Integrating gross pathology into teaching of undergraduate medical science students using human cadavers

Running title: Use of cadavers in pathology education

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ABSTRACT

Human cadavers offer a great opportunity for histopathology students for the learning and teaching of tissue pathology. In this study, we aimed to implement an integrated learning approach by using cadavers to enhance students' knowledge and to develop their skills in gross tissue identification, handling and dissection techniques. A total of 35 students enrolled in the undergraduate medical science programme were participated in this study. A three-hour laboratory session was conducted that included an active exploration of cadaveric specimens to identify normal and pathological tissues as well as tissue dissection. Majority of the students strongly agreed that the integration of normal and morbid anatomy improved their understanding of tissue pathology. All the students either agreed or strongly agreed that this laboratory session was useful to improve their tissue dissection and instrument handling skills. Furthermore, students from both cohorts rated the session as very relevant to their learning and recommended that this approach be added to the existing histopathology curriculum. To conclude, an integrated cadaver-based practical session can be used effectively to enhance the learning experience of histopathology science students, as well as improving their manual skills of tissue treatment, instrument handling and dissection.

Key-words: cadavers, pathology, teaching, education, undergraduate medical science

INTRODUCTION

The value of using human cadavers as a resource for educating students in science, medicine and many other health disciplines is well known.^{1,2} Cadaveric sessions vastly improve the learning experience of students in clinical and basic sciences.³ They also offer unparalleled opportunity to learn both normal anatomy as well as pathology because many of the cadavers have a variety of macroscopic pathological lesions.⁴ Additionally, this approach of teaching can supplement current teaching methods and be used to link normal anatomy with disease and clinical practice.⁵⁻⁷ Thus, the use of cadavers with pathological changes could supplement the existing teaching of pathology by an integrated approach to learn normal anatomy together with pathological processes.

Cadaver-based learning in pathology came into attention when Terman et al in 1975 reported that the macroscopic features of pathological lesions, such as cancers and infarcts, found in cadavers during the laboratory sessions tended to enhance the learning experience of medical students.⁸ Subsequent studies supported the utilization of cadavers to teach gross pathology.^{4,9} Moreover, tissues harvested from formalin-fixed cadavers are effective means of producing tissue sections on glass slides to study histology of human tissues.¹⁰ Hence, cadavers can be used as a valuable teaching resource in histology and microscopic pathology where students themselves can be trained to interpret tissue changes in disease, practice dissection skills and recruit human tissue for staining and microscopic analysis.

The education for undergraduate medical laboratory science students, who intend to become histopathology scientists, currently focusses on learning basic scientific skills in pathology such as tissue processing, microtomy, haematoxylin and eosin (H & E) staining of tissue sections and special staining techniques. Many of the practical sessions for these students were designed with very little or no time allocated to learning gross pathology, tissue handling and dissection techniques. As a result, many of these students receive their first

hands-on experience in tissue handling very late in the course during electives or after being employed as histopathology (anatomical pathology) scientists.

Education in pathology utilises a combination of traditional teaching methods such as lectures, tutorials and practical sessions as well as online modules for self-directed learning. Additional teaching resources such as digital image /audio modules and podcasts for gross pathology pots were also introduced recently for the advanced delivery of histopathology.¹¹⁻¹³ However, the majority of these learning/teaching tools, as well as the use of cadavers, are designed for medical students, their needs in histopathology training are substantially different from that of histopathology scientists. Histopathology scientists are required to skilfully and safely handle a variety of human tissues to assist pathologists in giving correct histopathological diagnoses. As such, basic knowledge about the normal anatomy of the organs and tissues, as well as the gross pathological appearance of tissues and organs affected by pathological conditions, would be beneficial for learning to become histopathology scientists.

In this study, we implemented an integrated learning approach by using cadavers to teach medical laboratory science students learning histopathology in both normal and morbid anatomy. The objective was to investigate the effectiveness of this approach in the enhancement of knowledge and skills of medical laboratory science students in gross tissue identification, handling and dissection techniques.

MATERIALS AND METHODS

Study group

This study was done to evaluate the impact of cadaveric teaching as a component of a newly developed histopathology course for the Medical Laboratory Science Programme at Griffith University, Queensland, Australia. This is a four year programme and the delivery of the histopathology course takes place in the 2nd semester of the 3rd year to prepare these students for their clinical placements in their final (fourth) year. During the course, students are expected to acquire skills in multiple histopathology techniques such as tissue handling, cut-ups, processing and staining as well as basic morphological interpretations. A total of 35 third-year students (n=17 in 2014 and n=18 in 2015) enrolled in the Medical Laboratory Science programme participated in this workshop. All the participants indicated that they had prior experience in learning normal anatomy using human cadaveric specimens.

