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Venous Hemodynamics After Total Hip Arthroplasty: A Comparison Between Portable vs Stationary Pneumatic Compression Devices and the Effect of Body Position

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ABSTRACT

Background: Improvements in device design have allowed for portable pneumatic compression devices (PPCDs). However, portability results in smaller pumps that move less blood. Additionally, although patients often stand when wearing PPCDs, few studies have evaluated the hemodynamic effects of PCDs while standing.

Methods: A crossover study was performed to compare a PPCD (ActiveCare+S.F.T.; Medical Compression Systems, Or Akiva, Israel) to a stationary pneumatic compression device (SPCD) (VenaFlow; DJO Global, Carlsbad, CA) on hemodynamics in supine and standing positions among 2 cohorts composed of 10 controls and 10 total hip arthroplasty patients. Differences in baseline peak venous velocity (PVV), PVV with each PCD, and delta PVV with each PCD were assessed. A multivariate analysis was performed to examine differences between cohorts, devices, and position.

Results: In both positions, the SPCD demonstrated a larger change in PVV when compared to the PPCD ($P < .001$). The total hip arthroplasty group had a greater delta PVV while standing when considering both PCDs together ($P < .001$). When considering both cohorts, delta PVV was greater while standing, only when the SPCD was used ($P < .001$). There was no difference between standing and supine positions when the PPCD was used.

Conclusion: The SPCD demonstrated a greater capacity to increase PPV in the supine and standing positions. The SPCD generated greater values of PVV and delta PVV in the standing position. Although these results demonstrate a difference between devices, it is important to establish the PVV necessary to prevent VTE before one is considered more effective.

Guidelines published by both the American Academy of Orthopaedic Surgeons (September 2011) and the American College of Chest Physicians (February 2012) support the use of mechanical compression devices alone or in combination with a pharmacologic agent after total hip arthroplasty (THA) for the prevention of venous thromboembolic (VTE) disease [1,2]. There has been sustained interest in the use of mechanical prophylaxis given its proven efficacy and the comparatively high risk of bleeding complications associated with pharmacologic agents. In the past, compression device efficacy has been limited by both patient compliance and the inability to continue use after hospital discharge. Newer portable designs of pneumatic compression devices are lightweight and potentially allow for better compliance, patient satisfaction, and continuation of mechanical prophylaxis after discharge [3–7]. However, such portable devices are battery operated and have a much smaller pump mechanism [3,4]. Prior studies have demonstrated that when compared to nonmobile stationary pneumatic compression devices (SPCDs), portable pneumatic compression devices (PPCDs) have a potentially higher

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rate of compliance and therefore the potential for lower rates of deep venous thrombosis (DVT) [3,5]. PPCDs have also been shown to be as effective as chemoprophylaxis in the prevention of DVT and pulmonary embolism (PE) after THA and total knee arthroplasty [8,9].

PCDs decrease rates of DVT formation by both enhancing venous return and augmenting venous endothelial fibrinolysis [10,11].Numerous designs are available with varying effect on venous flow as measured by the increase in venous velocity [6,7,11–13]. Several studies suggest that the magnitude of increase in venous velocity is a good hemodynamic measure of device efficacy as higher velocities may result in decreased rates of DVT [7,11,12,14]. Despite this, the minimum venous velocity augmented by mechanical compression necessary to prevent thromboembolic events is unknown.

Prior studies have demonstrated that THA alters venous hemodynamics within the lower extremity. Postoperative patients have been shown to exhibit decreased venous outflow, decreased venous capacitance, and a prolonged return to baseline that can persist for up to 6 weeks [15]. Despite this, most manufacturers use healthy subjects to assess the efficacy of new devices and many previous studies evaluating the effect of PCDs on changes in peak venous velocity (PVV) include only normal subjects [6,13]. Furthermore, although venous flow within the lower extremities is known to be position dependent, there is little evidence regarding the effect of both surgery and body position on venous hemodynamics.

The purpose of this study is to compare the effect of a PPCD (ActiveCare+S.F.T.; Medical Compression Systems, Or Akiva, Israel) to that of a stationary compression device (VenaFlow; DJO Global, Carlsbad, CA) on venous hemodynamics among both healthy control subjects and postoperative THA patients. The study also aims to determine the effect of patient position on venous hemodynamics by measuring hemodynamic changes in both supine and standing positions.

