JOURNAL OF INTEGRATIVE AND COMPLEMENTARY MEDICINE
Volume 29, Number 12, 2023, pp. 769–773

DOI: 10.1089/jicm.2023.0592

JICM

SAR TURNING POINTS

THE SOCIETY FOR ACUPUNCTURE RESEARCH

Birth of the Topological Atlas and Repository for Acupoint Research

Vitaly Napadow, PhD, LicAc,[1] Richard E. Harris, PhD, LicAc,[2] and Karl G. Helmer, PhD[3]

Vitaly Napadow

Richard E. Harris

Karl G. Helmer

Overview

Acupuncture is a millennia-old therapy, which is increasingly being integrated in conventional care for the treatment of a range of conditions, particularly chronic pain disorders.[1,2] A critical component of acupuncture therapy is the existence of specific locations across the body surface where inserting and manipulating a needle can engender salubrious, clinically beneficial effects. These locations are termed acupuncture points, or acupoints, and have been the source of much controversy for the acupuncture research field.[3–5] Indeed, lack of clarity on the biological basis of acupoints has greatly hindered their more widespread integration into clinical care.[6]

Several decades ago, the World Health Organization (WHO) sought to standardize body locations for 361 commonly acknowledged acupoints.[7,8] However, bringing together traditional acupoint nomenclature with conventional understanding of anatomy/physiology is still a work in progress, and a comprehensive understanding of the anatomy and physiology of acupoints continues to elude researchers in this field. Hence, the creation and sustained curation of an open-access repository and database for acupoint research could create an important bridge between traditional theory and a

[1]Spaulding Rehabilitation Hospital, Harvard Medical School, Boston, MA, USA.
[2]UC-Irvine, Irvine, CA, USA.
[3]Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA.

modern understanding of biomedicine. The creation of such a repository is the goal of the recent Request for Applications (RFA) put forth by the National Center for Complementary and Integration Health at NIH (RFA-AT-23-005).

In response to this RFA, our successful proposal detailed the creation of an open-access, web-based portal, and database incorporating (1) an acupoint ontology using both Traditional East Asian Medicine (TEAM) and conventional biological nomenclature systems; (2) male and female human, and rat body atlases, each with a standardized 3D coordinate system; and (3) a searchable database of acupoint information along with previously published physiological data, curated by an expert committee, associated with acupoint stimulation. Our platform, called the Topological Atlas and Repository for Acupoint research (TARA), will form an invaluable Research Resource Center for the acupuncture research and clinical community. This Center will be led by Principal Investigators Vitaly Napadow, PhD, LAc, Richard Harris, PhD, LAc, and Karl Helmer, PhD.

TARA consists of four Cores, Repository, Ontology, Map, and TEAM, each including working groups and advisory boards that will draw experience from a broad community of experts. The creation of the open-access database along with the repository of anatomical and physiological data will be led by co-PI Karl Helmer from Massachusetts General Hospital, whose team has deep experience in building open-access repositories containing a wide range of data types. He has also been involved with the NIH-funded Stimulating Peripheral Activity to Relieve Conditions (SPARC) consortium as part of the Data Standards Committee. Experience from SPARC will be leveraged to facilitate future interoperability between the TARA and SPARC databases, as well as other repositories containing acupoint-related data. The ontology creation team will be led by Maryann Martone from the University of California in San Diego and will focus on building an acupoint ontology using nomenclature from both western biomedicine and TEAM, and the ontology will be used to describe relations between acupoints and anatomical structures. The Map Core, led by Peter Hunter from Auckland University, will create a standard-space topographical body atlas that can be used for visualizing the anatomy near a

