

International Best Practice Guidelines

BPG2 Clinical Guidelines for the Use of Interface Pressure Mapping for Seating

Use of this document

As a code of practice, this Best Practice Guideline (BPG) takes the form of guidance and recommendations. It should not be quoted as if it were a specification, and particular care should be taken to ensure that claims of compliance are not misleading.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Background

This Best Practice Guideline (BPG) document is the outcome from one of a series of documents prepared in advance for discussion at the 4th International Interdisciplinary Conference on Posture and Wheeled Mobility, held in Glasgow in 2010. It is the outcome of over ten years of work and a number of public consultation processes.

The need for a set of Guidelines for the Clinical Use of Interface Pressure Mapping (IPM) arose from the work of the ISO CH173/SC1/WG11 working group on standards for wheelchair seating. The Working Group had a project being conducted by one of the Task Groups to establish means of assessing the physical characteristics of cushions. Research was carried out to see how well IPM systems might be used to characterise the immersion and pressure redistribution properties of a cushion. Certain indices were established as being consistent across different IPM systems, but the Group came to the conclusion that there were more rigorous tests available for these physical assessments.

However, the consensus was that IPM have important uses in the clinical setting for analysing, inter alia, posturally related pressure distribution, and that a Clinical Guideline would be of value to the seating community. The original scheme created a more ambitious task, placing IPM in the context of a complete seating assessment. While this continues to be worked on, a shorter project has been completed, which is the content of this BPG.

The text attached has also been submitted as an ISO Technical Report (ISO TR 16840-9), which was sent out for comments and voting at the end of 2013.

The BPG has been compiled from the work of an international committee which has included the following people:

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National and International standards and codes of practice, as well as professional experience, change over time, and the intent is that this document shall be updated from time to time, not least through the ISO processes. This document is therefore being placed on a publically available website (www.pmguk.co.uk) where individuals can place their comments, and updates can be posted.

1 Aims

The aim of these Guidelines is to provide information as to where Interface Pressure Mapping (IPM) can fit into a clinical assessment of an individual and their seating system, to highlight what can be achieved, and bring awareness of the limitations.

2 Scope

These Guidelines have been produced to guide users in the performance of the tasks that are directly involved in the clinical use of IPM or are synergistic with its use in a comprehensive wheelchair seating evaluation.

These Guidelines do not cover other aspects of the clinical assessment process (e.g. taking a medical history), nor the prescription or treatment process which might arise from an assessment. These Guidelines are not meant to be a substitute for clinical reasoning and judgement within the context of a complete assessment.

These Guidelines refer to the State of the Art of IPM experiences in a seating scenario: most of the principles covered can be extrapolated to whole body (in bed) and to foot assessments, for example.

3 Introduction

The use of IPM in Clinical Applications is increasingly used to support clinicians in the evaluation of individual seating systems for individual clients. To get the best value from IPM requires a knowledge of the basic concepts of the interface pressure distribution (see section 4 Definitions), the ability to define and apply a correct protocol for the application of IPM (see section 6 Clinical Test Protocol), the ability to prepare correct documentation of the IPM (see section 7 Documentation), and the skill in interpreting the collected data (see section 8 Interpretation).

The aim of an IPM test session can be different in a clinical or rehabilitation environment. In some cases, it may be a tool to compare the behaviour of different pressure care or postural cushions. It can be used also to support the clinician in finding the best match between cushion and client. Various applications, looking at the broader picture, are covered in section 5 (Applications). In any case, the main objective behind using an IPM needs to be clear from the beginning.

4 Definitions and Glossary

4.1 Calibration

Calibration is a process wherein the sensing mat is subjected to known forces: the sensor responses are monitored and modelled in the software. A record is kept of the responses (called a calibration file) and whenever the sensors output a similar response, the result is related to the previously known forces. In most cases, this is done by placing the mat in a purpose-built chamber with an air filled bladder. The bladder is inflated and the pressure in the bladder is measured. It is assumed to be evenly pressurized over the mat.

Calibration allows for the software to accommodate changes with time (creep) or pressure (hysteresis) exhibited by the sensors.

NOTE: Recalibrate the mat whenever the readings look suspicious, after excessive use, or at the manufacturer's recommended interval. Keep track of the uses of the mat and the date of the last calibration. Old calibration files should be retained. (You can load old calibration files to see the extent of change over a period.)

4.2 Coefficient of Variation (CoV)

This is one of the statistical measures available to assess how evenly the pressure is distributed across a support surface. The CoV is expressed as a percentage. The lower the CoV, the better.

