Validation of simple and inexpensive algometry using sphygmomanometer cuff and neuromuscular junction monitor with standardized laboratory algometer

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Abstract

Background and Aims: The availability, ergonomics and economics prohibit the routine use of algometers in clinical practice and research by the anesthesiologists. A simple bedside technique of quantitative pain measurement would enable the routine use of algometry. We proposed to validate simple pain provocation using sphygmomanometer cuff and the electric stimulation of neuromuscular junction monitor (TOF-guard, Organon Teknika) to measure pain against a standardized laboratory pressure algometer.
Material and Methods: Pain detection threshold (Pdt) and pain tolerance threshold (Ptt) were measured in forty healthy volunteers of both genders, using the above three techniques. All measurements were repeated three times. The co-efficient of inter-rater reliability (or consistency) between three independent measurements obtained from each of the techniques was determined by Cronbach's co-efficient alpha (α C). The correlation between the mean Pdt and Ptt values recorded by standardized algometer and the sphygmomanometer technique and nerve stimulator technique was performed using Pearson Correlation. An $r > 0.5$ and a two-tailed significance of < 0.05 were considered as good correlation between the standardized algometer and the tested techniques.
Results: There was a good inter-rater reliability (α C > 0.7) for the three techniques. There was a good correlation with $r > 0.65$ ($P < 0.001$) between the measurements of standardized pressure algometer and the two techniques being tested as alternatives for algometer to measure pain.
Conclusion: The sphygmomanometer cuff technique and electrical stimulation with the peripheral nerve stimulator to measure pain threshold and tolerance provide a simple, efficient, repeatable measure of pain intensity and can be used as suitable alternatives to standard algometers.

Key words: Algometry, analgesics, clinical research, cuff pressure, electrical stimulation, pain, pain threshold, pain tolerance, perioperative, pressure, validation

Introduction

Anesthetists frequently administer analgesics in the perioperative period and are interested in assessing their efficacy and comparing different drugs administered for this purpose. Most of the practical and theoretical basis of pain assessment relies on physiological and behavioral methods and is subjective. There has been a significant progress in the technology of pain measurement by algometers over recent decades.[1] Algometers are not readily available and are expensive. These factors limit their routine use in clinical practice and research though they are frequently used in preclinical testing on humans.[2] There is a need for a simple bedside, readily available technique of quantitative pain measurement to study and compare the effect of analgesic drugs in clinical practice.

The objective of this study was to validate the simple techniques of pain measurement using a sphygmomanometer cuff, and the electric stimulation of neuromuscular monitor as standardized pain stimulus to measure pain.

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We hypothesized that these simple, bedside ubiquitously available pain measurement techniques provide quantitative information on pain that could correlate with the measurements obtained from a standardized pressure algometer used in pain laboratory.

Material and Methods

The validation of two indigenous techniques of pain provocation and validation-one using sphygmomanometer and another using neuromuscular junction monitor (TOF-Guard nerve stimulator, Organon Teknika) was performed using a randomized cross-over design. The study was performed on forty healthy consenting volunteers of both genders after obtaining institutional ethical committee approval and written informed consent. Subjects with sensory impairment of upper limb, on drugs such as sedatives, analgesic drugs, drugs modulating pain pathways such as gabapentin and steroids, suffering from chronic pain, obesity (body mass index > 35) were not included. The measurements were carried out in a single session. The order of the tests was determined by computerized randomization. The investigator explained the procedures to the subjects before the start of the study. The study was performed in a quiet setting without any distractions. For training and familiarizing the subjects a trial run of each test was performed at a different site to avoid local sensitization. The actual testing was performed on the nondominant hand. Each technique was performed by a different investigator to reduce bias. Three independent readings were taken at intervals of at least 15 min between techniques. The mean of the three readings was taken for analysis. The subjects were allowed to withdraw their participation at any point of the study if they were apprehensive or experienced discomfort.

The point in which a steadily increasing nonpainful pressure stimulus turns into a painful sensation was defined as the pain detection threshold (Pdt). Pain tolerance threshold (Ptt) was defined as the highest level of pain which the subject was prepared to tolerate. For the standard testing of the Pdt and Ptt an established pressure algometer (Analgesy-Meter, Basile, Italy) was used. The standard protocol recommended by the manufacturer was followed for calibrating the algometer. The pressure algometer was applied to the nail of the middle fingers without touching the nail fold. The algometer reading at which the subject complains of pain was noted. This was called the Pdt (algometer). The stimulus was intensified until the subject experienced unbearable pain. This was called Ptt (algometer).

