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〔Original Paper〕

Principles in the arrangement of dermatomes and revaluation of dermatome charts

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SUMMARY

This study was undertaken to report the principles in the arrangement of dermatomes and thereby to reevaluate previously reported dermatomes. Dermatomes in rat fore and hind limbs were determined as Evans blue extravasation areas following electrical stimulation of spinal nerves, thereby principles in dermatome arrangement were determined. Dermatomes were in the shape of an elongated loop around the rostro-caudal axis of the body. The distal apex of each dermatome was aligned on the rostral and caudal axial lines of the limb and converged medially to the ventral and dorsal axial lines of the limb. Human dermatomes were determined based on the principles of dermatome arrangement revealed in rats. Based on the principles and the hypothetical dermatomes, the author proposed that the dermatome charts of Nozaki, von Lanz, and Bonica are desirable for clinical use.

Key words : dermatomes, arrangement, axial lines

I. Introduction

Despite the recent advances in computer-assisted diagnostic tools, neurological examinations remain as the primary procedure for the diagnosis of neurogenic diseases. Dermatomes are indispensable to evaluate and locate a lesion in the spinal cord, spinal nerve roots, and spinal nerves. However, the previously reported dermatome charts differ considerably in the shape, location, and arrangement of dermatomes (Fig. 1). Consequently, segmental diagnosis is variable with a dermatome chart used.

The inconsistency may be attributed to the following problems which accompany investigations on human subjects: 1) The number of subjects is insufficient particularly for rarely involved segments. 2) The anatomical variance in spinal segmentation is considerable. 3) The abnormal sensation of a given segment appears in a variety of regions due to the condition of the lesion. 4) The involved spinal segments can not be diagnosed perfectly. 5) Determination of the boundary line of an abnormal sensory area tends to

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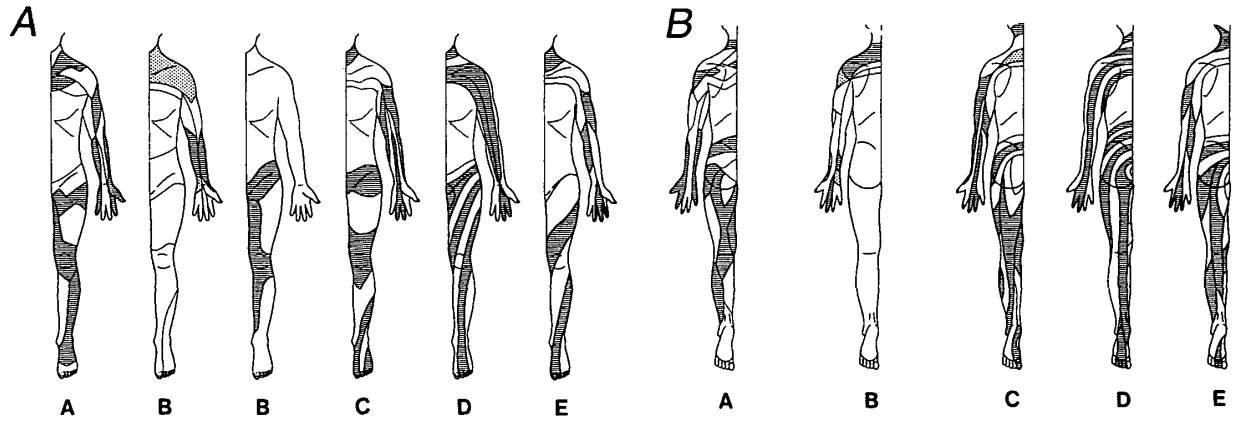

Fig. 1 Representative human dermatomes. *A*: the ventral side, *B*: the dorsal side. *A*: Head and Campbell[17], *B*: Foerster[23], *C*: Nozaki[20], *D*: Keegan and Garrett [18], *E*: Bonica[22](these figures were depicted by the present author based on the original charts). Hashed are C3, C5, C7, L1, L3, L5, and S2 dermatomes. Dotted areas are overlapped by two adjacent segments. Note the marked inconsistency in the shape and arrangement of dermatomes.

be equivocal due to subjective errors caused by either the examiner or subjects. Even with the most meticulous and strict methods these minor points seem unavoidable in clinical studies.

