A New Resource for Integrated Anatomy Teaching: The Cadaver’s Lung PG, A Pathology Guide

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Abstract
The purpose of this study was to develop a teaching guide to demonstrate the gross characteristics of pathology in embalmed cadaveric lungs and to and to assess the guide as an effective teaching tool. Ninety-eight embalmed cadaveric lungs were screened for pathology. The characteristics of pathologic states of the embalmed lungs were recorded and histopathologic confirmation was performed. Pneumonia, neoplasms, emphysema, chronic bronchitis and diffuse interstitial lung disease were the most commonly observed pathologic lesions. Discoloration of the parenchyma and edema were the most commonly observed artifacts from the embalming process. Medical and nursing students who used the guide had significantly more ability to identify pathologic lesions than control groups. This guide will assist faculty and students in obtaining the skills needed to examine and interpret the gross presentation of an embalmed cadaveric lung. doi: 10.21692/haps.2018.003

Key words: lung pathology, cadaver, gross anatomy, pathology, anatomy education

Introduction
There are many examples in the literature that highlight the educational importance of identifying pathology within a gross anatomy setting (Eisenstein *et al.* 2015, Wood *et al.* 2015, Geldenhuys *et al.* 2016, Rae *et al.* 2016). Although most of these reports cite specific examples of pathologic instances and how they can be utilized as integrative learning opportunities, none of them address the dependence that anatomy faculty must have on clinical collaborators on reaching this goal. Without the clinical knowledge of pathology, or the knowledge about how the embalming process changes the body, many questions remain unanswered about the normal and abnormal presentation of cadaveric lungs. For example, does the lung retain extra fluid after the embalming process? There is much information pertaining to the post-mortem changes that occur in lungs (Shiotani *et al*. 2004). However, little information is available that describes the uniqueness of the embalmed cadaveric lung. It has been shown that the embalming process causes artifacts (Rae *et al*. 2015) and it is possible that embalming affects the gross presentation of all of the cadaveric organs.

The lung is a dynamic organ that contributes to the respiratory and cardiovascular functions of the body. One end of the organ is open to the exterior environment and is subject to attack from microbial invasion and foreign bodies. The other integrating root of the lung is to the heart, where blood is progressively dwindled down into delicate pulmonary capillaries that make up the substance of most of the lung parenchyma.

When considering the pathologic lesions that are commonly found in the lower respiratory tract, inflammatory conditions from chemical and physical irritants and bacterial invasions are offending triggers, resulting in bronchitis, bronchiectasis, pneumonia, emphysema, pulmonary fibrosis and pneumoconiosis. Due to the integration of the lung with the cardiovascular system, the lung is frequently a site of metastasis by tumor cells that are traveling in the vascular system as well as a site for pulmonary congestion resulting from left-sided heart failure.

The delicate anatomic structure of the lung renders the organ susceptible to the normal pathologic processes such as tumors, inflammation and infections that occasionally occur in the body's internal environment, but also renders it susceptible to repeated insults of inhaled impurities, irritants and microbes.

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There are several textbooks and atlases that describe the gross and histopathologic presentation of diseased lungs (Cooke and Stewart 2004, Riede and Werner 2004, Kumar *et al*. 2014). However, resources that describe the presentation of an embalmed normal lung are scarce. This is most likely because autopsy patients are not usually embalmed prior to clinical evaluation.

Willed bodies are used in academic medical and health professional schools in dissection courses in human anatomy (Biasutto *et al.* 2014). It is been shown that individuals most often donate their bodies to science to advance the field of medicine (Bolt 2010). If pathologic lesions could be studied while the body is being dissected, the impact of the willed body would be greater than if the pathologic lesions are overlooked or not recognized (Rae 2016). An effective resource that describes the normal and abnormal presentation of embalmed lung tissue would assist faculty and students in identifying the pathologic lesions that are present and might serve to foster integrative learning opportunities.

