How is Forearm Compliance Affected by Various Circumferential Dressings?

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Abstract

Background The forearm is the second most common location for extremity compartment syndrome. Compliance is a physical property that describes a material's ability to expand with an increasing internal volume. The effect of circumferential dressings on extremity pressures has been investigated in various animal models and in some non-physiologic mechanical models, but the importance of this effect has not been fully investigated in the human upper extremity. In addition, the physical property of compliance has not been reported in the analysis of compartment volume-pressure relationships.

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Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Questions/purposes We created a physiologic cadaver model for acute compartment syndrome in the human forearm to determine (1) how much volume is required to reach the pressure threshold of 50 mm Hg in forearms, undressed and dressed with various circumferential dressings, (2) differences in forearm compliances that result from dressings, and (3) whether univalving or bivalving of those dressings adequately reduces compartment pressures. **Methods** A sealed inflatable bladder was placed deep in the volar compartment of seven fresh-frozen cadaveric forearms and overlying fascia and skin were closed. Compartment pressures were measured as saline was infused in the bladder, and compliance was calculated from pressure versus volume curves. This was repeated for each specimen using five external wraps, splints, and casts. At a baseline of 50 mm Hg, each dressing then was univalved (and bivalved, when appropriate for the material) and the decrease in compartment pressure was measured. For each of the seven cadaver forearms, one test was performed without dressings and then for each of five dressing conditions.

Results Forearms in fiberglass casts accommodated only a mean of 19 mL (SD, 11 mL; 95% CI, 9–28 mL) before reaching the 50 mm Hg pressure threshold, which was much less than in undressed forearms (mean, 77 mL; SD, 25 mL; 95% CI, 55–98 mL; $p < 0.001$). Mean compliances were as follows: ACE™ wrap (1.75 mL/mm Hg;

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SD, 0.41 mL/mm Hg), Webril™ (1.54 mL/mm Hg; SD, 0.56 mL/mm Hg), Kling® (1.23 mL/mm Hg; SD, 0.52 mL/mm Hg), sugar tong splint (1.05 mL/mm Hg; SD, 0.52 mL/mm Hg), and fiberglass cast (0.38 mL/mm Hg; SD, 0.27 mL/mm Hg). Univalving of all circumferential wraps dropped the mean compartment pressure from the 50 mm Hg starting point: ACE™ (46%; SD, 14%), Webril™ (52%; SD, 20%), Kling® (70%; SD, 18%), sugar tong splint (52%; SD, 19%), and fiberglass cast (58%; SD, 7%), with p less than 0.001 for all dressings.

Conclusions We observed the compressive effect of various commonly used upper-extremity splints and wraps, finding the least amount of accommodation afforded by fiberglass casts. Univalve release resulted in reduction in forearm compartment pressures, even in fiberglass casts.

Clinical Relevance A rigid circumferential dressing can have a dramatic effect on extremity compartment compliance. Contrary to common clinical teaching, univalving of forearm circumferential dressings effectively reduced compartment pressures, as shown in this physiologic model.

Introduction

Compartment syndrome of the extremities is a well-described clinical entity that must be recognized and treated promptly to avoid grave clinical sequelae. Increased tissue fluid pressure in a fascial muscle compartment results in capillary perfusion below the requisite level for tissue viability [1, 12, 15, 16]. If not properly addressed, irreversible muscle and nerve damage occurs, leading to necrosis, fibrosis, and contracture [10, 21]. Richard von Volkmann originally described this condition in the upper extremity after injury and subsequent application of tight, constricting bandages [23]. Several causative factors have been delineated and may be divided into those that are intrinsic (fracture hematoma, swelling, spontaneous bleeding, and inadvertent extravascular infusion of fluids [as through an infiltrated intravenous catheter]) [7, 11, 17] or extrinsic (external compression sustained during prolonged crush injuries and tight, circumferential dressings that become restrictive as the volume of the compartment increases) [4].

The forearm is second only to the leg as the most common site for extremity compartment syndrome. Compartment syndrome in the forearm usually occurs in the volar compartment but has been reported in other isolated compartments and also in individual muscles [3, 13, 14, 19, 20]. The effect of circumferential dressings on extremity pressures has been investigated in various animal models and in some nonphysiologic mechanical models, but the importance of this effect has not been fully investigated in the human upper extremity [6, 24, 25]. In addition, the physical property of compliance has not been reported in the analysis

of compartment volume-pressure relationships. Given the insults (swelling, hematoma) already incurred by tissues after injury, a better understanding of the effects of dressings on compliance is essential to prevent further injury.