Investigators of dermatomes have paid little attention in principles in the arrangement of dermatomes. The previously reported dermatomes are very inconsistent in arrangement patterns and thus no rule can be drawn. Recently I determined the location of rat dermatomes in detail using Evans blue extravasation method [1]. In the present study, I report principles in the arrangement pattern of dermatomes and the location of limb axial lines, and argue that the principles would be common to most of mammals including humans. Furthermore, I suggest human dermatomes which are proper for clinical use among previously reported charts comparing their arrangement patterns with the principles. In a previous article I reported hypothetical dermatomes of human lower limb based on the same methodology [2].

II. Methods

It is reported that the cutaneous innervation area of a sensory C-fiber can be visualized as Evans blue extravasation when induced by electrical stimulation of the nerve in rats [3,4]. I applied this technique to map dermatomes in rats; the detailed methodology is described in a previous report [1]. Briefly, in anesthetized rats pretreated with intravenous administration of Evans blue, the ventral rami of C1-T1 (forelimb) and T12-S2 (hindlimb) spinal nerves were stimulated individually with a 10 Hz pulse train of 0.5 msec duration at an intensity of 40 V prolonged for 5 min. The maximal innervation area of the spinal nerve, as represented by the blue stained skin, was drawn on rat body diagrams[1].

Most mammals including humans have anatomically homologous and morphologically analogous bones, muscles and nervous systems in the body trunk and limbs. Consequently, the spatial relationship of a somatic structure (e.g., muscle) to other structures (e.g., bone) is topologically similar throughout species. Therefore, it is

reasonable to assume that the segmental demarcation pattern of skin sensation, in other words, the shape and arrangement of dermatomes, follow a topologically similar pattern throughout species. It seems unreasonable if humans have exceptionally arranged dermatomes. Thus, hypothetical human dermatomes can be drawn based on the principles of dermatome arrangement. Further, I reevaluated previously dermatome charts comparing their patterns to the principles in Discussion.

Ⅲ. Results

The maximal innervation area of a spinal nerve was well delineated as an Evans blue extravasation area. For each segment, the maximal innervation area overlapped 2/3 to 3/4 of the adjacent areas. Dermatome boundary lines were defined as the midline of the overlapping areas and thus composite dermatomes were determined (Fig. 2). The following characteristics of dermatome arrangement in the limb were found.

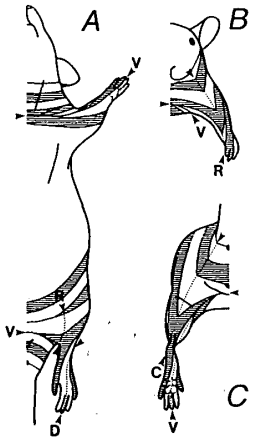

Fig. 2 The arrangement pattern of rat dermatomes (modified from the figures published in a previous article[1]). *A*: ventral, *B*: rostral, and *C*: caudal sides. Dotted lines between two arrowheads denoted with R, C, V, D represent the rostral caudal, ventral, and dorsal axial lines of the limb, respectively. Note medially tapering pattern in the intermediate dermatomes of the limb and the route of the axial lines.

1) The rostral dermatomes (C2-C4 in the forelimb; T12-L2 in the hindlimb) and the caudal dermatomes (T1 in the forelimb; L6-S2 in the hindlimb) showed a simple stripe looping around the rostro-caudal axis of the body trunk (Figs. 2-B and C).

2) The intermediate dermatomes (C5-C8 in the forelimb; L3-L5 in the hindlimb) in principle looped around the rostro-caudal axis of the body. They showed a "V"-shaped configuration from the rostral and caudal aspects as a result of lateral expansion of the limb. The distal apexes of the "V" ran along the rostral axial line (RAL) and the caudal axial line (CAL) of the limb (Figs. 2-B and C). From the ventral and dorsal aspects, these dermatomes tapered medially towards the ventral axial line (VAL) and the dorsal axial line (DAL) of the limb and were subsequently absent in the body trunk (Fig. 2-A).

3) In the forelimb, RAL was located between the first digit and the shoulder along the radius, and CAL was between the fifth digit and the axilla along the ulna. VAL was located between the third digit and the sternoclavicular joint, and DAL was between the third digit and the T2 spinous process (Figs. 2-A and B).