The purpose of this study is to investigate the anatomic characteristics of the embalmed cadaver lung that are normal and identify pathologic lesions that are detectable under gross examination. After the anatomic investigation, the information was used to create an pathology guide that was designed to help students identify pathologic lesions in the gross anatomy laboratory and to assess the effectiveness of the pathology guide as an educational tool.

Methods

The Institutional Review Board (IRB) of Louisiana State University Health Sciences Center deemed the protocol exempt from IRB oversight (IRB# 8406).
Ninety-eight cadaveric lungs were obtained from the gross anatomy laboratory after completion of the dissection process.

Gross evaluation of the organs
The lungs were weighed and the weight of each lung was recorded in grams. The pleurae were checked for abnormalities and lesions. The external surface of the lung was examined for any pleural adhesions, hard or opaque pleural regions. The lung was palpated from the external surface for any noticeable hard lesions from within the parenchyma. If lesions were palpable, then tissue sections were taken for histopathologic evaluation.

Using a cell-path lung knife, the lung was cut in a frontal plane to allow for visual inspection of the lobes. Then, the parenchyma was palpated to examine for lesions. If there were palpable lesions that were not visibly seen in the section, additional slices were cut to examine more of the parenchyma. The bronchi and blood vessels were visually inspected to detect any obstructive elements. One tissue sample was taken from the periphery of the lung (including the pleural surface) and one sample was taken of tissue from the central portion of the lung for all specimens. Additional tissue samples were taken for regions of lesions.

Histologic examination of organs
The tissue cassettes, disposable plastic containers used to hold and identify tissue samples, were processed and embedded with paraffin wax using a standard overnight protocol using an Excelsior ES tissue processor. After placing the tissue in paraffin blocks using a Shandon Histocentre 3, the tissue was sectioned at five micrometers using a Leica RM 2135 microtome and manually stained with Hematoxylin and Eosin. Two board certified pathologists, each with over 10 years of experience, along with a senior pathology resident, examined the slides. The clinicians were blinded as to the gross observations that were described with each case.

Methods of qualitative analyses
All of the gross observations were placed in categories using a qualitative content analysis approach that included an open coding process followed by a selective coding process. Content analysis is method of qualitative research where words are coded, grouped and recoded to identify themes that exist within documents. For this process, an anatomist (PhD trained) with experience in qualitative research methodology read the written notes that were compiled after the gross and histologic evaluations. The documents were then coded in a two-phase process as described below.

The open coding process
Each individual raw observation was taken from the notes made at the time of gross examination of the heart. The observations were listed in their original language. Then, they were grouped together based on common themes and attributes. For example, individual categories such as "black lines" and "black spots" were grouped together into one category, "black lines and spots". There were three rounds of grouping until the categories could not be condensed without losing their individuality. For example, "black lines and spots" would not be grouped together with "white lines and spots" because this would not allow an analysis between white and black discoloration of the parenchyma.

Selective coding process
After the grouping of observations, the list of categories was considered to be the proposed selective code. Then, using the selective coding system, the notes of the gross observations for each organ were re-read and the observations were placed in one of the categories from the selective code system. Saturation was achieved when all observations fit into a category and no additional categories were needed for completion of the analysis. The same coding process was used for the microscopic observations made by the pathologist.

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The most common selective codes for the gross and microscopic evaluations are presented in Tables 1 and 2.

Table 1. Most prevalent lung gross observations

Observation	**Prevalence**
Anthracotic pigment (marbeling, lines, splotches)	80.41%
Levidity or dark reddish brown parenchyma	80.41%
Hard lesions in parenchyma (small/Lg. nodules)	33.00%
Pleural discoloration or hardening	28.87%
Collapsed/wrinkled surface of lung	26.80%
Granular/ Cobblestone-like outer appearance	22.68%
Discoloration of parenchyma (grey or black)	20.62%
Emphysema or holes/pockets in parenchyma	20.62%
Discoloration of parenchyma (white or light beige)	18.56%
White material in bronchi	10.30%

Table 2. Most prevalent lung microscopic observations

Observation	**Prevalence**
Emphysema	53%
Chronic obstructive lung disease	41%
Chronic bronchitis	29%
Plexogenic arteriopathy	27%
Aspiration with foamy macrophages	20%
Acute bronchopneumonia	22%
Pleural scar	12%
Hemosiderin laden macrophages	12%
Atelectasis	10%
Aspiration pneumonia	10%
Squamous metaplasia	10%

Statistical analysis

A Phi correlation (φ) analysis was conducted among all categories in the selective coding systems (both gross and histologic) to determine statistical significance of correlations between the categories. This statistical analysis was conducted using the Graphpad Prism 6 software program. All correlations with a p value less than 0.05 were considered significant.