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}}$$

4.3 Conformity

The ability of the IPM mat to adapt to irregular shapes without creasing.

4.4 Contact Area.

Contact area is the area under load and is approximated to by the total number of sensors under load.

NOTE: Contact Area is representative of the aim to distribute the body weight over as large an area as possible. Given the defining equation of pressure (pressure = force/area) the larger the area, the lower the pressure given a constant load. (Sprigle et al (2007) have recommended that the minimum threshold to be used should be 5mmHg to avoid inclusion of fluctuating non-zero values and minimise the effect of noise.)

4.5 Creep

There are three different manifestations of creep that are of concern: sensor creep, cushion creep, and tissue creep. Sensor creep, inherent in most IPM sensor technology, is the tendency for the sensors to change their reading (output) over time, given a constant load (input). Most IPM systems for which this is a factor have built-in software correction for sensor creep. Creep is normally only corrected for during the time the mat is reading. Stopping and starting the readings may interfere with the creep corrections.

4.6 Dispersion Index (DI)

The DI is defined as the sum of pressure distributed over the IT and sacral-coccygeal region divided by the sum of pressure readings over the entire sensor mat, expressed as a percentage.

$$\text{Dispersion Index} = \frac{\sum A}{\sum A+B}$$

Where A = pressures of the IT and sacral-coccygeal area and B = pressures outside the IT and sacral-coccygeal area

NOTE: The DI represents the concentration of pressure in high risk areas vs low risk areas and can be indicative of a support surface's ability to redistribute pressures. DI is also a metric reported to have good reliability by Sprigle et al (2003). Drummond et al (1985) found that interface pressures were 'unacceptable' when > 55% of the pressure was at the IT/Sacral regions. DI, as compared with pure Contact Area, may be a more useful metric when performing relative comparisons between cushions. Effective pressure distribution can be achieved either via envelopment or off-loading of the high risk sites. If one cushion off-loads and the other envelops, DI may offer a better 'apples to apples' method of comparison than Contact Area alone.

4.7 Envelopment

The ability of a support surface to conform, so to fit or mould around the irregular shape of the body

4.8 Fomite

An inanimate object or substance, such as clothing, furniture, or soap, that is capable of transmitting infectious organisms from one individual to another.

4.9 Hysteresis error

Hysteresis error is the difference in two measurements of the same quantity when the measurement is approached from opposite directions. Hysteresis generally manifests itself in IPM applications as the difference in a given pressure reading depending on whether that pressure was reached by increasing from a lower pressure or decreasing from a higher pressure.

NOTE 1: Hysteresis is a natural phenomenon which occurs in all types of electrical, magnetic, and mechanical devices. A hysteresis loop is generally used to characterize hysteresis. If a sensor is held at a constant pressure, there is a corresponding electrical output value for that pressure. It would be expected that if that applied pressure rose or fell, the corresponding electrical output value would rise or fall in synchronicity with the applied pressure. Sensor hysteresis is a dynamic effect where the sensor output 'lags' behind the corresponding applied pressure as the applied pressure rises or falls, i.e. for a rising pressure, the displayed pressure will be lower than the pressure applied at the sensor and vice versa.

NOTE 2: Hysteresis can be reduced in two ways: by selecting a material which will be used in the sensor which inherently possesses less hysteresis, or by compensating for hysteresis via a calibration algorithm in the software.

4.10 Immersion

The depth of penetration into a support surface measured in the vertical plane. In other words, how far the body sinks into the cushion. It is important to immerse without bottoming out.

4.11 Pressure

Force per unit area in a direction perpendicular to the surface. The units of pressure used in most applications are pounds per square inch (PSI), Pascals (N/m^2), or millimetres of mercury (mmHg), etc.

NOTE 1: An IPM image is a visual representation of the normal pressures between two contact surfaces of two (usually deformable) bodies.

NOTE 2: Unit conversions:

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

$$1 \text{ kPa} = 1000 \text{ Pa}$$

$$1 \text{ mmHg} = 133.322 \text{ Pa}$$

$$1 \text{ PSI} = 6894.757 \text{ Pa}$$

4.11.1 Average Pressure

Average Pressure is defined as the average value of the pressure recorded by a group of sensors of predefined location and disposition around a significant landmark.

NOTE 1: the predefined groups of sensors can be called control areas or masks. As an extreme case, the overall Average Pressure can be calculated over the Contact Area.

4.11.2 Peak Pressure

Peak Pressure is the highest value of the pressures recorded by the sensor units in the mat.

