Observations on the inconsistency of dermatome maps and its effect on knowledge and confidence in clinical students

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Abstract

INTRODUCTION: Dermatomes are an important component of medical curricula and clinical practice. In addition to the intrinsic complexity of dermatome maps, their discrepancies in the literature make their learning among students even more difficult. These discrepancies are particularly evident in the lower deltoid ("regimental badge" area) and upper back. The aims of our study were firstly to identify and compare published versions of the dermatome map focusing on depictions of the "regimental badge" area and upper back, secondly to assess the perceived confidence and knowledge of dermatomes among medical students, and finally to create and introduce a simplified dermatome map.

MATERIALS AND METHODS: For the first part of the study, depictions of dermatome maps that included the "regimental badge" area and upper back in webpages and books were compared. For the second part, a dermatome exercise was given to 177 medical students who were asked to draw and label the dermatomes on blank figures.

RESULTS: A total of 45 sources depicting dermatomes of the "regimental badge" area and upper back were included in the study and showed significant discrepancies in both areas. In the dermatome exercise, the mean perceived confidence was 3.64±1.58 (scale 1-10). Based on our pre-set assessment criteria, upper limb, lower limb, nipple, umbilicus and perineum dermatomes were labelled correctly by 57.1%, 43.5%, 52.6%, 60% and 75.7% students respectively.

CONCLUSIONS: In light of our results, we propose a map of autonomous regions of clinically relevant dermatomes that can be used instead of whole dermatome maps for teaching purposes.

Keywords: dermatomes; discrepancies; regimental badge; upper back; autonomous regions; map.

INTRODUCTION

Segmental cutaneous sensory innervation is a fundamental concept in anatomy that underpins both diagnostic and therapeutic techniques in clinical practice. This segmental distribution of cutaneous sensation, known as "dermatome", is typically defined as the region of skin supplied by all the cutaneous branches of an individual spinal nerve (Kischner and McMyne, 2015). The clinical applications of dermatomes are manifold. A sound understanding of dermatomes may help the physician to elucidate the level of nerve root compression in radiculopathy (Downs and Laporte, 2011), to assess the level of anaesthesia in paravertebral nerve blocks (Congreve et al., 2006), or to identify the cause of referred pain from visceral disease (Murphy et al., 2009).

Despite the widespread applications of dermatomes in clinical practice, published dermatomal descriptions vary considerably, with clinically important dermatomes often placed in conflicting locations. These discrepancies arise primarily from the originally published dermatome maps in the early to mid-20th century, upon which all the current dermatome map versions are based. These discrepancies principally relate back to fundamentally different concepts, methodology and possible errors in the original pioneering research on dermatomal distributions. Misunderstanding of dermatome distributions may adversely affect patient welfare, as well as causing confusion amongst medical students and miscommunication between healthcare professionals (Downs and Laporte, 2011).

The cutaneous innervation of the lateral aspect of the upper arm is frequently tested in clinical practice, specifically a patch of skin covering the inferior aspect of the deltoid muscle, commonly known as the "regimental badge" area. Skin over this area is thought to be innervated by the superior lateral cutaneous branch of the axillary nerve (C5, 6), with reduced sensation from axillary nerve lesions (Drake et al., 2005). This is particularly relevant in orthopaedic injuries, such as mid-humeral fractures and shoulder dislocations, where the axillary nerve may be injured (Steinmann and Moran, 2001).

At our university, dermatomes are primarily taught through lectures and applied anatomy sessions, which invariably include a "station" on surface anatomy and dermatomes. Dermatomes are also described in our "Functional Anatomy of the Body (FAB)" manual which is distributed to all first-year medical students at the beginning of the academic year, and finally, there are two "dermatome mannikins" in our Human Dissection Room which are available to students throughout the year. Learning objectives include appreciating the concept of dermatomes, becoming familiar with testing clinically relevant dermatomes and linking abnormalities with pathology, and administering local anaesthesia. During preparations for an applied anatomy session which involved drawing "dermatome mannikins", considerable discrepancies were found in the depiction of the dermatome of the "regimental badge" area in online maps and in textbooks. The dermatome was variously given as C5, C6 and even C4 or C7, which are not accepted root values of the axillary nerve. In addition, these discrepancies extended to the upper back with dermatomal depictions ranging from multiple narrow transverse bands of C4-T2, to a C4 dermatome adjoining that of T2 with no intervening C5-T1 dermatomes.

