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ORIGINAL ARTICLE

# Differences in the epidermal pain threshold between different needle puncture sites

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## Abstract

**Purpose** Puncture of the skin by a needle, such as for peripheral nerve block or for intravenous or arterial catheter placement, may cause pain to the patient, so that analgesic method may be required to reduce pain caused by needle puncture. Nevertheless, there is little information as to which puncture sites are more painful than the other.

**Methods** After obtaining an approval of the study by a research ethics committee and written informed consent from all the participants, we studied 30 volunteers to quantify pain threshold at 13 skin sites of the body, using an algometer.

**Results** Compared with pain threshold at the cubital fossa (which was regarded as the control value), the relative pain threshold was significantly lower (with clinically meaningful difference) at the lateral carpus (median (interquartile range): 0.66 (0.56–0.73)) and the medial carpus (0.80 (0.73–0.94)); and was significantly higher (with clinically meaningful difference) at the olecranon (2.08 (1.93–2.42)), the forehead (1.59 (1.46–1.74)), the upper shoulder (1.52 (1.38–1.79)), and the dorsal shoulder (1.39 (1.18–1.55)).

**Conclusions** We conclude that there are significant differences in pain threshold between different puncture sites. Analgesic method before needle puncture may be required at the sites where the pain threshold is relatively low.

**Keywords** Epidermal pain threshold · Peripheral nerve block · Needle puncture

## Introduction

Puncture of the skin by a needle, such as for peripheral nerve block or for intravenous or arterial catheter placement, may cause discomfort and pain to the patient. Some analgesic methods, such as applying a local anesthetic cream to the skin, may be used to reduce pain caused by needle puncture, but decision to use such an analgesic method is largely based on practitioner's experience, and is not evidence-based. It is known that pain threshold may differ between the different sites of the body [1–4], but there is little information as to which puncture sites are more painful than the other.

The main aim of the study was to assess possible differences in pain thresholds at various skin sites, where a needle is frequently inserted for peripheral nerve block, intravenous or arterial puncture (or cannulation).

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## Methods

Research ethics committee of Dokkyo Medical University approved the study (approved number: 23077; approved date: 27th September, 2023), and written informed consent was obtained from all the participants.

We studied 30 volunteers (Table 1), without a skin disease and peripheral neuropathy. As a cross-over design, we studied pain threshold at the following 13 skin sites of the body: the forehead, the upper jaw, the lower jaw, the anterior region of neck, the upper shoulder, the dorsal shoulder, the proximal upper arm, the distal upper arm, the cubital fossa, the olecranon, the lateral carpus, the medial carpus, and the back of the hand. An algometer (Takei apparatus industry, Niigata, Japan) was used to quantify the threshold of the sense of pain. This device is a spring-type algometer developed on the conical needle and designed for directly reading in gram the continuously applied smallest pressure that induces pain. The tip of the algometer is conical with a 60 degree tip angle so that the area of its tip being pressed to the skin would be less than 1 $mm^2$, but cannot penetrate the skin. The tip of the needle

**Table 1** Participants' characteristics (mean (SD) [range])

| | Males ($n=13$) | Females ($n=17$) |
|---|---|---|
| Age (yr) | 28 (5.8) [22–44] | 32 (9.9) [22–55] |
| Height (cm) | 171 (4.6) [162–178] | 159 (6.0) [143–173] |
| Weight (kg) | 70 (11.0) [55–91] | 53 (9.5) [38–82] |
| Body mass index (kg $m^{-2}$) | 24 (3.4) [19–31] | 21 (3.1) [18–30] |

is conical and measures from 2 to 10 g with an error of up to 10%.

Each volunteer was asked to sit down on a chair and close the eyes. The tip of the conical needle was placed to each test site of the skin, and was pressed perpendicularly against the skin, until the volunteer sensed pain. The threshold of pain was quantified as the weight (in gram) at that moment. Measurements were taken in the same order (and thus not in a random order) for all participants, starting with the forehead toward the medial carpus (of the front side of the body), followed by the upper shoulder toward the back of the hand (of the back side of the body). To minimize possible habituation and sensitization of pain threshold [5], the measurement interval for each site was set at least 1 min. All measurements were performed on the same side for each participant, to minimize possible difference in the sensitivity between the right and left sides. [6]

We regarded pain threshold at the cubital fossa as the control value for each volunteer, as this puncture site would be most frequently used clinically. The degrees of pain threshold at the remaining of 12 sites are expressed as the ratios of the control value.