Study design for gross tissue handling and dissection

Human cadavers with both normal and morbid anatomy features were selected from the laboratory facility of the Griffith University Anatomy Facility. Cadavers and anatomical specimens used in the Griffith University School of Anatomy were fixed in formalin and were obtained through a body donation program utilising a valid and appropriate consent process or from a similarly licensed anatomy facility. This process was strictly in accordance with provisions in the Transplantation and Anatomy Act 1979, Australia. Gross pathology specimens with known macroscopic and microscopic features were also recruited from the Pathology discipline of the School of Medicine. Approximately 25 different cadaveric specimens and 55 potted specimens were used. A three-hour laboratory session was designed to include a cadaver-based spot quiz on basic anatomy and common pathological lesions (approximately 40 minutes), an active tissue handling exercise on both normal and

pathological tissues on the cadavers (approximately 80 minutes); and a tissue dissection session (approximately 60 minutes).

The quiz given to the students was designed to ascertain their prior knowledge of basic anatomy and pathology, and give them an opportunity to review that knowledge. Answers were provided at the end of the quiz session for them to self-mark. During the next 80 minutes, students were encouraged to actively explore the cadaveric materials, learn about normal anatomic structures as well as identify and differentiate abnormal lesions such as primary and metastatic tumours, cysts and other non-neoplastic lesions. Additionally, a one-hour tissue handling and gross pathology identification exercise was conducted on cadaveric organs, with various pathological conditions such as primary or metastatic tumours.

Students from each cohort (n=17 in 2014 and n=18 in 2015) experienced the dissection of tissues or organs by using different “potted” specimens or cadavers. In 2014 cohort, the tissue handling and dissection session consisted of a porcine heart dissection whereas in 2015 cohort, a cadaveric lung affected with multiple tumour nodules was used. Students were grouped in pairs (n=9 groups) and one specimen was shared between them for handling experience. To facilitate the dissection experience, a handout detailing the dissection procedures was provided prior to the exercise. The dissected tissue blocks were immediately fixed in 10% formalin solution, embedded in cassettes and processed in a semi-enclosed benchtop tissue processor (Leica Biosystems, Wetzlar, Hesse, Germany). The cassettes with tissues were labelled with individual student numbers for easy identification after processing. Tissues were then embedded in paraffin wax. Then, histological sections were cut and stained with haematoxylin and eosin (H&E) for light microscopic examination. These slides were later used by the students to review and reflect on the quality of staining, histological features and cutting/staining artefacts.

Student evaluation

At the end of the workshop, all the participants were requested to complete an anonymous, structured paper-based feedback questionnaire about their learning experience during the workshop. The questionnaire consisted of seven Likert-scale (with '0' being strongly disagree and "4" being of strongly agree) questions addressing the usefulness of the approach for improving knowledge, tissue handling and dissection skills, attitude towards cadaver based learning and recommendation for future delivery. Additionally, the participants were encouraged to provide any open-ended, qualitative comments regarding the effectiveness of the workshop. Student responses were quantified and open responses were categorised according to a thematic framework.

RESULTS

Student learning experience in pathology using cadavers

A variety of potted specimens of common pathological conditions from all body systems were used. Each potted specimen came with a brief clinical history of the patient and microscopic images (Figure 1A-C). Nearly all pathological conditions in the potted specimens were found on the cadavers used in this study (Figure 2A-C). Some pathological conditions such as metastatic cancer in liver, lung cancers and emphysematous lung were used from multiple cadavers to identify and differentiate the individual changes in gross morphology.

As depicted in Table 1, the majority of students (26/35) “strongly agreed” that the cadaver based integration of gross anatomy and the introduction of tissue dissection in histopathology was highly relevant to their learning. In addition, many of them strongly agreed that the workshop was an effective means of studying normal and morbid anatomy in an integrated manner, and a useful exercise to improve tissue handling and dissection skills. The students unanimously agreed that the session should be offered in the subsequent years. A small proportion (5%, 2/35) of students indicated that they were not comfortable working with cadaveric materials.

A comparison of the closed response feedback given by the 2014 and the 2015 cohorts is shown in Figure 3. Compared to the students enrolled in 2014, the students from 2015 cohort more strongly valued the pathology learning experience using cadavers.

