Understanding the Biomechanics of Cast-Induced Heel Pressure Sores using a Sensor Model: Novel Device Significantly More Effective at Alleviating Pressure Compared to other Interventions

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INTRODUCTION:

Casting is an important technique used within orthopaedics to immobilize a limb and either maintain a reduction or obtain an alignment among pediatric patients with congenital deformities. Greater than 90% of pediatric fractures are treated nonsurgically, often with cast immobilization at our institution. While often regarded as the “least invasive” treatment for a fracture, complications can occur. In one study, (Abzug et al), 40% of patients immobilized by primary care and emergency room providers reported soft tissue injuries. While many of these injuries are minimal, casts can lead to serious consequences and pressure sores are one of the most common. Pressure sores can range in severity, from a superficial discoloration of the skin to a deep wound exposing the underlying tissue or bone. These are thought to occur when pressure is placed on a region of tissue that restricts blood flow and perfusion, resulting in a lack of oxygen and nutrient delivery to the skin causing necrosis. Depending on the size and severity of the lesion, surgical interventions may be necessary. The literature pertaining to pressure sore prevention under a cast is sparse. Understanding the variables that put a limb at risk and what can be done to mitigate these risks should help prevent these injuries from occurring. In this study, we 1) tried to define the “current clinical state” of understanding of the risk factors associated with pressure sores by interviewing Health Care Professionals (HCP) familiar with caring for patients in casts to identify the scenarios and patients that seem most at risk and 2) We then developed a “heel pressure model” to test several clinical scenarios to determine their impact on heel pressure under the cast.

METHODS:

Eighteen HCP from two institutions who were familiar with casting were surveyed regarding experience and risk factors associated with pressure sores and responses summarized. A composite lower extremity model was equipped with 4 thin wire pressure sensors. A series of uniform, short leg lower limb casts were applied to simulate a well-fitting cast, a cast applied over a swollen foot/leg (edema simulated with inflatable air bladder), and a loose-fitting cast (following resolution of edema-deflating air bladder). Weight was applied (0-5 lbs) to the internal skeleton of the limb via an external fixature pin placed in the foot to simulate increased weight of the limb and/or hamstring muscle contraction. The model was designed to also allow longitudinal displacement of the cast to study the effects of motion within the cast. The effects of several clinically utilized strategies to minimize heel pressure were also tested. All variables were tested in triplicate. The maximum values from each trial were used to compare the relative differences in pressure at the heel for each variable. Two-sample equal variance, one-tailed distribution t-tests were performed on the data to determine statistical significance with an alpha = 0.05.

RESULTS:

In total, 100% of the 18 HCP surveyed have identified pressure sores among patients in the last year. Only 61% believed that the sores were reported in the medical record for every incident. The most common clinically reported location for a pressure sore in the lower extremity was the posterior heel, under a long leg fiberglass cast. The most commonly reported intervention utilized to mitigate these injuries was to place additional cast padding over the posterior heel (Figure 1).

The heel pressure model demonstrated that presence of a well-fitting cast distributed the pressure experienced on the heel significantly at each weight when comparing a bare leg to a well-fitting standard cast ($p < 0.05$). The pressure experienced at the heel was similar between well-fitting standard casts and loose swelling casts ($p > 0.1$). However, heel pressure significantly elevated with displacement of the cast (Figure 2). Additional padding over the heel did not significantly reduce pressure ($p = 0.21$) (Figure 3). However, a novel device (ND) demonstrated a significant reduction in heel pressure with displacement ($p = 0.038$) (Figure 3). Furthermore, ND significantly reduced heel pressure compared to other commonly used interventions (Figure 3).

DISCUSSION AND CONCLUSION:

Heel pressure sores are a significant problem as 100% of HCP surveyed had clinically observed patients with heel pressure sores. Our model has allowed testing of various risk factors and preventive interventions, indicating that displacement between the limb and cast significantly elevates heel pressure and has more of a significant effect than simply adding weight. Furthermore, this model demonstrates the most commonly reported preventive practice of adding extra heel padding is ineffective at reducing pressure at the heel. Other tested methods including felt wool (Difazio et. al., 2017) were less effective in reducing heel pressure compared to the ND. We are now in the process of validating our findings in humans.

Figure 1. What are current preventive measures used with casts?

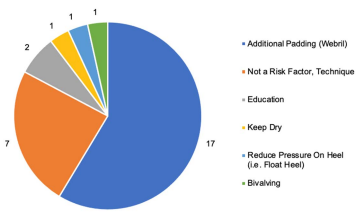

Figure 2. Heel Pressure Significantly Increases with Displacement of the Cast

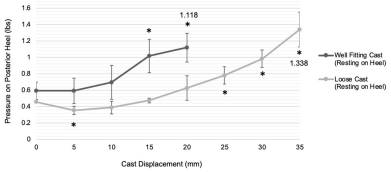

Figure 3. Novel Device Signficantly Decrease Heel Pressure with Displacement Compaired to Other Interventions