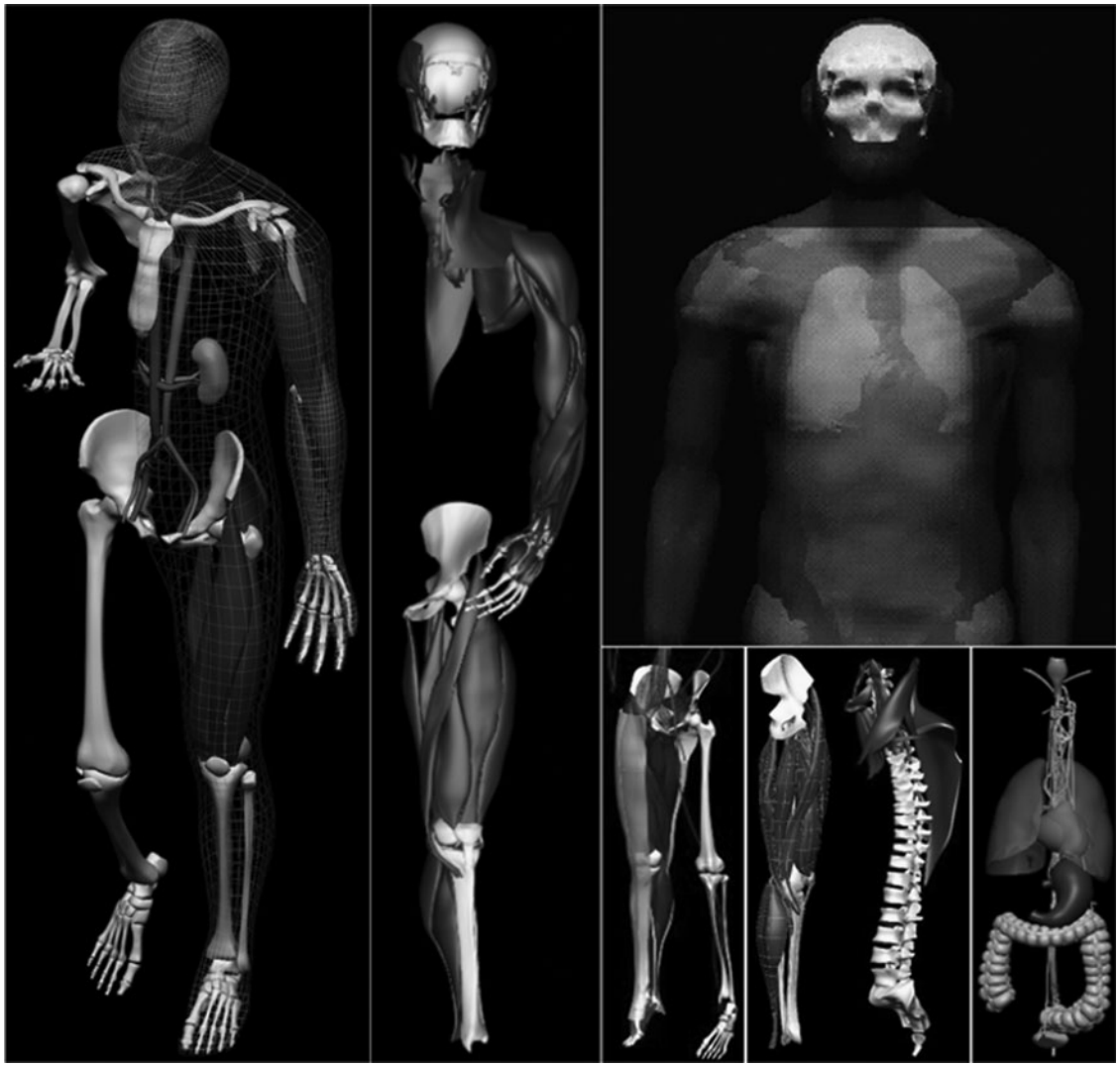

FIG. 1. The musculoskeletal system within the whole-body scaffold. The geometry, anisotropic structure, and spatial material properties of each muscle and bone are captured by a finite element scaffold.

selected acupoint. The acupoint and anatomical visualization will be based on the accurate coregistration of the atlas with detailed human anatomical data, supplied by (1) high-resolution MRI data we will collect from live models marked by MR-opaque acupoint fiducial markers, and (2) detailed anatomical human models segmented from prior MRI and cadaver cryosection data, supplied by the IT'IS Foundation team in Zurich, Switzerland, and Dongguk University in Korea. A parallel rodent acupoint atlas using prior MRI and cryosection data will also be created.

