Virtual medical and pedagogical applicability of human dermatome patterns: critical review of the literature

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Abstract

Dermatome is an area of skin supplied by the posterior (sensory) root of a spinal nerve derived from a single cord segment, which is a particular aspect of the peripheral distribution of sensory fibers. Its topographic study is important to identify nerve, radicular, or medullary damage. When mapped, these dermatomes are outlined on the body surface and their assessment poses a special challenge to physicians once the distinguished imaging methods are not concordant in some aspects. Computers have taken over increasingly importance as transmitters of anatomical information in both clinical and educational sceneries. The present study concerning the virtual teaching and learning of the human dermatome patterns carries out an update of the literature and its clinical and radiological applicability. Computed-based anatomy programs do not only complement conventional instructions methods, but also provide the groundbreaking means to represent, standardize, and disseminate knowledge of dermatomes. Computer-based programs capable of standardizing a tridimensional map of human dermatomes still need to be developed.

Keywords: dermatome, anatomy, teaching, learning, virtual.

1 Introduction

Dermatome is an area of skin supplied by the posterior root derived from a single cord segment, which is named after the root that supplies it (BLAKISTON, 1982; AGUR, 1993; DEFINO, 1999; MENESES, 1999; KINGSLEY, 2000; STOKES, 2000; LENT, 2005; BEAR, CONNORS and PARADISO, 2006). It is a specific aspect of the peripheral distribution of the sensory fibers (BRODAL, 1997). Each spinal nerve conveys sensory nerve fibers to a region of the body surface (CROSSMAN and NEARY, 1997). Medullary segmental organization derived from its particular embryologic origin causes each pair of posterior roots, on either side, to have fibers arising from a restricted area of the body surface (KINGSLEY, 2000; LENT, 2005).

The present study carries out a brief update of the literature concerning both virtual teaching and learning of the human dermatome patterns and its clinical and radiological applicability.

2 Dermatome distribution

When mapped, the dermatomes are outlined on the body surface (BEAR, CONNORS and PARADISO, 2006). Observing the dermatome maps, we can see that in they form into bands around the trunk. In the limbs, due to the great growth of the appendicular buds during the development, the arrangement becomes irregular (MACHADO, 2007). Dermatomes extend as a series of bands from the midline of the trunk posteriorly into the limbs (AGUR, 1993). In the head, especially in the face, the somasthetic input does not present a so clear segmental organization because all the tactile innervation is canalized to the central nervous system by the trigeminal nerve [V], which is subdivided into ophthalmic, maxillary, and maxillary divisions [V] (LENT, 2005).

The analysis of the dermatome maps has shown that the length of the dermatomes is variable from one individual to another, and that the boundaries between them are not accurate (CORSSMAN and NEARY, 1997; MENESES, 1999). There is considerable overlapping of the adjacent dermatomes. As a result, anesthesia of a certain region does not occur unless two or more consecutive posterior roots have lost their functions (AGUR, 1993; BRODAL, 1997; CROSSMAN and NEARY, 1997; MENESES, 1999; STOKES, 2000; LENT, 2005). Such information was demonstrated by Sherrington in monkeys by the method of “remaining sensibility”; Foerster, demonstrated it in humans after an amputation; and Dusser de Barenne demonstrated it using topical application of strychnine. Subsequently, in 1948, Keegan and Garrett relied on local anesthesia of the posterior root ganglia. Clinically, the distribution of the herpetic vesicles in cases of Herpes Zoster has also provided reliable information to the study of dermatome distribution (BRODAL, 1997).

3 Clinical and radiological applicability of dermatomes

Lesions in different levels of the nervous system cause specific events of a sensory deficit, which must be recognized by its clinical characteristics (BRODAL, 1997; CROSSMAN and NEARY, 1997). When there is a segmental, dermatome-type sensory loss, the interest in determining the level of lesion as exactly as possible is little, and a comparison with diagrams is recommended (BRODAL, 1997). In the presence of a clinical picture of loss of cutaneous sensitivity, it is possible to determine whether the lesion occurred in a peripheral nerve, in the spinal cord, or in the spinal roots (KINGSLEY, 2000; MUTARELLI, COELHO and HADDAD, 2000; MACHADO, 2007).

However, image maps of dermatomes in humans developed through diverse methods disagree in some aspects. In areas where the cutaneous territories of adjacent nerves are overlapped, although the fundamental principles are preserved, the maps are only approximate (BRODAL, 1997). An evaluation of the sensorial system poses an especial challenge because this is only part of a neurological evaluation, and from it a detailed map of the patient's sensitivity is outlined (CROSSMAN and NEARY, 1997; KINGSLEY, 2000; BEAR, CONNORS and PARADISO, 2006). Due to high cost and the nature of complementary exams, there is a great benefit in having ability to diagnose anatomicoclinically and accurately neuromusculoskeletal conditions (SHARPSTONE and COLIN-JONES, 1994; DAUB, 2007).

