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 a 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. Interface pressure is the standard for evaluating the mechanical conditions between devices and the skin. However, it is difficult to get a complete evaluation of interface pressure from *in vivo* studies. Measurement systems are mostly 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 internal 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 model a generic cervical collar design over an area of skin at risk of ulceration using a finite element model. The predicted mechanical conditions at the device interface were corroborated with physical model bench testing.

Methods

A physical model measured tension in the lateral straps and interface pressure at points across the collar back panel (Figure 1). The physical model consisted of a composite shell with a silicone skin layer matching the shape of a medium NIOSH head. The finite element model consisted of the back of a generic collar modelled as an 8 mm thick oval with second-order hexahedral elements (E = 0.5 MPa, ν = 0.4) (FEBio, USA). 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.

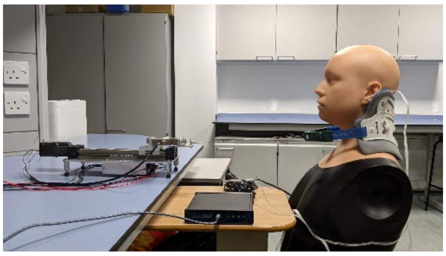

Figure 1: Physical model test setup

Results

Table 1 compares the strap tension and interface pressures between the physical and finite element models.

Test	Strap Tension [N]	Interface Pressure [mmHg]
Physical Test (Miami J)	9.9	36
Physical Test (Philadelphia)	9.9	88
FE Model	10.2	90

Table 1: Physical and finite element model strap tension and maximum interface pressures.

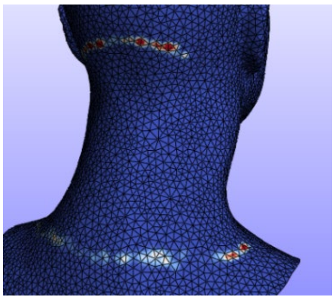

Figure 2: Finite element model interface map showing the back of the neck

Figure 2 shows the pressure distribution of the generic collar model. Areas of high pressure were present at the occiput and over the shoulders.

Discussion

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. By using a combination of 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 a generic collar design. Future work will develop finite element models specific to popular collar designs. In addition, population-based variations of head and neck shape will be included in parametric studies of collar design.

References

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2. Bader et al, BioMed Eng OnLine, 17:40, 2018.
3. Ham et al, Injury, 47:1924-1931, 2016.

Acknowledgements

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