Improvement in pathology tissue handling and dissection skills

Approximately 83% (29/35) of the students strongly agreed that their tissue handling skills were significantly improved by the use gross pathology tissues in the cadavers (Table 1). Also, all students agreed/strongly agreed that this laboratory session was extremely useful

to improve their tissue dissection and instrument handling skills. Similarly, the majority of students (77%, 27/35) strongly agreed that the integration of normal and morbid anatomy (pathology) during the workshop was well received with this new method of histopathology education. Some students recommended providing a video or handout for dissection procedure at least a day before the actual practical session for them to better prepare for the workshop.

Tissue dissection and histological interpretation

A cadaver with multiple metastatic tumour nodules on the right lung was used for this exercise. The entire lung was removed and students were facilitated to identify the gross pathological features such as tissue consistency, tumour margins, size of the tumours etc., prior to cut up. Students were taught to cut the tissues in < 4.0 mm thickness to fit in the tissue cassettes. Histological analysis confirmed that the lung tumour nodules were due to metastatic adenocarcinoma (Figure 4A &B). Students were also encouraged to identify and comment on the quality of staining, various artefacts such as background staining, folds and wrinkles in their sections.

DISCUSSION

It is important that students learning histopathology are given an opportunity to visualise the macroscopic changes of disease, and to know how they affect the human body. In addition, a competent histopathology scientist is required to distinguish abnormal tissues from their corresponding normal tissues. Tissue grossing and dissection are considered as important steps in the pre-analytical phase of the pathological diagnosis of disease.¹⁴ Therefore, tissue handling and dissection are vital skills expected from trainee histopathology scientists. In many of the busy histopathology laboratories, many of the smaller specimens are handled by histopathology scientists instead of pathologists.

For the first time, we investigated the effectiveness of using human cadavers with gross pathological changes for the teaching of undergraduate students in histopathology science. We analysed feedback provided by students regarding their experience of an integrated workshop on anatomy knowledge, pathology experience, tissue handling and dissection skills. Student feedback supported our hypothesis that an integrated session using cadavers would enhance student understanding of gross pathology, and improve their tissue handling and dissection skills. As evident in this and other studies,^{4,9} the cadavers offer a variety of macroscopic pathological conditions such emphysema, primary/metastatic tumours, renal cysts, uterine leiomyomas, cerebral infarcts, liver cirrhosis among other conditions (Table 2). Thus, cadavers provide a rich learning and teaching resource for many pathological conditions which are not a resource routinely made available to aspiring medical laboratory scientists.

It has been shown that cadavers not only provide exceptional opportunities for direct reflection of unique human anatomy, but also offer an excellent opportunity to understand extensive gross pathological changes in diseases.⁴⁻⁶ The inclusion of normal anatomy as well as pathological conditions makes cadavers ideal for comparing and contrasting organ and

tissue architecture in the learning and teaching of histopathology. As histopathology scientists, it is important to have sufficient skills to understand the morphological difference between normal and morbid tissue features macroscopically. The macroscopic tissue changes occur as a result of a pathological condition and the pathogenesis of a disease process is better understood by more hands-on experience.⁹ Furthermore, handling and dissection of tissue specimens provide students with a better appreciation of three dimensional tissue/organ features.¹⁵ In this interventional study, we provided students an opportunity to actively explore the cadaveric materials, identify abnormal tissues, compare the macroscopic characteristics of pathological lesions and corresponding normal tissues as well as subsequently engage in a tissue handling and dissection.

As evidenced by student feedback, students overwhelmingly agreed about the usefulness of cadaver-based sessions for improving their understanding of normal and morbid anatomy as well as the tissue handling and dissection skills. These skills would help in assisting anatomical pathologists to diagnose diseases with better quality tissue preparations giving a clear representation of pathological tissues. In addition, cadaver-based teaching helps in nurturing team-work skills, better communication, self-directed learning, careful observation and presentation skills⁴. All these are essential attributes expected from a health professional. Therefore, this integrated cadaveric approach in histopathology education has multiple benefits in the student learning environment, ranging from better learning experience to professional development skills.

