Knowledge Representation of Traditional Chinese Acupuncture Points Using the UMLS and a Terminology Model

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Abstract

An escalating global interest in Traditional Chinese Acupuncture (TCA) demands easy use and reuse of the medical knowledge associated with TCA points, which in turn require appropriate knowledge representation of TCA. A proper knowledge representation generally involves enumeration of conceptual symbols and arrangement of these symbols into some meaningful structure. This study uses the Unified Medical Language System (UMLS) as the source of conceptual symbols and proposes a terminology model as the structure to arrange terms. The purpose is to systematically capture and represent appropriate TCA knowledge in practice. The initial terminology model is refined in an iterative process. The resulting terminology model captures and represents key aspects of TCA knowledge through properly designed model attributes and relations.

1. Introduction

Since the Canon of Chinese Medicine, also known as Huangdi Nei Jing Su Wen, was compiled about 2500 years ago, there have appeared quite a number of treatises written in different dynasties, describing the basic theories of Traditional Chinese Medicine, such as Yin-Yang and Qi, as well as acupuncture points and needling methods. Millions of Chinese people have benefited from acupuncture, guided by these documents. In addition, the practice of Traditional Chinese Acupuncture (TCA) was introduced to other countries at a very early date. TCA was introduced to Korea and Japan as early as the sixth century, and further spread to Europe in the late seventeenth century. Nowadays, more and more people all over the world are interested in knowing more about TCA [1]. Therefore, the authors believe that an appropriate knowledge representation of TCA will leverage its international impact as well as allow people to study, practice, and potentially benefit from it in the long run. A proper representation should enable the use and re-use of the medical knowledge of TCA, which in turn not only allows computer systems to accomplish many tasks that will assist clinical decision-making, but also helps enhance the ability of healthcare professionals in diagnosis and treatment by representing knowledge in a human-understandable manner. In general, knowledge representation involves enumeration of conceptual symbols and arrangement of these symbols into some meaningful structure. Symbols are usually represented with terms from a controlled terminology, and structures are used to arrange the symbols [2]. In this study, we use the US National Library of Medicine's Unified Medical Language System (UMLS) as the source of symbols; we propose a terminology model for arranging and representing the terms.

1.1. Traditional Chinese Acupuncture

Basically, in Traditional Chinese Medicine, health is represented as a balance of Yin and Yang. The theory of Yin-Yang holds that every object or phenomenon in the universe consists of two opposite aspects, namely, Yin and Yang, which are at once in conflict and in interdependence [1]. These two forces represent the bipolar manifestation of all things in nature, and one must be present to allow the other to exist. Ancient Chinese believed that the relation between Yin and Yang is the universal law of the material world, the principle and source of the existence of myriads of things, and the root cause for the flourishing and perishing of things. If the balance is consistently altered, meaning one regularly dominates the other, then health is compromised, resulting in illness and disease. The inter-dependent forces of Yin and Yang regulate Qi, which the ancient Chinese believed is the vital energy or substance that

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every living thing has to power internal organs and enable their effective functions. Similar to modern energy systems, Qi also needs to be transported through a subtle transportation system to reach different organs. This transportation system is referred to as the channels or meridians. There are 12 main channels, named after the organs they are related to, and along each of them there are points for acupuncture. The points of the 12 channels, which make up the majority of all the acupuncture points on the human body, are 309 in number. Illness and disease can develop if the flow of Qi is blocked and not restored in a timely manner. Acupuncture is one tool used to restore the flow of Qi, by inserting needles into the acupuncture points located on the meridians. These insertions are said to clear any residing blockages, thus freeing the Qi to better feed the body in its entirety. Traditional Chinese Medicine uses these theories extensively to explain the physiology and pathology of the human body, and to guide diagnosis and treatment in clinical practice.

