SHORT REPORT

The viability of soft tissues in elderly subjects undergoing hip surgery

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Abstract

Aims: to assess the viability of soft tissues in elderly patients subjected to prolonged support pressures.

Design: measurements were performed on the soft tissues of patients undergoing surgery for fracture of the proximal femur.

Methods: 10 subjects, mean age 84 years, participated. Transcutaneous gas tensions were continuously monitored in an area adjacent to the contralateral greater trochanter, which was loaded with an external applicator. Subcutaneous interstitial pressures using a slit catheter were also measured.

Results: transcutaneous oxygen partial pressure fell in some patients to critically low levels, defined as below 2.7 kPa (20 mmHg), whilst they were subjected to normal interface pressures on the operating table. Transcutaneous partial carbon dioxide pressures rarely rose above 8.0 kPa (60 mmHg). The measured interstitial pressures could lead to local occlusion of skin microvessels.

Conclusions: this study confirms that tissue viability could be compromised in elderly patients undergoing surgical procedures. The methods employed may be of value in assessing support surfaces in the operating theatre to reduce the incidence of pressure sores in this high-risk patient group.

Keywords: elderly population, orthopaedic surgery, pressure sores, support surfaces, tissue viability, transcutaneous gas tension

Introduction

Pressure sores are a major cause of morbidity and prolonged hospital stay. Although the overall prevalence in hospitals in the UK is about 9% [1], this figure rises with age and ill-health [2]. Versluysen [3] reported an incidence of 32% overall in elderly patients who were admitted for elective hip surgery or management of proximal femoral fractures. Of these, 17% were present on admission, and of the remainder, 34% developed sores within the first week and a further 24% in the second week. In this comprehensive study, 16% developed a sore on the day of operation, suggesting that the day of surgery appears to be a critical period for sores to develop [4].

If body tissues are subjected to pressures which are applied in a non-uniform manner, then localized tissue damage can result. This occurs in many situations in which the body is placed on a support surface. The resulting stress and strain fields within the soft tissues may be sufficient to impair both the local blood supply, causing hypoxia, and the lymphatic circulation, resulting in an accumulation of toxic intracellular metabolites. If unfavourable interface conditions are prolonged, cell necrosis will follow, leading to local tissue breakdown and the development of pressure sores. Prolonged ischaemia reperfusion may also promote tissue damage [5], possibly due to the production of oxygen-derived free radicals [6].

The sacrum and greater trochanters have minimal soft tissue covering and have an inherent high compressive stiffness; these are two of the most common sites for pressure necrosis. The biomechanical changes associated with ageing may also predispose the soft tissues to breakdown in elderly people. Intermittent reductions in interface pressure allow higher pressures to be tolerated over prolonged time periods [7]. This forms the basis of pressure relief.
regimes, which are performed by regular turning of susceptible patients and lifting off of the support surface. The nature of tissue recovery following ischaemia is determined by the resilience of the specific tissues, including the blood and lymph vessels, systolic blood pressure and the reactive hyperaemic response. All these factors are likely to be affected by age [8].

The protective process of discrete movement associated with ischaemic discomfort is present in the normal sleep pattern but is obliterated during deep levels of surgical anaesthesia. Sudden reperfusion, as with rapid intravascular fluid administration, or sudden release of the source of external pressure, can be harmful as they can cause local capillary collapse, exacerbating the ischaemia and resulting in necrosis [9]. Elderly patients undergoing surgical treatment for proximal femoral fracture are at still greater risk of pressure sore development for they have severely limited mobility, often sit or lie on hard surfaces and are unable to turn due to the painful hip fracture [10]. They may also be malnourished [11]. Cardiac failure and atherosclerosis further impair the skin's circulation, and sensation may also be affected as a result of a stroke, analgesia or pre-medication.

The Oxford Pressure Monitor provides an accurate measure of the pressure distribution at the patient-support interface [12]. However, the measurement of interface pressure alone is not sufficient to alert the clinician to potential areas of tissue breakdown. Some measure of tissue viability is required which is dependent upon an adequate supply of nutrients as supplied by the blood. Transcutaneous oxygen tension measurements ($T_cPO_2$) have been used to objectively assess tissue viability in various clinical conditions, such as ischaemic limbs [13]. There is wide variation in the integrated pressure and time which the soft tissues will tolerate [14]. The applied pressures to produce, for example, a 50% reduction in the unloaded resting value of $T_cPO_2$ range from 3.0 kPa (22 mmHg) to 12.2 kPa (92 mmHg). This highlights the individual nature of the tissue response, which should be determined before clinical guidelines of safe pressure levels can be established.