The median and interquartile range were calculated for pain threshold at the cubital fossa, and for the ratios for the remaining 12 sites. Friedman's two-way analysis of variance was used to compare pain threshold between the different sites, and if this indicated a significant difference, Wilcoxon matched pairs signed rank sum test was used to compare pain threshold between the control site and the test site. $P<0.05$ was considered significant for the results of Friedman's two-way analysis of variance. Bonferroni corrections were applied to comparisons between the control site and a test site (of 12 sites) and $P<0.0042$ (0.05/ 12 = 0.0042) was considered significant for the results of Wilcoxon matched pairs signed rank sum test. We also defined that there was a clinical meaningful difference, when the median ratio for a test site was outside the interquartile range of pain threshold at the cubital fossa.

## Results

The median, the interquartile range, and the range, of pain threshold at the cubital fossa were 4.0 [3.3–4.8](2.4–5.3) g. When the individual value was converted to the ratio, by dividing each value by the median (4.0), the interquartile range for the ratio was 0.83–1.2. Therefore, we judged that there was a clinically meaningful difference in pain threshold between the cubital fossa and at a test site, when the median ratio for the test site was outside range of 0.83–1.2.

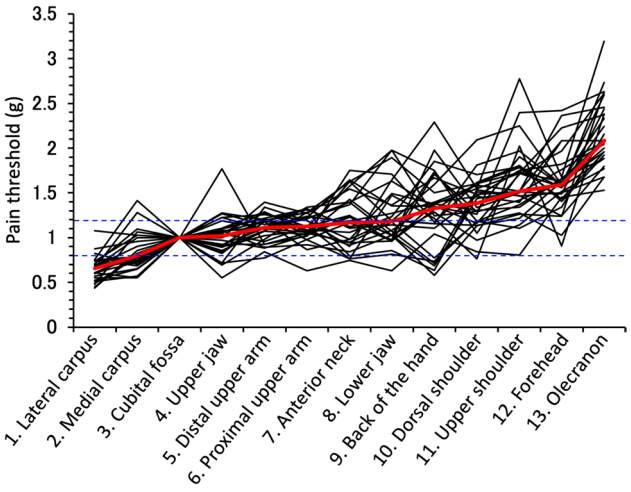


**Fig. 1** Individual data for pain threshold at different needle puncture sites of the skin. (The dotted lines indicate the minimally clinically meaningful difference in the pain threshold between the cubital fossa and another site)

There was a significant difference in pain threshold between the sites ($P<<0.0001$). Compared with pain threshold at the cubital fossa, pain threshold was significantly lower at the lateral carpus (0.66 (0.56—0.73)) and the medial carpus (0.80 (0.73–0.94)) (both $P<0.0042$), and the differences were clinically meaningful (Figs. 1, 2).

In contrast, compared with pain threshold at the cubital fossa, pain threshold was significantly higher at 9–10 remaining test sites (all $P<0.0042$), and whereas no significant difference was observed between the cubital fossa and the upper jaw (Figs. 1, 2). Significantly higher pain threshold was clinically meaningful at the olecranon (2.08 (1.93–2.42)), the forehead (1.59 (1.46–1.74)), the upper shoulder (1.52 (1.38–1.79)), and the dorsal shoulder (1.39 (1.18–1.55)) (Figs. 1, 2).

## Discussion

We have shown that pain threshold varies considerably between different skin sites of the body, and pain threshold is relatively lower at lateral and medial carpus than at the cubital fossa.

The reasons for these differences are not clear, but one possible reason may be due to the differences in the thickness of the skin at different skin sites. The free nerve endings that sense pain are located in the lower layers of the