For the pain testing using cuff pressure of the sphygmomanometer, a 2.5 cm × 2.5 cm circular metal bottle stopper of 2 mm height

with smooth corrugated edges was placed on the medial side of arm and the manometer cuff was wrapped around the arm [Figure 1]. The cuff of the sphygmomanometer was inflated until the subject perceived pain at the site of the stopper. The pressure reading at which the subject complains of pain was noted. This was called the Pdt (cuff). The cuff was further inflated until the subject experienced unbearable pain. This was called Ptt (cuff).

Two Ag/AgCl electrodes were applied on the ventral aspect of the forearm [Figure 2]. The active and neutral terminals of the electrical stimulator were attached to the electrodes. An incremental electric current was applied starting from 1 mA and increased by 1 mA at each step. The subjects were asked to inform the investigator when they perceived the electric current. The application of increments of electric current was continued until the subject first experienced pain at the point of application. The current at which subjects perceived the electric current was called perception threshold (PT). This was measured to eliminate the possible error in the measurement due to changes in skin impedance. All subjects with deviation of PT by 2 mA from the sample median were not included in the study. The electric current at which subjects detect pain was noted as Pdt (nerve stimulator) and the current at which subject experiences maximum tolerable pain was called Ptt (nerve stimulator).

Statistical analysis

Statistical analysis was performed using SPSS® version 13 (SPSS Inc. Chicago, IL, USA). The descriptive statistics for continuous variables was expressed as mean and 95% confidence interval (95% CI). The co-efficient of reliability (or consistency) for three independent measurements obtained from each technique was determined by Cronbach's co-efficient alpha (α C). A α C of >0.7 was considered as acceptable inter-rater variability.

Figure 1: Circular metal bottle stopper placed over the medial side of the arm and the sphygmomanometer cuff wrapped over it (cuff lifted to show the stopper)

The correlation between the threshold values and tolerance values recorded by standardized algometer and using the sphygmomanometer technique and the nerve stimulator technique was performed using Pearson correlation and a two-tailed significance of <0.05 was considered as agreement with the study hypothesis that there was correlation between the standardized algometer and the tested techniques.

Results

37 volunteers completed the test. Two subjects had the PT for electrical stimulation deviating by >2 mA and were therefore excluded from the analysis. Two subjects did not complete

Figure 2: Electrodes placed on the forearm for electrical stimulation using neuromuscular junction monitor

the test owing to work schedules. One subject withdrew from the study owing to apprehension. The analysis included 30 males and 5 females. The mean age was 29.02 (standard deviation [SD]: 8.8) and weight. The pain thresholds and tolerance assessed by the three techniques is shown in Table 1. There was a wide range of pain thresholds and tolerance in the population studied. The Cronbach's alpha α C for inter-rater reliability was >0.7 for all the three techniques [Table 1] suggesting that the techniques have relatively high internal consistency and low inter-rater variability. The correlation between the three techniques, their co-efficient and the significance are given in Table 2 and Figures 3 and 4. There was a very high degree of correlation between the Pdt and Ptt assesses by algometer and that assessed by sphygmomanometer technique and nerve stimulator technique. The correlation was better with the sphygmomanometer cuff technique than the nerve stimulator technique.

Discussion

It is important to quantify pain for experimental, diagnostic and monitoring purposes.[3] Several psychophysical and behavioral scoring techniques are commonly applied for pain measurement to assess clinical and experimentally induced pain. The psychophysical approaches use the cross-modality matching procedures to determine the relative magnitudes of verbal descriptors of pain. The common methods of assessment of pain are visual analog scale (VAS), numerical rating scale (NRS), McGill's pain questionnaire, etc. VAS is the standard method of assessment of pain, but it has certain

Table 1: Pain threshold and tolerance assessed by the standard algometer, cuff and nerve stimulator techniques and their inter-rater correlation

Measurement	Mean	95% CI for the mean		Cronbach's alpha	95% CI of α C	
		Upper limit	Lower limit		Upper limit	Lower limit
Pdt-algometer (Pascal)	1448	920	2240	0.76*	0.59	0.87
Ptt-algometer (Pascal)	2386	1520	3000	0.93*	0.87	0.96
Pdt-nerve stimulator (mA)	26.01	11.67	51.67	0.85*	0.76	0.92
Ptt-nerve stimulator (mA)	42.74	25.00	60.00	0.87*	0.81	0.94
Pdt-cuff (mmHg)	111.97	73.00	157.00	0.94*	0.90	0.97
Ptt-cuff (mmHg)	196.86	106.67	300.00	0.92*	0.87	0.95

