior to application of a method of stabilization. Of the surgeons, one utilized an aluminium rod splint, three used a caudal splint made from casting material and three used the caudal portion of a bivalve cast to provide rigid stabilization. Every student used a caudal splint made from casting material to provide rigid stabilization. Two rolls of VetRap were used as an external layer on the outside of the stabilization. All bandages were extended to the proximal aspect of the radius and ulna and all bandages allowed for visualization of metacarpal pads 3 and 4. The bandages were well tolerated by the dog except on one application (student 5). This bandage was removed after the hour 2 measurement readings because the dog had become anxious and appeared painful; no abnormalities were seen with bandage or dog after the bandage was removed.

A total of 830 bandage pressure measurements (415 repeats) were made. The average pressure measurement

was reflective of the two individual measurements; the difference between the repeated measurements was within 5 mm Hg 94.94% (394/415) of the time, within 10 mm Hg 4.82% (20/415) of the time and the remaining measurements (0.24%, 1/415) had a difference of 17 mm Hg.

Across time and location, mean sub-bandage pressures from the surgeons were significantly greater than students at all transducer locations and at all time points (► Fig. 2A–E). For example, at the accessory carpal pad location at hour 0, mean pressure was 85.1 ± 19.3 mm Hg for surgeons and 46.2 ± 30.2 mm Hg for students (► Fig. 2A). Similarly, when all five locations were collectively considered, mean sub-bandage pressure immediately after bandage application was 75.7 ± 24.9 mm Hg for the surgeons and 51.0 ± 28.1 for the students. For surgeons, average sub-bandage pressure significantly decreased from hour 0 to hour 1 at all five transducer locations. Following hour 1, pressure did not change. For students, bandage pressure remained the same over time at four of five transducer locations (pressure significantly decreased from hour 0 to hour 1 at the dorsal antebrachium location over the cephalic vein (► Fig. 2D)).

Across all measurements, students recorded both the lowest (12 mm Hg) and highest (132.5 mm Hg) sub-bandage pressure; the range of pressures across all measurements for people in the experienced group was 40.5 to 129.5 mm Hg. Students had significantly higher-pressure differences across the five sub-bandage pressure locations. For students, the average difference was 88.08 ± 43.91% (range: 34.74–173.85 mm Hg) and for surgeons the average difference was 47.86 ± 22.77 (range: 11.8–77.17 mm Hg). Sub-bandage pressure varied based on location of the sensor on the limb. However, within the surgeon group, pressure was only significantly different (decreased) at location 3 (lateral antebrachium) when compared with the remaining four locations. No differences in pressure were found across sensor locations in the student group.

Discussion

In this study, we found that group assignment significantly affected mean sub-bandage pressures and the consistency of sub-bandage pressures at the locations tested. Therefore, we reject our null hypothesis that group assignment would not influence sub-bandage pressure. We are uncertain if the decreased sub-bandage pressures and/or consistency in sub-bandage pressures measured in this study would translate to a greater risk of bandage complications.

The locations where we measured sub-bandage pressure were selected because they are common locations for bandage sores (accessory carpal pad and medial and lateral aspect of the foot) could lead to venous congestion (cephalic vein) or could serve as a control region that is generally unaffected by bandage complications (lateral mid-radius). When designing an instructional methodology, a recommendation of a sub-bandage pressure(s) depends upon the bandage method, purpose, location and where sub-bandage pressure is measured. It is also important to note that sub-bandage pressures from members of the experienced group greatly varied making