1.2. Terminology Model

According to Bakken, et al. [3], a terminology model is defined as an explicit representation of a system of concepts that is optimized for terminology management and that supports the intentional definition of concepts and the mapping among terminologies. It depicts the associative relationships between an aggregate (molecular) expression and more primitive (atomic) concepts. Within a terminology model, a type definition explicitly states which descriptors or attributes must be specified for every concept of a particular type [4]. It is the formality of the terminology models that facilities knowledge representation in structural categorizations.

1.3. UMLS

Initiated by the US National Library of Medicine, the UMLS was developed in 1986 as a repository of biomedical vocabularies to improve the ability of computer programs to "understand" the biomedical meaning in user inquiries and to use this understanding to retrieve and integrate relevant machine-readable information for users [5]. The UMLS integrates over 2 million names for some 1,021,000 concepts from more than 60 families of biomedical vocabularies, as well as 16 million relations among these concepts [6]. Over years, its three experimental Knowledge Sources, the Metathesaurus, the Semantic Network, and the Specialist Lexicon have been distributed to interested researchers, many of whom have tested and evaluated them in a range of applications [5]. Therefore, we use the UMLS as the coding system to provide conceptual symbols for the proposed terminology model due to its comprehensiveness and popularity.

In the following sections, we will elaborate how the UMLS and a terminology model are used to represent the medical knowledge of acupuncture points used in Traditional Chinese Medicine.

2. Materials and Methods

The research questions we address include:

- Does the UMLS Metathesaurus cover an acceptable number of acupuncture points?
- Is the current UMLS suitable for knowledge representation in the domain of acupuncture?
- How can the current UMLS contents be used to represent the terminology model attributes and relations?
- How can the proposed terminology model capture and represent the key aspects of the knowledge of acupuncture points?
- Is the proposed terminology model general enough to be applied to points with different attribute values?

2.1. Study scope

In terms of the study scope, there are two aspects, UMLS coverage and knowledge representation using a terminology model. For the former, all the 309 points associated with the twelve regular channels are used to query the knowledge source server. Regarding the latter, this study works with a group of sample points including all the points in the Heart channel, and one point from each of the other eleven regular channels.

2.2. Procedures

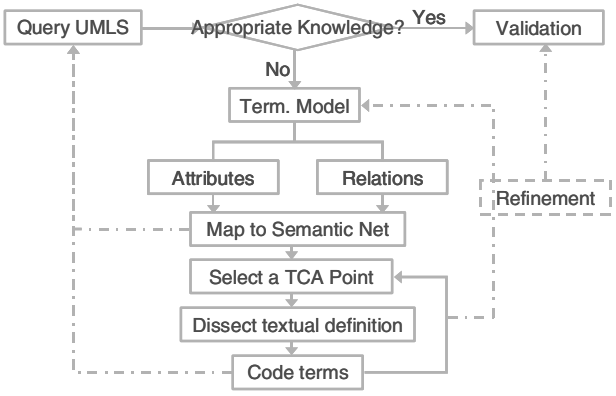

Figure 1: The Procedure for Representing Knowledge of Traditional Chinese Acupuncture Points Using the UMLS and a Terminology Model