The evidence for effectiveness of this integrated learning session was further strengthened by the additional qualitative comments from the students (Table 3). In brief, students described their experience of this workshop as “fantastic”, “extremely valuable”, “highly relevant”, “very worthwhile”, “excellent hands on training”, and “ highly engaging”. Some students have commented that this workshop has provided a “good introduction to

tissue cut up skills” and an “outstanding first time experience in feeling tissue abnormalities”. On the other hand, the duration of the workshop was considered insufficient for some students, and they recommended increasing the duration from 3 hours to 4 hours for future workshops. Also, “multiple tissues from diverse pathological conditions” and a “tissue cut up video prior to the workshop” were recommended from students to further improve the quality of this workshop. Two students from the 2014 cohort also recommended the use of real pathological human tissue for dissection/cut up practices, which was later introduced in 2015 cohort. Only a single student out of 35 from 2014 reported “feeling uncomfortable in handling cadaver materials” during the questionnaire. This might be related to the anxiety related issues while handling cadaveric materials.¹⁶⁻¹⁷ We would suggest de-briefing these students about their experience to reduce potential anxiety in their subsequent professional environment.

While student feedback from both cohorts was positive, an apparent increase in students strongly agreeing about the usefulness of the workshop was noted in the second cohort (2015). This overall improvement of the positive feedback by 2015 cohort might be due to increased exposure of gross tissue pathologies in large sections and due to the introduction of a metastatic lung tumour tissue from a cadaver, instead of the porcine tissue dissection carried out by 2014 cohort. Furthermore, the differences in student exposure to cadaveric materials during their undergraduate anatomy programmes might have also contributed to this positive change.

Many studies have suggested that prosections and audiovisuals can produce better learning outcomes in teaching anatomy when compared to cadaver-based teaching methods.¹⁸⁻²⁰ However, these methods have limited value in teaching histopathology because the gross tissue changes and pathogenesis of a disease process will be better understood with greater hands-on experience.^{9,15,21} In this study, our findings concurred with the view that the

histopathology learning experience can be enhanced by direct physical handling of pathological tissues and undergoing training in dissection. This approach can be further strengthened by supplementation with other online and traditional teaching techniques to obtain desired learning outcomes in the different health disciplines.

To conclude, the human cadavers are excellent resources of common macroscopic pathological conditions. As such, the cadavers can be effectively used, in an integrated manner, to enhance the learning experience of students in histopathology science with regard to understanding normal anatomy and macroscopic pathology. In addition, it provides invaluable experience in handling and dissection of tissues. We recommend similar (or improved) sessions to be included in the curricula for histopathology students in other health disciplines.

ACKNOWLEDGEMENTS

We would like to thank the Learning and Teaching Grant from Griffith University to support this project. Also we would like to acknowledge the help and assistance from the technical staffs from both schools of anatomy and medical science in setting up the laboratory and tissue processing.

DISCLOSURE STATEMENT

None declared

Figure Legends

Figure 1: Comparison of gross and microscopic pathological features using potted specimen. **A-** Large intestine with a huge tumour (tubulovillous adenoma). Normal mucosal lining was visible for comparison and sharp area of demarcation between normal and adenoma area was noticeable. **B-** Microscopy at low power of the lesion shows tubular and villous architecture of intestinal mucosal epithelium with no invasion of these epithelial cells into the basement membrane and lamina propria. **C-** High power of tubulovillous adenoma showing dysplastic cells with high nuclear cytoplasmic ratio and frequent mitotic figures.

Figure 2: Gross pathological features in the cadaver specimens: **A-** The cadaver specimen showing multiple nodules of metastatic tumours in the lung. The largest one was noted in the right lobe (arrow). **B-** A non-neoplastic simple cyst (arrow) in lower pole of left kidney.

Figure 3: Comparison between the feedback scores between 2014 and 2015. The mean scores indicate that students from 2015 cohort have highly valued all the components in the workshop compared to 2014 cohort. A- This laboratory session was useful to improve my tissue handling techniques; B- This laboratory session was useful to improve my tissue dissection skills; C- A knowledge of normal anatomy of the organs and tissues is important for me; D- Integration of normal and morbid anatomy helped me better understand tissue pathology; E- I was comfortable working with cadaveric material; F- This laboratory session should be offered next year; G- Overall, this laboratory session was relevant to my learning.

Figure 4: Histological features of lung adenocarcinoma. A- Low power shows tumour nodules with neoplastic glandular cells and extensive necrosis. Normal alveolar lining can be also seen adjacent to the nodule (haematoxylin & eosin x 4). B- Higher power view from the tumour nodule shows that it is an adenocarcinoma with proliferation and invasion of pleomorphic glandular cells (haematoxylin & eosin x 20).

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