We created a physiologic cadaver model for acute compartment syndrome in the human forearm to determine (1) what volume is required to reach the pressure threshold of 50 mm Hg in forearms, undressed and dressed with various circumferential dressings, (2) differences in forearm compliances that result from dressings, and (3) whether univalving or bivalving of those dressings adequately reduces compartment pressures.

Materials and Methods

Cadaver Model

Forearm compartment pressures were studied in seven fresh-frozen cadaveric upper extremities. The specimens were thawed overnight and then were amputated at the midhumerus. They included the hand and digits. A longitudinal incision was made in the volar forearm from 2 cm proximal to the radial styloid to 2 cm distal to the biceps tendon. Small proximal and distal windows were made in the superficial volar fascia between the brachioradialis and the flexor carpi radialis, and a sealed inflatable bladder (Fig. 1A) was placed deep in the volar compartment (Fig. 1B). The fascial and skin incisions were closed tightly with nonabsorbable sutures (Fig. 1C). A small infusion port was connected to the bladder and exited distally at the radial side of the wrist. Saline was infused in the bladder while compartment pressure measurements were made with a wick catheter in the proximal ulnar aspect of the volar compartment placed percutaneously. The pressure-measuring catheter was not in contact with the bladder but was in the same compartment. The catheter tubing was connected to a pressure-monitoring device (ProPac® 106; Protocol Systems Inc, Beaverton, OR, USA) and compartment pressures were measured as fluid was infused in the bladder. With each incremental increase of fluid in the bladder, the pressure was allowed to equilibrate and reach a stable value. The bladder was drained through the tubing and the measurements were repeated for each specimen using five commonly used upper-extremity wraps, splints, and casts. Each compressive dressing preparation then underwent univalve release and the compartment pressures were measured again.

The compressive dressings were applied in the following manner and sequential order. A 4-inch (10-cm) ACE™ wrap (Becton Dickinson and Co, Franklin Lakes, NJ, USA) was applied with 50% overlap and moderate tension to extend the length by approximately 50%. A 4-inch (10-cm) Webril™ wrap (Kendall Co, Princeton, NJ, USA) was applied with 50% overlap, two-layer thickness, and tension

Fig. 1A–C The images show the infusion and pressure-measuring devices in the cadaver forearm model. (A) The inflatable bladder, (B) the bladder inserted in the volar compartment, and (C) the skin and fascia closed over the measuring and infusion portals are shown.

enough just to begin to tear the Webril™. Three-inch (8-cm) Kling® wrap (Johnson & Johnson Co, New Brunswick, NJ, USA) was used with 50% overlap to provide two layers of thickness. For the sugar tong splint, a layer of Webril™ was followed by 10 layers of 3-inch (8-cm) plaster (Specialist® plaster bandage; Johnson & Johnson Co), and a Kling® wrap in the standard fashion (Fig. 2). A short-arm Muenster-type cast included stockinette, Webril™, and fiberglass cast material (Delta-Lite S®; BSN Medical, Charlotte, NC, USA) to just below the humeral epicondyles (Fig. 3). The fiberglass wrap was stretched slightly to avoid wrinkles, was not folded, and was applied to achieve four to five layers of thickness. All wraps were applied and tested in the same order for each specimen.

Volume Required to Reach Threshold

An intracompartmental pressure of 50 mm Hg was set as the threshold for the endpoint of the compliance measurements.

Fig. 2 A sugar tong splint was applied on this forearm. The infusion portal is radiodistal and pressure-measuring tubing exits proximoulnar.

Fig. 3 A Muenster-type fiberglass cast was applied on this forearm.

This value was chosen based on the clinical recommendations that compartment pressures should remain less than 30 mm Hg and more than 30 mm Hg below diastolic blood pressure. A compartment pressure of 50 mm Hg in a patient with a normal diastolic blood pressure would clearly be dangerous. For each of the seven cadaver forearms, measurements were taken once for each of six conditions (undressed and then wrapped serially in one of five circumferential dressings, as specified above), saline was injected in the bladder, and the volume of fluid used to reach the 50 mm Hg threshold was recorded.

