Technical note

Pressure relief characteristics in alternating pressure air cushions

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Abstract
In this study a computerised system was used which continuously measured air pressure, interface pressure and pressure-time cycle characteristics of an alternating pressure air cushion (APAC), and calculated the time the interface pressure remained below three chosen thresholds of 20,40 and 60mm Hg. Ten healthy volunteers were used to evaluate the pressure relieving characteristics of four APACs. Results indicated significant differences between products when the threshold periods were analysed, showing some devices were not capable of relieving interface pressures below 20mm Hg. Though deflation pressure decreased to nearer zero, interface pressure did not follow suit.

Introduction

Commercially available alternating pressure (dynamic) air cushions, used for the prevention and treatment of pressure sores, are documented as actively enhancing tissue perfusion by increasing and decreasing the pressures under the body seating area (Donald and Clark, 1993; Kosiak *et al.,* 1958). Consideration of seating pressure is an important aspect of comprehensive assessment when prescribing equipment for disabled persons. Recently, increased interest in the subject has led to significant improvements in seating systems and their provision (Bardsley, 1993). The hammock seat and back of a conventional wheelchair provide very little support to the pelvis and spine (Seeger and Sutherland, 1981; Medhat and Redford, 1978). Thus, unless a comfortable and functional posture is achieved with minimal risk of developing deformities and pressure sores, wheelchair users are not able to achieve their full potential during work, school or recreational activities, and therefore the provision of suitable support systems becomes a key factor in their rehabilitation.

Various support surfaces are commercially available for the management and prevention of pressure sores. These vary considerably in design, ease of use, maintenance, reliability, durability and cost (Rithalia, 1991). The majority of these support systems reduce pressure concentration on local areas by redistributing the load over as large an area as possible. Such pressure-reducing support surfaces include foam, gel and static air cushions. Other support systems operate a cyclic alteration of pressure on various parts of the body by changing the point where the subject is supported. These include alternating pressure air cushions (APACs), which achieve pressure relief by a system of cells which alternately inflate and deflate, resulting in lower interface pressure at the deflated cell during the deflation period of the cycle, thus attempting to ensure an adequate level of tissue perfusion.

The action of an APAC is time dependent and, therefore, any indicator which measures pressure relief should take the time factor into account as the effectiveness of pressure relief is related to the period of time the interface pressure remains below capillary closure pressure (McLeod *et al.,* 1994). The aim of this study was to evaluate the pressure-time-cycle characteristics of four commercially available

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APACs, with the aim of ranking each cushion according to its performance regarding pressure relief.

Methods and materials

Ten healthy adult volunteers (6 males, 4 females), whose age, weight and height ranged from 25 to 55 (mean ± SD, 31.9 ± 9.1) years,, 66 to 91 (76.1 ± 14.7)kg and 165 to 178 (169 ± 11) cm, participated in this study. The procedure for the investigation was fully explained to every volunteer and verbal consent gained before each subject took part in the study.

The four commercially available APACs investigated in this study included:

(a) Alpha Trancell - Active Pressure Relief Seat Cushion (Huntleigh Healthcare, Luton). This uses an arrangement of 9 cylindrical air cells, set transversely that alternately inflate and deflate. The cells are attached by fabric loops to a one piece plastic cover that folds over the underside and fastens in the manner of an envelope. The air is delivered by a mains powered pump via a 2-pipe system, each pipe feeding one set of cells, with an operating cycle time of 10 minutes.

(b) Bellows Air Support Equipment (B.A.S.E.) - Sequential Seating System (Talley Group Ltd, Hampshire). The cushion has eight rows of cells set transversely and each row contains six air bellows. The bellows are contained within a soft foam jacket controlling their lateral movement but allowing free up and down motion, thus not impeding the inflation and deflation pattern. A light weight pump, powered by a rechargeable nickel-cadmium battery, inflates the bellows sequentially with a cycle time of 10 minutes.

(c) Care Chair - Dynamic Posture System (British Astec, West Midlands). This consists of a complex, double-layer, interwoven single piece cell structure, with 20 transverse air cells operating in a l-in-2 cycle over 7.5 minutes. In construction, it resembles a mattress with nearly half the cells placed on the seat and the rest covering the back-rest. The air is delivered by a mains powered pump via a 2-pipe system, each pipe feeding alternate cells

(d) Pro-Active Seating System (Pegasus Airwave Ltd, Hants). The cushion consists of six air cells arranged longitudinally, plus a foam section in front to support the thighs. Two outer cells, one on each side, are permanently inflated while the other four cells inflate and deflate in pairs. All cells are connected to a battery powered pump with an operating cycle time of 12 minutes. They are encased in a waterproof cover and placed on to a plywood base, which can be attached directly to a wheelchair. The resulting seating system including the pump and battery weights 6.6kg.