The TEAM Core will be led by Dr. Richard Harris and acupuncture domain expertise will bolster the above efforts, and we will lead the outreach effort to populate the TARA repository by soliciting high-quality anatomical and physiological data from the international acupuncture research community. This outreach will be led by co-PI Richard Harris and supported by the Society for Acupuncture Research (SAR), the leading international academic acupuncture research organization, thus ensuring broad outreach to research communities worldwide.

What Is an Ontology and Why Would We Make One?

An ontology is a structured collection of terms, related to a domain, that meaningfully describes the types of things that exist in that domain along with their properties, and the connections between terms. The acupoint ontology effort will leverage state-of-the-art ontologies including the growing SPARC ontology for the autonomic nervous system. The SPARC Connectivity Knowledgebase uses terms from the SPARC ontology to describe anatomical and functional connections in SPARC-related anatomy that was populated through the development of detailed circuitry based on SPARC data and expert knowledge using a platform called ApiNATOMY. This knowledge graph will be extended to include connections to acupoints that are proximal to specific nerve pathways. In TARA, TEAM experts and anatomists will provide connectivity information to the ontology working group to be incorporated into the Knowledgebase and ontology. The goal is to provide researchers with a framework to understand acupoints in relation to anatomical and physiological data and provide a common language within which to understand these relationships. The TARA Acupoint Ontology will be made available on a regular release cycle through the web-based ontology repository BioPortal, under an open license so that it is available to the wider community (Fig. 1).

Creating an Accurate, Probabilistic, Multiperspective Acupoint Atlas

TARA's Acupoint atlas will be standard space whole-body templates for both human and rat, onto which acupoints will be labeled. For each acupoint, anatomical