Knowledge of dermatomes among students has typically been somewhat deficient as evidenced by the frequency of incorrect answers at our end-of-year practical examination. This deficiency is likely to be multifactorial, owing to the intrinsic complexity of the human dermatome map, its varying depictions in the literature, and the inadequate attention it receives in medical curricula. To that end, there were two principal objectives of this study: firstly, to identify and compare published versions of the dermatome map in medical reference texts and webpages in order to evaluate the extent of inconsistency and speculate on the origins and implications of this variation. Owing to the clinical importance of the "regimental badge" area and the significant inconsistencies of the upper back dermatomes observed before the study, particular attention was paid to these regions. Secondly, given the potential implications on medical education, we aimed to evaluate the knowledge of dermatomes among students and their perceived confidence in applying and recalling dermatomal distributions. Our final aim was to create a simplified, clinically-relevant dermatome

map that could potentially be introduced to medical curricula with a view to minimising confusion in dermatome teaching.

MATERIALS - METHODS

Literature search

For the first part of the study, depictions of the dermatomes of the shoulder and upper back in webpages were identified via an electronic search. The following phrases were used as separate searches in Google images: “upper limb dermatomes”, “shoulder dermatomes” and “upper back dermatomes”. The first 15 different maps illustrating dermatomes of both the “regimental badge” and the upper back were selected and saved. Duplicate maps were removed prior to data analysis. In addition, 30 books were used, all of which included dermatomes of the “regimental badge”, and 25 depicted dermatomes of the upper back. The publication year of the books ranged from 1954 - 2015.

Observational study

For the second part of the study, a dermatome exercise was given to 177 fifth-year medical students of the University of Cambridge as part of a compulsory anatomy revision session in the Human Dissection Room. The students completed a survey and were then given 5 minutes to draw and label the dermatomes in blank anterior and posterior figures to the best of their abilities (Fig. 1). No opportunity for revision was given and each group, which consisted of 9 or 10 students, was invigilated to ensure that everyone completed the exercise individually. The data were subsequently tabulated and analysed using Microsoft Excel 2015®.

The survey enquired about the following: a) last time of relevant revision on dermatomes, b) last time of teaching on dermatomes, c) timing of relevant clinical placements (orthopaedics and neurology), and d) perceived confidence in knowing the dermatomes. Perceived confidence was rated from 1 (not at all confident) to 10 (very confident) (Fig. 2).

When assessing for significant associations between the participants' answers in the survey and their performance in the dermatome exercise, the following pre-set criteria were used to label drawn dermatomes as "correct": a) upper limb: "regimental badge" area C5 or C6, thumb C6, index and middle fingers C7, ring and little fingers C8, medial forearm T1; b) lower limb: L1 over inguinal ligament/upper anterior thigh, L2 in the mid-anterior thigh, L3 in the anterior knee, line drawn vertically along the anterior leg separating L4 (medial leg) from L5 (lateral leg), hallux L4, 5th digit and heel S1, posterior leg S2; c) nipple: transverse band labelled T4; d) umbilicus: transverse band labelled T10; e) perineum: concentric circular dermatomes S3-5 with S5 being the smallest, perianal region. These criteria were based on the dermatome map used in the University of Cambridge FAB manual. Each of the 5 regions scored one point for fully correct labelling based on the aforementioned criteria; no points were given for partly correct labelling. Minimum and maximum achievable scores were 0 and 5 respectively. Each participant's answers were marked by two investigators who agreed on the total score.

Statistical Analysis

Statistical analysis was performed using the base installation of R 3.1.2®. One way ANOVA was used to compare perceived confidence between groups that a) correctly or incorrectly labelled dermatomes of each region; b) that had had relevant teaching in <6 Vs 6-12 Vs >12 months; and c) that had undertaken relevant revision in <6 Vs 6-12 Vs >12 months . The Bonferroni method was used for post-hoc analysis to locate significant differences. Chi-square testing was then used to compare student scores according to the last time of relevant revision and teaching on dermatomes. A p-value of <0.05 was accepted as significant. All percentages are presented to one decimal place.

