The relationship between tip diameter and mechanical nociceptive threshold

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Background

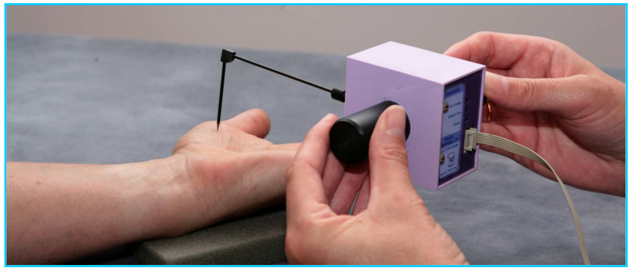
Pressure stimuli are commonly used to measure mechanical nociceptive thresholds (MNT) for studies in pain and analgesia. A probe tip, usually circular and hemispherical or flat, is advanced into the tissue to be tested. Compression of the tissue causes nociception. At threshold, force (or sometimes pressure) is reported.

Testing is carried out in various locations, ranging from soft (abdomen) to relatively stiff (over bone), and on surgical sites. Numerous probe tip diameters are reported, making comparison of the data difficult. Previously we have attempted to apply the simple relationship Pressure=Force/Area to normalise data from different tip diameters.

If this equation applied, and MNT was proportional to the tip area, then halving the area of the tip would halve the force required to produce the same pressure on the nociceptors. Our experience has indicated, however, that this relationship does not apply. We therefore set out to evaluate the effect of probe tip diameter on MNT in the absence of confounding factors.

Methods

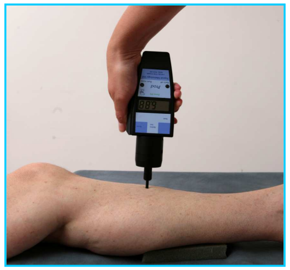
Two human subjects, blinded to the probe tip diameter, were tested on two sites (base of thumb and anteriomedial tibia) using a force algometer (Prod) and, for the smallest tip diameter, an electronic von Frey system (MouseMet), both from Topcat Metrology Ltd. In sessions over several days, each site was tested 5 times at 6 minute intervals with hemispherical tip diameters of 0.2, 0.5, 1, 2, 4, 6, 8, 10 and 12 mm in random order. Force rise rate was $2Ns^{-1}$, guided by rate lights on the algometer. MNT was recorded in N. End point was the first painful sensation.



MouseMet (force range 0.1-7gf), in use on the base of the thumb

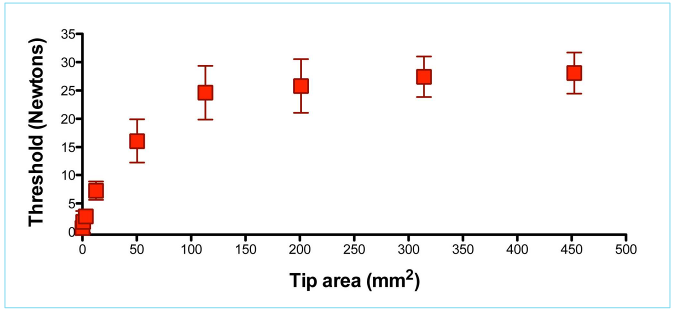
The Prod (0.5N -25N) in use on the thumb

The tips used with the Prod



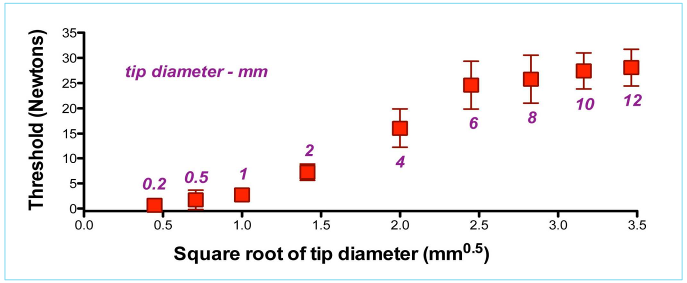
The Prod in use on the leg

Results



The relationship between MNT and probe tip area

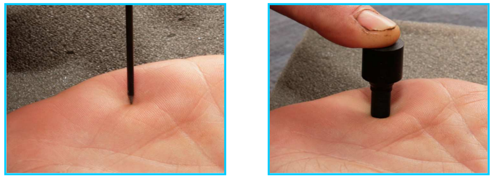
MNT were not proportional to the area of the probe tip. If they were, and the relationship Pressure=Force/Area applied, this graph would be a straight line. Note that, with the larger probes, tip diameter has very little effect on threshold force and that variability generally increases with tip size.



The relationship between MNT and the square root of probe tip diameter

By experimentation, MNT was found to be approximately proportional to the square root of the probe tip diameter(= the cube root of the tip area) and described more completely by a 4th order polynomial.

This S graph has three distinct regions: (i) For tip diameters 2-6mm there is a near linear relationship between the square root of the tip diameter and the threshold force. (ii) Below 2mm, tip diameter has a smaller effect on threshold force. We believe this is due to tissue deformation around the probe spreading the load, so that it acts on a larger effective area. (iii) Above 6mm, MNT becomes almost independent of tip diameter (and therefore also of its square root) and variability increases. We believe that this is caused in part by the difficulty in applying these larger forces manually.



A small probe causes substantial tissue distortion around the edge and therefore has a larger effective area than would be calculated from the equation Pressure=Force/Area. A larger probe distorts a similar area but the calculated pressure (from its area) is much less.

Conclusions

MNT is not proportional to the area of the probe tip over this range of probe diameters. Plotting MNT against the square root of the tip diameter results in an S curve.

At tip sizes of 2mm and below, the effective area of the probe is increased substantially by local tissue deformation, giving one tail to the S curve. At tip sizes above 6mm, the threshold force is almost independent of tip area and the higher forces required to reach threshold are difficult to apply manually, resulting in increased variability and the other tail to the S curve.