Can an integrated physical and virtual library of anatomical cross sections and diagnostic images enhance anatomical knowledge, diagnostic image interpretation and spatial awareness?

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Project Overview

Currently at the RVC we have a number of examples of good practice in terms of using diagnostic imaging to enhance anatomy teaching and learning in the BVetMed curriculum. Radiographs are available during all anatomy classes to view alongside cadaver material and integrated widely in assessment. Students are also encouraged to borrow radiograph packs featuring key radiographic views of clinically important musculoskeletal structures in conjunction with annotated overlays. The importance of radiographic anatomy is emphasised through a 'Radiologist' team member in every dissection group as part of a near-peer teaching scheme used in Year 2 locomotor strand dissections (Hall et al, 2013). Additionally, a canine radiograph e-learning package is available for further independent study. Whilst radiographs are the primary imaging modality for many veterinarians, the increased availability and use of alternative imaging technologies such as ultrasonography, CT, and MRI means that increasingly clinicians must possess a thorough appreciation of 3D and sectional anatomy in order to accurately interpret diagnostic images. Conversely these imaging modalities aid in the understanding of topographic anatomy which is a fundamental pre-requisite for any clinical work, but especially surgery. Currently, for a number of reasons, integration of ultrasound, CT and MRI images within our anatomy teaching is very limited. **There are unutilised opportunities to enhance the student learning experience by integrating advanced diagnostic imaging in anatomy and clinical teaching**

This LIVE teaching development project aims to develop both imaging and anatomical resources that can be used to reciprocally enhance anatomy and clinical teaching. The equine distal limb is of huge clinical importance with the majority of lameness attributable to foot pathology (Dyson and Marks, 2003; Turner, 2003). Dissection of the equine distal limb and foot is however challenging due to the complex spatial relationships and small size of the structures, and due to the presence of a rigid horn capsule. Coupled with this, students find interpretation of diagnostic images of this region difficult. Over the last decade CT and especially MRI of the foot has become standard procedure in equine referral practice as has ultrasonography for the soft tissues in the pastern and metacarpal region (Barrett and Frisbee, 2012; Neelis and Roberts, 2012). We therefore propose to focus this project on the musculoskeletal system, specifically on the equine distal limb in the first instance, however if successful it will provide a benchmark for developing further similar resources for other clinically relevant body regions / systems and species, and a useful method to illustrate pathology.

We propose to develop a 'physical library' of serial plastinated cross sections of equine distal limbs, accompanied by a 'virtual library' of corresponding ultrasound, CT and MRI images from the same animal at each slice level. We aim to place QR codes on each cross sectional slice to provide instant matching to the related diagnostic image(s) using a tablet device or smart phone. Both diagnostic images and plastinated cross sections will be firmly integrated into Year 2 locomotor strand teaching, by forming the basis of a revised Equine distal limb anatomy practical class and will be available in years 3-5 for revision and as a reference guide during extra- and intramural rotations. The effectiveness of the resources will be determined by comparing the learning outcome of the plastinated cross sections, diagnostic images, and the combination of both modalities when compared to our current standard teaching methods (dissection and radiographs). We will assess anatomical knowledge and diagnostic image interpretation skills using an online image based test, as well as monitoring potential improvements in spatial ability using the Mental Rotation Test (Vandenberg & Kuse, 1978) and a modified version of Guay's Visualization of Views test (Eliot & Smith, 1983).

Background

Spatial understanding of anatomy is a key requirement for medical and veterinary students, in particular in preparation for carrying out clinical procedures (e.g. rectal exam) and surgery (Garg et al, 2001). Several studies have demonstrated a relationship between surgical skills and performance in spatial awareness tests (Murdoch et al, 1994; Gibbons, et al, 1986; Gibbons,et al, 1983; Steele, et al, 1992). Spatial cognition is also central to understanding medical images which are essentially two-dimensional images of three-dimensional objects. When orienting themselves on medical images specialists have to infer the three dimensional anatomy of a patient on the basis of both the two-dimensional view given in the image, and their knowledge of anatomy. Correct interpretation of diagnostic images, therefore, relies on spatial representations and processes (Hegarty et al, 2007) as well as good knowledge of cross-sectional anatomy (Erkonen et al., 1990; Shapiro et al., 1998; Barros et al., 2001), clinical knowledge and reasoning skills.