RESULTS

Evaluation of discrepancies in anatomy textbooks and webpages

"Regimental badge" dermatomes were depicted by a total of 45 sources (30 books and 15 webpages) and upper back dermatomes were depicted by a total of 40 sources (25 books and 15 webpages) (Tables 1, 2).

Significant discrepancies were identified in dermatome maps depicting the shoulder and upper back. C5 was most commonly used for the "regimental badge" area, cited in 27 (60.0%) maps; C6 was used in 11 (24.4%), C7 in 4 (8.9%), and C4 in 3 (6.7%) sources. Akin to variation seen with the "regimental badge", discrepancies were also identified between maps with regard to the upper back dermatomes. Of the 40 maps that depicted upper back dermatomes, 13 (31.7%) illustrated a C4 dermatome directly adjoining that of T2 without intervening bands. A further 15 sources (36.6%) represented the upper back dermatomes as a series of narrow transverse bands from C4-T2 and the remaining 12 (31.7%) included some but not all dermatomes between C4 and T2.

Assessment of dermatome knowledge of medical students and relation to perceived confidence

Confidence

Perceived confidence (on a scale of 1-10) ranged from 1 to 8. The mean 'perceived confidence' was 3.64 (SD = 1.58). Students who had revised dermatomes within the last 6-12 months and those who had not revised dermatomes in the last year had significantly lower perceived confidence than those who had revised dermatomes in the last 6 months ($F(2,173) = 14.8$, $p < 0.001$; Fig. 3). Moreover, perceived confidence in those who were exposed to dermatome teaching within the last 6 months was significantly higher than in those who had received teaching over 6 months ago ($F(2,173) = 7.328$, $p < 0.001$) (Fig. 4). There was no significant difference in perceived confidence between

students who correctly and incorrectly labelled dermatome maps, irrespective of region ($F(1,766) = 2.691$, $p = 0.101$) (Table 3).

None of the students had undertaken their neurology or orthopaedics placements at the time of the study, therefore no analyses with these parameters were performed.

Competence

Anterior dermatomes were attempted by 168 out of 177 students (94.9%). By contrast, posterior dermatomes were attempted by only 36 students (20.3%). Of these 36 students, 17 (47.2%) labelled dermatomes in the upper back but none included areas supplied by C5-C8.

Based on our pre-set assessment criteria, 57.1% and 43.5% of all students correctly marked the upper limb and lower limb dermatomes, respectively. The dermatome of the nipple was correctly labelled by 52.5% of all participants, that of the umbilicus by 60.0%, and dermatomes of the perineum by 75.7%. These percentages reflect correct labelling of each dermatome region out of the total number of participants (n=177) and regardless of how many actually attempted to label each specific region. Table 3 shows the proportions of students who labelled dermatomes of each region correctly or incorrectly, out of all those who attempted to label that region, and the mean perceived generic confidence of each subgroup. Students who had revised dermatomes in the past 6 months and those who had been taught in the past 12 months were more likely to correctly label all regional dermatomes, however this difference did not reach statistical significance ($\chi^2(10) = 7.15$, $p = 0.711$).

DISCUSSION

The concept of segmental cutaneous innervation was first described in Sir Wilmot Herringham's landmark paper on the anatomy of the brachial plexus in 1886 (Herringham, 1886). Herringham's observations were based on careful dissection of segmental nerve fibres in the brachial plexus in adult and neonatal cadavers. Throughout the 19th century, a multitude of studies exploited different methods to provide further insight into the extent of each dermatome, resulting in the establishment of a number of varying and, to some extent, contradictory dermatome maps.