Figure 1 shows the main steps of this study. First of all, it is critical to know how many points are currently covered by the Metathesaurus. Querying the UMLS online Knowledge Source Server addresses this issue. In this study, UMLSKS Version 4.1 and the UMLS release 2003AC are used to perform the basic concept search. No advanced options are used to perform the focused search. Based on the query results, we analyze whether the current UMLS provides appropriate knowledge for those points it includes. More precisely, the annotation of appropriate knowledge of each acupuncture point implies that key medical information, such as point location and function, should be provided so that inexperienced users will be able to determine its basis by reading the definitions, and the representation should be formal enough to be machine-processable. If the covered points meet the above criteria, we will further validate the knowledge representation. If the current included knowledge is either inadequate or informal, we will propose a terminology model that has proper attributes and relations, to represent concepts of acupuncture points. The UMLS Semantic Network provides a consistent categorization of all concepts represented in the Metathesaurus through its Semantic Types. The links between the Semantic Types provide the structure for the network and represent important relationships in the biomedical domain. This is akin to what is proposed in a terminology model -- the model provides information about the basic attributes that are assigned to the acupuncture point concept, and it defines the relationships that may hold between different attributes. The broad and well-defined UMLS Semantic Network intuitively inspires us to map terminology model relations to Semantic Relations and model attribute values restriction to Semantic Types. The mapping involves queries to perform searches in the UMLS Semantic Network. However, it is also because of the comprehensiveness of the UMLS Semantic Network and a potential risk of ambiguity that we propose a terminology model specifically designed to represent pertinent TCA knowledge. Then, the terminology model is applied to a selected TCA point. Since the knowledge of that point is obtained from literature, books, and reference papers, we will only have a textual definition to work with. The next step will be to dissect the textual definition into atomic concepts, and use controlled terms to code those concepts, including attribute descriptors, qualifiers, and values. The coding step involves matching terms in the Metathesaurus again. Finally, to ensure generality of the terminology model, as described in the study scope section, we will apply the terminology model to more acupuncture points, and continue refining the terminology model until we finalize it and validate its knowledge representation.

3. Results

3.1. UMLS Coverage

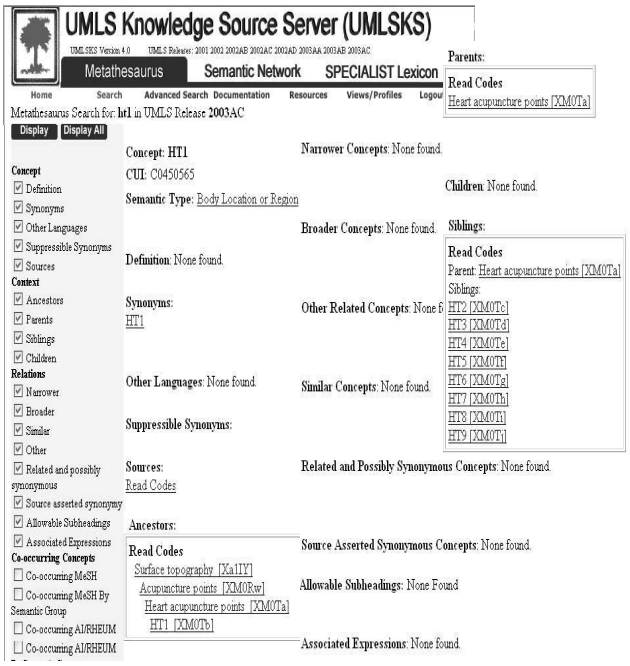

Figure 2: Search Results of an Acupuncture Point in the UMLS

The query results show that the UMLS 2003AC includes 307 out of 309 TCA points on 12 regular meridians, which yields 99.4% coverage. The sources of those terms are Read codes. The only missing codes are the last two points of the Urinary Bladder Channel, Foot-Tonggu and Zhiyin, or BL66 and BL67 according to the naming convention used by Read codes. However, for each point there lacks detailed definition and sufficient knowledge. Figure 2 is the screen shot of a search page of the first acupuncture point in the Heart Channel. Besides parent and sibling relations, no further information is available in the UMLS.

Initial Terminology Model Figure 3 is the initial design of a terminology model. It includes four pertinent attributes: *Indication*, *Method, Site*, and *Regional Anatomy*. Each point is therapeutically related to some indications, which may be qualified by signs, symptoms,

and the body part where they occur. Certain methods can be used at a TCA point. It may be qualified by course, extent, or option, specifying needling direction, duration, route, extent, and applicable options such as moxibustion (burning of a thimble-sized, smoldering plug or cone of moxa, often Mugwort at a TCA point). To characterize where the point is, we not only need to know the site information, including anatomic landmark and location, but also the regional anatomy to understand the vascular and nerve network going viscerally.