Evaluation of pulmonary weight for evidence of artifact

The normal mass for a male lung is 583g±216, mean± standard deviation, (left) and 663g±239 (right). The normal mass for a female lung is 467g±174 (left) and 546g±207 (right) (Grandmaison *et al*. 2001). Figure 1 shows the cases that had lungs above the normal range. Eight of the cadavers with "heavy" lungs had bilateral heavy lungs. Sixteen cadavers had unilateral "heavy" lungs. There are many reasons why a lung will weigh outside of the normal range such as infection, edema, hemorrhage and the presence of tumors. Any additional fluid or cells will increase the weight of the organ above the normal range. It is unknown whether the fixative solution used in the embalming process alters the weight of the cadaver's lung; however, there has been an account of formalin fixation altering lung volume in rats (Dugiud *et al*. 1964). Out of all of the specimens, 36.08% of them were above the normal range for weight. Out of these cases, 50% did not have a gross or histologic cause for this change in weight. Fifty percent of the cases of "heavy lungs" had pathology that was consistent with the observed increase in weight. Therefore, it is likely that the embalming process causes a subsequent increase in the cadaver's lung weight.

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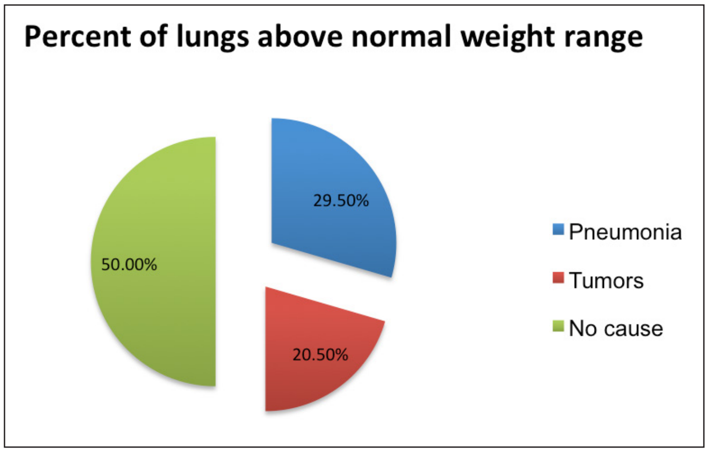

Figure 1

Development of the cadaver pathology guide for the lung

After statistically analyzing all of the correlations between the gross and microscopic observations, a list of significant correlations was generated. The list was then analyzed based on basic pathologic principles to determine whether any of the correlations were indirect, or artificially created by the categorization process. Those items were removed from the results. The remaining correlations were considered of importance for creating the pathology guide (Table 3).

Table 3. Significant correlations between gross and histologic observations

Gross observation	Histologic observation	phi coefficient
Collapsed/wrinkled lung	Pleural scar	rφ = .337
Firm but not hard palpable lesions	Pneumonia all types	rφ = .535
Hard lesions in parenchyma	Neoplasm (all types)	rφ = .501
White material in bronchi	Chronic bronchitis	rφ = .325

This table lists the significant correlations between the gross and histologic observations. The phi coefficient is used to detect an association between two variables. All of the significant correlations were positive, meaning that if one variable was present there was an association of another variable being present. Values represent a weak (0.3-0.5), moderate (0.5-0.7) and strong positive correlation (0.7-1.0).