4 Virtual learning and teaching of human dermatomes

The high cost with cadavers, maintenance of laboratories, and the increased scarcity of high-qualified experts for teaching is encouraging the development of virtual methods to teach anatomy based on the distribution of software of educational contents (WARREN, AGONCILLO, FRANKLIN et al., 2006). Computers are taking over an increasing segment as transmitters of anatomical information in both clinical and educational scenarios (KIM, BRINKLEY and ROSSE, 2003). Many debates have been taking place over how to teach anatomy. At opposite sides are those who are in favor of dissecting human cadavers and others who rely on new modalities of teaching, such as the self-directed teaching, problem-based teaching, and computer-assisted teaching (TURNEY, 2007). It was assumed that computers would become omnipresent tools to transmit medical knowledge (LINK and MARZ, 2006).

Changes in anatomy teaching are not only the result of the reduced time available for learning and teaching, but also many times they require the use of new teaching methods (MOXHAM, 2006). Communication and information technology are universal descriptors of the use of technology to spread and share knowledge among educators and apprentices (FEENEY, REYNOLDS, EATON et al., 2008). Electronic systems also called on-line learning management systems, or virtual learning environment are used in higher education institutions assisting the traditional live learning in several disciplines, including medicine (MASTERS and GIBBS, 2007).

Computer graphics offers a real rupture in the representation of anatomical knowledge since the publication of the first school-based Treatise of Anatomy, in 1546, providing a resource to obtain a natural tridimensional dynamics of the human body (BRINKLEY, WONG, HINSHAW et al., 1999). Due to its imagenologic nature, anatomy poses especial challenge to its representation and access to information. Anatomists have been entrepreneurs in creating computer graphics-based educational resources in the last three decades (KIM, BRINKLEY and ROSSE, 1999). The tridimensionality provided by the computer software allows cutaneous areas under-addressed in the teaching and learning of dermatomes to be visualized.

5 Discussion

Anatomy has been the foundation of medical education for hundreds of years (TURNEY, 2007). It is a knowledge of critical domain to be mastered by all health care professionals in their daily practice (KIM, BRINKLEY and ROSSE, 2003; MOXHAM, 2006). Anatomical knowledge is the base for patient's examination, to collect information for diagnosis, and to communicate the conclusions to the patient itself and to other practitioners (TURNEY, 2007). It is a discipline of highly visual essence (BRINKLEY, WONG, HINSHAW et al., 1999). General Anatomy is one of the critical resources to the practice of medicine (WARREN and BRINKLEY, 2005; WARREN, AGONCILLO, FRANKLIN et al., 2006). Anatomy provides the basis to other biomedical specialties such as physiology and pathology, as well as clinical practice (KIM, BRINKLEY and ROSSE, 2003).

The interaction of new teaching modalities and modern technology favor interest and retaining of anatomical knowledge, just as it highlights their clinical significance (TURNEY, 2007). There is no doubt that the impact of systems and information services has changed teaching (REYNOLDS, MASON and EATON, 2008). A survey suggests there is great need regarding access to understandable and detailed anatomical information, as well as the development of methods allowing the direct manipulation of tridimensional graphic models (KIM, BRINKLEY and ROSSE, 1999). Relatively few computer programs do explore the opportunity offered by computers to represent the third dimensional space in anatomy (KIM, BRINKLEY and ROSSE, 2003).

Database, electronic static illustrations, videos, and interactive computer applications have been interacting aiming at the new type of learning (WARREN and BRINKLEY, 2005). The widespread use of the web-atlases suggests that they can provide an alternative way of learning, which complements conventional learning methods (KIM, BRINKLEY and ROSSE, 1999). The possibility of access to interactive images to acquire human anatomy knowledge can lead to a withdrawal from the primary principle of the traditional means of anatomical learning based on text-books, printed atlases, and cadaver dissection (KIM, BRINKLEY and ROSSE, 2003). Internet-based education offers the possibility of clinical education and training imputing the use of technology as a new access to teaching and sharing far-reaching content, which enhances users' knowledge and performance and facilitates both knowledge acquisition and absorption besides offering the opportunity to optimize the system of education (SARAVANAN and SHANMUGHAVEL, 2007; REYNOLDS, MASON and EATON, 2008; WALDORFF, STEENSTRUP, NIELSEN et al., 2008).

Different subspecialties of computer science have evidenced the significance of an information system towards human anatomy. The variable, complex, irregular essence of human biological structures generates a particular interest and poses a great challenge to computer graphics (BRINKLEY, WONG, HINSHAW et al., 1999). On-line teaching methods cannot supersede teachers and expositive classes, but they do increase teaching quality and decrease the time spent in their management (SARAVANAN and SHANMUGHAVEL, 2007). Computer-based human anatomy programs can not only complement conventional teaching methods, but also offer groundbreaking means to represent anatomical knowledge (KIM, BRINKLEY and ROSSE, 2003). The challenge is not to determine the superiority of either methodology, but to maximize the benefits provided to teaching and learning human anatomy through different methods (TURNEY, 2007).