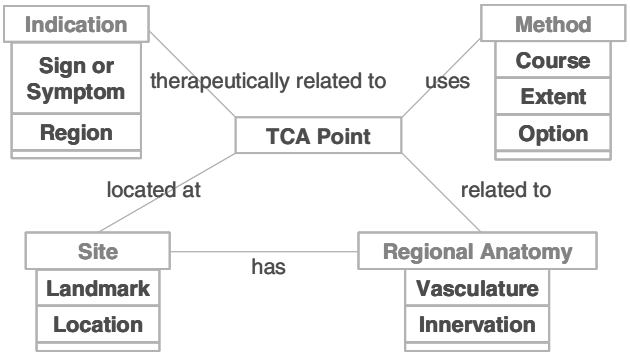

Figure 3: Initial Terminology Model

3.2. Mapping to the UMLS Semantic Network

The purpose of this mapping is to see to what extent the existing UMLS Semantic Types and Semantic Relations can represent the point attributes and relations in the terminology model. It is desirable to have close matches, as the UMLS Semantic Network has a broad range of types and relations that have been developed, widely used, and tested by a number of institutions across the country in the past two decades.

There are 135 Semantic Types in the UMLS Semantic Network and thirteen attributes and qualifiers in the terminology model. Table 1 shows the only two close matches between them. Therefore, instead of using UMLS Semantic Types, we use terms in the Metathesaurus to represent terminology model attributes, qualifiers, and modifiers.

Table 1: Mapping Terminology Model Attributes to UMLS Semantic Types

Semantic Types	TM Attributes
Sign or Symptom (TUI: T184)	Sign or Symptom
Body Location or Region (TUI: T029)	Site

Table 2: Mapping Terminology Model Relations to UMLS Semantic Relations

UMLS Semantic Relations	TM Relations
uses (TUI: T155)	Uses
location_of (TUI: T135)	Located at
part_of (TUI: T133)	Has
associated_with (TUI: T166)	Therapeutically related to
spatially_related_to (TUI: T189)	Related to

Table 2 shows a satisfactory match between UMLS Semantic Relations and terminology model relations. Most of the terminology model relations are similar enough to their UMLS counterparts to be used interchangeably. The exceptions are in the last two rows. In the bottom row, the UMLS provides more precise definition than that of the terminology model relation, whereas in the row above, "Therapeutically related to" gives more specific classification than "associated-with" in the UMLS.

3.3. Traditional Chinese Acupuncture Point in Terminology Model

Figure 4 is the text description of the first point in the Heart Channel (Heart 1) [1]. Aggregate expressions in this narrative description need to be dissected into more primitive concepts and associative relationships as the "intermediate representation" for both users and computer applications. However, to remain at the same level of granularity as well as to avoid significant semantic misinterpretation, an appropriate structure is

required to capture sophisticated hierarchies and relations among primitive concepts. Moreover, concept constraints are represented through attributes, qualifiers, and modifiers. Each concept has attributes to define its essential meaning, and each attribute has particular qualifiers to specify the attribute scope and limits. Modifiers are used to provide detailed definitions for specific attributes to eliminate ambiguity. Figure 5 shows how to use the terminology model to represent the point Heart 1. The same information and knowledge in Figure 4 are captured and represented in a structured format (Figure 5) that can be easily accessed by human as well as machines. In Figure 6, all the attributes, qualifiers, modifiers, and values are coded using UMLS controlled terminologies.

Heart1: is in the center of the axilla, on the medial side of the axillary artery. It applies to pain in the costal and cardiac regions, scrofula, cold and pain of the elbow and arm. Axillary artery, ulnar nerve, median nerve and medial brachial cutaneous nerve are in the same area. Puncture perpendicularly 0.5-1.0 inch. Moxibustion is applicable.

