The effects of two different pressure relieving support surfaces on the blood circulation deep in the tissues – A positron emission tomography (PET) study

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Introduction

A pressure ulcer is localized injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure, or pressure in combination with shear (NPUAP, EPUAP & PPPIA 2014). Pressure and shear induce complex stress reactions within tissues which may be major pathophysiological phenomena in the PU development. Thus mechanical loading of tissues may cause critical deformation i.e. the deformation threshold is exceeded. Capillary flow changes may lead to hypoxia and by reaching the hypoxia threshold (Gefen 2015, Oomens 2015).

We have previously shown in randomized controlled trial that the minimum pressure air mattress (MPA, Carital Optima) compared to foam mattress decrease significantly the development of PUs in severely ill intensive care patients (RR 0.95, CI 0.00;0.42, p=0.0059, Takala et al. 1996). One of the mode of actions of the minimum pressure mattress is that the hypoxia threshold is not reached (Soppi et al 2015). Using the experimental design of the current study we wanted investigate other potential modes of action of this mattress.

Methods

Crossover study design was used. Healthy volunteers (N = 8) received both venous and arterial cannulas after signing their consent. One study subject was studied daily since it took 7-9 hrs for the subject to pass all the study procedures. The region of interest (ROI) for study procedures was pelvic region with sacral area focus.

The study subjects were to lie supine for 90 min on either foam (density 46 kg/m^3 and CLD-hardness 6.5 kPa, Levy et al 2014) or computerized, individually and precisely adaptive minimum pressure air mattress system (MPA, Carital Optima). Surface contact area was determined by FSA Pressure Mapping Systems (Vista Medical) after a stabilization period in the beginning of exposure on both mattresses (Figure 1). Thereafter the FSA system was removed and the study subjects were asked to lie immobile in supine position for the next 90 min. The temperature (Phillips Intell Vue X2) from the skin - mattress interface was recorded throughout the 90 min exposure. Subepidermal moisture was measured by MoistureMeter (Delfin Technologies) before and after the exposure from the sacral region as well as from the control non-exposed region. Skin oxygen tension (Radiometer TCM 4/40) was recorded close to anterior iliac crests as well as from the control region.

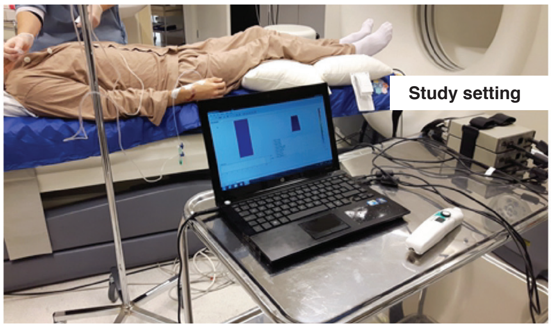

Figure 1. The study setting in the beginning of procedures with the FSA mat in place

PET is an imaging technology enabling non-invasive study of physiological processes within different tissues. We applied PET with low energy CT to study the effects of mattresses on tissue perfusion (ROI) utilizing radiowater ($^{15}O-H_2O$).

Approvals. The study plan was approved by the ethical committee of hospital district of Southwest Finland (ETMK:88/1801/2016, §78 27.2.2017) as well as by the National Supervisory Authority for Welfare and Heath. The study fulfills also the requirements of clinical trials for medical devices (ISO 14155:2011).

Results

Skin temperature reached about 0.5-1°C higher values on foam than on the air mattress (Figure 2, p<0.001).

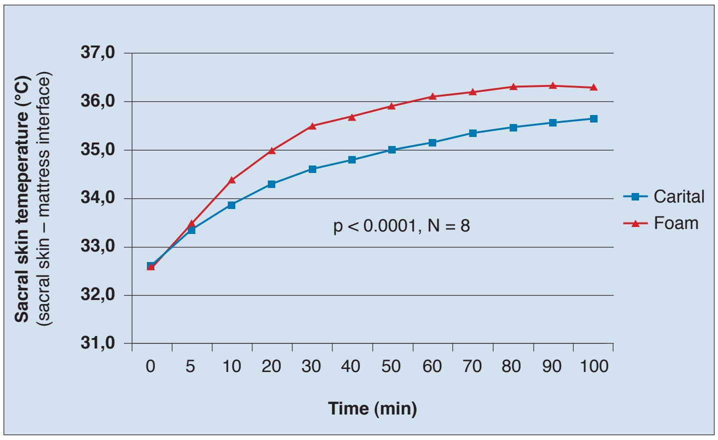

Figure 2. The behavior of temperature on skin – mattress interface

The body-mattress contact area around ROI was significantly smaller on foam than on MPA (Figure 3, p<0.0034).

Minimum pressure air mattress **Foam mattress**

ROI: 1589 (sd 165) Contact area (cm^2), mean (sd) **p = 0.0034** **ROI: 1202 (sd 60)** Contact area (cm^2), mean (sd)

Figure 3. Body –mattress contact area as measured by the FSA mat

The body contour on ROI as detected by CT remains more unchanged on the air mattress compared to foam which induced 1-26 % (Figure 4, p < 0.0001) lateral spreading of tissues indicating major tissue deformation and within tissues on foam.

Minimum pressure air mattress Foam mattress

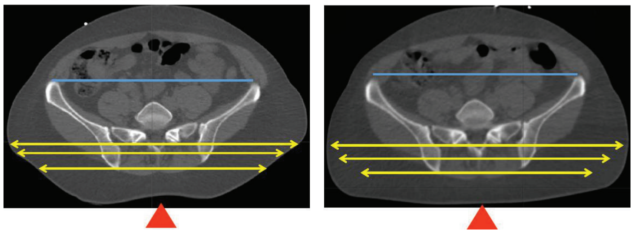

Figure 4. Low energy CT to determine ROI for the PET images. Tissue flattening on foam compared to minimum pressure mattress is here 3.4, 10.4, and 25.2% from top to down, respectively. The range is from 1 to 26 % depending on individual characteristics

PET results show complex, dynamic and unexpected blood flow changes deep in the tissues between the mattresses which seem to be dependent on body shape and the pressure on ROI (Figure 5).

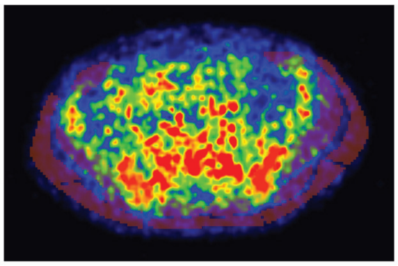

Figure 5. The one 3,3 mm section of positron emission tomography (PET).

Conclusions

The results indicate that there is a difference regarding the microclimate environment between the two mattresses. The body contact area was significantly higher on the minimum pressure air mattress (MPA) than on the foam mattress in spite of the tissue spreading on foam (Figure 3,4). This indicates that pressure redistribution within the MPA leads to superior immersion-envelopment equation and pressure equalization within the tissues. As a result the tissue deformation and strain leads are apparently minimal on the minimum pressure air mattress compared to the foam mattress. Thus on the foam mattress both hypoxia and deformation thresholds may be exceeded while on the MPA mattress neither will take place. This is an indication of the additional mode of actions that are explaining the superior clinical results that have been previously achieved with MPA (Takala et al 1996, Soppi, 2013, Soppi et al 2015).

Literature

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