NOTE 1: From a general view point, there can be a single Absolute Peak Pressure, as well as several Relative Peak Pressures

NOTE 2: If data collection is taken over time, there will be also a maximum Peak Pressure over a given time interval.

NOTE 3: The location of the Peak Pressure on an image can change over time in the case of a dynamic recording.

4.11.3 Peak Pressure Index (PPI).

PPI is the pressure average value calculated within a 10cm² area (i.e. the approximate contact area of an IT) around the highest recorded peak pressure values.

NOTE 1: A high gradient from peak to adjacent sensors indicates poor envelopment of the bony prominence.

NOTE 2: Historically, single peak pressures were used to rate cushions. Sprigle et al (2003) studied reliable metrics for IPM, and single peak measures were not repeatable. The result was that researchers recommended the use of a Peak Pressure Index.

NOTE 3: Overall average pressure across the whole cushion is not of clinical relevance because it is too general a term for differentiating cushions.

4.12 Sensor Saturation

Sensor saturation is the point at which the individual sensor's output cannot increase any further with continuing increase in applied pressure.

NOTE: Sensor saturation may be due to either the physical restraints of the sensor or the constraints imposed by the software: e.g. If the sensor is calibrated to a maximum pressure of 200mmHg, the maximum pressure it will indicate will be 200mmHg regardless if the applied pressure is greater than 200mmHg. Some IPM systems can extrapolate to pressures above the maximum calibration value to allow the operator to see if the pressure values are just slightly over the maximum threshold or considerably higher.

4.13 Shear

Shear stress occurs when two forces are in opposing directions such that there is a deformation of the tissue in parallel planes. Shear strain occurs when there are two perpendicular forces of different values near each other giving differential deformation of the tissue.

5 Applications

This section is intended to guide the operator through possible choices of IPM as a tool for clinical and rehabilitation applications. The list is not necessarily exhaustive. Please note that there are limitations of which the operator should be aware, and various of these are listed in Section 9.

5.1 Cushion comparison

The most common use of IPM is to compare cushions for prescription for a client. The value is for comparison of each cushion's ability to distribute pressure evenly across the body, and minimize pressure at the bony prominences. This application can demonstrate that a less expensive cushion can be as effective for that client, for static pressure redistribution, as a more expensive one, for example, but it may not indicate which cushion would provide greater protection in dynamic situations.

An IPM image should not be the sole deciding factor. Additional considerations for cushion selection include:

- Form, Fit, and Function
- Postural stability
- Functional mobility – transfers
- Weight of cushion
- Heat/moisture
- Perceived comfort

- Complexity - maintenance and set-up requirements
- Client's ability to perform, or direct, care
- Ability to provide client and care-giver education
- Number of care-givers /staff turnover

This application has its limitation since the readings taken are usually in a static situation, whereas the client usually uses sitting as a dynamic activity (see 5.4).

5.2 Wheelchair set-up

Using an IPM is an essential tool for setting up the adjustable parts of the wheelchair while observing the effects on the distribution of pressures across either a seat or back support surface. Swain (1997) showed that the most effective means of redistributing pressures across a cushion is by adjusting the height of foot supports. Remember that the foot and arm supports will need to be adjusted for different cushions with differing thickness or adjustability/compressibility. You may find that the optimal pressure distribution will be achieved with a different position of parts of the body than you expect – for example, aiming to have the top of the thigh parallel with the seat base does not provide the optimum angle for pressure distribution under the thigh, since the femur does not usually run parallel with the skin surfaces.

5.3 Client/Caregiver education

IPM is useful as a visual feedback mechanism for client education. Seeing one's own pressure distribution and peak areas drives home the message of the importance of pressure management. It is also a very valuable tool to demonstrate the effectiveness of manual or power-assisted pressure relief techniques. Use the tool to teach movement - help the client find alternative pressure redistributing positions in their seating. (E.g. Use IPM as a biofeedback tool to help a nervous T3 discover how much (little) they have to move to achieve significant pressure reduction for their at risk areas.) Pressure mapping is also an excellent visual tool to show caregivers the consequences of setting up the cushion and chair incorrectly for the client. Likewise, it can be used to show the effects of different degrees of tilt or recline.

5.4 Dynamic activity

Current generation IPM systems give you instant feedback as to the impact of changing position on pressure distribution, and therefore just using mapping to look at non-representative static positions is wasting its potential. Leaving a client 'unattended' on the mat – say while writing up some notes – lets the client move into a natural position that they are likely to adopt when they leave the clinic. You can record what they are doing over time while arriving at that position, and see how long they stay in that chosen position, or if it is one of a selection of preferred positions.