Figure 4: Textual Description of an Acupuncture Point

Heart 1
Site:
- Landmark: **axilla**
- Location: **center**

Regional Anatomy:
- Vasculature: **medial axillary artery**
- Innervation: **ulnar nerve, median nerve, medial brachial cutaneous nerve**

Indication:

Sign or Symptom	Region
Pain	**costal and cardiac regions**
Scrofula	
Cold and pain	**elbow and arm**

Method:
- Course: **perpendicularly**
- Extent: **0.5-1.0 inch**
- Option: **moxibustion**

Figure 5: Representing an Acupuncture Point Using Terminology Model

Heart 1
Site **C0205145:**
- Landmark **C0504075: axilla C0004454**
- Location **C0450429: center C0205099**

Regional Anatomy **C0002812:**
- Vasculature **C1187030: medial axillary artery C0004455**
- Innervation **C0021516: ulnar nerve C0041602, median nerve C0025058, medial brachial cutaneous nerve C0278448**

Indication **C0237000:**

Sign or Symptom **C0037088**	Region **C0205147**
Pain C0030193	**costal and cardiac regions C0521328**
Scrofula C0036467	
Cold C0234192 and pain	**elbow C0013769 and arm C0003792**

Method **C0025663:**
- Course **C0449922: perpendicularly C0205128**
- Extent **C0439792: 0.5-1.0 (value) inch C0439204**
- Option **C0008300: moxibustion C0026652**

Figure 6: Representing an Acupuncture Point Using Terminology Model and Controlled Terms

3.4. Refined Terminology Model

As mentioned in the procedure section, selecting other points and applying the terminology model to them are iterative processes, in which we refine and modify the model design when necessary. Figure 7 shows an example of improving the terminology model according to points with significantly different features. The upper part is a partial text description of the fourth point of the Heart Channel (Heart 4), and the lower part is the representation using an improved terminology model. Extra pieces of information are captured using new attribute qualifiers such as “Measure” and “Position”, which are difficult to represent in the original terminology model. Experiments with other points confirm that those new descriptors are pertinent site information. As a result, in the refined terminology model, these qualifiers have been added to the site attribute to avoid significant semantic loss, as shown in Figure 8 (See examples of sample points in the Appendix). The new terminology model does not affect the mapping to the UMLS Semantic Network.

Heart 4: On the radial side of the tendon of muscle flexor capi ulnaris, 2 inches above the transverse crease of the wrist when the palm faces upward…

Site:

Landmark: M. flexor carpi ulnaris
Side: radial

Location: Crease of wrist
Modifier: transverse
Orientation: above
Measure: 2 inches
Position: palm faces upward …

Figure 7: Partial Text-based Description of another Acupuncture Point

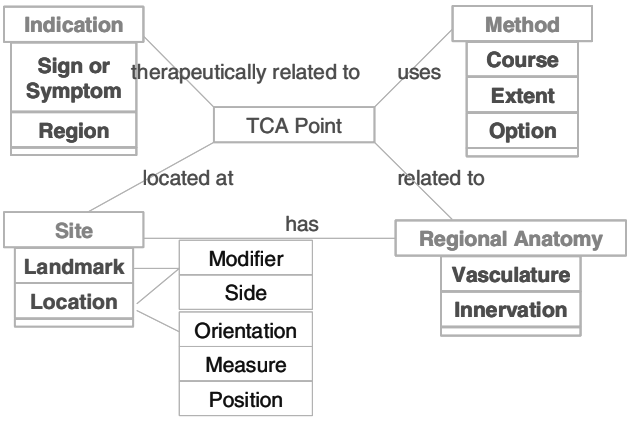

Figure 8: Refined Terminology Model

4. Discussion

4.1. Proper Balance in Terminology Model Design

It is as important to keep a proper balance in the terminology model design as it is in remaining healthy through the balance of Yin-Yang. Yet, achieving this balance is not an easy task. On the one hand, the terminology model should be expressive enough to capture detailed medical knowledge of the given concepts. On the other hand, it should be general enough to be applicable to similar situations so that we will not have the situation where each individual acupuncture point needs a unique terminology model to represent pertinent knowledge.

