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A Comparison of Sitting Pressures on Wheelchair Cushions as Measured by Air Cell Transducers and Miniature Electronic Transducers[a]

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ABSTRACT

With increasing attention to cushion selection for patients subject to decubitus ulcers, greater efforts are being made to prescribe cushions based on individual need. Pressure measurements during sitting frequently are utilized as a clinical guide to the process of selection and fitting.

To determine the relationship between pressure values recorded from different types of transducers, simultaneous measurements were made beneath the ischial tuberosities using a Scimedics air cell transducer on one side and a matrix of 5 Kulite electronic transducers on the other side of a subject while sitting on a series of 21 commercially available wheelchair cushions. Although these transducers are different in structure and function, statistically similar results were obtained. The air cell type of transducer appears to be more appropriate for routine clinical use, but caution is advised regarding interpretation of results in terms of absolute pressures due to the many variables involved — these techniques are suitable primarily for comparative measurements to obtain the optimal seating support for a given patient.

INTRODUCTION

Monitoring of pressure at the skin surface-cushion interface is an important aspect in clinical care of patients susceptible to decubitus ulcers. Transducers which may be utilized to measure pressures at this interface during seating have been reviewed by several authors (1, 2, 3, 4).

The two types of devices in most common use are miniature, electrical (solid-state or strain gaged), diaphragm pressure transducers and pneumatic (air cell) transducers, (2, 4, 6). As there are major differences in the structure and function of these two types of transducers, this study was designed to compare them by simultaneous pressure measurements during controlled sitting tests.

METHODS

The sitting tests were performed on a series of 21 commercially available wheelchair cushions of which 10 were classified as foams, 2 as viscoelastic foam, 5 as gels and 4 as "fluid floatation" (7). To insure standardization, a single, twenty-four year old male weighing 60 kilograms and in good health served as the instrumented subject for all measurements. The pressure transducers to be tested were sited directly on the skin and only thin, loose, cotton shorts were worn over

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TABLE I – Comparative Pressure Measurements (mm Hg) on 21 Different Cushions Using Two Types of Transducers.

Foam					Viscoelastic Foam					Gels				
Cush	Kulite		Scimedics		Cush	Kulite		Scimedics		Cush	Kulite		Scimedics	
Id. #	Mean	S.D.	Mean	S.D.	Id. #	Mean	S.D.	Mean	S.D.	Id. #	Mean	S.D.	Mean	S.D.
1	69.0	6.4	65.7	2.1	11	82.5	4.4	73.2	4.4	13	96.6	7.1	102.8	3.8
2	72.5	12.0	66.2	4.3	12	71.6	5.0	67.3	2.0	14	93.4	5.4	92.8	5.7
3	68.7	10.5	65.3	3.8						15	99.0	12.4	104.3	2.1
4	62.3	7.6	64.2	1.8						16	79.9	11.4	73.8	2.5
5	65.8	9.9	75.5	6.3						17	89.9	13.3	99.4	4.3
6	96.4	5.8	90.3	3.3										
7	90.8	8.0	81.8	6.2										
8	74.5	9.3	71.3	3.1										
9	83.7	12.3	82.3	2.1										
10	85.2	6.7	84.2	3.4										
Mean Foam	76.9 mmHg		74.68 mmHg		Mean V. Foam	77.1 mmHg		70.3 mmHg		Mean Gel	91.8 mmHg		94.6 mmHg	

them. To obtain direct comparisons, the electrical transducers were located beneath one ischial tuberosity and the air cell transducer beneath the other so that simultaneous measurements could be made during each seating trial.

A Kulite Model LQS-125-200 (O. D., 4 mm; diaphragm diameter, 2 mm; thickness, 0.8 mm) was selected as representative of miniature electrical diaphragm transducers utilized. A 0—200 psi unit was employed to guard against catastrophic breakage and reduce shear sensitivity of the diaphragm. Calibration tests in a pneumatic chamber gave linear results in the 0—5 psi range. Readout from the Kulite transducers was obtained by means of a Strainsert TN8C Strain Indicator with 2.0-V square wave excitation to the bridge circuit. (A cluster of five Kulites was employed.)

A Scimedics, Inc., single-air-cell pressure evaluator unit was selected as representative of the pneumatic type of transducer (size 90 mm x 100 mm oval, thickness 0.5 mm). This transducer utilizes electrical contacts bonded to opposing inner surfaces of a flexible pneumatic chamber. When deflated, these surfaces are in contact and a small indicator lamp is illuminated. As air is hand pumped into the chamber, the opposing surfaces separate, causing the lamp to go off; then air is slowly released from this chamber until the indicator lamp is relit. At that instant, the pressure is read on the manometer and assumed to represent the pressure on the external surface of the chamber at the skin cushion interface.