Arguably the most influential of these were two dermatome maps created by Foerster (1933) and Keegan and Garrett (1948), upon which the majority of current reference texts are based. Given that these two maps themselves show considerable differences and have not since been validated by further studies, the reason for their pervasiveness in medical reference texts is unclear. Foerster's map was developed after isolating single dorsal nerve roots by sectioning at least two adjacent dorsal nerve roots both above and below to relieve spasticity and pain (mostly secondary to tabes dorsalis) and subsequently mapping the distribution of cutaneous sensation. This data was augmented through electrical stimulation of cut ends of posterior nerve roots, before observing vasodilatation within the affected dermatome. His method was limited by a small sample size (2-4 patients for each selected spinal level), inconsistent results, and poor documentation of testing and reporting methods. Foerster did not explain the reason for leaving a single root intact other than for experimental purposes. By contrast, Keegan and Garrett's map, in 1948, was developed through observation of regions of diminished cutaneous sensitivity in cases of patients with intervertebral disc prolapse causing nerve root compression. Although this study is commendable for its relatively large sample size (n=1429), the methodology was severely flawed, as reviewed by Lee et al. (2008). Specifically, most cervical root compressions were only demonstrated by myelography and not confirmed at surgery, and their map included dermatomes that were not assessed in their study (e.g. L1 and L2). Moreover, their study only investigated limb dermatomes; distribution of truncal

dermatomes was based upon previous studies, and finally, they reported that areas of hypoalgesia were highly reproducible in their patients and did not vary by more than one centimetre, which is in contrast to other published studies (Falconer et al., 1947; Davis et al., 1952).

A further point of contention that complicates dermatome mapping is the overlap between zones of cutaneous sensation from adjacent spinal nerves. During the 19th century, it was recognised that nerve roots did not occupy discrete bands of sensory innervation; rather, these zones displayed overlap. Despite this recognised property of dermatomes, dermatomes continue to be depicted as discrete bands in many modern reference texts. The anatomical basis of this overlap remains primarily speculative, though several mechanisms have been proposed. Anthoney (1994) provides two plausible explanations. First, assuming that the dermis within each mature dermatome is derived from the corresponding embryologic dermatome, precursor cell migration from spatially distinct embryologic dermatomes into adjacent units may provide a means for sensory overlap in mature dermatomes. The second idea posits that, following the establishment of spatially distinct mature dermatomes from their embryologic precursors within somites, migration or growth of nerve processes into adjacent dermatomes creates sensory overlap. Promisingly, this latter idea has recently been given credence by the discovery of physical neural intercommunications between nerves derived from contiguous spinal nerves (Ladak et al., 2014). Irrespective of the mechanism of sensory overlap, recognition of its existence and appropriate depiction in medical references is relevant for its clinical purpose, particularly in correct assessment of nerve root lesions in neurological examinations.

One objective of the current study was to assess the extent of variation in dermatome maps between different modern medical resources. Our results support the findings of previous studies, that contradictory dermatome distributions are prolific in medical reference texts and webpages (Lee et al., 2008; Downs and Laporte, 2011). This inconsistency may result in conflicting information being relayed between medical professionals, and may contribute to confusion in medical student

education. As a secondary objective, we aimed to evaluate the perceived confidence and knowledge of fifth year clinical students in drawing dermatome maps. Our results indicate that medical students lack confidence in their knowledge of dermatomes, and a large proportion did not have an accurate knowledge of the dermatomes in all four regions assessed. Moreover, confidence levels were generally low, irrespective of whether dermatomes were accurately presented. Variability in dermatome maps provides one potential reason for a perceived lack of confidence in marking dermatome maps, but this is not the only plausible explanation. The anatomy of dermatomes is taught early in medical curricula due to its wide-ranging clinical uses. The time interval since students last received formal anatomy teaching might also contribute to poor confidence and knowledge. Additionally, another assumption is that our findings might relate to difficulties experienced by first year students in conceptualising the dermatomes through the two-dimensional representation of a three-dimensional concept. A simple method of overcoming this latter problem is the mapping of dermatomes on skin, allowing both visualisation of three-dimensional structures and integration of other anatomical concepts, such as bony landmarks (Finn, 2015). Other teaching groups have described the use of low fidelity models to highlight spatial relationships between various patterns of cutaneous innervation (Kooloos and Vorstenbosch, 2013). These low-fidelity, low-cost models may provide a useful adjunct to more traditional text-based methods of learning, and help to improve medical student confidence and knowledge.

Finally, with regard to the discrepancies in the depiction of dermatomes in the upper back specifically, the version of the map including all bands between C4-T2 would appear to be more realistic than that with the dermatome of C4 adjoining that of T2 with no intervening dermatomes as, in the latter version, one would wonder where the posterior rami of C5-T1 are distributed.