Interpreting the results of the statistical analysis

The correlation between gross and microscopic observations suggested that those two observations occurred together but did not necessarily suggest any causative relationship between them. The clinically or diagnostically important correlations can do two things: assist an examiner in identifying likely microscopic observations that would be present if the gross characteristic is observed and support the current theories in the field of pathology that those gross and microscopic findings are related to each other.

The correlations that were determined as having diagnostic or clinical importance are seen in Table 3. The justification for their inclusion into the pathology guide is discussed below.

White material in the bronchi was positively correlated with the presence of chronic bronchitis. Chronic bronchitis is a form of chronic obstructive lung disease with anatomic alterations that are specific to the bronchi: increased bronchial glands (Restrepo and Heard 1963), hyperplasia of bronchial muscle (Hossain and Heard 1969), and metaplasia of the bronchial epithelium (Sanderud 1958; Christensen *et al*. 1977). In addition to these alterations in the bronchi, chronic bronchitis also involves small airway modifications that are seen in other diseases such as asthma and, therefore, cannot always be differentiated from asthma (Hargreave and Parameswaran 2006). The white matter found in the cadaver's bronchi most likely consists of mucus, because mucus is secreted in increased amounts by both goblet cells and submucosal glands in this condition.

The collapse of a lung and wrinkling of the visceral pleural surface was positively correlated with pleural scarring. The collapse of a lung is called atelectasis and fibrotic scarring of the pleura can cause retraction of the lung tissue (Williams 1969, English and Leslie 2006). Grossly, this retraction can be seen as a wrinkling of the surface or collapsed lung (Figure 2).

Figure 2. *Normal and collapsed lung.*
This figure shows the inside of a cadaver's thorax with a normal lung (right lung) and a collapsed lung (left lung).

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Palpable firm but not hard areas were positively correlated with the presence of pneumonia. This gross characteristic found in the cadaver's lungs is also found in fresh lungs examined at autopsy (Cooke and Stewart 2004, Kumar *et al*. 2014). The palpable areas are respiratory regions filled with neutrophils, pus and bacteria (Figures 3 and 4).

Figure 3

Figures 3 and 4. *Presentation of bronchopneumonia.*

The photo above shows the gross presentation of bronchopneumonia and the photo below shows neutrophils and pus in the airways (20x).

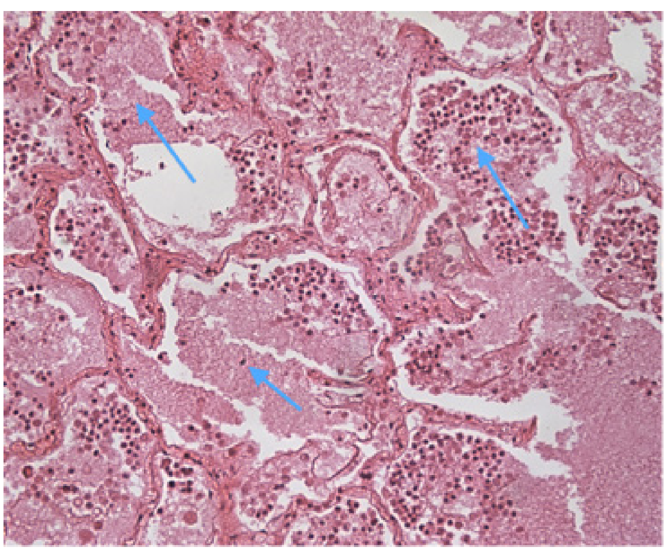

Figure 4

Hard lesions in the parenchyma were positively correlated with neoplasms both metastatic and primary. Regardless of the body region, neoplasms are commonly found as dense, palpable masses (Kumar *et al*. 2014). The increased cellular growth associated with neoplasms renders them denser than the normal organ parenchyma. The increased density of the neoplasm makes it "palpable", meaning that the inspector can feel them as hard areas within the organ. Therefore, even if the area looks similar in color, or is obscured from view, one can palpate the organ and feel for the presence of tumors.