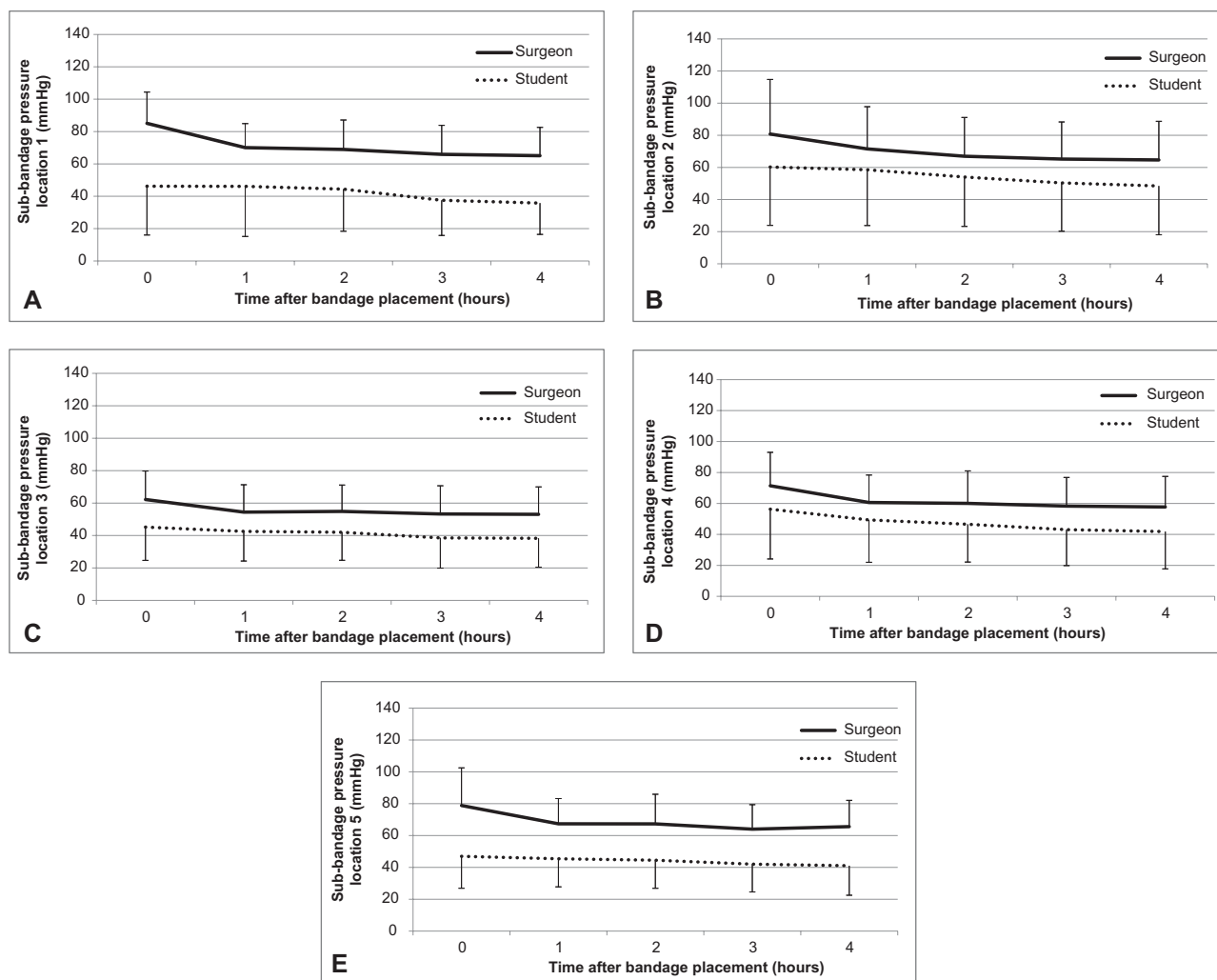


Fig. 2 (A–E) Comparison of surgeon and student pressures over time at the five transducer locations. Bars represent standard deviation.

a single recommendation impossible. In addition, since surgeons applied their splint bandages with ~50% greater pressure and 50% less variability between locations, it may be prudent to design an instructional method that allows for measuring of sub-bandage pressures in more than one location.

We elected not to control the type or amount of splint bandage applied because we did not want to induce a procedural bias by having people apply a bandage they were unfamiliar with. We also provided no additional instructions to surgeons or students on how to apply the rigid splint bandage in an effort to mimic a clinical practice situation and because there is no clearly defined correct way to apply a splint. However, since the dog was identical for all participants, the bandage material provided was limited to the specific brand available within the hospital, all surgeons work at the same facility and all students received the same bandage training from those surgeons; it was not surprising that all participants used a similar amount of bandage material and similar bandage techniques. While these methodological decisions were made so we could determine how bandage application experience influences sub-bandage pressures, they affect the pressures found in this study.

Thus, while the sub-bandage pressure difference between the groups is supported by the data, the pressures should not be translated to other situations because of changes in the patient and bandage material used.

We only measured sub-bandage pressure over a 4-hour period. From pilot work, utilizing the dog and one of the surgeons in this study, we found that after the initial hour, sub-bandage pressure did not change much over a 24-hour period. In addition, we did not want to place the dog used in this study at undo risk (17 bandages) so we elected to focus on the initial bandage period. Although we found that pressures did not significantly change in either group after the first study hour, future work would need to address long-term sub-bandage pressures. Prior to this study, discussing and utilizing sub-bandage pressures as part of the curriculum were not performed. Thus, inadequate training is a simple explanation for the differences found between faculty and students. We did not perform a training session and follow-up with the same 10 veterinary students to evaluate the effectiveness of bandage instruction utilizing a recommended sub-bandage pressure range (identified from surgeon data) and a pressure measurement system. Utilizing methods similar to the Taylor and colleagues' study, students could be provided

their initial pressure results (baseline), receive instruction and time to practice their bandaging technique and then be retested.¹⁵ This information could provide insight into the effectiveness of utilizing a pressure measurement system in bandage instruction within a veterinary curriculum.