While there are a number of inherent limitations to this study, including the short time allowed for completion of the exercise, and the difficulty in ascribing the cause of poor confidence and performance to discrepancies in published dermatome maps, the results do reveal a general lack of

knowledge of dermatomes in clinical students which should be remedied. For teaching purposes, we would therefore propose that attention should be paid to teaching students the autonomous regions for testing clinically-relevant dermatomes rather than asking them to remember the whole dermatomes map. Figure 5 illustrates a suggested “autonomous regions map” which should be much easier for students to remember and use in clinical practice. For the effectiveness of our “autonomous regions map” to be assessed, students’ learning of dermatomes should be compared between teaching programmes using our proposed map and programmes using a conventional version of the map. Additionally, the results of such a comparison will determine the suitability of incorporating our “autonomous regions map” into medical curricula.

CONCLUSIONS

Despite widespread recognition that studies underpinning current dermatome maps are severely flawed, these maps continue to be depicted in modern medical reference texts. Moreover, as supported by the findings in the current study, the variability between maps in different texts is substantial. This has the potential to compromise communication between healthcare professionals, to generate confusion amongst students, and, most significantly, to compromise patient care.

We believe that our proposed map depicting only autonomous regions of cutaneous innervation by specific spinal nerve roots will be more effective than currently used dermatome maps for students learning the necessary clinically applicable dermatomes, and we therefore recommend its use in medical curricula. While students must understand the principles governing dermatomal distribution, the memorisation of whole dermatome maps would not be warranted. Further studies that will use our proposed map will assess its superiority over the conventional versions of the dermatome map and its suitability to be introduced to medical curricula.

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Figure Legends

Figure 1: The anterior and posterior body figures used for the dermatome exercise

Figure 2: The survey that students had to complete prior to the dermatome exercise

Figure 3: Perceived confidence according to time since last revision. Error bars represent 95% confidence intervals. * p = 1.1e-04; ** p = 3.3e-05

Figure 4: Perceived confidence according to time since last teaching. Error bars represent 95% confidence intervals. * p = 0.0027

Figure 5: A suggested map of “autonomous areas” for clinical testing

Tables

Table 1: Dermatome maps identified in textbooks.

Source	Publication year	"Regimental Badge"	Upper Back				
			C5	C6	C7	C8	T1
Surface Anatomy (4th Ed)	2008	C4	×	×	×	×	×
Integrated Anatomy	2007	C5	×	×	×	×	×
Moore Clinically Oriented Anatomy (4th Ed)	1999	C5	✓	✓	×	×	×
Clinical Anatomy Principles	1996	C5	not depicted				
Textbook of Human Anatomy (2nd Ed)	1976	C5	✓	✓	✓	×	×
Sobotta Atlas of Human Anatomy (14th Ed)	2008	C5	✓	✓	✓	✓	✓
Anatomy – Regional and Applied	1973	C5	not depicted				
Principles of Anatomy & Physiology (13th Ed)	2011	C5	×	×	×	×	×
Cunningham's Manual of Practical Anatomy (15th Ed)	1992	C5	not depicted				
Clinically Oriented Anatomy (4th Ed)	1999	C5	×	×	×	×	✓
The Human Nervous System	1993	C5	×	×	×	×	✓
BRS Gross Anatomy	2011	C5	not depicted				
Basic Anatomy	1954	C5	✓	×	×	×	×
Anatomy of the Human Body	1969	C5	✓	×	×	×	✓
Gray's Anatomy Atlas for Students (2nd Ed)	2015	C5	×	×	×	×	×
Moore Essential Clinical Anatomy (5th Ed)	2015	C5	✓	✓	×	×	×
Regional Anatomy Illustrated	1983	C5	✓	×	×	×	✓
The Human Brain and Spinal Cord (2nd Ed)	1995	C5	not depicted				
McMinn's Functional & Clinical Anatomy	1995	C5	×	×	×	×	×
Cecil Essentials of Medicine (4th Ed)	1997	C5	✓	✓	×	×	×
The Central Nervous System	1992	C5	✓	✓	✓	✓	✓
Integrated Systems	2016	C6	×	✓	✓	✓	×
Atlas of Clinical Gross Anatomy	2005	C6	✓	✓	✓	✓	✓
Textbook of Anatomy (2nd Ed)	1967	C6	✓	✓	✓	✓	✓
Sobotta/Figge Atlas of Human Anatomy	1977	C6	✓	✓	✓	✓	✓
Langman's Medical Embryology	2006	C6	✓	✓	✓	✓	✓
Essential Clinical Anatomy	1996	C6	✓	✓	✓	✓	✓
Essentials of Human Anatomy (7th Ed)	1983	C7	✓	✓	✓	✓	✓
Surface and Radiological Anatomy	1975	C7	✓	✓	✓	×	✓
Wolf Heidegger's Atlas of Human Anatomy (5th Ed)	2000	C7	✓	✓	✓	✓	✓