Fig 1. Equipment used to record air pressure, interface pressure and pressure-lime cycle characteristics of the cushions.

A computerised system (Fig. 1) was used to record the air pressure, interface pressure (IP) and pressure-time cycle characteristics of the APACs. Interface pressure was measured continuously using the Oxford Pressure Monitor 2 (Talley Group Ltd, Hants) and the air pressure inside cushion cells was recorded simultaneously. A graphical programming language (Lab View, National Instruments Inc, USA) is used by the monitoring system. The method employs a minimal amount of hardware and maximum flexibility by turning the computer into a data acquisition tool and its screen into a control panel. The computer interface reads the pressure sensor outputs, analyses them and then graphically represents the results. The software is developed to calculate the time IP remains below any three chosen thresholds for a chosen length of time and expresses pressure relief (PR) as a percentage of the cycle, which allows like-for-like comparisons to be made choosing any common multiple of the cycle times. For example, one hour requires six 10-minute cycles or twelve 5-minute cycles. In this investigation, for PR calculations as a percentage of the APAC cycle the IP thresholds were set at 20, 40 and 60mm Hg.

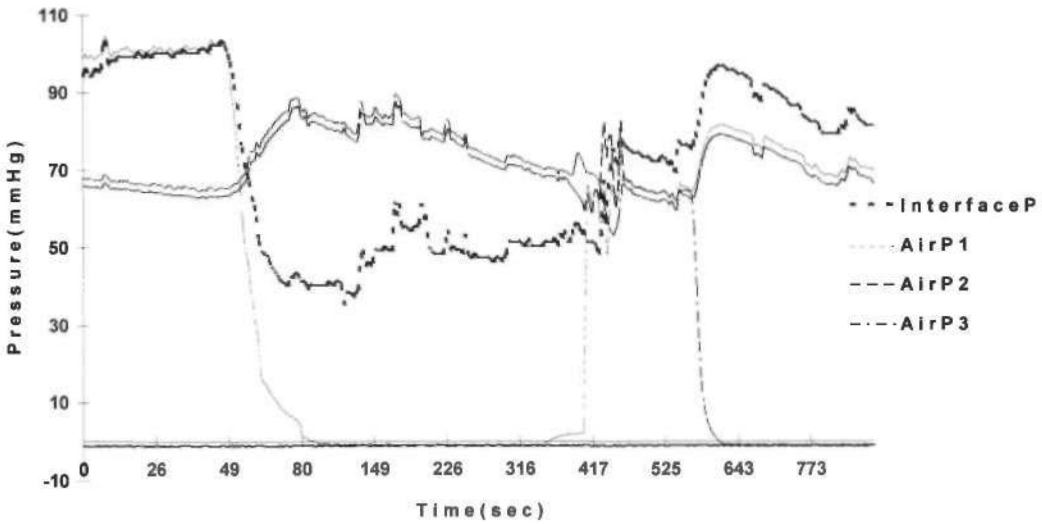

Fig. 2. Pressure-time tracings of the Pro-Active cushion showing interface and air pressures.

Subjects were seated in a standard wheelchair, with sling seat and back, in a comfortable upright position. Arm supports and foot rests were adjusted for each subject so that the hips were at right angles. For the Care Chair, measurements were taken with the subjects seated in a high seat hospital chair.

Measurements were taken at both right and left tuberosities for each subject, thus giving a set of 20 readings for each cushion in 10 volunteers. The tuberosity was palpated for location and the single sensor (20mm diameter) attached with a tape over its feeding tube. The sensor from the Oxford Pressure monitor was positioned between the centre of an inflated cell of the cushion and buttock. The duration of the readings varied between 10 and 15 minutes, depending on cycle time of each cushion, allowing an extra cycle for the subject to settle down.

From the initial data (Fig. 2) the maximum, minimum and mean interface pressures as well as the air pressure in the cushion cells were recorded or each cushion. Pressure relief characteristics were obtained as a percentage of the amount of time the interface pressure remained below the chosen thresholds throughout one cycle. This was then converted to pressure relief per hour (Table 1) as explained above.