The non-wheelchair population moves about once every 6 minutes when seated, while observations of wheelchair occupants indicates they move a tenth of this, and therefore are putting their buttock tissues at greater risk (Stockton et al, 2002; Linder-Ganz et al 2005). Thus we should be prescribing cushions that allow the client to move comfortably from one position to another more frequently.

With various IPM systems it is possible to record sessions, either by storing data in the interface module, or by wireless transmission, of the client self-propelling their wheelchair. This will provide you with information as to whether left-right strength differences, for example, result in the client rotating in the seat to accommodate. Comparing a 10m run on a tiled surface, with a 10m run on a carpeted surface, with a figure-of-8 run, with a run up a slope, will inform about the effects, if any, of the seating system in applied dynamic circumstances.

One protocol that has been suggested for assessing the individual on a range of seating scenarios is to take images with the client at maximum reach to left, to right, and forward.

The image linked to the range of movement achieved can be more informative as to the best seating option to prescribe. Sprigle et al (2007) have published measures of postural stability: getting the right balance between stability and dynamic activity is very important for the functionality of the individual.

5.5 Relevance to ADL

Ideally, the client should be assessed with the IPM in simulations of the Activities of Daily Living (ADL) they are likely to undertake. The impact of the activity on the seating setup, or v.v., can be assessed for what are key elements for *that* individual client, e.g. sitting at a computer, feeding, self-propelling, toileting, in transport, relaxing in front of a television, etc.

6 Clinical Test Protocol

This section is intended to guide the operator through the IPM test protocol, once that their clinical objectives are clear and which applications, conditions, or setups need to be measured have been planned. This set of instructions has been prepared with the intention to answer to the question “How shall I perform the tests?”: basic explanations regarding the justification of the proposed actions are contained in NOTES.

The different steps of the protocol are accompanied by an introductory paragraph with the aim of explaining the ambit and some background to the instructions that are stated.

6.1 Infection Control

Before starting an assessment, please be aware of the risks to you and your client of cross-contamination. IPMs may function as a ‘fomite’ (vector) transferring infectious agents from one client to the next. Recent research indicates that *both* sides of sensor mats used in pressure mapping are at risk from contamination acquired from seating cushions, and other components of the seating system, since these frequently contain significant microbial loads (Davis & Call, 2013]. IPM covers do not necessarily offer sufficient protection, especially against microbes, body fluids, or blood. Isolation bags are the most efficient protection for the sensor mat and for the client. If the mat becomes contaminated with urine or faecal material, clean with disinfectant wipes. However, contamination with blood or tissue fluids may result in the mat needing to be disposed of.

6.1.1 Wash hands

Wash your hands before and after the evaluation.

NOTE: Local infection control protocols may indicate using gloves when undertaking client assessments)

6.1.2 Avoid cross-infection

Don't touch the computer until you have cleaned your hands or removed your gloves

6.1.3 Protect the mat

Make sure you use an isolation bag if you wish to protect the mat.

6.2 Setting up

The success of the test session with the client is based on the ability of using the available time in the most effective and efficient way. All arrangements that can be prepared in advance to the client's arrival should be carried out: all the materials and instrumentation should be checked out, and all the testing and the combination of seating elements to be explored should be planned in advance, whenever possible.

6.2.1 Set up mat

Before the client arrives, ensure that the mat is working (by sitting on it yourself), that the correct mat has been selected in the software, and the most recent calibration file selected.

6.2.2 Prepare test protocol

Have a protocol prepared to be followed during the session. List the type of cushions/seats/postures/activities to be tested, and their order, in such a way as to minimize client discomfort.

6.2.3 Prepare client file

To save the assessment time with the client, have a mapping client file prepared and open into which you can add the session's readings. These might be adding to a previous session's records, or might be a new file for a new client.

6.2.4 Be consistent

Be consistent with the orientation of the IPM on the surface to be evaluated during the client session: the IPM cable should be placed in the same orientation (e.g. front, right) for all readings and all sessions.

6.2.5 Check mat orientation

Make sure the IPM is square on the seat.

6.2.6 Check mat position

Place the IPM on the cushion to assure that the buttocks will be fully captured by the active sensing area of the mat. This usually is accomplished by having the rear row of the IPM behind the posterior edge of the seating surface.

The mat may be significantly larger than the surface being studied if the wheelchair is small. If so, take care to avoid the formation of large folds in the IPM at the edges of the cushion or surface.

6.2.7 Smooth mat into cushion

Make sure the mat is relaxed into any contours of the cushion to avoid hammocking. Use your hands to smooth the mat into contours as needed.