Although we took steps to limit variation in placement and movement of the balloons during bandaging, it is likely that there was some variation present. In addition, movement of the balloons could have occurred after bandage placement even though we elected to limit the dog's activity to a small room during the 4-hour testing period (as opposed to cage confinement). While this makes the results more of an estimate, we feel it makes them more similar to a clinical situation. The PicoPress Compression Measurement System likely only had small contributions to variation in our results. Thomas reported that the unit used in this study performed well relative to a reference transducer; the correlation coefficient between the two was $R^2 = 0.998$ with a difference in mean instrument readings of only 0.02 mm Hg.¹⁷ However, deformation of the balloons effected their performance and when the testing environment (large, foam covered cylinder surface) was similar to that of this study (antebrachium of a large breed dog), the sensor overestimated pressures.¹⁷ If a different pressure measurement system is used, the results may vary.

While application of a bandage too tight can create immediate problems to the patient, our finding that students had lower sub-bandage pressures suggest that we should also be aware of bandages that are too loose and perhaps result in motion over a region. To limit suboptimal bandage application and bandage complications and optimize treatment, it is critical to establish safe sub-bandage pressure ranges and instructional methods for veterinary students, interns and residents. As demonstrated by other authors, utilizing a pressure measurement system during training 'gives direct feedback on sub-bandage pressure...' which '...can help to improve the confidence and competence concerning the application of compression bandages'.¹⁰

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Conflict of Interest

The authors declare that there were no conflicts of interest.

References

- 1 Simpson AM, Radlinsky M, Beale BS. Bandaging in dogs and cats: basic principles. *Compend Contin Educ Vet* 2001;23:12–16
- 2 Campbell BG. Dressings, bandages, and splints for wound management in dogs and cats. In Swaim SF, Krahwinkel DF, eds. *Veterinary Clinics of North America: Small Animal Practice. Wound Management*: Elsevier; 2006:759–791
- 3 Weinstein J, Ralphs SC. External coaptation. *Clin Tech Small Anim Pract* 2004;19(03):98–104
- 4 Anderson DM, White RA. Ischemic bandage injuries: a case series and review of the literature. *Vet Surg* 2000;29(06):488–498
- 5 Meeson RL, Davidson C, Arthurs GI. Soft-tissue injuries associated with cast application for distal limb orthopaedic conditions. A retrospective study of sixty dogs and cats. *Vet Comp Orthop Traumatol* 2011;24(02):126–131
- 6 Iodence AE, Olsen AM, McGilvray KC, Duncan CG, Duerr FM. Use of pressure mapping for quantitative analysis of pressure points induced by external coaptation of the distal portion of the pelvic limb of dogs. *Am J Vet Res* 2018;79(03):317–323
- 7 Swaim SF, Vaughn DM, Spalding PJ, Riddell KP, McGuire JA. Evaluation of the dermal effects of cast padding in coaptation casts on dogs. *Am J Vet Res* 1992;53(07):1266–1272
- 8 Simpson AM, Radlinsky M, Deale BS. Bandaging in dogs and cats: external coaptation. *Compend Contin Educ Vet* 2001; 23:157–163
- 9 Partsch H, Clark M, Mosti G, et al. Classification of compression bandages: practical aspects. *Dermatol Surg* 2008;34(05): 600–609
- 10 Keller A, Müller ML, Calow T, Kern IK, Schumann H. Bandage pressure measurement and training: simple interventions to improve efficacy in compression bandaging. *Int Wound J* 2009; 6(05):324–330
- 11 Canada NC, Beard WL, Gyan ME, White BJ. Comparison of sub-bandage pressures achieved by 3 abdominal bandaging techniques in horses. *Equine Vet J* 2015;47(05):599–602
- 12 Dougherty P. Somatosensory Systems. In: Byrne JH, ed. *Neuroscience Online*. Available at: nba.uth.tmc.edu/neuroscience/s2/chapter02.html. Accessed December 2018
- 13 Nelson EA, Ruckley CV, Barbenel JC. Improvements in bandaging technique following training. *J Wound Care* 1995;4(04): 181–184
- 14 Reynolds S. The impact of a bandage training programme. *J Wound Care* 1999;8(02):55–60
- 15 Taylor AD, Taylor RJ, Said SS. Using a bandage pressure monitor as an aid in improving bandaging skills. *J Wound Care* 1998;7(03): 131–133
- 16 Partsch H, Mosti G. Comparison of three portable instruments to measure compression pressure. *Int Angiol* 2010;29(05): 426–430
- 17 Thomas S. Practical limitations of two devices used for the measurement of sub-bandage pressure: implications for clinical practice. *J Wound Care* 2014;23(06):300–313, 302–306, 308–309 passim
- 18 Partsch H, Damstra RJ, Mosti G. Dose finding for an optimal compression pressure to reduce chronic edema of the extremities. *Int Angiol* 2011;30(06):527–533