Compliance Calculation

Compliance was defined mathematically as the change in volume over change in pressure in a specific pressure range. Pressure versus volume curves were generated for each specimen, and the compliance then was calculated from the slope of the curve in the linear region between

10 mm Hg and 50 mm Hg. The starting value of 10 mm Hg approximates a normal value for a resting compartment pressure, and it was the beginning of the linear portion of the curve in most specimens.

Effects of Univalving and Bivalving

Once maximal pressure had been reached, fluid was drawn back until the pressure equilibrated at 50 mm Hg, the compressive dressings were released on one or both sides (depending on material), and the final compartment pressure was recorded. ACE™ wrap, Webril™ wrap, and Kling® wrap were released to the skin for the univalved condition. Release of the sugar tong splint and fiberglass cast was performed only on the plaster and fiberglass material. Any padding beneath the rigid material was maintained. Univalving was performed on the ulnar border of the forearm completely from the most proximal to distal aspect, with scissors or a cast saw, as appropriate to the material. Bivalving included a similar linear cut on the radial aspect of the forearm through the full thickness of the material. Bivalving was performed only for the fiberglass casts, as the rigidity of the fiberglass material is thought to require release on both sides to effect a sufficient increase in compliance. Once the material was cut, there was no additional spreading or loosening of any of the constricting wraps. After the pressure measurement was taken, the bladder was drained, dressings were removed, and the cadaver forearm was exposed to the next dressing condition.

Statistical Analysis

The data were analyzed using ANOVA with Tukey's Honest Significant Difference test to compare volume to reach the threshold and compliance between dressing treatment groups. Univalve pressures were analyzed using the Mann-Whitney test against a value of 50 mm Hg. Univalve and bivalve pressures for the fiberglass cast also were compared using the Mann-Whitney test. All statistical analyses were performed using commercially available software (StatView®; SAS Institute Inc, Cary, NC, USA). All p values were two-tailed and the significance level was set at p values less than 0.05. The power of the study as detected post hoc by ANOVA in StatView® was 0.93.

Results

We recorded pressure versus volume (Fig. 4) and mean compliances for each dressing (Fig. 5). The undressed forearms accommodated the largest volume of saline before reaching the 50 mm Hg threshold (77 mL), whereas fiberglass casted forearms accommodated the least (19 mL) (Table 1).

The calculated compliance values (Table 1) revealed that the fiberglass cast (0.38 mL/mm Hg; SD, 0.27 mL/mm Hg) had less compliance compared with undressed forearms and those wrapped with ACE™ (1.75 mL/mm Hg; SD, 0.41 mL/mm Hg), Webril™ (1.54 mL/mm Hg; SD, 0.56 mL/mm Hg), and Kling® (Table 1) (1.23 mL/mm Hg; SD, 0.52 mL/mm Hg); however, the compliance from

Fig. 4 The graph shows representative pressure versus volume curves for the undressed forearm and each dressing in a single specimen. Each dressing has a notably different curve, with the cast requiring the lowest volume to reach 50 mm Hg in the compartment.

sugar tong splinting (1.05 mL/mm Hg; SD, 0.52 mL/mm Hg) and fiberglass casting approached, but did not reach, a statistically significant difference ($p = 0.06$) (Table 2).

Regarding the effects of dressing release, univalving decreased measured pressure from a starting point of 50 mm Hg in all groups (Table 3): ACE™ (46%; SD, 14%), Webri™ (52%; SD, 20%), Kling® (70%; SD, 18%), sugar tong splint (52%; SD, 19%), and fiberglass cast (58%; SD, 7%), with a p less than 0.001 for all

dressings. Furthermore, bivalving resulted in an additional 38% (SD, 3) reduction in pressure after initial univalving (Table 3). The final pressures after univalving and bivalving, however, were similar ($p = 0.07$).

Discussion

Assessment of compliance on human tissues is paramount to understanding the volume-pressure relationship with a limb injury so that medical intervention may offer the most benefit to the patient, without inadvertently jeopardizing the function or viability of the extremity.

Deficiencies in previous clinical investigations have prompted development of a more accurate model. The forearm is a complex structure that cannot be modeled by a simple tube and is anatomically different from the lower extremity [18]. Skin surface pressures under casts have been measured and shown to correlate with intracompartmental pressure measurements, but we sought a more accurate assessment by directly measuring intracompartmental pressure [22]. The installation of a latex balloon, as introduced by Sheridan and Matsen [21], was used but was

Fig. 5 The bar graph provides a comparison of the mean compliance in relation to each dressing. The vertical bars indicate the SD in the group. Of the dressings, the ACE™ had the highest mean compliance, whereas the cast had the lowest.