NOTE: The ability of the IPM to conform to these contours is essential for understanding the surface's ability to redistribute pressures.

6.2.8 Acclimatise test cushions

Ensure all cushions are at room temperature before they are used in an IPM assessment.

NOTE: Variations in temperature can affect certain cushion materials' response to loading. For example, a viscoelastic foam or a gel cushion which has been stored in cold temperatures may initially be stiffer and take longer to settle into.

6.3 Transferring the client, and getting the client into position

Some clients will need assistance in transferring onto the mat. Adequate help may be required to transfer the client safely into position for the IPM session, e.g. assisting with lifting the patient, to minimize shear forces on the mat and client during transfer.

6.3.1 Transfer boards

Avoid the use of transfer boards if there is risk of damaging the sensors.

6.3.2 Slings and pads

Place the mat as close to the skin as possible by, where feasible, removing unnecessary items such as slings, pads, etc, which may have been employed while bringing a client into interaction with the mat.

NOTE: Consideration should be made about mapping an individual in the normal set-up that the individual exists within from day to day i.e. if the sling is normally left in place

during the day, map the individual with the sling in place, but with the IPM between the sling and the individual.

6.3.3 Post-transfer checks

Make sure the sensor mat is still in place after the transfer – squared on the seat, without wrinkles. Re-adjust the mat as needed.

NOTE: Use of a plastic isolation bag often contributes to the mat sliding out of place during the transfer. The isolation bag may cause the client to slide on the seat. Be extremely cautious with clients who may be predisposed to sliding forward, such as those with poor balance, low muscle tone, posterior pelvic tilt, and/or an open hip angle.

6.3.4 Consistency between tests

Make sure the client is in a seated position from which you can compare one set-up or surface with another. Use standard protocols for describing the patient posture on the wheelchair (Vaughn et al, 2013).

6.3.5 Settling time

Allow time to sit prior to recording the session: this takes into account the time to settle into the cushion (accommodating the effects of tissue and cushion material creep).

NOTE 1: Settling time varies based on differences in tissue and cushion material – cushions composed of time-dependent materials take longer to settle into. Cushions which are air-filled or comprised of elastic foam have a short settling time (3-5 minutes), in contrast with cushions made with viscous materials (viscous fluid or viscoelastic foam) which take longer (5-7 minutes) to adjust (Davis & Call, 2013).

NOTE 2: For client safety, total maximum sitting time during the IPM evaluation should not be exceeded if sitting duration limits are in place (e.g. due to current pressure injury).

6.4 Introducing pressure mapping to the client

Many clients and caregivers will be intrigued by the IPM and the information they see on the screen. Take this into account and possibly take advantage of this attitude. Conversely, they may be apprehensive about what is going on.

6.4.1 Position of the screen

Get the IPM mat under the person right away so they can play a bit while you are getting organized. You may want to consider having the screen out of sight of the client while you are taking readings, otherwise the client may twist to see the screen, or may voluntarily adjust their position, thereby affecting the readings. On the other hand, for education purposes, you may wish to use the images on the screen to demonstrate points to the client or caregiver.

6.4.2 Explaining the process

Explain the process to the client to remove any apprehensions; to involve the client and/or caregivers in the process; and to allow them to interact with the technology.

6.5 Capturing data

Data may validate or challenge initial assessments, but should not be used exclusively for making decisions. Clinical observation and expertise should always be part of the assessment process.

6.5.1 Identify position of boney prominences

As a prelude to assessing the client on their existing cushion (if they have one), if possible have the client sit upright on the IPM mat on a firmer surface like a mat table or a foam cushion. Scan, store, and describe where the boney prominences are, confirming their

existence with your hands and noting the on-screen coordinates. This will help answer the questions:

- What is the client's boney architecture like?
- Is it all there?
- Flexible?
- Is there an obvious obliquity?
- How rotated is the pelvis, etc.?

6.5.2 Record one or more images

After you have taken your reading(s) of the first set-up (6.5.1), document (see section 7) the details of the setup before moving to the next scenario (which could be the seating set-up that the client came in with). You will have the options of taking a single 'snap shot' of the set-up, or take continuous recordings over a period of time. The latter will be of more value for assessing dynamic sitting and seated activities.

6.5.3 Repeat the process

Repeat as above until all required set-ups have been recorded.

6.5.4 Check the images

While the client is in the set-up being recorded, use this unique opportunity to confirm with your hands what you see! Don't necessarily trust all you see on the screen. Unexpected pressure points may be caused by wrinkles in the mat or clothing, or items in pockets (see section 8.1).