Methods

A crossover study was performed to evaluate the hemodynamic effects of 2 PCDs in both supine and standing positions. Ethical approval from the hospital's institutional review board was obtained prior to conducting the study. Written consent was obtained from each study subject prior to obtaining measurements. The 2 devices under investigation were the ActiveCare+S.F.T. (Medical Compression Systems), a PPCD, and the VenaFlow (DJO Global), an SPCD. The ActiveCare+S.F.T. delivers sequential compression at a pressure of 50 mm Hg and uses 8 seconds of compression followed by 36-56 seconds of decompression in synchronization with the respiratory-related venous phasic flow. The VenaFlow is a rapid inflation asymmetrical compression device. It is inflated rapidly once every minute with a duration of compression of 6 seconds, at a preset pressure of 45-52 mm Hg.

All study subjects were analyzed with both devices. Computer randomization was used to determine which device was applied and tested first.

Two cohorts were evaluated in the study, one composed of 10 healthy control subjects and the other composed of 10 postoperative THA patients. All patients were >18 years of age and those within the THA cohort had undergone primary unilateral THA for an indication of primary osteoarthritis. All surgeries were performed by a single surgeon (senior author G.W.) via a posterolateral approach during a 6-month period between the dates of September 2015 and February 2016. Within the THA cohort, the study was performed on postoperative day 2 for all study subjects. The healthy cohort was composed of employees at the authors' institution who volunteered to be part of the study. No patient with a history of DVT, PE, congestive heart failure, peripheral vascular disease, prior arterial reconstruction, saphenous vein stripping, vasculitis, varicose veins, venous insufficiency, or morbid obesity (body mass index >40) was included in the study.

For each study subject, the PCD selected to be tested first was applied to both lower extremities, with readings obtained from only the operative extremity in the THA cohort and the right lower extremity in the control cohort. The application of each PCD was performed by the testing ultrasound technician and conformed to the manufacturer's specifications. Both devices are calf pump design PCDs and were therefore placed directly onto the leg and wrapped circumferentially around the calf region. Baseline readings of PVV were obtained while in the supine position after the PCD had been applied, but not turned on. Before measurement of the PVV, the common femoral vein was checked for the absence of acute thrombosis; none was seen within any of the test subjects. Using the LOGIQ e9 (GE Healthcare) ultrasound unit with a 9-MHz linear probe, the common femoral vein above and below the junction with the greater saphenous vein was identified, and the skin was marked with an indelible marker by the ultrasound technician performing the readings. Baseline venous velocity was determined at the 2 marked locations. At each position, 3 separate measurements of PVV were obtained using either power Doppler or color Doppler sonography.

Next, the device was powered on and the device pressure, cycle time, inflation time, and hold time were set to the respective manufacturer's recommended settings. After several pump cycles of compression (minimum 5 minutes), a wave tracing of venous blood flow, consistent with inflation of the pump, was recorded. Using the proprietary software within the ultrasound scanner, the PVV was calculated. The change in venous velocity from baseline to peak was also calculated and defined as delta PVV. Next, the device was turned off and the patient was placed in a standing position. Again, baseline readings were obtained 3 times, the device was turned on, allowed to cycle, and 3 readings, timed with inflation of the pump, were then obtained. The study subject was then asked to lie back down in the supine position, and the same series of events was performed for the alternate PCD.

Statistical Analysis

Univariate Analysis

Differences between the control cohort and the THA cohort in baseline PVV, PVV with VenaFlow, PVV with ActiveCare+S.F.T., delta PVV with VenaFlow, and delta PVV with ActiveCare+S.F.T. were assessed using Wilcoxon rank-sum test in either the supine or standing position. To determine the effect of position on hemodynamics, Wilcoxon signed-rank test was used to compare, within each cohort, supine to standing baseline PVV, supine to standing PVV with VenaFlow, supine to standing PVV with ActiveCare+S.F.T., supine to standing delta PVV with VenaFlow, and supine to standing delta PVV with ActiveCare+S.F.T.

Multivariate Analysis

Multiple linear regression based on generalized estimating equation was performed with delta PVV as the primary outcome. The multivariate analysis was designed to examine differences in delta PVV between cohorts, the devices tested, and patient positions to account for the repeated measure design of the study when controlling for age, gender, and baseline PVV. In addition, an interaction term was introduced between position and device tested. This allowed for the examination of the relationship between devices and delta PVV to be different between positions or the relationship between positions and delta PVV to be different