Overall, from the data obtained during the gross and microscopic observations, there were several considerations that needed to be included in the pathology guide that are specific to the lung. In many instances, it seems more clinically necessary to palpate the lung for the presence of lesions than it is to visually inspect it, when compared to other organs that can be primarily visually inspected. For example, pleural plaques and calcifications, neoplasms and pneumonia all depend on the examiner's ability to palpate the organ and differentiate normal and abnormal tissue in a tactile way. Therefore, this method of examining the lung was included as an important and necessary step in the inspection process.

Although photographs were used to assist the reader in visually targeting certain areas for examination, such as areas of pleural thickenings, the photographs are more important for detecting non-palpable pathologies such as chronic bronchitis and emphysema. From the survey of grossly observable characteristics, most lungs had levidity and anthracotic pigment. Although these observations are not directly the result of any pathologic process, they were included in the guide to give the students an explanation of their appearance. A cobblestone surface appearance was present in many of the lungs (Figure 5). The cobblestone surface was not statistically tied into any histologic observation. However, this gross presentation is tied to a general pathologic process of scarring and increased collagen deposition, which is supported by literature and was included in the guide (Kumar *et al*. 2014). Emphysema and chronic bronchitis were prevalent in the cadaver population. Therefore, the guide includes background information on these conditions along with the instructions for identifying them.

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Figure 5. Cobblestone appearance of the surface of the lung. The rough surface of the lung is commonly referred to "cobblestone appearance".

Evaluation of the Guide's Effectiveness

Content validation of the guide was performed by pathologists (n=3) and students (n=6; three second semester nursing students and three second year medical students). The guides were reviewed for the following categories: clarity in wording, relevance of items, use of standard English, absence of biased words or phrases, formatting of items, clarity of instructions (Fowler 2002). The content validation forms were qualitatively analyzed to identify themes in the reviewers' comments. The major suggestions were to add definitions of selected terms to the beginning or end of the guide and to elaborate on the instructions for palpating the lung specimens**.**

<u>Assessment of the cadaver pathology guide's effectiveness</u>

At Louisiana State University Health Sciences Center, both medical and nursing students take gross a anatomy laboratory that involves cadaver dissection. In addition, both student populations also take a course in pathology in their second year of study. After the students completed dissection during their gross anatomy course, but before they were enrolled in pathology, students were recruited to participate in a short educational intervention to measure the effectiveness of the pathology guides as a teaching resource.

Medical (n=87) and nursing (n=84) students were asked to use the guides to identify pathology when examining cadaveric lungs. Cadaveric lung specimens were arranged at six stations in the laboratory. For each specimen, students were asked to evaluate the organ and determine if the organ had any signs of pathology based on the specimen's gross anatomical characteristics. Half of the students used the provided pathology guide to assist them in their evaluation of the organ (experimental group) and half of the students had a laboratory guide that only included definitions of the pathologic terms (control group).

The control group scores were compared to the experimental group scores by performing a t-test using Graphpad Prism 6 software program. Effect size was estimated by calculating Cohen's d. The internal consistency of the assessment was determined by calculating KR-20.

Results

The group using the pathology guide, overall, had a higher average percentage of items correct than the control group with a medium effect size for both comparisons ($p < .001$; Figure 6). For the nursing student population, the control group had 42.2% correct compared to 50.8% in the experimental group. For the medical student population, the control group had 47.3% correct compared to 55.6% in the experimental group. The internal consistency of the assessment was calculated and was KR-20= 0.50, which is a good level for an instructor made assessment.