4.2. Mapping to the UMLS

The satisfactory matching results in the Metathesaurus are due to two major factors, proper dissection of textual definition, and comprehensiveness of Metathesaurus contents [7]. Moreover, diverse sources of the Metathesaurus with different coding schemes, including both pre-coordination and post-coordination, contribute to its completeness and facilitate the process of text dissection. For example, even though "medial brachial cutaneous nerve" may not be considered an atomic term in some cases, it can be successfully matched to the code "C0278448" in the Metathesaurus.

A possible explanation for the relatively disappointing result in mapping the proposed terminology model attributes to UMLS Semantic Types is that UMLS Semantic Types are high-level categories used to provide consistent categorizations for about one million concepts covered by the Metathesaurus, whereas the terminology model attributes are meant to capture high-level concepts of the acupuncture knowledge specifically. Although they both represent top-level categories in each structure, they are not at the same conceptual and semantic level when compared to each other, given the significant differences between the scopes and specificity of the two domains.

4.3. Verification of Terminology Model

One way to verify the model is to use an inference engine to test whether a machine can follow the formal definition and reason through explicit hierarchies and relations to reach desired concepts or to draw proper conclusions. Since the ability of expressing a collection of relationships with other concepts in a terminology [8] is the central requirement for any definitions that are in a format that can be readily accessible to manipulation by machines, the authors believe that without formal knowledge representation, there can be little reasoning or inference carried out from the terminology model.

Another verification is to compare the results achieved with those obtained by other approaches, such as conceptual graphs [9], frame-based representations [10], and categorical structures [11], as these methods are all in forms that can be manipulated symbolically, i.e. machine executable, as opposed to the unstructured narrative text variety [8].

Studies in knowledge representation and artificial intelligence show that description logics have been developed to allow formal representation of the meanings of concepts and their inter-relationships. These formal descriptions can be used by inference algorithms to determine equivalence of different concept descriptions

[12]. In other words, description logics make it possible to automatically determine the equivalence of concepts and relations represented elsewhere.

Last but not least, human experts often play an indispensable role in knowledge validation. In many clinical cases, their opinions are considered the “Gold Standard” to evaluate clinical information systems. Therefore, consultations from human experts will undoubtedly help us validate the proposed knowledge representation.

5. Conclusion

The current UMLS covers an acceptable number of acupuncture points. It also contains certain relations, such as parent-child relations. However, the UMLS does not provide formal and adequate TCA domain knowledge, and thus is not suitable for TCA knowledge representation.

The proposed terminology model captures and represents key aspects of knowledge of TCA points that are important in practice. Attributes and relations of the terminology model can be represented by current UMLS contents to some extent. Certain mismatches may indicate the need to add concept definitions to the Metathesaurus and new types and relations to the Semantic Network. Iterative experimentation improves and validates the generality of the proposed terminology model.

The terminology model can be viewed as an "intermediate representation" oriented to users and "perspectives" adapting it to specific computer applications. The Semantic Network and controlled terminologies in the Metathesaurus, along with the formal definition represented in the terminology model make it possible for computer systems to access and process information and knowledge captured, and thus help care providers locate acupuncture points as well as practice TCA in the process of patient care.

Acknowledgments

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Appendix: Sample TCA points used in this study

Heart 1
Site **C0205145**:
- Landmark **C0504075**: **axilla C0004454**
- Location **C0450429**: **center C0205099**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **medial axillary artery C0004455**
- Innervation **C0021516**: **ulnar nerve C0041602**, **median nerve C0025058**, **medial brachial cutaneous nerve C0278448**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
Pain C0030193	**costal and cardiac regions C0521328**
Scrofula C0036467	
Cold C0234192 and pain	**elbow C0013769 and arm C0003792**

Method **C0025663**:
- Course **C0449922**: **perpendicularly C0205128**
- Extent **C0439792**: **0.5-1.0 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**

