An evaluation of the effectiveness of teaching anatomy to rheumatologists through combined musculoskeletal sonoanatomy and human cadaveric dissection.

Running head: Combining musculoskeletal ultrasound with human cadaveric dissection

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Abstract

Objectives. To evaluate the effectiveness of teaching anatomy through combined musculoskeletal sonoanatomy and human cadaveric dissection for rheumatologists practicing musculoskeletal ultrasound.

Methods. The principle focus was on scanning and then dissecting relevant musculoskeletal structures. Outcomes measured included confidence levels and objective knowledge. A mixed methods approach of evaluation and descriptive statistical data analysis was performed.

Results. Change in delegates' confidence ratings after the teaching event as represented by the mean difference ± SD (SEM) for identifying surface anatomy was 1.846 ± 1.281 (0.355), with paired t = 5.196 and p value = 0.000223. Mean difference ± SD (SEM) for performing intra-articular injections was 1.538 ± 1.266 (0.351), with paired t = 4.382, p value = 0.001, and for recognising sonoanatomical structures it was 1.769 ± 1.235 (0.343), with paired t = 5.165 and p value = 0.000235. There was significant increase in correct identification of anatomical and sonoanatomical knowledge in the pre and post course assessments. Rotator cuff interval region improved from 13 to 73%; p = 0.004, knee tendons insertion sites from 47 to 93%; p = 0.016 and muscles not adjacent to joints from 27 to 93%; p=0.002.

Conclusion. Dissection of joints enabled a three-dimensional relational mind map of the relevant regions of the human body, producing clarity in understanding regional relational topographic anatomy and sonoanatomy. Combining ultrasound and cadaveric dissection improved learners’ satisfaction, confidence and knowledge in areas where soft tissue complaints are common, likely to lead to accurate early diagnosis and cost conscious, better overall care.

Key words: Clinical anatomy, sonoanatomy, cadaveric dissection, ultrasound.

Key Messages:

1. Knowledge of musculoskeletal anatomy is essential for correct diagnosis of regional musculoskeletal soft tissue pathology.

2. The level of competency in clinical anatomy is perceived to be deficient amongst rheumatologists.

3. Combining cadaveric dissection and sonoanatomy is effective in increasing confidence and knowledge of anatomy amongst rheumatologists.
## Introduction

This study aimed to evaluate the effectiveness of teaching anatomy to rheumatologists in Singapore, using a training course combining musculoskeletal sonoanatomy with human cadaveric dissection. Many studies have shown that the level of competency in clinical anatomy of the musculoskeletal system is deficient in rheumatology trainees, fellows and consultants [1,2]. Despite that up to 30% of rheumatology consultations are made up of regional pain syndromes, musculoskeletal anatomy has been identified as a relatively neglected component of postgraduate training in rheumatology on a global scale [3].

A deep knowledge of clinical anatomy enables the rheumatologist to perform a skilled history, interpretation and well-informed physical examination, which is essential in uncovering the underlying etiology of the patient’s problem and in providing a more cost-effective and efficient diagnostic plan. Additionally, there has been widespread use of musculoskeletal ultrasound (MSUS) amongst rheumatologists, of which a key component is the integration of an accurate knowledge of anatomy with the ultrasound images obtained. The European League Against Rheumatism (EULAR), European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) and American College of Rheumatology (ACR) have produced minimal training requirements, comprehensive guidelines and standardized scanning protocols to cover anatomic structures relevant to rheumatology [4,5,6].

There is significant evidence suggesting that teaching skills in musculoskeletal examination and clinical anatomy are inadequate, in that too often both are taught poorly and superficially, and in most rheumatology training syllabi competency in musculoskeletal anatomy is assumed rather than verified before obtaining accreditation [7,8,9]. In the past few decades, the curriculum time for anatomy instruction has also been significantly reduced in undergraduate medical programmes. This may be the reason for general decrease in residents and doctors’ knowledge of clinical anatomy. [10].

In view of these deficiencies, we developed a novel approach to enable rheumatologists with intermediate MSUS experience, (deemed equivalent to EULAR Competency Level 1 or 2), to benefit from didactic lectures on sonoanatomy, hands-on scanning and demonstrated dissection of the upper and lower limb using fresh human cadaveric specimens [11]. The goal of the dissection component was to enable learning anatomy with relevant clinical sonoanatomical correlation.

The use of cadaveric dissection component in learning sonoanatomy for rheumatologists is not clear. Hence, this study aimed to investigate the impact of a clinical anatomy course combining musculoskeletal sonoanatomy
with human cadaveric dissection on rheumatologists’ knowledge of musculoskeletal anatomy and to explore the perceived effectiveness of the dissection component in learning sonoanatomy.