6.5.5 Validate the images

Use the collected data and your experience to validate or challenge the good judgments you make.

NOTE: One mistake new users of IPMs make is to stand back and attempt to let the system make decisions for them. Another is to throw out their years of experience and start from scratch with all the solutions at their disposal. This can turn into an unnecessary frustrating and time-consuming process for the person doing the assessment and the client.

7 Documentation

Good documentation is key to effective use of IPM. The first level is to record information about the client. This could include (in no particular order of importance):

- ID#/name (observe privacy guidelines)
- Date
- Equipment set-up (baseline)
- Cushion model, age, width x depth, thickness
- Back support model
- Wheelchair model, width x depth
- Seat to back angle
- Seat tilt
- Foot support (thigh loading- distribution of pressure)
- Posture: Note postural deformities or asymmetries - express the posture with a repeatable method using quantitative values (Waugh et al, 2013).
- Upper and lower extremity position – as pertinent for pressure redistribution
- Risk level on a standardized scale (e.g. Braden, or Norton) or use low, medium, high based on sensation, mobility, history of pressure injury and frequency of pressure relief.

- Clinicians and carers as appropriate

7.1 File naming protocol

Use a consistent file naming protocol for each client and for all IPM sessions.

7.2 File location

Determine the IPM session save-to location - this can be configured in many different ways. The goal is for an orderly, easily retrievable file.

7.3 Make notes immediately

Record notes alongside the images at the time the data are captured, of the set-up, position, posture, and circumstances existing at that time, as these are the most important things when taking pressure readings, and may not be easily recalled some minutes, hours, or days later. Use standard protocols for describing the patient posture on the wheelchair (Vaughn et al, 2013). Keep your comments related just to the specific scan stored with that scan.

Make your notes with the thought in mind that you need to understand them several months later. This will help answer the questions:

- Why did we need to make changes or spend money?
- Why wouldn't a simple solution be sufficient?
- How well did the usual solution perform?
- How well did the alternative solution perform for your client?

7.4 Reporting

Most IPM software provides the opportunity to print a report or export the data or a set of readings into Microsoft Office software – Word, Excel, or PowerPoint, or similar.

Alternatively you can consider copying a specific screen shot into one of these applications. The report can also be saved as a pdf.

7.5 Photo documentation

Use correlative photo or video documentation to record posture and seating set-ups, and label them accordingly. IPM software can insert the photos or videos into the sessions. You may wish to write the cushion or setup under test on a board or label visible in the picture, so as not to mismatch the video/picture with the data. Be sure to obtain a photo release statement.

7.6 Data back-up

Keep back-ups of your records in case of failure of your computer hardware, or loss of the computer.

8 Interpretation

Historically, single peak pressures were used as the primary interpretive tool for analyzing IPM data. However, research has shown that single peak pressure values are not reliable and/or repeatable (Sprigle et al 2003). It is also important to know where the pressure has gone after an intervention to reduce the peak pressure – has a new peak pressure appeared where the client is more vulnerable to tissue damage? Thus the trend has shifted away from reporting single peak values to assessing the distribution of pressure over the entire support surface and relative comparisons thereof.

8.1 An unexpected image

If you see an image you do not expect to see, maybe it's the tool. Unexpected readings can come from:

- Wrinkles in the mat
- Wrinkles, seams, pockets, etc in clothing

- Poor placement of the mat
- Hammocking of the mat
- Out of date calibration
- Damaged mat
- Items left in pockets

Get your hands in there and find out. Your IPM may be telling you something important that, despite your years of experience, you have overlooked or you cannot detect with the human eye.

8.2 An image that is not ideal

Sometimes the picture you see may not be ideal, but the best advice could be to leave 'well enough alone': for example: a client's right Greater Trochanter is reading at or above 200 mmHg, and has been for some time without incident. If the only alternative is high pressure on an alternative proven risk area of, say, the right Ischial Tuberosity, the best approach could be to leave things as they are - but monitor it over time.

8.3 The image shows nothing abnormal

Sometimes the client has evidence of tissue damage, but everything in the seat looks good with the IPM. If it does, review the location of the wound and the clinical history. What is not obvious and unseen during the assessment? Activities away from the wheelchair may be the source of the problem. Some research and anecdotal evidence indicates that while the referral is for a perceived seating related pressure issue, much of the time the problem is in the bed and not the seat. It may therefore be necessary to conduct IPM assessments on other surfaces such as a bed or furniture in the home. Even if you only have a seat sized mat, use it to pressure map the client in bed or other surfaces. Tissue problems may also be caused microclimate issues of humidity or heat. Tissue problems may also be caused by shear forces which cannot be determined using the IPM. Shear forces could be generated in the seat (for example due to sliding) or arising during activities such as reaching, propelling, or transferring.