All inter-rater correlation were significant at P < 0.001. Pdt = Pain detection threshold, Ptt = Pain tolerance threshold, CI = Confidence interval

Table 2: Correlation between pain threshold and tolerance assesses by the standard algometer, cuff and nerve stimulator techniques

Measurement	Pdt-algometer	Ptt-algometer	Pdt-nerve stimulator	Ptt-nerve stimulator	Pdt-cuff	Ptt-cuff
Pdt-algometer	1	907**	797**	780**	864**	813**
Ptt-algometer	907**	1	754**	796**	861**	895**
Pdt-nerve stimulator	797**	754**	1	735**	654**	663**
Ptt-nerve stimulator	780**	796**	735**	1	793**	755**
Pdt-cuff	864**	861**	654**	793**	1	746**
Ptt-cuff	813**	895**	663**	755**	746**	1

**Correlations were significant at P < 0.001. Pdt = Pain detection threshold, PTT = Pain tolerance threshold
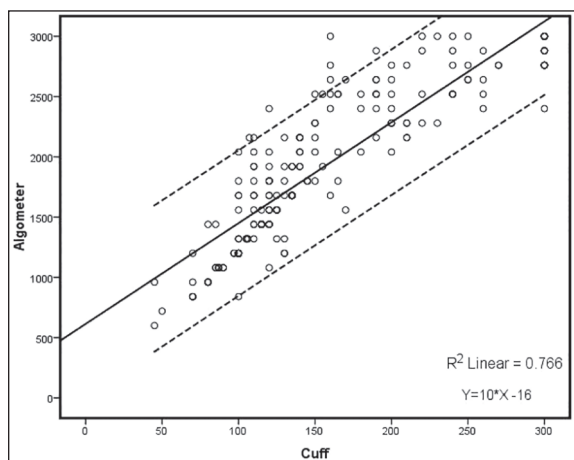
Figure 3: Scatter plot showing relationship between pain measured by standard algometer and sphygmomanometer cuff technique

Figure 4: Scatter plot showing relationship between pain measured by standard algometer and nerve stimulator technique

drawbacks, namely that the scales are subjective and lack the precision necessary for accurately assessing the degree of pain in patients. McGill's pain questionnaire was developed as a tool for the study of pain management. However, this is very elaborate and time-consuming. Several behavioral measures of pain have been developed. However, the use of such scales by patients and observers to assess the amount of pain may introduce a subjective bias.

Heart rate, blood pressure, electrodermal activity, electromyography, and cortical evoked potentials are used as physiologic correlates of pain experienced. Though these changes are frequently used by anesthesiologists, there can be several limitations. These physiologic responses tend to habituate with time despite the persistence of pain. They can occur under conditions of general arousal and stress and are not specific to the experience of pain.

Techniques for quantitative measurement of pain using sensory testing paradigms and assessing the response have been developed in the recent years. Researchers have developed several algometers for quantitatively measuring pain for pain research and to aid in the clinical diagnosis and treatment of pain syndromes.[1]

The gold standard for measuring pressure pain sensitivity is the application of quantifiable mechanical pressure.[2] The pressure needed to evoke pain can be recorded using a force gauge with a well-defined probe area using a manual or computer-controlled pressure Algometer. Monitoring of the force application rate facilitates the generation of repeatable results. The individual pressure Pdt and/or pressure Ptt are determined by applying measured amounts of pressure.

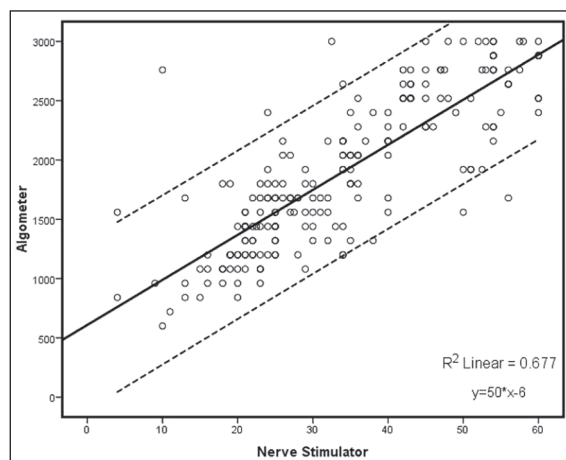The importance of quantitative and objective methods to evaluate pain is well documented in patients

with neuropathy,[4] fibromyalgia,[5] tension headache[6] and several other problems. The effects of physiotherapy, pharmacological treatments and other interventions documented for clinical as well as research purposes using the algometer.[7] The quantitative measurement would also provide accurate data for the pharmacological studies. Though anesthesiologists are extensively involved in management and monitoring of pain and in the research of analgesic drugs, there are very few clinical studies in the anesthetic literature involving algometry.[8-15] The major limitations to the use of algometry in routine clinical practice and research are the cost and availability of the equipment.