Heart 2
Site **C0205145**:
- Landmark **C0504075**: **m. biceps brachii C0224235**
- Location **C0450429**: **H3 C0450567**
  - Orientation **C0037744 : above C0205105**
  - Measure **C0079809**: **4 inch C0439204**
  - Position **C0449846** : **elbow C0013769 flexed C0231453**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **basilica vein C0226801**, **superior ulnar collateral artery C0226426**
- Innervation **C0021516**: **medial antebrachial cutaneous nerve C0228851**, **medial brachial cutaneous nerve C0278448 and ulnar nerve C0041602**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
Yellow sclera C0240962	
Pain C0030193	**hypochondriac region C0230186**, **shoulder C0037011** **arm C0003795**

Method **C0025663**:
- Course **C0449922**: **perpendicularly C0205128**
- Extent **C0439792**: **0.3-0.5 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**

Heart 3
Site **C0205145**:
- Landmark **C0504075**: **m. biceps brachii cubital C0431856 crease C0459397**
  - Modifier: **transverse C0205106**
- Location **C0450429**: **medial epicondyle of humerus C0223690**
  - Orientation **C0037744 : anterior to C0205094**
  - Measure **C0079809**: **4 inch C0439204**
  - Position **C0449846**: **elbow C0013769 flexed C0231453**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **basilica vein C0226801**, **inferior ulnar collateral artery C0226427**, **ulnar recurrent artery C1185909 and vein (ulnar vein) C0226810**
- Innervation **C0021516**: **medial antebrachial cutaneous nerve C0228851**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
Cardiac pain C0423636	
Numbness C0028643	
Hand tremor C0239842	
Elbow contraction C1140999	
Pain C0030193	**axilla C0577659 hypochondriac region C0230186**
Scrofula C0036467	

Method **C0025663**:
- Course **C0449922**: **perpendicularly C0205128**
- Extent **C0439792**: **0.3-0.5 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**

Sanjiao 20
Site **C0205145**:
- Landmark **C0504075**: **temple C0935456**
- Location **C0450429**: **ear apex C0931638**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **superficial temporal artery C0226130 and superficial temporal vein C0226521**
- Innervation **C0021516**: **auriculotemporal nerve branches C0459287**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
Redness and swelling	**ear C0549297 & C0576848**
Redness, swelling, pain	**eye C0235267 C0270996 C0151827**
Toothache C0040460	

Method **C0025663**:
- Course **C0449922**: **obliquely C0205315 downward C0542339**
- Extent **C0439792**: **0.1 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**

Liver 14
Site **C0205145**:
- Landmark **C0504075**: **6th intercostals space C0446486**
- Location **C0450429**: **mammillary line C0230087**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **6th C0205440 intercostal artery C0459917 and intercostal vein C0226641**
- Innervation **C0021516**: **6th C0205440 intercsotal nerve C0021725**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
Pain C0030193	**hypochondriac region C0230186**
Abdominal distension C0000731	
Fullness C0439650	**chest C0008031**
Vomiting C0042963	
Hiccup C0019521	

Method **C0025663**:
- Course **C0449922**: **obliquely C0205315**
- Extent **C0439792**: **0.3 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**

Gall Bladder 4
Site **C0205145**:
- Landmark **C0504075**: **4th toe C0230496**
- Location **C0450429**: **corner of nail C0027342**
  - Orientation **C0037744 posterior to C0205095**
  - Measure **C0079809 0.13 inch C0439204**

Regional Anatomy **C0002812**:
- Vasculature **C1187030**: **dorsal C0205095 and plantar digital artery C0226481 and vein networks**
- Innervation **C0021516**: **dorsal digital nerve C0446827**

Indication **C0237000**:

Sign or Symptom **C0037088**	Region **C0205147**
One-sided headache C0239891	
Ophthalmalgia C0151827	
Deafness C0011053	
Dream-disturbed sleep C0037317	
Febrile diseases C0015967	

Method **C0025663**:
- Course **C0449922**: **obliquely C0205315**
- Extent **C0439792**: **0.1-0.2 (value) inch C0439204**
- Option **C0008300**: **moxibustion C0026652**