Table 1. Volume and compliance for each dressing

Dressing	Saline volume to reach 50 mm Hg (mL)		Compliance (mL/mm Hg)	
	Mean (SD)	95% CI	Mean (SD)	95% CI
None (undressed)	77 (25)	55–98	1.82 (0.72)	1.19–2.45
ACE™ wrap	72 (28)	47–97	1.75 (0.41)	1.39–2.11
Webri™ wrap	68 (26)	45–91	1.54 (0.56)	1.05–2.03
Kling® wrap	47 (29)	21–72	1.23 (0.52)	0.77–1.68
Sugar tong splint	45 (21)	26–63	1.05 (0.52)	0.59–1.51
Fiberglass cast	19 (11)	9–28	0.38 (0.27)	0.14–0.61

Table 2. P value matrix for compliance differences between respective dressings

Dressing	Undressed	ACE™	Webri™	Kling®	Sugar tong	Cast
Undressed		0.15	0.41	0.09	0.09	< 0.001
ACE™	0.15		0.52	0.79	0.41	< 0.001
Webri™	0.41	0.52		0.36	0.15	< 0.001
Kling®	0.09	0.79	0.36		0.57	0.01
Sugar tong	0.09	0.41	0.15	0.57		0.06
Cast	< 0.001	< 0.001	< 0.001	0.01	0.06	

Table 3. Effects of dressing release on compartment pressures

Dressing	Pressure after release (mm Hg)		Pressure decrease with release (%)	
	Mean (SD)	95% CI	Mean (SD)	95% CI
None (undressed)	–	–	–	–
ACE™ wrap (univalve)	27* (7)	21–33	46 (14)	34–58
Webri™ wrap (univalve)	24* (10)	15–33	52 (20)	34–70
Kling® wrap (univalve)	15* (9)	7–23	70 (18)	54–86
Sugar tong splint (univalve)	24* (9)	16–32	52 (19)	36–68
Fiberglass cast (univalve)	21* (4)	18–24	58 (7)	51–64
Fiberglass cast (bivalve)	13* (1)	12–14	74 [‡] (3)	71–76

* A one-group t-test significance of $p < 0.001$ compared with the value 50 mm Hg; [‡]Percentage decrease from the starting 50 mm Hg. This corresponds to 38% additional decrease after initial univalving.

enhanced by the use of a more accurate pressure-monitoring device connected to a catheter placed in the compartment. By creating this forearm cadaveric model, we aimed to determine (1) how much volume is required to reach a 50 mm Hg threshold under various circumferential dressings, (2) differences in forearm compliances that result from dressings, and (3) whether univalving or bivalving of those dressings adequately reduces compartment pressures.

Our study has some limitations. Specifically, forearm compliance and its correlation with compartment syndrome were measured only in the volar compartment. The volar compartment, however, is the most commonly affected with forearm compartment syndrome, and while the dorsal and mobile wad compartments were not directly assessed, the findings are likely representative of these compartments as well. Additionally, our analysis had a relatively small sample size of seven cadaveric specimens. Nonetheless, our sample size is larger than those of a couple studies, and analysis revealed adequate power [22, 24]. The skin was not reopened after each test to check the integrity of the fascia. We felt we would observe any suture failure with a sharp dip in the pressure tracer, so it was not worth the repeated trauma to the tissues to open and reclose the fascia after each trial. Finally, for each cadaver, measurements were taken once in each of six dressing conditions (undressed or with one of five circumferential dressings). While it is a limitation that only one iteration was performed in a particular cadaver for each dressing, we thought it preferable to have measurements from different specimens in the same conditions than to perform repeated measurements on one cadaver. At the other end of the spectrum, it may be argued that exposing the cadaveric fascia to numerable repetitions would change the mechanical properties of the tissue; thus, we elected to perform one measurement for each condition per cadaver.