There is evidence that students with poor spatial abilities have difficulty acquiring a spatial understanding of anatomy. Spatial ability has been shown to predict achievement in anatomy classes, with 'low-spatial' medical students attaining consistently lower marks than 'high-spatial' individuals in both practical anatomy examinations and multiple-choice questions requiring spatial anatomical knowledge (Rochford, 1985). A similar relationship has been established within the field of dentistry, with spatial reasoning predicting success in the demanding fields of operative dentistry, endodontics, and dental anatomy (Just, 1979).

Learning resources have been implicated as important in terms of developing the spatial ability to mentally relate 2-D and 3-D representations of anatomy. It has been suggested that providing students with high quality resources induces them to interact which leads to improved task performance (Hegarty, 2007). Cadaveric dissection is considered the gold standard interface for learning anatomical spatial relationships due to its engagement of multiple senses, 3D interaction and tactile manipulation of tissues (Sugand et al., 2010; DeHoff et al., 2011). Plastinated specimens (Latorre et al., 2007), hand- held manipulatives (Krontiris-Litowitz, 2003; Jittivadhna et al., 2009, 2010), clay (Waters et al., 2005; Motoike et al., 2009; Oh et al., 2009; DeHoff et al., 2011) and physical (Preece et al, 2013) models have also been shown to complement traditional approaches and to enhance anatomical knowledge and visuospatial understanding.

Anatomical cross sectional slices have long been widely used (e.g. Fritsch and Hötzinger, 1995) in anatomy teaching. When plastinated (von Hagens, 1985; Marigos et al, 1997) they are versatile and portable teaching aids that can be used both in the dissection laboratory as well as stored in boxes as a museum resource (Latorre et al, 2001; Figure 1). Such cross sections have high clinical value when used together with other diagnostic imaging techniques such as radiology, MRI and CT (Baptista, 1989; Fritsch, 1996) and plastinated cross sections have been shown to enhance diagnostic imaging teaching. Teaching imaging anatomy via instructor-led small group discussions alongside the use of plastinated anatomical sections improved students' interpretation of CT sections (Barros et al., 2001). Similarly, making 3D clay models, slicing them into cross sections, and using these in conjunction with CT images enhanced students' later performance at interpreting CT images (Oh et al, 2009). There are also documented reciprocal benefits to using medical images to enhance gross anatomy teaching such as enhancing clinical relevance (Bohl et al, 2011; Nwachukwu, 2013), integration and synthesis of different areas of teaching (Bohl et al, 2011) and student confidence (Nwachukwu, 2013). It has also been suggested that presenting both anatomical slices with medical images together enhances the benefits to students since having the same information presented in multiple formats aids conceptual development (Khalil et al, 2005).

The RVC case

Currently Royal Veterinary College students study the anatomy of the equine distal limb in detail during their second year visit to the Locomotor strand. Face-to-face teaching consists of a lecture on the anatomy of the equine foot followed by a 2 hour dissection of the equine distal limb and accompanying short demonstration of shoeing by our farriers. The locomotor strand receives good feedback from students, however historically students find the dissection of the distal limb challenging to complete in 2 hours. Sample comments from past feedback surveys include "distal limb was hard, very hard, so we couldn't see much" and "would have liked a little more time in the equine distal limb dissection". This dissection class has been lengthened in recent years, along with other locomotor strand dissection classes, however there is no more room in the busy timetable (due to both student time and room availability constraints) to lengthen these classes further. Coupled with the timetabling constraints, lecturers and demonstrators feel that students find this region challenging to

