Development of a Surrogate Bruising Detection System to Describe Bruising Patterns Associated with Common Childhood Falls

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Executive Summary

Child abuse is a leading cause of trauma-related fatality in children 0-4 years of age [DHHS, 2006]. Roughly 1500 children are fatally injured each year in association with child abuse and 150,000 are permanently disabled [DHHS, 2006]. Fatalities were greatest amongst children 1 year of age and younger. Many serious injuries and fatalities could have been prevented if clinicians and child protective services were able to better distinguish between those injuries associated with abuse and those injuries caused by accidents. Clinicians, child protective services and law enforcement personnel would greatly benefit from knowledge related to the types of injuries that are truly possible from common household accidents often reported to be the underlying cause of injury in child abuse. Knowledge of the type of injuries that can result from common household accidents can equip personnel responsible for distinguishing between abusive and accidental injuries with information that is key to decision-making. Although not life threatening injuries, bruising patterns provide a "roadmap" documenting a child's exposure to violence or a simple childhood fall. That is, for each and every substantial impact to the child's body, a resulting soft tissue injury will likely develop. Previous studies have shown that bruising patterns resulting from abuse are significantly different than those resulting from accidents [Atwal, 1998; Dunstan, 2002; Pierce, 2010]. This distinguishing feature of abuse is often overlooked in the clinical setting, as well as in forensic investigations. In a forensic investigation of physical child abuse, a child's bruising "roadmap" can permit engineers to evaluate the compatibility of the biodynamics of the stated cause (e.g. stairfall or bed fall) and the presenting soft tissue injuries. Failure to verify biodynamic compatibility between the bruising pattern and stated cause should raise questions regarding the veracity of the provided history. It is this evaluation of biodynamic compatibility based upon the bruising "roadmap" that our study aimed to address.

Our long-term goal was to develop a forensic tool that can be used to delineate between child abuse and accidents based upon presenting bruising patterns. Our project goal was to design and develop a prototype surrogate bruising detection system capable of capturing and recording potential bruising patterns that occur in child surrogates when used in simulated household fall events often stated as false histories in child abuse (US Patent No. 12/154,166). Since children 1 year of age and younger experience increased abusive fatality rates, our bruising detection system was designed for use with a surrogate representing a 1-year-old child. This forensic tool will ultimately be utilized to develop a knowledge base of bruising "roadmaps" that are associated with common childhood fall events. The data generated from use of our system could also aid in assessment of events stated as causes of bruising in specific child abuse forensic investigations.

Our approach consisted of 1) designing and fabricating customized force sensors that can be of varying sizes and arranged in matrices contouring to the various segments of a pediatric anthropomorphic test device (ATD), 2) designing and developing a prototype force sensing skin that was adapted to the ATD forearm, 3) designing and developing a prototype data acquisition system that collected and compiled sensor output data from the ATD forearm, 4) designing and developing a prototype computerized visual body mapping system capable of displaying impact force application and corresponding locations and patterns of potential bruising on the ATD forearm, 5) integrating and demonstrating functionality of the surrogate bruising detection system consisting of the prototype forearm sensing skin adapted to the ATD, data acquisition system and computerized body (forearm) mapping image system, and 6) extending the prototype surrogate bruising detection system to the entire ATD.

In our study we designed and developed a surrogate bruising detection system that can used to predict and investigate potential bruising patterns in simulated falls or events involving children. The system consists of 1) custom-designed, low-cost pressure sensors that are integrated into matrices incorporated into a "skin" that adapts to a commercial 1-year-old ATD (CRABI ATD), 2) a data acquisition system capable of capturing and

recording force sensor output and location during a simulated fall or other event, 3) a computerized body mapping system that displays color-coded sensor output indicating the level of applied force to specific body regions. Our surrogate bruising detection system will be capable of predicting potential bruising numbers, patterns and location when adapted to a 1-year-old ATD and used in simulations of falls or other events. (Note: simulations of falls and other events are beyond the scope of this project.) It is important to note that our system will indicate *bruising potential*, and will not definitively indicate whether a bruise would occur or not given variations in bruising thresholds across individuals. Our bruising detection system is limited by the biofidelity of the ATD (how "human-like") to which it is applied. For example, material representing the ATD soft tissue may not possess the same biomechanical properties of human soft tissue, thus influencing the measured force application to a specific region of the ATD body. Moreover, movement or dynamics of the ATD during a fall are typically dependent upon joint biomechanical properties; in relatively low speed events such as falls, the CRABI ATD joint responses may not be consistent with those of a human child. Such differences can influence fall dynamics, and thus predicted bruising patterns.

When used to simulate an event, the surrogate bruising detection system will have the potential to aid in the overall assessment of whether a child's injury was a result of abusive or accidental trauma. The surrogate bruising detection system will be a tool that can aid in child abuse diagnosis, investigations, and prosecution by providing objective data regarding bruising patterns. (Similarly, this data can also aid in the exoneration of caregivers who are innocent of inflicting physical abuse.) In the diagnosis, investigation and legal prosecution of child abuse cases, bruising patterns are often disregarded by pediatricians, child protective services, law enforcement personnel, biomechanics experts, and the judicial system given that these injuries are typically non-life threatening. However, ignoring the presence of bruising patterns is a missed opportunity to gain a better understanding of the environment that a child has been exposed to since bruising provides a "roadmap" of the child's exposure to force application.

Bruising patterns are critical to biomechanical expert witness testimony in child injury litigation, providing key evidentiary data in the assessment of biodynamic compatibility of a stated cause and resulting injuries. The cumulative number of bruises and their location has been shown to aid in the discrimination between abuse and accident in children. Use of our device is expected to provide clinicians, child protective services, law enforcement personnel, biomechanical experts, and judiciary personnel with objective data as to the bruising patterns that can be expected in common household accidents that are often provided as false histories in an effort to conceal child abuse. Conversely, use of the surrogate bruising detection system in its ability to provide objective data regarding bruising patterns can also serve to exonerate those who are innocent of alleged abuse. In summary, the surrogate bruising detection system will have the potential to objectively elucidate the differences in bruising patterns that may occur in abusive vs. accidental trauma to aid in the diagnosis and prosecution of child abuse.

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