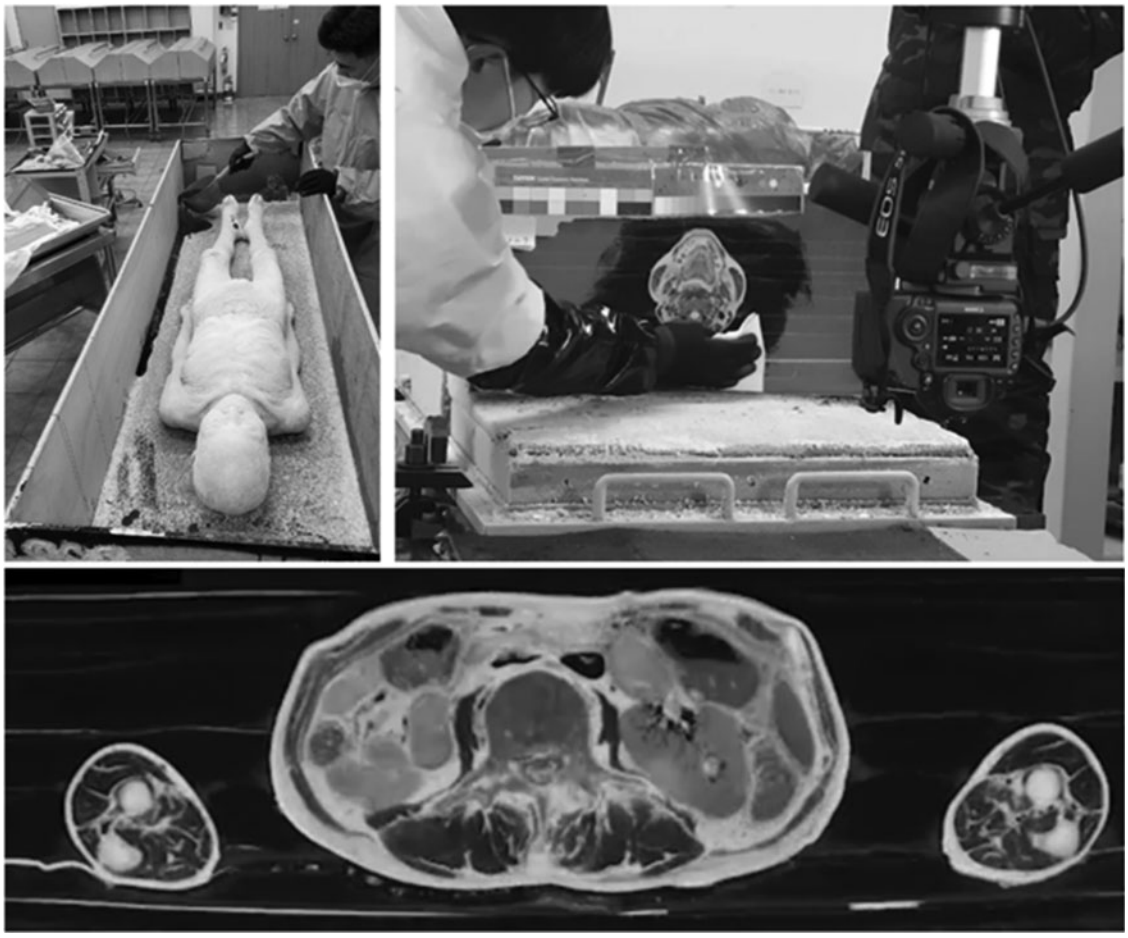

FIG. 2. The 0.1 mm resolution human (and rat) cryosection datasets were created by Prof. Park at Dongguk University.

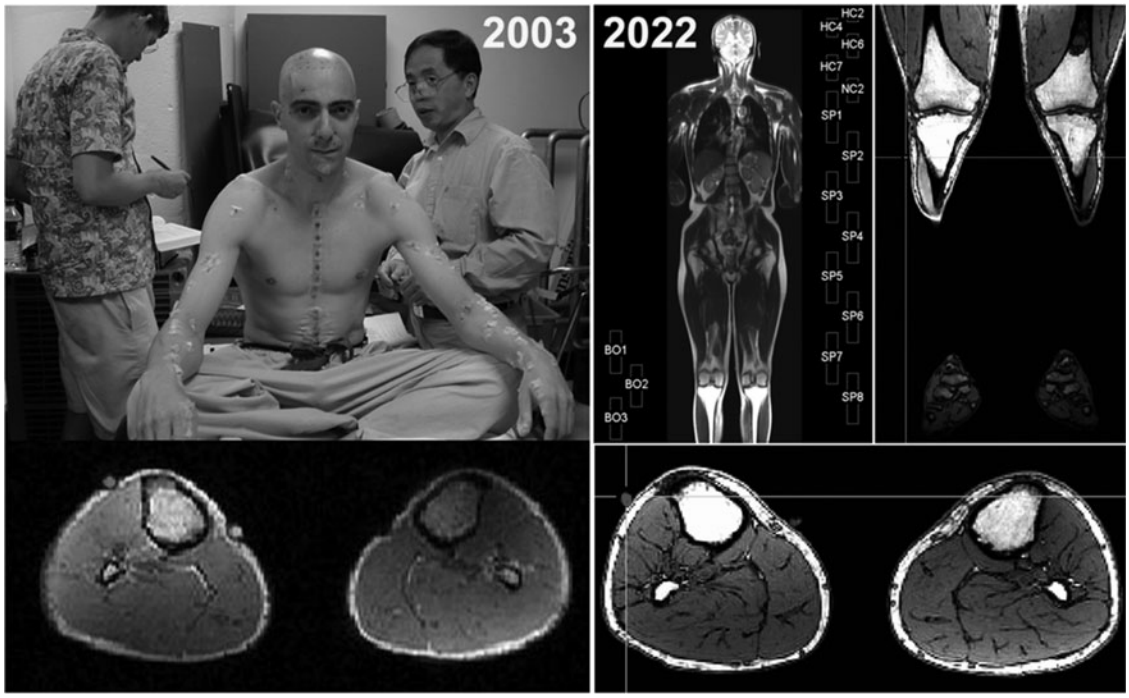

FIG. 3. (*Left*) Early effort by co-PI to collect whole-body MRI data with MR-opaque markers placed over acupoints (e.g., ST-36, *crosshair*). (*Right*) New pilot dataset with 1 mm resolution (cross-hair on ST-36).