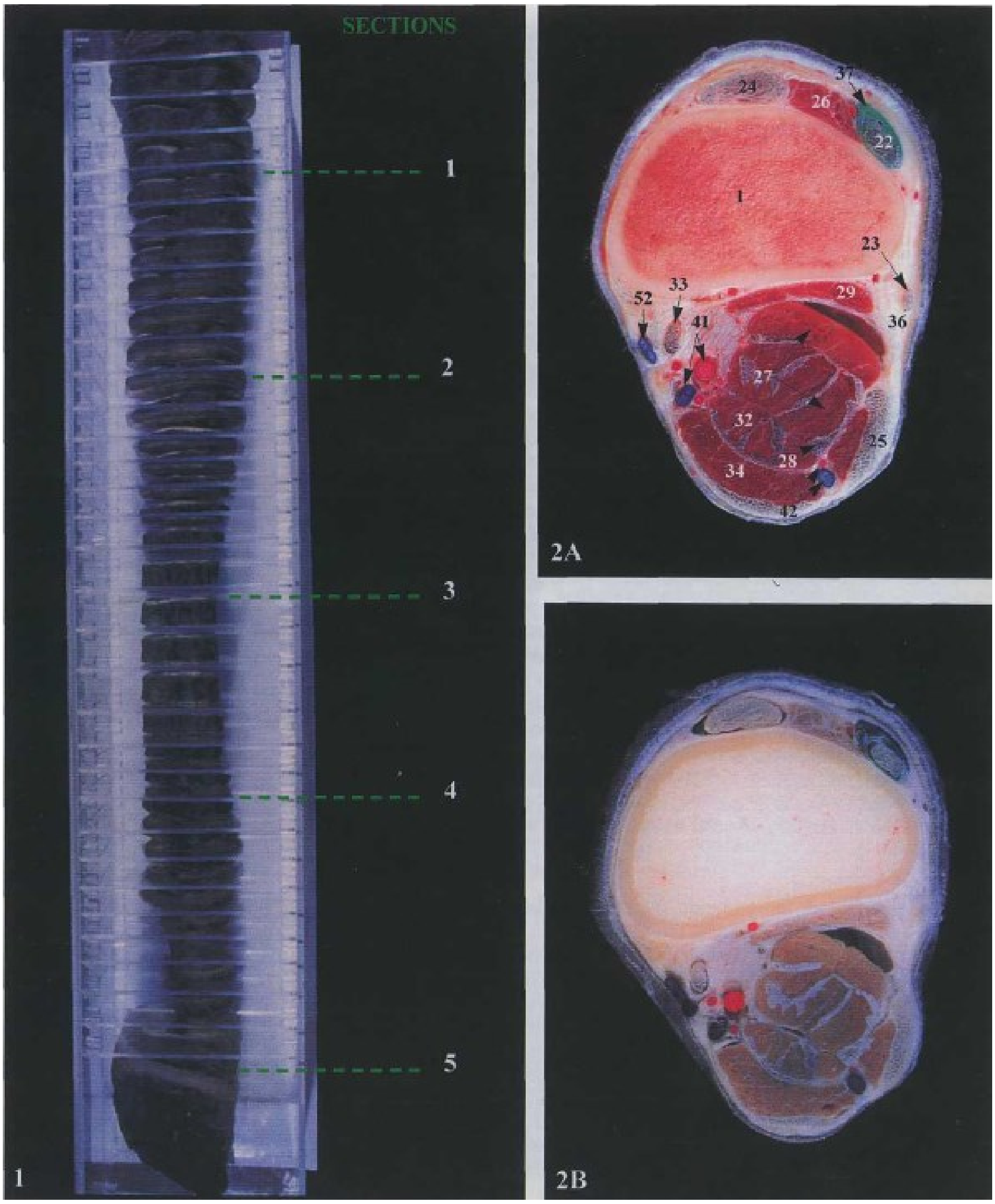


Figure 1. Examples of plastinated cross sections of the equine distal limb, and a physical library of slices (left panel) at a range of anatomical levels. From Latorre et al, 2001.

dissect. They have difficulty skinning, preserving and identifying digital nerves, vessels, ligaments and tendons in the pastern and fetlock region and often do not manage look inside the hoof capsule itself due to the highly time consuming and difficult nature of accessing this region. Consequently we believe students do not currently come away with a good understanding of equine distal limb anatomy, and this is reflected in the feedback from equine clinicians which find the level of anatomical knowledge the students have when they start rotations often very disappointing. This lack of anatomical understanding of these clinically highly relevant areas hinders the students to make the most of their clinical experience.