8.4 IPM Views and Metrics

The metrics listed below may be used to guide the interpretation of the IPM images. Other possible measures are defined in Section 4.

8.4.1 Isobar (2-D) View

This type of view displays the pressures of the same or similar values as a single colour. The blue end of the spectrum represents lower pressures, while the red end represents areas that are under higher pressures.

Most IPM systems allow the user to adjust the scale which correlates colour to a specific pressure range. Thus, great caution should be taken in automatically assuming a certain colour is good or bad.

Always check the scale.

It is useful to set the minimum value a little above zero pressure to remove the background 'noise' levels that are not relevant to the seated individual.

Adjusting the scale so that the readings take up most of the scale has the benefits of differentiating more clearly what is happening under the client at different contact points. For lightweight clients it is particularly useful to expand the scale for their readings – look to see what the maximum pressure is on any image for that client, and set the upper limit of the scale to slightly above that value.

NOTE: Some clinicians reset the maximum value of the scale to an artificially low value to encourage clients to change their behaviour to lessen the 'red' zones.

8.4.2 3-D View/Contour map:

This view provides a '3-D' graphical representation of pressure in relation to its location on the mat. Higher pressures are represented by peaks in the 3-D display. What looks like a mountain range in this view is worse for the client than a collection of 'foot hills': the mountain range appearance represents higher gradients, or rate of change of pressure from one point to the next. (See also Gradient (8.4.4) or Coefficient of Variation (4.2) definitions.)

Please be aware that the shape of the 3-D view does *not* represent the profile of the client's anatomy, and therefore cannot be used as a profile to contour a piece of foam, for example. It is a graph of the pressures across the IPM mat at each of the sensor points. Similar to the 2-D view, the 3-D view helps to bring out the areas of higher pressure, and therefore possible areas of greater risk of tissue breakdown

8.4.3 Centre of Pressure (CoP):

This feature displays a marker of the CoP which represents the location on the mat where the resultant load of all contact pressure (i.e. the portion of body weight that is being transferred to the seating through the mat) is applied, as if it was a concentrated load instead of a distributed load. This marker can be used to assess asymmetry (see also 8.4.5). The CoP marker helps to assess whether an intervention has taken pressure forward from the Ischial Tuberosities and more under the thighs. On the other hand, where a client presents with a flexible left pelvic obliquity, the baseline map would likely show a shift in the CoP to the left. Different cushions and seating set-ups will have variable effectiveness in reducing the obliquity. Noting which intervention shifts the CoP towards a midline point may aid in choosing the best solution.

When taking continuous recordings of a dynamic activity, tracking the CoP will give an indication of how symmetry is affected by the activity.

NOTE: the CoP location is mainly affected by the client's overall posture. Small changes in the subject's posture (e.g. head flexion or extension, foot placement, arms or shoulder placement) can produce large changes in the CoP position. Make sure to have the client in a standardized and repeatable posture before taking the measure and before comparing two seating or two test sessions before and after a treatment.

8.4.4 Gradient

Gradient recordings reflect the spatial changes in pressure. High gradients occur where the pressures change quickly from low to high on neighbouring sensors. The 3-D view is useful in assessing gradient. The steeper the 'slope of the hill' created by the peaks, the higher the gradient. High gradients are indicative of either poor envelopment or poor off-loading of the bony prominences. The higher the gradient, the higher the shear forces that the tissues are likely to be experiencing. The higher the gradient, the greater damage that will occur to the subcutaneous cells (especially around bony prominences), and the greater resistance to blood flow reaching the higher pressure points.

8.4.5 Asymmetry

This visual and numerical measure demonstrates a pressure or shape differential. This is usually referred to as the amount or direction of asymmetry. Asymmetry indicates a probable need for further postural evaluation and seating modifications. It is often reflective of an orthopaedic deformity (e.g. pelvic obliquity, scoliosis, etc), postural imbalance (e.g. functional lean), or improper seating set-up (e.g. incorrect foot support height). Asymmetry across the IPM is not always a 'bad' thing: for some clients, asymmetry offers increases stability, or allows a more functional position of other parts of the body, such as the head or shoulder girdle.

8.4.6 Interpolation

Most people use a display where the software is looking at each sensor's individual value, and at the values of the neighbouring sensors, and spreads the differences into a number of steps, as if there were a number more sensors across the area than really exist. This

produces a view that is more like that of a contour based map, and is more intuitive for the user to understand. This software process is called interpolation.