Table 2: Dermatome maps identified in webpages

Source	Access Date	"Regimental Badge"	Upper Back				
			C5	C6	C7	C8	T1
patient.info	22 Sep 2017	C4	×	×	×	×	×
instantanatomy.net	22 Sep 2017	C4	×	×	×	×	×
studyblue.com	22 Sep 2017	C5	×	×	×	×	×
instantmedic.netai.net	22 Sep 2017	C5	×	×	×	×	×
almostadoctor.co.uk	22 Sep 2017	C5	×	×	×	×	×
ppcpaedia.wikispaces.com	22 Sep 2017	C5	×	×	×	×	×
arthritisresearchuk.org	22 Sep 2017	C5	×	×	×	×	×
epsomtissuetech.wordpress.com	22 Sep 2017	C5	✓	✓	✓	✓	✓
aafp.org	22 Sep 2017	C5	✓	✓	✓	✓	✓
completesoccertraining.blogspot.co.uk	22 Sep 2017	C6	✓	×	×	×	×
pinterest.com	22 Sep 2017	C6	✓	✓	✓	✓	✓
medicalcriteria.com	22 Sep 2017	C6	×	✓	✓	✓	✓
usmle-forums.com	22 Sep 2017	C6	✓	✓	✓	✓	✓
medicaldictionary.com	22 Sep 2017	C6	✓	✓	✓	✓	✓
netterimages.com	22 Sep 2017	C7	✓	✓	✓	✓	✓

Table 3: Mean perceived confidence in those who labelled each of the five regions correctly Vs incorrectly. * = p>0.05

Body region	Dermatome Mapping	N (%)	Mean generic perceived confidence
Nipple	Correct	93 (69.4)	3.74
	Incorrect	41 (30.6)	3.68*
Umbilicus	Correct	106 (76.8)	3.70
	Incorrect	32 (23.2)	3.78*
Upper Limb	Correct	101 (60.5)	3.88
	Incorrect	66 (39.5)	3.32*
Lower Limb	Correct	77 (47.2)	3.78
	Incorrect	86 (52.8)	3.62*
Perineum	Correct	134 (76.1)	3.68
	Incorrect	42 (23.9)	3.52*

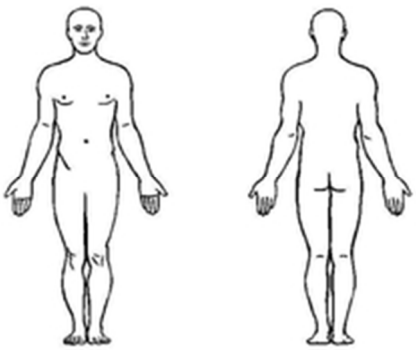

Figure 1: The anterior and posterior body figures used for the dermatome exercise

17x14mm (300 x 300 DPI)

Figure 2: The questionnaire that students had to complete prior to the dermatomes exercise

9x4mm (600 x 600 DPI)