structures impacted by a needle below the skin surface will be noted, based on textbook descriptions, cross-referenced to whole-body MRI and cryosection atlas segmentations, and confirmed by TARA anatomists. The whole-body datasets will include (1) *in vivo* male and female MRI, (2) cadaver cryosections, and (3) tissue segmentations based on the MRI and cryosection datasets. The whole-body template, created using finite element model computer-aided design software, will contain a scaffold system containing muscles, bones, visceral organs, and the peripheral nervous system (Fig. 1). Here the term ''scaffold'' indicates that it is a coordinate framework into which many different aspects of tissue structure can be assembled, including muscle fiber orientations, vascular geometry, neural pathways, and the spatial distributions of physiological data. The anatomical scaffolds are generated to follow the features of the skin, or an organ, or any other anatomical part. The tools for fitting the whole-body scaffold to image data (MRI or cryosection) have already been developed under the SPARC MAP project and will be applied for TARA.

Several existing whole-body datasets will be coregistered to the whole-body template. The IT'IS Foundation in Zurich, Switzerland, will provide two surface-based models that can be used for visualization. The human model will include an image-based segmentation coregistered with cadaver cryosection data provided by the Visible Korean project (from Professor Jin Seo Park at Dongguk University, Fig. 2).

As the vast majority of basic science acupuncture research has been performed with rodents, we will also create a parallel rat atlas for the TARA platform. We will incorporate the NeuroRat model from our partner IT'IS Foundation. This model contains 179 segmented tissues with neurofunctionalized nerve trajectories (i.e., electrophysiological fiber models). IT'IS will also perform hybrid electromagnetic-electrophysiological simulations at several acupoints to illustrate the potential of data integration using anatomical models, nerve trajectories, physiological data from the SPARC initiative, and biophysical modeling. Electromagnetic simulations will couple regional human nerve models with electrophysiological simulations of nerve fiber recruitment. This modeling is particularly relevant for stimulation at various acupoint depths. These simulations are relevant clinically, as different acupuncture techniques target deep (e.g., Chinese) versus shallow (e.g., Japanese) needle insertions at acupoints, and different clinical applications may arise from targeting different peripheral nerves.

To create the whole-body high-resolution MRI datasets, acupoints will be marked on each volunteer by three different acupoint localization experts, during three different MRI scan sessions using consensus acupoint definitions provided by the WHO Standard Acupuncture Point Locations booklet.[7,8] Recent advances in MRI technology now allow the acquisition of high-resolution whole-body MRI. Close to 20 years ago, co-PI Napadow et al. engaged in an effort to image acupoints across the body using MRI (Fig. 3). While the spatial resolution and tissue contrast was inferior to what can be achieved today, our team learned many lessons which will now be incorporated to collect the whole-body MRI datasets for TARA.

Database of Acupoints and a Repository of Prior Research

The TARA repository will strive to meet the FAIR principles[9] (Findable, Accessible, Interoperable, and Reusable). The TARA web portal will give users access to the database containing the information for each acupoint and a search interface to find previously published data by related acupoint, anatomical region, or by disease/condition

(Findable, Accessible). One common issue with data sharing is deciding whether an available dataset is appropriate to answer a specific research question and whether the data could be used in conjunction with other existing data. To address this issue, each dataset will be accompanied by a rich set of metadata that gives a full description of the data (Interoperable, Reusable). Data contributors will be asked to provide data acquisition information as well as data descriptions and links to publications using the data. Datasets will be organized in a standardized format based on the SPARC data format,[10] modified to accommodate acupoint data. Data under consideration for inclusion in TARA will be evaluated for quality by the TARA TEAM Core.