The RVC has been using plastinated resources in its anatomy teaching for some time. Recently the college invested in and developed a plastination suite at its Camden campus, to enable the college to produce high quality plastinated prosections 'in-house'. Early stage material that has been produced is excellent (isolated organs, such as testes, hearts, and kidneys, as well as some small whole animals). We are therefore well equipped to begin to produce more technically demanding resources to enhance our growing specimen collection. Plastinated cross sectional slices would be a valuable teaching resource for both anatomy and diagnostic imaging teaching, particularly when used in conjunction with ultrasound, CT and MRI images. **We propose to create and evaluate a physical library of cross sectional slices to be used in conjunction with a virtual library of associated diagnostic images that can be used together during face-to-face teaching as well as for independent student learning.**

Aims and objectives

The specific aims of this project are:

- To enhance the teaching of anatomy and diagnostic imaging by creating a physical library of plastinated anatomical cross sections and a virtual library of diagnostic images, to be used in locomotor strand practical classes, for independent study, and during diagnostic imaging and equine rotations.
- To evaluate the resources by considering the effect of their use on anatomy learning, diagnostic image interpretation, and spatial ability of students.

The objectives are:

- To produce a set of serial plastinated cross sections of the equine distal limb
- To produce matching ultrasound, CT and MRI scans of the cadaveric limbs
- To make the diagnostic images available online as a virtual library, and to link each plastinated cross section with its reciprocal diagnostic image via QR scanning codes for easy access through mobile devices
- To integrate the resources into a Year 2 practical class (equine distal limb), and a Year 4 practical class (equine diagnostic nerve blocks), clinical skills stations (e.g. nerve block and joint block simulators) and in diagnostic imaging and equine rotations teaching
- To carry out a study considering the effect of the resources on anatomical knowledge, diagnostic image interpretation and spatial ability.
- To gather student feedback on their experiences using the resources and evaluate student enjoyment and confidence

Project Method and Evaluation

Four cadaver equine limbs (two fore and two hind limbs) will be used from a horse with no signs of musculoskeletal pathology, and euthanized for reasons unrelated to this study. One forelimb and one hindlimb will undergo ultrasonography, CT and MRI. Ultrasound will be performed on the palmar aspect of the leg in transverse and longitudinal planes from the carpus/tarsus to the pastern region. CT images will be collected in one series from the carpus/tarsus to the foot and MRI images will be collected in the transverse, dorsal and sagittal planes of the proximal metacarpal, midmetacarpal, fetlock, pastern area and the foot in separate scans.

All images will be stored as DICOMs on our picture archiving and communication system (PACS) and representative images will be selected to match the plastinated slices. This virtual library will be stored within RVC Asset Bank, allowing each image to have its own URL for QR code linking. An index of the images will be created within RVC Learn to enable accessibility for students, and full integration with other online RVC learning resources. Images stored within Asset Bank will also be accessible to the Online Veterinary Anatomy Museum (OVAM) to enable open access sharing of resources with external organisations.

Once imaging is complete all cadaver limbs will be formalin fixed and sliced using a bandsaw into serial sections. Limbs will be sliced at 2 cm intervals: two limbs will be sectioned in the transverse plane, one in the dorsal plane and one in the sagittal plane. Slices will undergo the process of plastination in the RVC plastination suite. This process can take up to 6 months. Once plastinated, the slices will be housed as a physical library within slotted transparent acrylic boxes. Full methodology for producing plastinated cross sections of the equine distal limb can be found in Latorre et al, (2001). Each cross section will be assigned a QR code which will be attached to the slice to enable linking with the associated diagnostic images from the corresponding anatomical level.