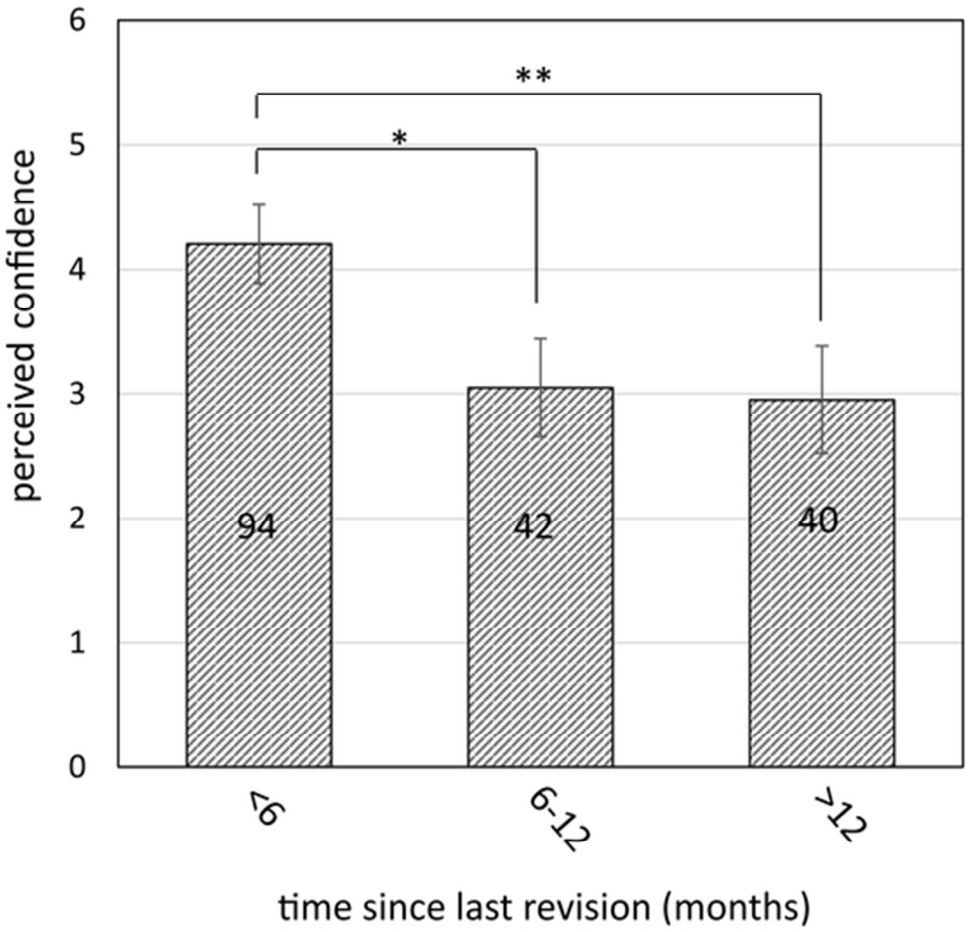

Figure 3: perceived confidence according to time since last revision. Error bars represent 95% confidence intervals. * p = 1.1e-04; ** p = 3.3e-05

24x23mm (600 x 600 DPI)