The present study investigates the effects of support pressures on objective measures of soft tissue viability in a group of elderly patients undergoing surgery for fracture of the proximal femur.

**Materials and methods**

Ethical approval of this study was obtained from the central Oxford research ethics committee. The study comprised 10 patients—seven women and three men—who underwent dynamic hip screw fixation of their proximal femoral fractures. The mean age was 84 years (range 67–95 years).

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**Figure 1.** Typical position of the patient during an operation for dynamic hip screw fixation of the proximal femur.

On admission to the ward, skin traction was applied to the patient's leg to stabilize the fracture. Intramuscular analgesia was usually administered. The median waiting time between admission and surgery was 12 h (range 2–72 h). Intravenous fluid rehydration was provided in the interim. Fracture fixation was performed with the patient supported on a standard orthopaedic table which is both hard and narrow to give good stability and ease of access for the surgeon (Figure 1). The sacrum and coccyx transmitted the whole weight of the lower trunk through a small surface area. The patient's feet were supported in shoes attached to the table by adjustable arms to allow positioning and traction of the lower limbs. The reactive force against traction was a small area, a circular cylindrical support against the perineum. The following measurements were made at the sacrum and the contralateral hip:

1. Interface pressures between sacral tissues and operating table;
2. Transcutaneous oxygen and carbon dioxide levels of skin over the greater trochanter;
3. Subcutaneous interstitial pressures, using a slit catheter technique;
4. Interface pressures under pressure applicator.

The pressure at the interface between sacral tissues and operating table was first recorded with the Oxford Pressure Monitor (Talley Group Ltd, Romsey, UK), and the recorded pressure subsequently applied over a more accessible area, the contralateral greater trochanter. The skin over this site was chosen since the technique of skin preparation, draping and the operation itself afforded excellent access to this susceptible site. An indenter, of 38 mm diameter, incorporating the transcutaneous gas electrode (which has been previously described by us [7]) with a single annular pneumatic cell attached to its base was attached to the skin overlying the greater trochanter.
Soft tissues in elderly subjects undergoing surgery

A load applicator was positioned and strapped around the indenter to load in a direction perpendicular to the skin surface, as illustrated on a model limb (Figure 2). The level of loading and the resulting interface pressure could be controlled by a regulatory valve positioned between the loading rig and the pneumatic supply. At the chosen tissue area, a fine plastic catheter was introduced through a 16 gauge needle and its tip positioned to a standardized depth into the subcutaneous tissues immediately beneath the centre of the gas electrode.

The $T_cPO_2$ and transcutaneous carbon dioxide ($T_cPCO_2$) were measured using a Radiometer TCM3 monitor connected to the TCR3 chart recorder (Radiometer, Copenhagen, Denmark). The combined oxygen and carbon dioxide electrode (Model D841, Radiometer) was calibrated using gas containing 20.9% $O_2$ and 5% $CO_2$ in nitrogen. The temperature control system of the monitor was set at 44.5°C. This temperature ensured that local arterialization or maximal vasodilatation was achieved in the transcutaneous tissue underneath the electrode. The variation of room temperature over the course of the investigation was 21 ± 1°C. Epidural anaesthesia and sedation or general anaesthesia alone were performed depending on the anaesthetist's preference.

Results

None of the patients experienced important perioperative changes in blood pressure or oxygen saturation. In addition, all patients made an unremarkable recovery following surgery.

Table 1. Summary of transcutaneous gas tension measurements in patient group

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Age (years)</th>
<th>$O_2$ (kPa)</th>
<th>$CO_2$ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>90</td>
<td>&gt;5.4 (100%)</td>
<td>5.3 - 8.0</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>83</td>
<td>&lt;2.7 (42%)</td>
<td>4.7 - 6.7</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>75</td>
<td>&lt;2.7 (85%)</td>
<td>4.7 - 7.1</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>89</td>
<td>&lt;2.7 (94%)</td>
<td>5.2 - 7.2</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>89</td>
<td>&gt;5.4 (100%)</td>
<td>4.4 - 6.3</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>67</td>
<td>&lt;2.7 (88%)</td>
<td>5.5 - 8.3</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>90</td>
<td>&lt;2.7 (69%)</td>
<td>5.5 - 8.4</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>95</td>
<td>&lt;2.7 (63%)</td>
<td>5.7 - 8.0</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>76</td>
<td>&lt;2.7 (68%)</td>
<td>5.7 - 8.9</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>86</td>
<td>&lt;2.7 (42%)</td>
<td>5.0 - 7.0</td>
</tr>
</tbody>
</table>

*Percentage of the total support time above or below the stated value.