4) In the hindlimb, from the rostral (rostroventral) aspect, the apexes of intermediate dermatomes (i.e., RAL) ran along the femoral and saphenous nerves, and went towards the first digit. From the caudal aspect, the apexes of dermatomes ran along the sciatic and sural nerves and then towards the fifth digit. Thus, CAL was located between the fifth digit and the anus along with the sciatic and sural nerve, VAL was located between the third digit and the

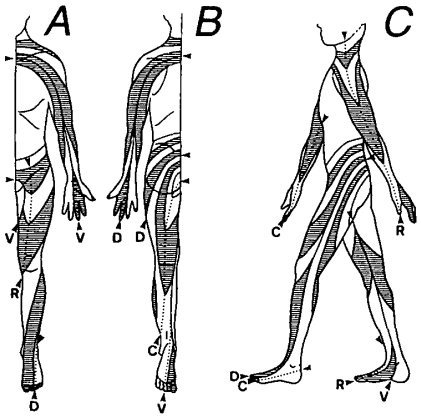

Fig. 3 Hypothetical human dermatomes drawn based on the principles of dermatome arrangement demonstrated in rats. Hashed areas are C3, C5, C7, L1, L3, L5, and S2 dermatomes. *A*: anterior, *B*: posterior, *C*: lateral sides. Dotted lines between two arrowheads denoted with R, C, V, D represent the rostral, caudal, ventral, and dorsal axial lines of the limb, respectively.

pubic symphysis. DAL was located between the third digit and the back over the hip joint (Figs. 2-A and C).

Hypothetical human dermatomes were determined based on these principles of dermatome arrangement (Fig. 3).

IV. Discussion

Dermatomes have been investigated in animals using more strict methods, such as the determination of the 'remaining sensibility' after posterior rhizotomy [5-9] and recording sensory evoked potentials at dorsal nerve roots after mechanical skin stimulation [10-16]. In these studies the looped stripe pattern was revealed in dogs[7,9,11], sheep[6], and cows[5]. The closed loop and medially tapered pattern which I demonstrated in rats was found in cats [10,12,14-16] and monkeys [8,13]. These results indicate that the characteristics of dermatome arrangement are common to almost all of mammals.

Physicians probably may have little interest in the regularity of dermatome arrangement, rather they require precise and practical dermatome charts applicable for many individuals. A clinical value that can be attributed from the principles is a suggestion on skin sensory examination. The boundary lines of dermatomes perpendicularly cross the rostral and caudal axial lines while in parallel with the ventral and dorsal axial lines (Fig. 3). Therefore, it is indicated that the segmental diagnosis of neurogenic diseases is more concisely examined along the rostral and caudal axial lines.

I assume that the previous human dermatomes were somewhat erroneously determined from their 'true' locations, since the narrow area in the corner of dermatomes is prone to be overlooked due to overlapping from adjacent segments. Considering the arrangement pattern of dermatomes, the mosaic-like arrangement reported by Head and Campbell (1900) [17] is unlikely. Although widely used, I assume dermatomes of Keegan and Garrett (1948) [18] are inappropriate because they were established based on a unique concept of "distally tapering pattern in the ventral side". In conclusion, I propose dermatomes of von Lanz and Wachsmuth (1938) [19], Nozaki (1938) [20], Wakasugi (1982) [21], and Bonica (1990) [22], which nearly follow the closed loop and medially tapered pattern, are proper for clinical use.

要　旨

動物実験より決定した感覚神経の分節性支配領域（皮節）の分布の規則性を報告し，その規則性を根拠として既存のヒト皮節図の再評価を行なった。

あらかじめ Evans blue を静注投与したラットの，前肢・後肢の脊髄神経を感覚神経の C 線維の興奮強度で電気刺激すると，その脊髄神経の支配領域の皮膚に色素漏出が発生した。この方法を用いてラットの C1-T1（前肢），T12-S1（後肢）脊髄神経を刺激し四肢の皮節図を決定した。四肢の皮節は体幹部の皮節と同様

に，原則として体幹前後軸を集回するループ状構造を示し，そして腹側面・背側面では中枢側に向かい四肢の中心軸へ収束し，前側面・後側面では末梢に向かい四肢の中心軸に沿って伸長していた。

ラットとヒトの四肢は解剖学的に相同関係にあり，骨・筋・末梢神経の空間的位置関係も同一である。さらに，今回ラットに認められた皮節分布の原則性は，霊長類を含めた他の哺乳類においてもすでに報告されており，ヒトの皮節分布もこの原則性に従うことが演繹的に推論される。そこで，この原則性をもとに仮説的なヒト皮節図を描き，この仮説図からヒト皮節図を再評価した。その結果，神経根切断症例より得られた野崎の図（1938年）や，神経ブロックより決定したBonicaの図（1990年）などがこの皮節分布の規則性を比較的によく示しており，臨床応用にふさわしい図であると結論した。

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