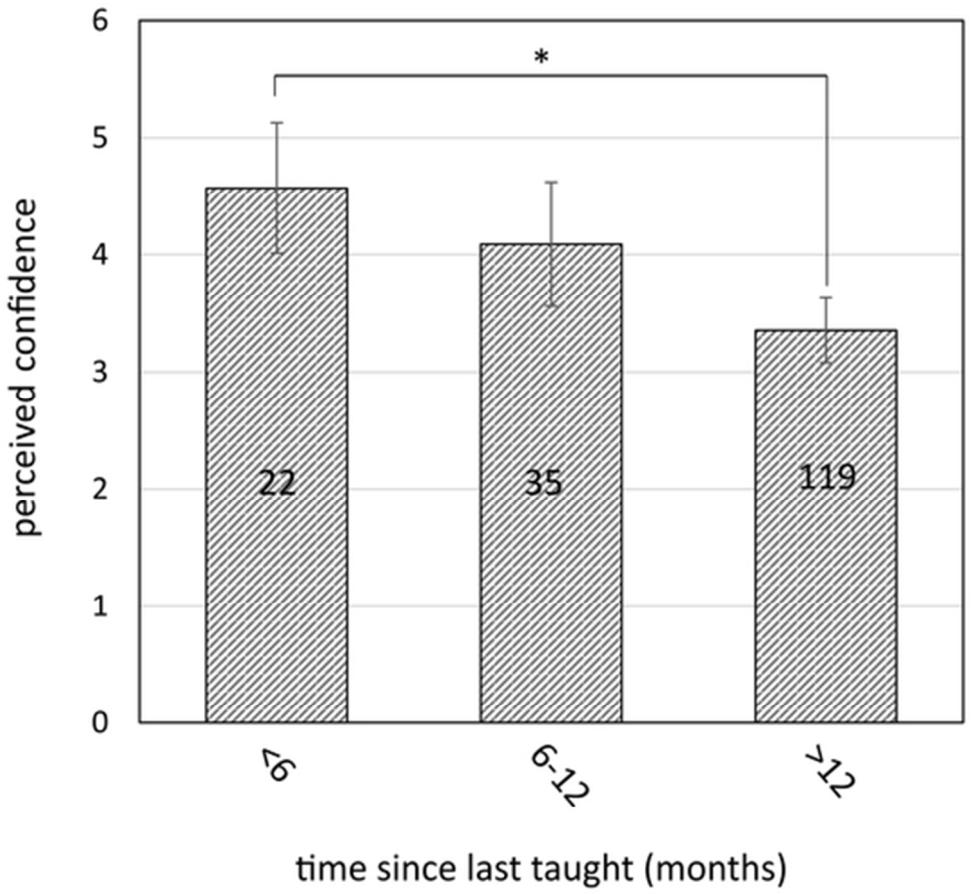

Figure 4: perceived confidence according to time since last teaching. Error bars represent 95% confidence intervals. * p = 0.0027

23x21mm (600 x 600 DPI)

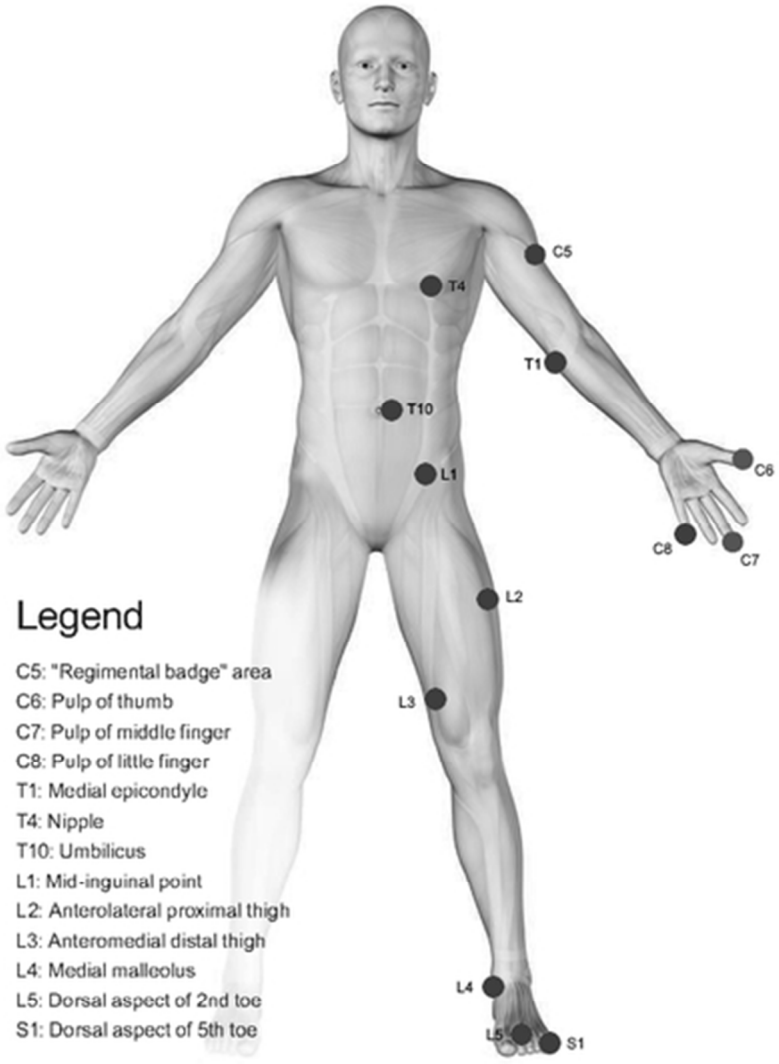

Figure 5: A suggested map of "autonomous areas" for clinical testing

35x50mm (300 x 300 DPI)