*Patients for whom interstitial pressures were recorded under the pressure applicator.
Typical results of $T_c\text{PO}_2$ and $T_c\text{PCO}_2$ levels measured at the greater trochanter during the operation are illustrated for two subjects (Figures 3 and 4). In all cases, there was a clear reduction in $T_c\text{PO}_2$ levels at the point of pressure application during at least part of the surgical procedures. This reduction fell to below 2.7 kPa (20 mmHg) in eight of the 10 subjects, for significant support periods, as indicated in Table 1. These values occurred at similar interface pressures to those measured underneath the patient’s sacrum. The changes in $T_c\text{PCO}_2$ were less remarkable and values exceeded 8.0 kPa (60 mmHg) in only three out of the 10 subjects. There was some variation in the relationship between interface pressures and interstitial pressures. This is illustrated for two subjects in Figure 5, where the slopes of the highly significant linear models predicted that the interstitial pressures were 29 and 41% of the values of pressures measured at the skin surface.

Discussion

This study employed the measurement of transcutaneous gas tensions to assess the viability of soft tissues during a single surgical procedure, that of hip screw fixation of intertrochanteric femoral fractures. These measurements were performed with heated sensors, as the absolute values of $T_c\text{PO}_2$ and $T_c\text{PCO}_2$ at physiological temperatures are small and any changes must be interpreted with caution. At elevated temperatures, normal regulation of blood flow is abolished and perfusion under the electrode is mainly determined by the arterial blood pressure. Although the absolute $T_c\text{PO}_2$ levels measured were elevated, it was the relative changes which were of interest.

Most patients sustained critical depression of the $T_c\text{PO}_2$ values to below 2.7 kPa at pressures to which they were subjected on the operating table. Such depressed levels may produce compromised tissue viability in other at-risk subjects, such as those with acute spinal cord injury [15]. The increased $T_c\text{PCO}_2$ levels—in some cases well above the normal equilibrium values of 6.2 kPa in soft tissues [16]—also indicate impairment of the vascular drainage. The current objective results are supported by an examination of the support tissues in several areas revealing redness, which often persisted for some time after surgery.

There is little evidence in the literature to relate interface pressures at the skin surface to interstitial stresses in the tissues. Of the few studies, Sangeorzan and co-workers [17] noted that the two values were not equivalent and depended on the degree of subcutaneous muscle and the proximity of bony prominences [17]. The present data suggest that the skin interface pressures were dissipated within the depth of the tissues, resulting in reduced internal stresses and a linear model whose slope was less than unity (Figure 5). This indicates the protective nature of elderly human tissues in attenuating the effects of sustained pressure. However, in some cases the interstitial pressures, although much less than the interface pressure, exceeded 5.3 kPa, a local value which could occlude skin capillaries and lead to tissue ischaemia [18]. It is important to note that interstitial pressures were not always successfully measured and depended on the precise positioning of the tip of the interstitial catheter directly beneath the point of maximum pressure application. This technique would have to be improved in future studies.

These results suggest that the support surfaces for sick patients undergoing surgery for fractures of the proximal femur are inadequate. Peterson [19] showed that low-risk patients developed distinct pressure marks when supported on a conventional operating table with a 40-mm-thick mattress during short operations. The present study highlights the danger to which patients are subjected during hip fracture surgery, particularly if the operation is prolonged. There is a disproportionate increase in the number of elderly patients sustaining proximal femoral fractures [4, 20]. Such patients are at risk of pressure sore development, and support surfaces should be re-designed to relieve pressure. There are major potential disadvantages with water or gel mattresses, since leakage could prove disastrous in the operating room. Air-filled mattresses are unstable and may allow the patient to move. There has been little research on effective support surfaces for use on the operating table [21]. Randomized clinical trials are needed for the objective assessment of a range of support surfaces.
Acknowledgements
The authors would like to thank P. Burge, orthopaedic surgeon, for his advice and help with this study.

Key points
- The viability of soft tissues can be assessed by objective measures in elderly patients during a surgical procedure.
- Local transcutaneous gas tensions are compromised in the anaesthetized soft tissues of elderly people subjected to representative support pressures. This may cause tissue breakdown in this at-risk group.
- Interstitial pressures may be important in predicting local tissue damage.
- New designs of support surfaces should be assessed by objective measurements on patients in a clinical setting.

References