**Methodology**

**Anatomy sessions**

The anatomy sessions were undertaken in small groups setting. In each group there were 4-5 course attendees and 2 faculty members. The teaching was divided into 2 parts, with the hands-on ultrasound sonoanatomy training preceding the demonstration of gross anatomy through dissection. Entire limbs, rather than whole cadavers were utilized. The shoulders and upper limb extremities (including, wrists and hands) were taught on Day 1 of the course, and the hips as well as lower limb extremities (including, knees, ankles and feet) were taught on Day 2 of the course. On average, 4 hours were focused on hands-on sonoanatomical aspects, and a further 3 hours on anatomical dissection and demonstration.

The faculty included expert anatomists and orthopaedic consultants for the dissection sessions; and interventional radiologists and sports physicians for the injection techniques and sonoanatomy sessions. A list of relevant and clinically significant areas to be identified was given to the dissection faculty and participants prior to the session (Table 1), however the programme allowed for some flexibility during dissection, taking into account the learners’ needs and areas of interest.

The anatomy suite at Singapore General Hospital adhered to the code of conduct and license from the Human Tissue Authority with respect to the use and disposal of human tissue regulated by Human Tissue Act. The course was non-profit, endorsed by the Singapore Society of Rheumatology and designed purely for educational purposes. The total cost per attendee to run this course over 2 days was $1000 SGD.

**Questionnaire Survey and Pre- and Post-Course Assessment**

Pre and post course questionnaires were administered to participants (Supplementary Data S1 and S2, available at *Rheumatology* online). A list of 20 pertinent anatomical areas was assembled by an organising faculty member (MM) and independently reviewed for face validity by 2 other rheumatologists. Consequently, 18 questions (Supplementary Data S3, available at *Rheumatology* online) were selected to cover all 10 anatomical areas. The objectives were to assess anatomical knowledge of the candidates, and evaluate their confidence in identifying sonoanatomical structures and performing ultrasound guided interventions as a result of attending the course. The faculty ensured that the pre-test questions were not discussed during the course. Ethics approval
for waiver of consent was obtained for the study, (NHG DRSB 2018/00263). Personal data and responses of the course attendees completing the questionnaire were anonymised.

**Data and statistical analysis**

Data was collected and interpreted manually from the online questionnaire, following which descriptive data analysis was performed using SPSS Version 23.0. Means were calculated from the numeric percentage rating scales, and paired t-test was used to compare the before and after scores in identifying surface anatomy, identifying sonoanatomy structures, and performing intra-articular injections.

**Results**

**Prior anatomical knowledge**

17 attendees completed the pre and post course questionnaires, all of whom practiced musculoskeletal ultrasound on a weekly basis. 83.3% (n=14) felt that the anatomy teaching they received during their rheumatology post-graduate training was either ‘somewhat inadequate’ or ‘inadequate’, and 76.5% (n=13) felt that their current anatomical knowledge was either ‘somewhat inadequate’ or ‘inadequate’. In regards to knowledge of sonoanatomy, 76.5% of attendees (n=13) felt that their knowledge was either ‘somewhat inadequate’ or ‘inadequate’. Despite this, all attendees responded that their practice of ultrasound had improved their knowledge of anatomy, clinical examination skills, and diagnostic skills.

**Overall perceptions on use of human cadavers and dissection component**

None of the attendees had previously attended a sonoanatomy course incorporating dissection. Scanning of the cadaveric specimens, followed by dissection was felt to be a useful way of learning anatomy and sonoanatomy, with 76.5% (n=13) ‘strongly agreeing’ and 23.5% (n=4) ‘agreeing’. The majority of attendees responded that the cadaver style learning compared very positively to previous forms of training, with respect to personal engagement, technical demonstration and efficiency of learning. In regards to the usefulness of the dissection component of the course in daily practice of musculoskeletal ultrasound and in understanding sonoanatomy, all of the attendees responded that it was either ‘extremely useful’ or ‘very useful’.

**Confidence levels pre and post course**

Following the course, the mean confidence rating in identifying surface anatomy increased by 1.85 (±1.3), the mean confidence rating in performing intra-articular injections increased by 1.54 (±1.3), and the mean confidence rating in recognising sonoanatomical structures increased by 1.77 (±1.2). This was statistically significant (t = 5.196, p <0.001; t = 4.382, p = 0.001; t = 5.165, p <0.001, respectively).
Anatomical and sonoanatomical knowledge pre and post course

Table 2 shows the numbers and percentages of respondents (n=15), who correctly answered the questions related to anatomical and sonoanatomical areas based on the pre-course and post-course quizzes. The regions which showed greatest improvement in knowledge were the shoulder (rotator cuff interval), knee and ankle. Correct answers pertaining to the pes anserinus, coracohumeral ligament, superior glenohumeral ligament, anterior inferior tibio-fibular ligament and soleus increased from 47 to 93% (p = 0.016), 13 to 73% (p = 0.004), 13 to 53% (p = 0.031), 20 to 60% (p = 0.031) and 27 to 93% (p = 0.002) respectively. Although there was a trend towards an increase in knowledge in other areas (wrist), this was not statistically significant.