Results

A pressure-time graph (Fig. 2) shows the experimental results obtained on a cushion regarding interface pressure and air pressure inside each cell. The mean interface pressure on inflation and deflation as well as pressure relief characteristics were then calculated and are summarised in Table 1. This showed that the Alpha Trancell had better pressure relief

Table 1. Mean interface pressure (IP), air pressure (peak) and pressure relief (PR) below 60 (A), 40 (B) and 20 (C) mm Hg in 60 minutes.

Cushion	Mean (±SD) IP Inflation (mm Hg)	Mean (±SD) IP Deflation (mm Hg)	Mean (±SD) Air Pressure (mm Hg)	Mean (±SD) PR		
				(A) (min)	(B) (min)	(C) (min)
Alpha Trancell	61 (7.3)	22 (10.3)	64 (6.2)	50 (6.3)	24 (6.1)	8 (8.9)
B.A.S.E.	68 (6.2)	29 (3.1)	77 (7.1)	37 (16.6)	12 (11.9)	0
Care Chair	78 (9.3)	35 (13.9)	82 (5.1)	31 (9.6)	13 (14.4)	5 (6.8)
Pro-Active	103 (21.2)	36 (7.9)	90 (8.6)	21 (8.2)	6 (7.8)	0

characteristics than any other cushion. All cushions displayed varying degrees of pressure relief measurements below 60 and 40mm Hg, but only the Alpha Trancell and Care Chair gave relief measurements below 20mm Hg. The interface pressures and pressure relief measurement characteristics in B.A.S.E and Care Chair cushions were similar.

The maximum and minimum interface pressures were recorded when the cells were in inflation and deflation modes respectively. The Alpha Trancell recorded the lowest mean interface pressure at both inflation and deflation, while the Pro-Active recorded the highest interface pressures. However the Pro-Active gave the highest pressure differential between inflation and deflation (67mm Hg) while the Alpha and B.A.S.E. gave the lowest (37mm Hg). When the interface pressures were compared to the peak or maximum air pressure inside the cushions, only the Pro-Active gave higher readings of maximum interface pressure than the peak air pressure. The initial data also showed that on deflation the air pressure inside a cell reached a minimum of zero, but interface pressure did not.

Discussion

• One commonly asked question is whether body weight affects the magnitude of the interface pressure created between the subject and support surface. Obesity can either increase or decrease the susceptibility to pressure sore development (Natow, 1983). Small quantities of adipose tissue can provide protection and cushioning for bony prominences, but due to its poor blood supply it is more vulnerable to shear forces and prolonged pressure. However, pressure alone does not cause pressure sores but, the time for which pressure is maintained above a critical level is very important (Hussain, 1953). Capillary pressure has been quoted to range from 12 to 47mm Hg (Clark, 1987) and from 32 to 60mm Hg (Wytch *et al*, 1989). Thus, the question arises as to which thresholds to consider when evaluating pressure relief in APACs.

Over the years pneumatic cells have rendered accurate and reliable results for interface pressure measurements. One theoretical drawback is that because they conform so well to the body-support surface interface they tend to reduce the measured peak pressures (Bowker and Davidson, 1979). However at low pressures this effect is minimal and during this investigation results were only used for comparative purposes.

It could be argued that the subjects who participated in this study were all normal and healthy and would not normally be candidates for the prescription of APACs. But patients who would normally use APACs, e.g. paraplegics, are those who can least tolerate high interface pressure and would run the risk of tissue breakdown during the course of such an investigation. Thus, healthy volunteers are probably the safest.

Only 3 out of 10 subjects gave interface pressure readings below 20mm Hg for Care Chair and 5 out of 10 for the Trancell cushion. The B.A.S.E. and the Pro-Active cushion were unable to give pressure relief below 20mm Hg.

Conclusion

The B.A.S.E. and the Pro-Active cushion were unable to give pressure relief below 20mm Hg. However, there is more to prescribing a support surface for disabled persons than just interface pressure measurements. It is important to consider other factors such as age, level of activity and motivation. The optimum criteria for the design and evaluation of the APACs are inconclusive and more extensive studies are necessary. The authors are continuing the investigation in the clinical environment to assess the factors, such as, long term durability, comfort, maintenance and ease of use.

Acknowledgements

The authors would like to thank all the volunteers who participated in this study for their cooperation, and the Medical Illustrations Department, Hope Hospital, Salford for their assistance.

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