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Pressure Distribution at the Device Skin Interface of a Cervical Collar: Finite Element and Physical Modelling

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Introduction

Cervical collars form part of the standard immobilization procedures for patients with suspected cervical spine injury. However, several issues with their use have been identified [1], including the risk of pressure ulcers from prolonged mechanical loads at the device-skin interface. Direct measurement of device-skin interface pressures has been used to evaluate this risk. However, these measurements are limited to discrete points or small regions of interest. To get a better understanding of the pressure ulcer risk, it is important to evaluate the distribution of pressure across the whole interface and to evaluate the interface stress and strain values in the skin and sub-dermal tissues. Several studies have successfully used finite element modelling to evaluate the device skin interactions [2]. However, to date, cervical collars have not been thoroughly investigated. This study aimed to evaluate the interface biomechanics of the rear portion of a cervical collar using a finite element model. The predicted mechanical conditions at the device interface were corroborated with physical model bench testing.

Methods

A Stiffneck cervical collar, commonly used in the prehospital treatment of suspected spinal injury patients was evaluated in this study. A physical model measured tension in the lateral straps and interface pressure at points across the collar back panel. The physical model consisted of a composite shell with a silicone skin layer matching the shape of the medium head shape from the NIOSH database. The collar padding was modelled with second-order hexahedral elements with a Neo-Hookean material model (E = 200 kPa, v= 0.3). The collar plastic was modelled with second-order quadrilateral elements with a Neo-Hookean material model (E = 100 MPa, v = 0.4). The head was modelled from surface scans of the physical model as a rigid surface. Displacements applied to the sides of the collar represented the applied strap tension.

Results & Discussion

Figure 1 shows the interface pressures observed from the finite element model across different strap tensions. The finite element model corroborated with expected maximum interface pressures at a normal loading tension, measured with the physical model. Areas of high pressure observed in the finite element model match those identified as high risk in the literature [3], corresponding to the occiput and shoulders.

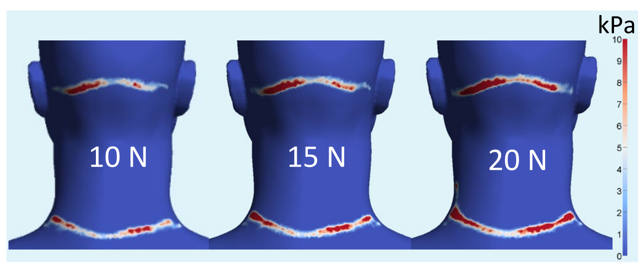

Figure 1: Finite element model interface pressures

Conclusion

By combining physical and finite element modelling a better understanding of the biomechanics at the device-skin interface can be established. This work has demonstrated that pressure distribution can be evaluated for cervical collars. Future work will develop finite element models that also consider the role of soft tissue in the device-skin interface mechanics. In addition, population-based variations of head and neck shape will be included in parametric studies of collar design and fit.

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References

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