Summary of qualitative data

The key themes that emerged included: i) positive feedback on the relevance of the dissection component, (ii) relationship of gross anatomy to the ultrasound findings, (iii) new approaches to injection techniques, (iv) knowledgeable and experienced tutors, (v) adequate hands-on practice, (vi) interactive teaching methodology, and (vii) relevance to pathology seen in clinical practice. Scanning followed by dissection enabled the visualization of a three-dimensional map of the relevant regions, producing clarity in understanding regional, relational and functional anatomy and relating it to sonoanatomy. The attendees benefited from being taught in an interactive manner; and found that both the group and peer learning with a multi-disciplinary faculty incorporating anatomists, orthopaedic surgeons, sports physicians, and interventional radiologists were rewarding.

Comments included:
“…the most useful component of the course was dissection of joints and related structures by experienced tutors..”
“By seeing gross anatomy I am able to better understand and recognize structures in sonoanatomy…”
“Scanning structures followed by the dissection helped consolidate my knowledge of anatomical course, attachments and function… I can link sonanatomy better to the pathology”
“Practising probe –needle alignment in human cadavers while scanning was great as it gave me a better understanding of relational structures and realistic feeling of needle progression”
“Learnt a lot from faculty…good to have a mix of disciplines”

Discussion
Our study demonstrated that the majority of respondents felt that the teaching of musculoskeletal anatomy was suboptimal during their postgraduate rheumatology training and that their anatomy knowledge fell short of expectation, despite the fact that all used ultrasound in daily clinical practice. Although this perceived deficit was felt to have a negative impact on sonoanatomy knowledge, respondents thought their ultrasound practice and upskilling had resulted in an overall improvement in their anatomy knowledge, clinical examination and diagnostic skills.

The level of confidence of the attendees indicated significant improvements in terms of identifying surface anatomy, performing intraarticular injections and recognizing sonoanatomy. The percentage of correct answers for each of the anatomic items in particular the shoulder, knee and ankle improved post-course, suggesting that a hands-on workshop, adopting an interactive methodology, strengthens the learners’ knowledge base. Areas that showed poor knowledge pre-course included the rotator cuff interval/ biceps pulley system and the knee. Given that shoulder, (specifically rotator cuff pathology), and knee complaints form a significant proportion of musculoskeletal referrals, implications of poor anatomical knowledge amongst rheumatologists in these areas may lead to inaccurate/incomplete diagnoses.

**Limitations**

The major limitations of this study include the small sample size of rheumatologists, attending a single centre educational course. The small sample size may have accounted for the lack of statistical significance in some of the anatomical items tested in the pre and post course assessments that showed a trend towards an increase in knowledge.

Further limitations included the lack of formal validation of the pre and post course assessments, the small number of anatomical items assessed and lack of more longer term validity. Increasing the number of items assessed may be counterproductive, as it would shorten the actual time devoted to the actual workshop. Organizing another post course assessment 4-5 weeks following the course would have ensured longer term validity.

The attendees of this course all had prior expertise in ultrasound, and were therefore likely to have more advanced knowledge anatomy, and greater awareness of their deficiencies compared to rheumatologists with no ultrasound experience. Future courses should be designed to address the needs of both rheumatologists with and without ultrasound experience, with appropriate standards for both groups.
Conclusion
In summary, it appears that MSK anatomy teaching is neglected in rheumatology teaching programs. This study shows that the dual approach of ultrasound scanning complemented by the dissection of fresh human cadavers is very useful in increasing the confidence and anatomical knowledge of rheumatologists. We feel that cadaveric learning can and should be integrated in the post-graduate setting, and that such workshops run by a multidisciplinary faculty are not only feasible, but a valuable educational initiative for rheumatologists. Three dimensional anatomical models and anatomical specimen maps can be used as an adjunct to support such cadaveric courses. Every rheumatologist, particularly those practicing ultrasound, needs a good knowledge of anatomy in order to diagnosis and manage MSK soft tissue pathology in a cost conscious, effective manner.