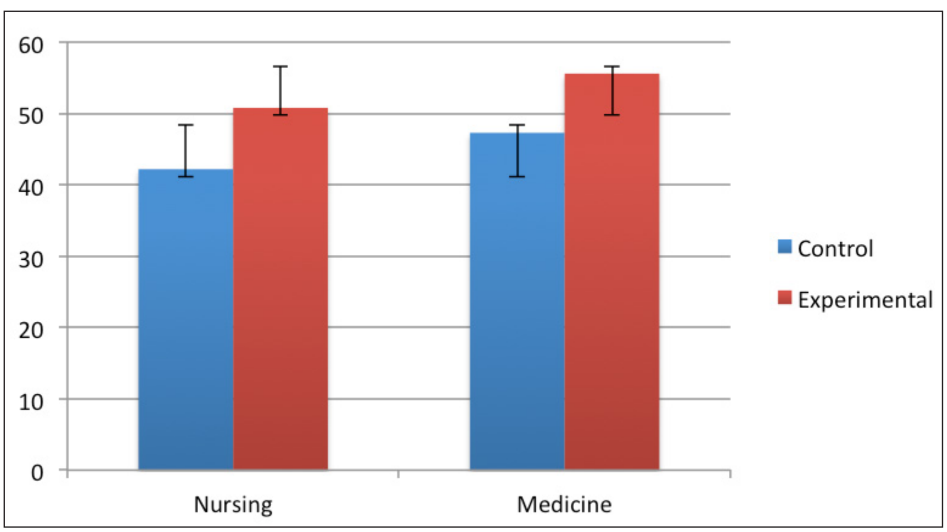

Figure 6. *Assessment scores for nursing and medical student population. In both populations, the experimental group was significantly higher than the control group, p<0.01. Values represent the percent of the total number of questions the student got correct.*

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Discussion

After the anatomic evaluation of cadaveric lungs, pneumonia, neoplasms, emphysema, chronic bronchitis and diffuse interstitial lung disease were the most commonly observed pathologic incidences. This differs slightly from another large-scale account of pathologic lesions in the gross anatomy laboratory, where tuberculosis was the most commonly found lesion (76% of cadavers; Geldenhuys *et al*. 2016). There was only one case of tuberculosis within our specimens, which represented less than 1%. The main discrepancy between these findings may be regional, since the other anatomical survey was performed on a cadaver population in Western Cape, South Africa. Bronchopneumonia and emphysema was also commonly found in the cadaver population in South Africa (over 45% for each condition), as well as our population here in New Orleans, Louisiana (35% and 53% respectively). There has also been a similar prevalence of anthracosis reported in the South Africa population as in the Louisiana population.

The authors suggest that the high amount of pulmonary edema observed in this study is most likely due to embalming artifact although they did not report how many cadavers that had edema also had pathology (Geldenhuys *et al*. 2016).

Descriptive accounts of the specific pathologic lesions discovered in embalmed cadaver lung populations include the presence of: pulmonary fibrosis, chronic obstructive pulmonary disease, pneumonia, squamous cell carcinoma and chondro-sarcoma of lung, pleural adhesions, old tuberculosis and lung metastasis (Wood *et al*. 2010 and 2015). We found these lesions to be detectable in our Louisiana based cadaver population.

Discoloration of the parenchyma and edema were the most commonly observed artifacts from the embalming process observed in our cadavers as well as the Western Cape population of South Africa (Geldenhuys *et al*. 2016).

After creating the pathology guide for the students, the implementation of a short assessment to determine if the guide could assist a user in identifying pathology revealed that even short term use (20 minutes) significantly increased student ability to identify pathologic lesions in a cadaveric lung. This finding is a little surprising, considering that the skill of palpation is purely a psychomotor skill that heavily relies upon the ability to feel differences in tissue density. Although the guide only provided photographs and verbal descriptions of the technique, the students were still able to detect differences from trying the maneuver for the first time. Informal feedback from the students was very positive regarding the utility of the pathology guide. This was similar to the feedback that was received during the content validation process.

Conclusion

There are several common pathologic lesions that can be detected grossly in an embalmed cadaver population. Students and faculty could use these instances as learning opportunities to complement the teaching of the anatomical sciences. These integrative learning opportunities may also be a way to deepen the impact that the willed body donor has on the health professional field.

The authors would like to acknowledge the individuals who donated their bodies for the advancement of science. Their contribution made the development of these resources possible.

The Cadaver Lung PG guide is freely available for download on LSUHSC's website at:
http://virtualhumanembryo.lsuhsc.edu/GIFT/PathGuides%20-%20Copy.html.

About the Authors

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