The pressure values remain the same. The only thing that changes is how the 2-D pressure image is drawn. This can aid an experienced therapist to identify objects or other features in the display that might not be visible or obvious in the non-interpolated display.

8.4.7 Smoothing

Smoothing is a mathematical technique that attempts to capture important patterns in the data that may not be visible or obvious in the original data, while eliminating noise. In other words the software identifies the values that are outliers and thus probable sources of error. (Smoothing involves fitting a 3D spline to a 3D set of points.) From an isobar display perspective, smoothing blends the colours and margins of adjacent sensors. In some IPM systems, the smoothing preserves the highest value.

If you choose the smoothing option for one cushion, you should also use smoothing for all cushions in a given client evaluation session to perform a fair relative comparison of the cushions.

9 Limitations

This section considers the main factors that may influence the effectiveness of an IPM measuring session or its Clinical relevance in the assessment of wheelchair seating systems.

9.1 Prediction of pressure injuries

A vast majority of papers on the aetiology of pressure injuries have attempted to identify the level of sustained mechanical loading on skin and soft tissue, beyond which the tissue will break down. This has led to a number of qualitative observations that can be summarized as follows:

- As pressure and shear forces are applied, tissue damage occurs. There is a relationship between time and magnitude of an externally applied load and the risk of acquiring a pressure injury. It is generally accepted that a high magnitude requires less time to cause a pressure injury. Low loads can also lead to a pressure injury, but may require a longer time.
- In certain cases, muscle is more susceptible to breakdown than skin or adipose tissue.
- Externally applied shear forces are more damaging than normal forces. (However, shear forces cannot occur in the absence of normal forces.)
- The highest stresses and strains can be found internally (i.e. adjacent to bony prominences), leading to deep tissue injury (Gawlitta et al, 2007).
- Pressure will be a factor in combination with other factors leading to tissue breakdown, but at the surface (most Stage 1 and 2 pressure injuries) other elements are most likely to be the primary cause such as microclimate (9.2), friction, or shear. Stage 3 and 4 pressure injuries *are* more likely to be caused by pressure, and frequently this has been the result of damage to tissue adjacent to bony prominences, and working outwards.

Thus, whereas IPM is used as a tool to help in the prediction of pressure ulceration, it has to be used with caution and awareness of the other factors involved.

9.2 Microclimate

Microclimate, namely local temperature and moisture, have an important impact on skin integrity at the surface, and are considered by some to be the primary causes of Stage 1 and 2 pressure injuries, alongside friction and shear force damage. IPM will not provide any

guidance as to the influences any of these factors may have, but all of them need pressure for their influences to apply.

9.3 Clothing

Clothing does have an impact on tissue integrity, and most people are assessed with the clothing they are wearing when they attend clinic. For those who are concerned about any hammocking affects the IPM may have between the cushion and the client, most clothing is going to have more of a hammocking affect than a modern IPM mat. Furthermore, if the clothing and the mat are not changed during the assessment, comparisons under these conditions can be made between surfaces or positions.

Do watch out for 'artefacts' that will appear on the picture arising from studs and seams in jeans, for example. If they show on the image, they are possibly affecting the client. You will also often find various objects such as keys, combs, wallets, etc in back pockets show up well on images, and the client should be advised of the potential harm these objects may be causing them.

9.4 Repeatability and Relative Values

IPM shows values of pressures taken at a certain time within a certain setup. However, if you are looking for reproducible absolute values, there are better engineering tools for this purpose than IPM, such as strain gauges. Clinically, it is the *distribution* of pressures that is more important than the individual pressure values. Equally, as pressure is redirected from one place to another, is the new place better or worse for the client? There is no right or wrong pressure, though there may be better or worse values for an individual client. Values for the individual will change, and will not be repeatable, due to creep in the person's tissues and their cushion, changing position, fatigue, etc.

9.5 Influence of posture

An 'ideal' posture for an individual of, say, a neutral pelvis, may be a posture that increases forces through the ITs. The 'best' pressure map may have the client in a non-functional position. It is therefore essential that all aspects are taken into consideration, and the image alone is not used to determine whether a cushion or the posture is the right one or not.

9.6 Sampling frequency

The inbuilt sampling rate (rate of data collection) of an IPM system is not usually greater than 100 Hz at best: this will not be enough to collect significant data regarding, say, the vibrational behaviour of a wheelchair or seating set up, as the frequency of vibrations can be higher than the sampling frequency of the system.

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