The TARA website will provide a generalized portal for user interaction with TARA resources. Users will be able to create accounts, browse, and request access to data. Searching for information will be either through a visual model displaying acupoints or a text-based search function, the latter using terms from the TARA ontology. The visual interface will, as noted above, provide links not only to contributed datasets but also to MRI, cryosection, and even ultrasound data (the latter provided by Dr. Sanghun Lee at the Korean Institute of Oriental Medicine) so that users can visualize anatomical structures around acupoints. The website will also contain project information such as news, contact information, project leadership, data-use agreement(s) for data requests, and instructions for preparation and submission of data.

In conclusion, TARA will form an invaluable Research Resource Center for the acupuncture research community by providing data and information which can be used to strengthen the understanding of the biological basis of acupoints. Moreover, future TARA extensions will (1) integrate acupoint-related data in other physiological databases, such as SPARC, to the TARA infrastructure, thereby incorporating cutaneous neuromodulation data from across the body, and (2) allow for electromagnetic source simulations at acupoints and cutaneous/subcutaneous locations across the entire body surface. We hope that TARA, working with SAR, will help galvanize the acupuncture community to further our understanding of the physiological basis of acupuncture.

Authors' Contributions

R.E.H., V.N., K.G.H.: Drafted, edited, and finalized the final manuscript.

Author Disclosure Statement

R.E.H. and K.G.H. declare no conflicts of interest. V.N. is a consultant for Cala Health, Inc., and Click Therapeutics, Inc.

Funding Information

K.G.H. was supported by the National Institutes of Health: National Center for Complementary and Integrative Health (NCCIH, U24-AT012560) for the purposes of this manuscript. V.N. was supported by the National Institutes of Health: National Center for Complementary and Integrative Health (NCCIH, U24-AT012560, R01-AT012144, R33-AT009306, P01-AT009965), and National Institute of Mental Health (NIMH, U54-MH118919). R.E.H. was supported by NIH NCCIH U24AT012560 and by an endowment from the Susan Samueli Integrative Health Institute for the purposes of this manuscript.

References

1. Cummings M. Modellvorhaben Akupunktur—A summary of the ART, ARC and GERAC trials. Acupunct Med 2009; 27(1):26–30; doi: 10.1136/aim.2008.000281
2. Vickers AJ, Cronin AM, Maschino AC, et al. Acupuncture for chronic pain: individual patient data meta-analysis. Arch Intern Med 2012;172(19):1444–1453; doi: 10.1001/archinternmed.2012.3654
3. Langevin HM, Wayne PM. What is the point? The problem with acupuncture research that no one wants to talk about. J Altern Complement Med 2018;24(3):200–207; doi: 10.1089/acm.2017.0366
4. Langevin HM, Wayne PM, Macpherson H, et al. Paradoxes in acupuncture research: Strategies for moving forward. Evid Based Complement Alternat Med 2011;2011:180805; doi: 10.1155/2011/180805
5. Yan X, Zhang X, Liu C, et al. Do acupuncture points exist? Phys Med Biol 2009;54(9):N143–N150; doi: 10.1088/0031-9155/54/9/N01
6. Napadow V, Ahn A, Longhurst J, et al. The status and future of acupuncture mechanism research. J Altern Complement Med 2008;14(7):861–869; doi: 10.1089/acm.2008.SAR-3
7. Pacific WHO. WHO Standard Acupuncture Point Locations in the Western Pacific Region, WHO Publications: Geneva, Switzerland; 2009.
8. Lim S. WHO Standard Acupuncture Point Locations. Evid Based Complement Alternat Med 2010;7(2):167–168; doi: 10.1093/ecam/nep006
9. Wilkinson MD, Dumontier M, Aalbersberg IJ, et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 2016;3; doi: 10.1038/sdata.2016.18
10. Bandrowski A, Grethe JS, Pilko A, et al. SPARC Data Structure: Rationale and design of a FAIR Standard for Biomedical Research Data. bioRxiv 2021;2021.02.10.430563; doi: 10.1101/2021.02.10.430563

Address correspondence to:
Vitaly Napadow, PhD, LicAc
Spaulding Rehabilitation Hospital
Harvard Medical School
Boston, MA 02129
USA

E-mail: vitaly@mgh.harvard.edu