Pneumatic cuffs are widely used for indirect noninvasive measurement of arterial pressure. The cuff pressure is directly related to the tissue pressure under the cuff. These devices can be used to quantify deep-tissue pain sensitivity and thus allow the pain assessment on a large volume of tissue.[14,16] A computerized cuff pressure algometry has also been developed.[17,18] This technique assesses the muscle sensitivity by the pressure-induced pain in a large volume of tissue under the cuff. Factors influencing measurement by cuff pressure algometer can be external factors such as probe dimension and examiner skills or intrinsic factors such as tissue type and geometrical characteristics of the limb.[16,19] We, therefore, attempted to convert this deep somatic pain into cutaneous pain in order to reduce this variability by applying a corrugated bottle stopper under the cuff of a sphygmomanometer. The main concern of such placement might be injury. There was only a mild redness of the skin and no evidence of other injury, and none of the participants complained of discomfort.

Another method of algometry is the use of electrical stimulator devices connected to electrodes applied to the skin surface evoke electrical stimulation. The type of stimulation patterns

delivered by these stimulator devices varies in waveforms, frequencies, and duration of the stimulus.[20] We have used frequency of 1 Hz to avoid summation. This stimulus evokes a different kind of pain from the pressure algometer. However, there was a significant correlation between the standard laboratory pressure algometer and the tested method of pain assessment using a peripheral nerve stimulator.

The important requirements of any technique that measure pain, efficacy, reliability, consistency, and it should be validated. The cuff technique and nerve stimulator technique appear to meet all of these requirements. The preliminary results from this study designed to examine the efficacy of indigenous algometers to assess the pain threshold and tolerance show that they can be useful alternatives to standard algometry. There was a good correlation between the two tested algometric methods even though the stimulus used for measurement different for the two methods. The methods had little inter-individual variability and were easily reproducible. The advantages of these techniques include their ease, brevity of administration, minimal intrusiveness, and its conceptual simplicity. The equipment required for measurement of using these techniques is ubiquitous world-wide and are low-cost methods for assessing pain.

Quantitative pain testing is often advantageous in the studies of analgesics and anesthetic procedures as they exclude the confounding factors such as psychological, cognitive and social aspects. Assessment of preoperative pain threshold would enable us to predict postoperative pain and analgesic requirement.[9] It has been shown that labor pain could be predicted with supra threshold heat VAS, heat tolerance, and pressure tolerance.[11] A recent systematic review that included fifteen studies has shown that the intensity of preoperative pain thresholds correlate with postoperative pain.[8]

Intensity of pain measured as Ptt or Pdt by these techniques has scalar properties unlike many other pain measurement scales, which are qualitative. Thus, ratio statements may be made that describe pain in one group of patients as being several times that of another or as being reduced by a certain value. The ratio scale property also means the measurements are suitable for description using parametric statistics (such as the mean, SD, and Pearson correlation co-efficient, analysis of variance and regression analysis etc.) and the sample size of the studies can be minimized.

However, there are certain limitations. The correlation with pain measured on available scales such as verbal and NRS has not been assessed. Their use is limited in infants and preverbal children. Mental clouding or confusion also limits their use. It does not measure the "unpleasantness" dimensions of pain.

It measures systemic pain and analgesia at the site of testing and does not measure pain at the affected site. It is not useful to assess the efficacy of regional pain management techniques. Deep pain involves different pain pathways from cutaneous pain. The data from cutaneous testing cannot be extrapolated to such pain.[16,21] Despite these limitations, the possibility of using these simple techniques of pain measurement would encourage anesthesiologists to use algometry in both research and clinical practice. Validation of these experimental pain models to show that the proposed model detects the effect of different analgesic drugs and doses and variation in the baseline intra- and inter-individual variation of pain will be undertaken in a subsequent study.

Conclusion

The sphygmomanometer cuff technique and electrical stimulation with the peripheral nerve stimulator provide quantitative measurement of pain comparable to standard algesiometer. They are ubiquitous, simple, efficient, reliable and minimally invasive. They can be used in clinical and research settings where a quantitative index of pain is required.

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