The forearms on sugar tong splints accommodated more than twice as much fluid in the volar compartment than the forearms in fiberglass casts before reaching 50 mm Hg. This shows the tolerance for swelling that a splint affords as compared with an unyielding cast. The forearms enclosed in fiberglass casts required only 19 mL of fluid to create a simulated compartment syndrome, thereby emphasizing how a small amount of swelling or hematoma in the volar forearm could create dangerous pressures if a circumferential cast is applied. Literature reports contextualize our findings. von Volkmann cited tight, constricting bandages as the cause of post-ischemia contracture [23], and according to Bingold [5], Watson-Jones cautioned that “at the first sign of circulatory embarrassment, the plaster must be cut until the skin is widely exposed in the gap.” Using an air-filled tire inner tube, Bingold investigated the effects of splitting plaster and inner wrap around a compressible body [5]. He concluded that splitting plaster and creating a gap resulted in only 20% pressure reduction, but

complete release of the inner wool layer resulted in a 60% decrease. His study was one of the first to describe pressure changes after splitting of plaster and often is used as evidence that all of the deep padding below a cast must be removed to create any appreciable pressure drop. However, the simplistic model does not accurately reflect the complex architecture of the human extremity. Specifically, the circular inner tube shape does not mimic the open-ended tubular shape of the forearm. In addition, air is less dense than saline and thus is less pressure-sensitive to volume changes. Sheridan and Matsen [21] introduced an animal model to study the effects of increasing compartment pressures on nutrient blood flow and the histologic appearance of muscle necrosis [21]. Rabbits underwent placement of a latex balloon in the anterior compartment of the hindlimb which was connected to a water reservoir. Necrosis of anterior compartment musculature occurred after an increase of pressure between 50 and 60 mm Hg. Hargens et al. [9] used a canine model in which autologous plasma was infused into the anterolateral compartment of the hindlimb and pressures were monitored with a wick catheter [9]. They observed nerve and muscle damage proportional to the magnitude of intracompartmental pressure elevations.

Our results reveal a marked difference in compliance among the circumferential dressings studied. The forearm in a fiberglass cast had lower compliance compared with the specimens using all other extremity wraps. Although previous studies have examined pressure-volume relationships, they have not specifically assessed compliance [5, 9, 21, 23].

The order of dressing materials, from the most-to-least forgiving in terms of relative compliance, was ACETM wrap, WebriTM, Kling[®] wrap, sugar tong splint, and fiberglass cast. Univalving of all five compressive dressing preparations resulted in a mean pressure decrease of 56% (with a minimum decrease of 46%) resulting in a mean volar pressure of 22 mm Hg, with all values being less than 30 mm Hg. However, even with univalving, compartment pressures do not normalize to healthy, uninjured pressures (approximately 9 mm Hg in healthy volunteers) [2]. This observation is not meant to deemphasize the importance of complete release of all constricting bandages if a compartment syndrome is suspected but shows that univalve release does result in a large decrease in the compartment pressure. Using the canine model of Hargens et al., Garfin et al. [8] investigated the effects of plaster casts on volume containment and the effects of sequential splitting of casts and padding on intracompartmental pressures. Similar to our study, they discovered that, after univalve release and spreading of the casts, there was a 65% reduction in compartment pressures. This indicates that minimal trauma and swelling can create dangerously high pressures in a

confined compartment, jeopardizing tissue perfusion. Univalving of the dressing material decreased compartment pressures, even for fiberglass casts. These data contradict the widely held belief that a cast must be bivalved and the deep padding sectioned to achieve any meaningful pressure decrease.

Our study has identified the volumes required to reach dangerously high forearm compartment pressures and the compliance associated with six circumferential dressings. Additionally, dressing release (whether through univalving or bivalving) was shown to effectively reduce compartment pressures. These findings can be an important guide when considering the effects of different commonly used, compressive dressings, which markedly influence the tolerance of the forearm to volume increases. Future investigations should incorporate larger sample sizes and living, as opposed to cadaveric, tissue to achieve the most accurate assessment of the true clinical scenario.