A preliminary direct calibration in mm Hg of all transducers was obtained using a pneumatic chamber. On the first day of testing, the high pressure area beneath each ischial tuberosity of the test subject was located using a barograph device as described previously (7). The Scimedics air cell transducer then was placed onto the skin under the right ischial tuberosity and attached loosely, using tape along one edge only. Beneath the left ischial tuberosity a matrix of five Kulite transducers in a diamond pattern (with diaphragm contacting the skin) was employed so that the five transducers were distributed over the same area on the left as the air cell transducer on the right (Fig 1). Care was taken to avoid impingement of tape over the transducers or adjacent cable. For each seating test, the readings from the five Kulites in this matrix were averaged to derive one pressure reading for the entire area; this mean was utilized for comparison to the single reading from the Scimedics unit.

After zero readings were obtained, the test subject sat on the first cushion, and adjustments in arm and foot rests made with care to achieve a standard, erect, balanced configuration. Pressures were measured first with the Scimedics air cell and then with each Kulite transducer. The subject then stood briefly and reseated himself on the same cushion for a second set of readings made in reversed order. This test procedure was repeated for each of the 21 cushions in the series on the same day. Adjustments were made for loaded cushion thickness by placing shims beneath cushions as necessary to achieve the same trochanter height above the table each time. A complete series of tests was carried out on each of three separate days, providing a total of six readings from each transducer tested on each cushion.

On the second and third day, transducers were reapplied to the test subject in the same location using skin markings made on the first day. (Right/left revised tests were not done because of the large number of cushions utilized.)

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Fluid Floatation				
Cush	Kulite		Scimedics	
Id. #	Mean	S.D.	Mean	S.D.
18	66.6	9.5	68.5	4.7
19	77.7	5.5	81.5	2.4
20	73.5	11.9	72.0	2.0
21	69.7	8.1	60.3	3.8
Mean Float.	71.9 mmHg		70.57 mmHg	

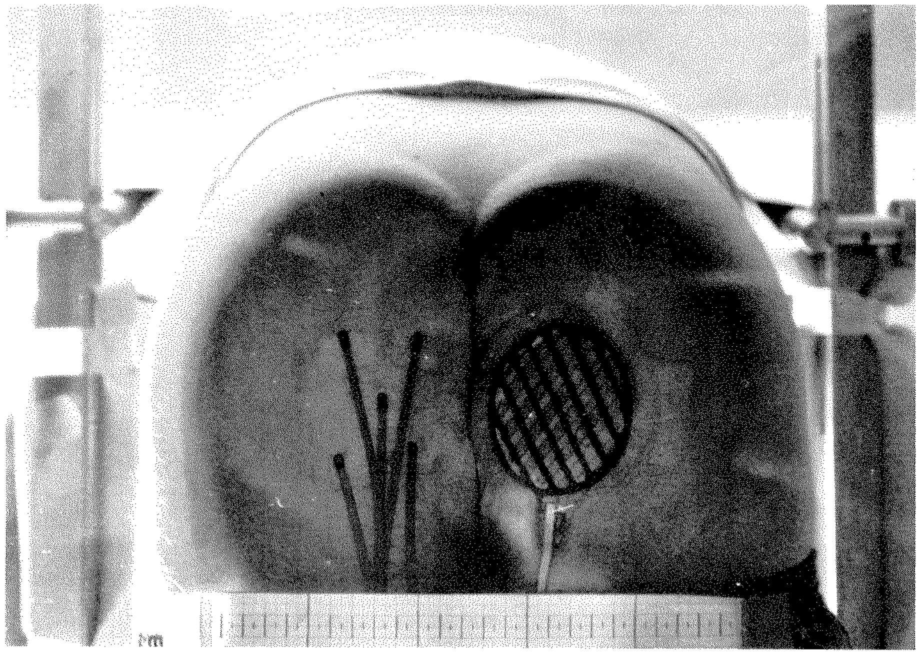

FIGURE 1.
View of instrumented subject as seen through glass plate of the VA barograph. The matrix of Kulite pressure transducers is seen beneath the left, and the Scimedics transducer beneath the right ischial tuberosity.

RESULTS

Data on the means and standard deviations, for each cushion and for the major types of cushions, are presented in Table 1. Statistical significance of the differences between the average readings from the Kulite transducer matrix and the Scimedics air cell, for each cushion, was determined using t-test evaluation at the significance level of P=0.05. In all but two instances, the differences between the Kulite matrix readings and the Scimedics air cell readings were determined to be statistically not significant. In the two cushions where significant differences were noted, structural differences in the cushion probably accounted for the differing reactions.

Concerning type categories of cushions, it may be noted that foam, viscoelastic foam, and fluid filled cushions gave mean readings in the range of 70–77 mm Hg with both types of transducers in the selected configuration with this subject. On the other hand, the mean reading from gel cushions was approximately 15 mm Hg higher (over 90 mm Hg).

DISCUSSION

This study has demonstrated that similar pressures are measured at the skin/cushion interface during sitting, regardless of whether a Scimedics air cell transducer or a matrix of five Kulite semi-conductor transducers is employed. Data from individual Kulite transducers was not examined alone because of the variability in repeated readings from a single transducer and because, while one could be certain that the matrix area was beneath the tuberosity, it would never be possible to be certain of the location of a single transducer with respect to bone. Though pressures did vary from cushion to cushion, the two types of transducers gave statistically similar readings on all but two cushions in the series. It was also noted that within each of the four categories of cushions, a similar order of cushion pressure was established when pressure was rated from highest to lowest — using either transducer. In general, the Scimedics air cell readings tended to be more consistent on a day to day basis, as evidenced by a lower standard deviation.