Presently, hundreds of websites dedicated to anatomy can be seen on the Internet (KIM, BRINKLEY and ROSSE, 2003). All information technology and systems have advantages and disadvantages (FEENEY, REYNOLDS, EATON et al., 2008). Human anatomy atlases are different from the traditional ones because their pages are developed in response to user demand. In addition, the atlases help in the acquisition of anatomical knowledge regarding the spatial relationships (KIM, BRINKLEY and ROSSE, 1999). As the learning of virtual content is unavoidable, the development of high-quality virtual content is required (SARAVANAN and SHANMUGHAVEL, 2007). The first understandable set of data and images of both male and female human cadavers was made available through the Visible Human Project sponsored by the National Library of Medicine. This was an outstanding example of resources of anatomical knowledge (KIM, BRINKLEY and ROSSE, 2003).

The Visible Human Project was created in 1986 in order to produce a library of digital images with a complete, anatomically detailed three-dimensional representation of the normal male and female adult human bodies. The initial goal of the National Library of Medicine was to produce a database of public domain with magnetic resonance, computed tomography, and anatomical images (TEMKIN, ACOSTA, HATFIELD et al., 2002; WALKER, LEE, SLOV et al., 2002). The long-term goal of the Visible Human Project was to produce a system of knowledge structures that would transparently link visual knowledge forms to symbolic knowledge formats. Many applications have been developed such as *Anatquest, AnatLine,* and *Insight Toolkit*. Each of them contains twice as many tools for three-dimensional representation, segmentation, recording, and classification of data image (ACKERMAN and YOO, 2003; THE VISIBLE HUMAN PROJECT, 2008). Despite the great development, such a project does not include human dermatome maps.

Among the computer systems available on-line concerning anatomy education is also the Biolucida System. It is a generator of interactive and dynamic anatomical scenes allowing the creation of three-dimensional virtual reality. Ontology is used to build up primitive models besides integrating heterogeneous models and presenting audio. The Biolucida architecture has four main components: 1) an anatomical knowledge base; 2) a 3-D model database; 3) a central server; and 4) an authoring and viewing client. A query is issued from the client and received by the central server, then, it is reissued and sent to the anatomical knowledge base. The answer is promptly processed and sent to the three-dimensional database; then, the data are converted into the central server and thence sent to the client who has sent the query. The Biolucida System is currently in a prototype stage, and it is necessary to compare its current functionality with user requirements solicited from anatomy education experts (WARREN and BRINKLEY, 2005; WARREN, AGONCILLO, FRANKLIN et al., 2006). In the same way, the Visible Human Project has not evidenced patterns or representation of dermatomes.

Another program, the Digital Anatomist Web Atlas, has been available over the Internet since 1995. It was developed by the Structural Informatics Group from the University of Washington to represent, organize, and disseminate on-line anatomical information. Its presentation is in an atlas mode and comprises some regions of the human body (available only for the cerebrum, thoracic viscera, and knee). The Digital Anatomist Web Atlas does not allow direct manipulation by the user. It presents images with interactive labels and highlights anatomical outlines. Also, it does not allow image zoom-in and zoom-out, does not play audio, and does not allow personal resolution or color scheme. The Digital Anatomist atlas limits the identification of anatomical image regions by their names (BRINKLEY, WONG, HINSHAW et al., 1999; KIM, BRINKLEY and ROSSE, 1999). Dermatome maps are not available.

The Virtual Anatomy Lab, developed in 1997 by the Human Interface Technology Laboratory at the University of Washington, is based on the Digital Anatomist Web Atlas, a color environment that allows students to organize their learning process by means of tools made available on-line provided with a permanent and dynamic lab. The virtual Anatomy lab focuses on students' personal learning through an interactive interface that lets them build their own three-dimensional anatomy study space on-line. Text and images can be imported into their space. Three-dimensional models are provided for import onto a virtual cadaver table. The program also allows identifying hierarchies that define relationships among body parts. Students can control the visualized area and dissect and rebuild the body as if in a physical cadaver lab. The Virtual Anatomy Lab prototype effectively integrates components of personal anatomy learning into a three-dimensional, interactive, and organized space (CAMPBELL, ROSSE and BRINKLEY, 2001). Like the previous programs mentioned, the Virtual Anatomy Lab does not include a dermatome representation.

There is a great lack of virtual content focusing representation, standardization, or range of dermatome maps. Once the printed atlases comprise only two-dimensional images, such a fact restricts health care students or professionals' learning and comprehension. Moreover, the observation of dermatome delimitation in certain body surfaces, such as the perineal region and internal surface of upper and lower limbs became difficult. Computer-based anatomy programs cannot only complement conventional teaching methods, but also offer groundbreaking means to represent, standardize, and disseminate knowledge of dermatomes. Computer programs capable of three-dimensionally standardize a map of human dermatomes needs to be developed.

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