References

- Aliano K, Gulati S, Stavrides S, Davenport T, Hines G. Low-impact trauma causing acute compartment syndrome of the lower extremities. *Am J Emerg Med*. 2013;31:890.e3–4.
- Ardolino A, Zeineh N, O'Connor D. Experimental study of forearm compartmental pressures. *J Hand Surg Am*. 2010;35:1620–1625.
- Baek GH, Kim JS, Chung MS. Isolated ischemic contracture of the mobile wad: a report of two cases. *J Hand Surg Br*. 2004;29:508–509.
- Bariteau JT, Beutel BG, Kamal R, Hayda R, Born C. The use of near-infrared spectrometry for the diagnosis of lower-extremity compartment syndrome. *Orthopedics*. 2011;34:178.
- Bingold AC. On splitting plasters: a useful analogy. *J Bone Joint Surg Br*. 1979;61:294–295.
- Deignan BJ, Iaquinto JM, Eskildsen SM, Woodcock CA, Owen JR, Wayne JS, Kuester VG. Effect of pressure applied during casting on temperatures beneath casts. *J Pediatr Orthop*. 2011;31:791–797.
- Eroglu A, Uzunlar H. Forearm compartment syndrome after intravenous mannitol extravasation in a carbosulfan poisoning patient. *J Toxicol Clin Toxicol*. 2004;42:649–652.
- Garfin SR, Mubarak SJ, Evans KL, Hargens AR, Akeson WH. Quantification of intracompartmental pressure and volume under plaster casts. *J Bone Joint Surg Am*. 1981;63:449–453.
- Hargens AR, Akeson WH, Mubarak SJ, Owen CA, Evans KL, Garetto LP, Gonsalves MR, Schmidt DA. Fluid balance within the canine anterolateral compartment and its relationship to compartment syndromes. *J Bone Joint Surg Am*. 1978;60:499–505.
- Harvey EJ, Sanders DW, Shuler MS, Lawendy AR, Cole AL, Alqahtani SM, Schmidt AH. What's new in acute compartment syndrome? *J Orthop Trauma*. 2012;26:699–702.
- Kagel EM, Rayan GM. Intravenous catheter complications in the hand and forearm. *J Trauma*. 2004;56:123–127.
- Kalyani BS, Fisher BE, Roberts CS, Giannoudis PV. Compartment syndrome of the forearm: a systematic review. *J Hand Surg Am*. 2011;36:535–543.
- Kumar PR, Jenkins JP, Hodgson SP. Bilateral chronic exertional compartment syndrome of the dorsal part of the forearm: the role of magnetic resonance imaging in diagnosis: a case report. *J Bone Joint Surg Am*. 2003;85:1557–1559.
- Kupersmith LM, Weinfeld SB. Acute volar and dorsal compartment syndrome after a distal radius fracture: a case report. *J Orthop Trauma*. 2003;17:382–386.
- Leversedge FJ, Moore TJ, Peterson BC, Seiler JG 3rd. Compartment syndrome of the upper extremity. *J Hand Surg Am*. 2011;36:544–559; quiz 560.
- McQueen MM, Duckworth AD, Aitken SA, Court-Brown CM. The estimated sensitivity and specificity of compartment pressure monitoring for acute compartment syndrome. *J Bone Joint Surg Am*. 2013;95:673–677.
- Newman MI, Kent KC, Clair DG, Nolan WB. Management strategy for compartment syndrome of the upper extremity arising during anticoagulation or thrombolytic therapy: an increasingly common surgical dilemma. *Ann Plast Surg*. 2003;51:308–313.
- Ronel DN, Mtui E, Nolan WB 3rd. Forearm compartment syndrome: anatomical analysis of surgical approaches to the deep space. *Plast Reconstr Surg*. 2004;114:697–705.
- Schmidt GL, Uroskie JA. Isolated compartment syndrome of the extensor carpi ulnaris: a case report. *Am J Orthop (Belle Mead NJ)*. 2004;33:519–520.
- Schumer ED. Isolated compartment syndrome of the pronator quadratus compartment: a case report. *J Hand Surg Am*. 2004;29:299–301.
- Sheridan GW, Matsen FA. An animal model of the compartmental syndrome. *Clin Orthop Relat Res*. 1975;113:36–42.
- Uslu MM, Apan A. Can skin surface pressure under a cast reveal intracompartmental pressure? *Arch Orthop Trauma Surg*. 2000;120:319–22.
- von Volkmann R. Ischaemic muscle paralyses and contractures. 1881. *Clin Orthop Relat Res*. 2007;456:20–21.
- Walker RW, Draper E, Cable J. Evaluation of pressure beneath a split above elbow plaster cast. *Ann R Coll Surg Engl*. 2000;82:307–310.
- Younger AS, Curran P, McQueen MM. Backslabs and plaster casts: which will best accommodate increasing intracompartmental pressures? *Injury*. 1990;21:179–181.