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**Table 1**: Guide for dissection – list of relevant anatomic areas

| SHOULDER                                      | WRIST                                             | HAND                                      |
|-----------------------------------------------|---------------------------------------------------|-------------------------------------------|
| Long and short head of biceps                | Extensor retinaculum                              | Flexor digitorum profundus and superficialis|
| Subscapularis tendon                         | Extensor tendon compartments (I-VII)              | Volar plate                               |
| Deltoid muscle                               | Carpal tunnel                                     | Pulleys                                   |
| Coracoid process                             | - Proximal carpal tunnel                          |                                           |
| Supraspinatus tendon                         | - Distal carpal tunnel                            |                                           |
| Subdeltoid bursa                             | Volar Wrist ligaments                             |                                           |
| Infraspinatus tendon                         | - Scapholunate ligament                           |                                           |
| Teres Minor                                  | - Long and short radiolunate ligaments            |                                           |
| Transverse Humeral Ligament                  | Dorsal wrist ligaments                            |                                           |
| Coracoacromial Ligament                      | - Scapholunate ligament                           |                                           |
| Coracohumeral ligament                       | - Dorsal intercarpal ligament                      |                                           |
| Rotator Interval                             | - Radiotriquetral ligament                        |                                           |
|                                              | Triangular fibrocartilage, ulnocapitate and       |                                           |
|                                              | ulnolunate ligaments, meniscal homologue          |                                           |
|                                              |                                                   |                                           |
| **KNEE**                                      | **ANKLE**                                         | **FOOT**                                  |
| Quadriceps tendon                            | Flexor Retinaculum                                | Flexor hallucis longus                    |
| Suprapatellar recess                         | Anterior ankle tendons                            | Flexor digitorum longus                   |
| Patellar tendon                              | - Tibialis tendon                                 | Plantar aponeurosis                       |
| Pes Anserinus                                | - Extensor digitorium                             | Metatarsophalangeal joint                  |
| Medial collateral ligament                   | - Extensor hallucis longus                        |                                           |
| Lateral collateral ligament                  | Medial ankle tendons                              | Plantar plates                            |
| Biceps femoris                               | - Tibialis posterior                              |                                           |
| Gerdy’s tubercle                             | - Flexor digitorum                                |                                           |
| Popliteus tendon                             | - Flexor hallucis longus                          |                                           |
| Gastrocnemius                                | Lateral ankle tendons                             |                                           |
| Infrapatellar fat pad                        | - Peroneal tendons and superficial                |                                           |
| Popliteal artery                             |   peroneal retinaculum                            |                                           |
| Tibial nerve                                 | - Deltoid ligament                                |                                           |
| Common fibular nerve                         | - Spring ligament                                 |                                           |
|                                              | - Anterior talofibular ligament                    |                                           |
|                                              | - Soleus                                          |                                           |
|                                              | - Achilles tendon                                 |                                           |
|                                              | - Kager’s fat pad                                 |                                           |
Table 2: List of anatomical and sonoanatomical knowledge items answered correctly during the pre-and post-course quiz.

| Item                                | Pre-workshop (N = 15) | Post-workshop (N = 15) | p-value |
|--------------------------------------|-----------------------|------------------------|---------|
|                                      | #  | %  | #  | %  |         |         |
| Iliotibial band                      | 6  | 40 | 11 | 73 | 0.180   |         |
| Pes anserine                         | 7  | 47 | 14 | 93 | 0.016   |         |
| Carpal tunnel boundaries             | 11 | 73 | 14 | 93 | 0.250   |         |
| Flexor wrist tendons                 | 11 | 73 | 14 | 93 | 0.250   |         |
| Coracohumeral Ligament               | 2  | 13 | 11 | 73 | 0.004   |         |
| Superior Glenohumeral Ligament       | 2  | 13 | 8  | 53 | 0.031   |         |
| Extensor tendons II                  | 9  | 60 | 10 | 67 | 1.000   |         |
| Extensor tendons V                   | 9  | 60 | 15 | 100| -       |         |
| Extensor tendons VI                  | 11 | 73 | 15 | 100| -       |         |
| Volar plates                         | 5  | 33 | 7  | 47 | 0.687   |         |
| Anterior Inferior Tibiofibular Ligament | 3 | 20 | 9  | 60 | 0.031   |         |
| Anterior Tibiofibular Ligament       | 11 | 73 | 11 | 73 | 1.000   |         |
| Soleus                               | 4  | 27 | 14 | 93 | 0.002   |         |
| Achilles tendon                      | 15 | 100| 14 | 93 | -       |         |
| Retrocalcaneous bursa                | 10 | 67 | 14 | 93 | 0.125   |         |
| Kager Fat Pad                        | 9  | 60 | 13 | 87 | 0.125   |         |

p-value based on McNemar’s test; (-) McNemar test was not valid