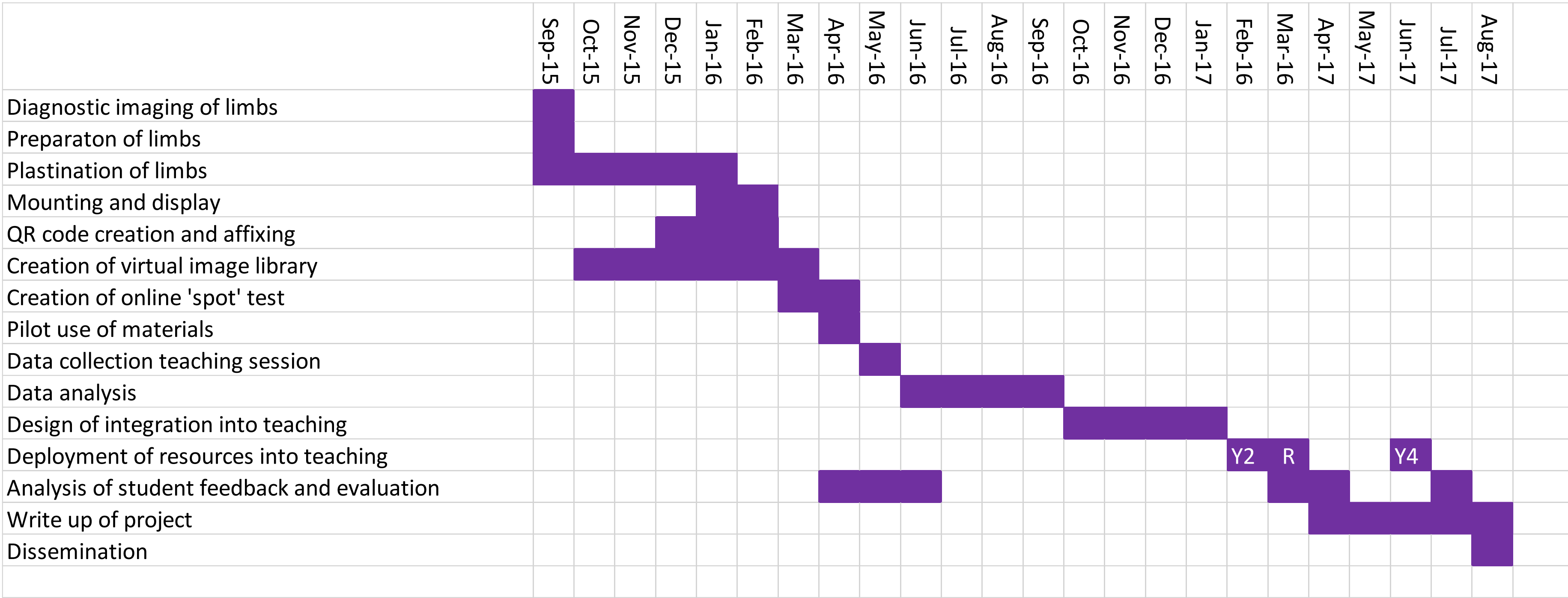
Once created, the physical (anatomical slices) and virtual (online diagnostic images) libraries will be integrated into a dedicated locomotor strand equine distal limb practical class, to improve the student experience and associated learning during this class and to enhance the integration of anatomy and diagnositic imaging teaching. The resource will be used as a teaching aid to enhance diagnostic imaging teaching on the diagnostic imaging and equine rotations and it will be integrated into equine clinical skills stations where appropriate (e.g. nerve and joint block simulators). Both the sectioned limbs and online images will be available for students of any cohort to access for independent study.