In view of the recent work by Patterson and Fisher (4) showing that certain Kulite transducers were notably inaccurate when used for interface measurement, uncertainty arises as to the suitability of the diaphragm transducers utilized in these and other studies in this laboratory. It should be noted that there was a distinct difference in the transducers in question: one of the Kulite units utilized by Patterson and Fisher had a rimmed diaphragm and the other had a Silastic dome (5); all Kulite transducers used in this study had a flush diaphragm, a major mechanical difference.

As a check on the problem, the flush diaphragm transducers were recalibrated in limited tests using the methods devised by Patterson and Fisher (4). First, using a condom inflated within a 3-cm diameter tube as an interface, it was found that the Kulite transducers in this study provided a linear response (±5–10%) in the range 40–200 mm Hg. Below 40 mm Hg, it was impossible to obtain accurate measurements. Second, when tested using the blood pressure cuff technique over the gastrocnemius, flush-diaphragm transducers did show initial inaccuracies, but improved markedly with repeated cycling of the system as they became seated on the skin. Adequate tests of the air cell transducer could not be made with the cuff because of the large size of the air cell compared to the test site and cuff.

Despite the questions concerning accuracy of the Kulite transducers, the overall results of the present study were reasonably repeatable and within the expected range. Also, it is possible that the diaphragm transducers perform better in the experimental environment of buttock vs. cushion than with the cuff, particularly since the seating tests were highly repetitious, and allow the diaphragm to stabilize against the skin. Further tests would be required to select the "best" diaphragm transducer for clinical use — since Patterson and Fisher (5) have indicated recently that the Sensotec Type F they identified as having superior accuracy does not stand up well to moist environments.

Although comparable readings resulted from the transducers studied, the question of the clinical meaning of pressure values obtained with any type of interface pressure transducer remains in doubt and requires further investigation. It probably is safe to say that readings obtained with a specific transducer on an individual patient are useful for comparative measurements, particularly within a given category of cushion materials such as the foams. Absolute values, however, are affected by the size of the transducer, degree of envelopment by cushion and tissue, shear force artifact, and other matters. For example, gel cushions gave higher readings than foam cushions; no doubt this is in part due to the higher vertical spring characteristic of the gel which diminishes the support area of the cushion, but other experiments by the authors indicate that the difference also may result *partially* from an artifact related to the fact that the gel does not envelop the transducer as well as does the foam.

For clinical applications, air-cell type transducers have several practical advantages over the miniature diaphragm-type transducers. First, the size of the air cell or matrix of cells can be made large enough to overcome the problem of exact central placement over high pressure areas, whereas placement of the electronic transducers is more critical. Also, the air-cell transducers are far less expensive, with respect to both the transducers themselves and the associated readout equipment. Precision electronic transducers are delicate and subject to catastrophic breakage while the expense of damaged or worn out air cell units is more reasonable. Finally, the air cell types are inherently less sensitive to shear loads, an advantage which at least tends to produce more consistent readings on repeated tests. On the other hand, the Scimedics transducer requires a significant degree of training and skill to operate effectively, and can easily give grossly inaccurate results if hasty measurements are made without providing adequate time for equilibration.

While not tested formally in this limited study, small (2.2 cm) air cell transducers are available also in a 12 x 12 matrix form in the pressure evaluator pad (PEP) devised by Krouskop and associates at the Texas Institute of Rehabilitation and Research (6). With this device, a pattern of pressures at 144 points over the entire seating area can be obtained. Preliminary measurements with the PEP in conjunction with this study showed that, on several of the foams, comparable readings were obtained using the same test subject and conditions, although on the majority of the cushions the maximum pressure readings tended to be higher using the PEP than with the single air cell — possible because the single air cell tends to distribute the peak pressure.

CONCLUSIONS

1. Air cell transducers (Scimedics) and a matrix of electronic transducers (Kulite) provide comparable results when employed for comparative measurements of sitting pressure at the skin cushion interface.
2. The air-cell type of transducer requires care and skill to obtain accurate measurements, but it is more convenient than an electronic diaphragm transducer for routine clinical applications, particularly those involving comparative measurements during cushion selection and fitting.
3. Further investigation is essential to determine the relationship between readings made with interface transducers and the actual pressure that exists at the skin buttock interface and within the tissues.

As the intent of the report is to focus primarily on the problems of measurement and cushion type, cushion identification has been omitted purposely. As seen in the prior study (7), interface pressure is only one of the many factors to be considered in cushion prescription, and pressure variation measured between most cushions tested is relatively small. In the past, much unwarranted commercial attention has been focused on the results of studies such as this and it is best to avoid this problem. In the problem of seating, it is becoming increasingly clear that in patients with critical problems, selection, fitting and adjusting must be done on an individual basis using pressure measurement techniques as an adjunct. For critical patients, it would be a mistake to select a cushion based on test reports alone.

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