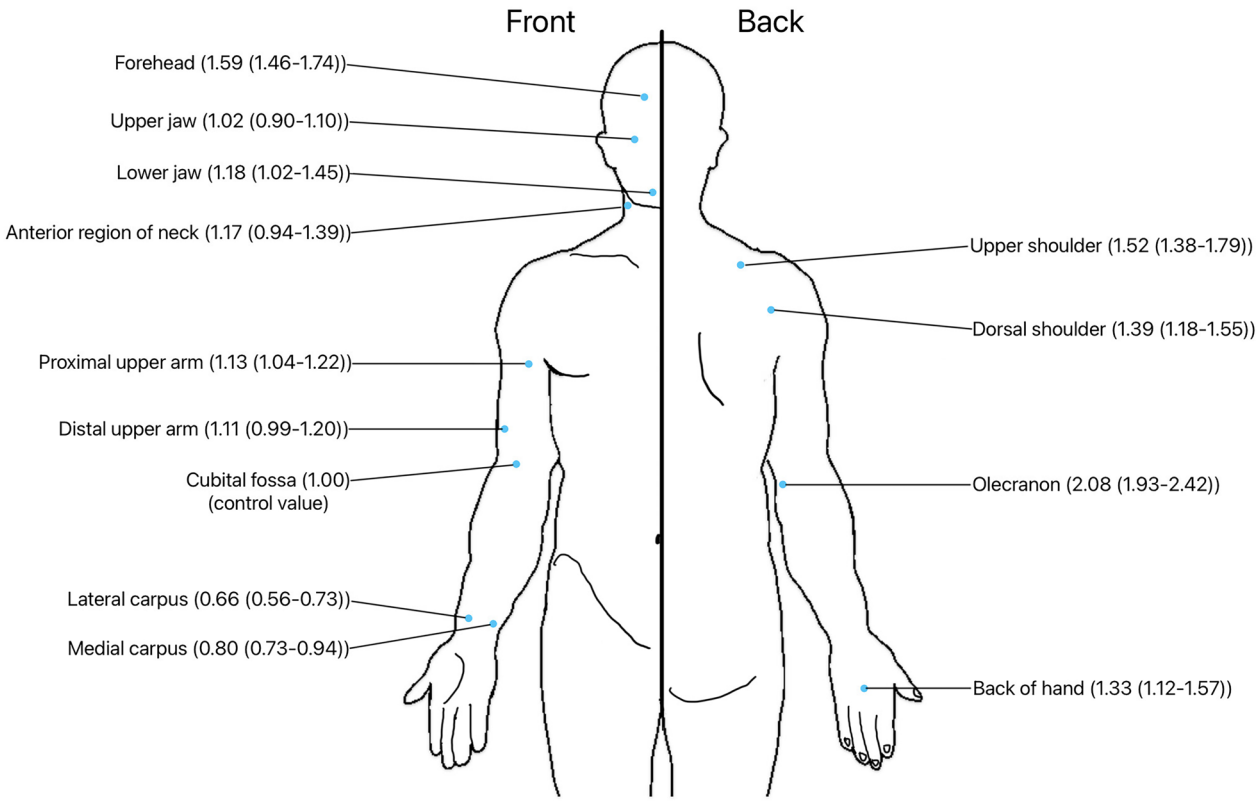


**Fig. 2** Relative pain threshold (median (interquartile range)) at different needle puncture sites of the skin (the cubital fossa as the control site)

epidermis [3]. The thickest epidermis among the measurement sites was the olecranon where the pain threshold was highest in our study, and the thinnest was the carpus where the pain threshold was lowest [7]. These results suggest that the skin thickness may be positively correlated with pain threshold. Another possibility is that the density of intraepidermal nerve fibers varies at different body regions [8, 9], and thus these density differences might have contributed to the differences in pain threshold.

Limitations of the study include that we studied fit and healthy young volunteers, and thus it is not clear whether or not the results are applicable to different populations, such as elderly people, children, or some patients with certain diseases (e.g., fibromyalgia) who are known to be more sensitive to pain [10]. In addition, we studied volunteers of both sexes, but there might have been differences in pain threshold between males and females. [11]

We assessed pain threshold using an algometer with its tip being pressed to the skin would be less than 1 $mm^2$, but pain threshold might be different when the area of the skin being pressed are different [12]. We chose the use of the algometer with a thin tip, because it has been shown that, compared with thicker algometer probes (100 $mm^2$ or 10 $mm^2$), a thinner probe (1 $mm^2$) would serve as an alternative to the needle pinprick [12]. Pain threshold might also have been different if another test method, such as thermal (cold or heat), ischemic, electrical or chemical stimulus, had been used. [7]

When pain stimuli are applied repeatedly, there may be habituation or sensitization to repeated stimuli [5]. We assessed pain threshold at 13 sites with the same order for all the participants (and thus not in a random order), so that there might have been a trend in a decrease or an increase in pain threshold during assessment of these 13 sites. We made a measurement interval of at least 1 min between assessment to minimize possible effects of habituation and sensitization. In fact, there seemed no such a trend identified in our results.

In conclusion, there are significant differences in pain threshold between different puncture sites. Analgesic method before needle puncture may be required at the sites where the pain threshold is relatively low.

**Author contributions** KM: This author made the study conception and design, proposal writing, data management, analysis and interpretation, as well as drafting and approving the final version of the manuscript. TA: This author helped in the study conception and design, proposal writing, data management analysis and interpretation, as well as writing and approving the final version of the manuscript. Funding: none.

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**Data availability** Data are available from the authors.

## Declarations

**Conflict of interest** KM has no conflict of interest; TA is an Associate Editor-in- Chief of the Journal of Anesthesia.

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