The resource will be evaluated in two ways: via a dedicated research project to quantify any learning gains of using such a resource, and via student feedback and consultation. The dedicated research project will be advertised as a suggested RP2 project, to encourage student engagement with the resources and to provide a relevant and structured pedagogical research experience. In order to directly evaluate the effect of the resource on learning, we will consider three areas of potential learning gain: anatomy knowledge, diagnostic image interpretation, and spatial ability of students. Both enhancing anatomy knowledge and diagnostic image interpretation, specifically in the context of the equine distal limb are direct goals of the resource and associated teaching. This learning will be assessed via an online 'spot' test which will comprise in equal measure questions featuring images of anatomical cross sections, anatomical images (not cross sections) and diagnostic images. Year 2 students will voluntarily join the study, which will take place as a voluntary teaching session, and will initially take the online test. They will subsequently be assigned randomly to four different groups for study: standard anatomical specimens (control group), plastinated cross sections using the physical library, diagnostic images using the virtual library, and a combined approach using the whole resource. The learning gain of each study group in each of the areas of cross sectional anatomy, non-cross sectional anatomy, and diagnostic image interpretation will be assessed against the control group using the MCQ test. At the end of the prescribed study session, all students will be provided allowed to access all of the resources.

In addition to the measurement of specific learning gains, we also wish to evaluate the effect of our resource on a more general skill, spatial ability, which is considered to be both important to develop in clinicians, as well as being closely linked to both anatomy and image interpretation performance. For this aspect of the study, students will take two tests of spatial ability prior to and after their session using the resources - the Mental Rotation Test (Vandenberg & Kuse, 1978; freely available at http://www.cambridgebrainsciences.com/) and a modified version of Guay's Visualization of Views test (Eliot & Smith, 1983; also freely available). The change in spatial ability of each student will be recorded and compared between study groups.

At two stages during the project we will also seek student evaluation and feedback on the resource. Prior to the research study teaching session, a small group of students will be allowed to pilot the resource, and we will gather their feedback via a focus group session. Improvements/ adjustments will be made accordingly. After the resource has been integrated into the Year 2 teaching session for its first use we will also gather student evaluation via a questionnaire to the whole class. This will include evaluation of student enjoyment using the resource as well as their confidence in anatomical knowledge and diagnostic image interpretation skills.

Work Plan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Diagnostic imaging of limbs
Preparaton of limbs
Plastination of limbs
Mounting and display
QR code creation and affixing
Creation of virtual image library
Creation of online 'spot' test
Pilot use of materials
Data collection teaching session
Data analysis
Design of integration into teaching
Deployment of resources into teaching
Analysis of student feedback and evaluation
Write up of project
Dissemination
Y2
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Y4

Budget

Equipment and consumables	Days/Units	Cost
Ultrasound imaging of cadaver limbs		£180
CT imaging of cadaver limbs		£250
MRI imaging of cadaver limbs		£900
Equine cadaver material		£400
Embalming solutions	100 L @ £25 for 10L	£250
Printing and laminating consumables for QR codes		£20
Plastination reagents	£50 per leg	£200
Acrylic box custom made	4 @ £92.40	£369.60
Acrylic sheets for mounting		£237.36
Tablets (i pad 32 GB) for display of images in practical classes	4 @ £359	£1436
Waterproof covers to protect tablets	4 @ £29.99	£119.96
Incentives for student participation (chocolate, Amazon vouchers)		£200
Data storage	0.25 TB	£125
Staffing		
E Media technical time (B Audsley, Sonya Powney)	3 days @ £300 per day	£900
Anatomy technician time*	3 days @ £300 per day	£900
Student assistant time reimbursement (diagnostic imaging assistance; editing and selection of diagnostic images; QR codes; assisting with creating plastinated slices)	21 days @ £10 p hour	£1680
Dissemination		
Conference attendance at AMEE 2017 for 1 x staff and 1x student		£1500
Total Cost		£9667.92
Amount Requested		**£8767.92**

*Departmental contribution

Head of Department Signature:

Dr Nigel Goode

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