APPLICATION OF INFORMATICS IN THE WORK OF A PATHOLOGIST: GUIDELINES FOR LEARNING HOW TO CREATE AND USE A DIGITAL ARCHIVE OF GROSS IMAGES

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Pathology informatics has been developing as a response to a large amount of diagnostically relevant morphological information and attempt to the best store and use it. The main components of pathology informatics include digital images of histological slides and gross photographs, telepathology, and electronic data collection. Photo documentation of gross specimens is an integral part for efficient work of a pathologist. Currently, many grossing stations are equipped with continuously recording video cameras. A logical and detailed description of the macroscopic specimens, supported by properly obtained digital photographs, should be the standard of a modern pathology report. However, with the increasing workload of the pathologists, they have less and less time to take gross photographs. That is why, in our opinion, it is important to ask questions such as: what is necessary to photograph, how to take a photo of the gross specimen, and in which order? There are only a few publications on this topic in both domestic and foreign literature. This paper attempts to summarize the literary data on this topic, based on which a list of medical use cases that require a mandatory photo documentation has been created. Practical recommendations have been developed and are outlined for gross photographs. In the context of widespread use of digital photography as a resource for deep learning of neural networks and digital analysis, this article will be useful not only for postgraduate education of pathologists, but also for physicians of other specialties.

Keywords: postgraduate medical education; pathology informatics; digital gross photography; pathological anatomy; training of neural networks.

ПРИМЕНЕНИЕ ИНФОРМАТИКИ В РАБОТЕ ПАТОЛОГОАНАТОМА: ОБУЧЕНИЕ СОСТАВЛЕНИЮ И ИСПОЛЬЗОВАНИЮ ЦИФРОВОГО АРХИВА ИЗОБРАЖЕНИЙ МАКРОПРЕПАРАТОВ

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Патоморфологическая информатика возникла как ответ на огромное количество диагностически значимой морфологической информации и попытку наилучшего ее хранения и использования. Основными составляю-

щими патоморфологической информатики можно считать цифровые изображения макро- и микропрепаратов, телепатологию и сбор электронных данных. Фотодокументация макропрепаратов — неотъемлемая часть эффективной работы врача-патологоанатома. В настоящее время многие станции вырезки снабжены камерами непрерывной видеосъемки. Логичное и детальное описание макропрепарата, подкрепленное правильно выполненными цифровыми фотографиями, должно быть стандартом современного патологоанатомического заключения. Однако в условиях повсеместно возрастающей рабочей нагрузки на врачей-патологоанатомов времени для занятий фотосъемкой остается все меньше. Поэтому очень важными, на наш взгляд, являются вопросы: что необходимо фотографировать обязательно, как фотографировать макропрепарат, и в какой последовательности? Публикации на эту тему и в отечественной, и в зарубежной литературе немногочисленны. В этой работе сделана попытка обобщения литературных данных по данной теме, и на основе этих данных составлен перечень медицинских случаев, которые требуют обязательной фотодокументации; разработаны практические рекомендации по проведению съемки макропрепаратов; дана оценка возможностей использования цифровой фотографии макропрепарата для дифференциальной диагностики. В условиях широкого использования цифровой фотографии как ресурса для глубокого обучения нейросетей и цифрового анализа эта статья будет полезна не только для последипломного образования патологоанатомов, но и для врачей других специальностей.

Ключевые слова: последипломное медицинское образование; патоморфологическая информатика; цифровая фотография; макропрепарат; патологическая анатомия; обучение нейросетей.

Today, most educated people are aware of informatics as a science about the methods and processes of collecting, storing, processing, transferring, analyzing, and evaluating information using computer technologies that allow its use for decision-making [5]. Medical informatics is a branch of science that focuses on biomedical information. It studies the patterns and methods of obtaining, storing, processing, and using knowledge in medical science and practice to prevent and treat diseases. However, nowadays, the rapidly developing branch of informatics in the field of pathological anatomy ("pathology informatics") remains in progress in the Russian healthcare system. Therefore, not every doctor is even familiar with the term "pathology informatics" or pathomorphological informatics. In Russia, researchers such as I.M. Vorontsov, E.V. Gubler, M.O. Ioffe, I.P. Kulbush, N.N. Melnikov, V.G. Chasnyk, V.V. Shapovalov, and V.V. Yuriev implemented informatics and pathological anatomy, in specific, into medical practice [2, 3].

Unfortunately, at that time, their ideas were not widely adopted by pathoanatomists for use in their practices. Pathology informatics arose due to a considerable amount of diagnostically important morphological information and an attempt to store and use it optimally. Digital imagery, teleconsultation, and mining or electronic data collection can be considered the main components of pathology informatics. Digital images of gross specimens or histological preparations represent a vast archive of data on pathological anatomy in electronic format. These images are used for education, diagnostics, consultation, and research. As a branch of telemedicine, telepathology has already become an integral part of the work of pathoanatomists worldwide. However, in current practice, when it comes to "digital pathology," the work with a digital image of histological micro preparations is mainly implied. Much less attention is paid to the digital images of gross specimens. In our opinion, this preference seems completely unfounded since a photograph of a clinical tissue sample is an integral part of an anatomic pathology report and electronic medical case history. Also, it is part of a legal document since it is integrated into the laboratory information system [7, 11].

Many digital systems for documenting autopsy materials and surgical specimens are integrated into modern cutting stations. These systems enable continuous video and audio recording during the entire macroscopic examination process. Some experts consider it to be sufficient [18].

We disagree with this point of view. The considerable amount of digital video information recorded at the cutting station requires vast storage space and consumes a great deal of viewing time. In most cases, this laborious use of resources is entirely unreasonable. Moreover, not all gross specimens require conventional digital photography, particularly video documentation [13]. According to the authors of the article, in the context of the ubiquitously increasing workload on the pathologist, questions about what is necessary to photograph, how to photograph, and in what sequence are very significant.

Our study aims to perform the following:

1) A critical analysis of modern literature on photographing gross specimens in pathological anatomy and compiling a list of medical cases that require mandatory photographic documentation;

2) Develop practical recommendations for imaging of gross specimens;

3) Assess the possibilities of using digital photography of a gross specimen for differential diagnostics based on digital analysis.

The literature on this subject is scarce in the Russian language and is mainly represented by works on forensic photography [4, 6, 19].

The international literature on photography regarding the practice of a pathologist is mainly focused on photography equipment, and various hardware and software used to transfer and store digital photographs [10, 14, 16].

Only a few works focused on the technique and strategy to obtain high-quality imaging of gross specimens [8, 15, 17, 20].

By combining literature data and many years of our experience into a single array, we offer the following list of cases requiring mandatory photo documentation:

1) All findings associated with a tumor process (Fig. 1, *a*) and a pronounced inflammatory process (Crohn's disease);

2) All gross specimens during transplantation surgeries (Fig. 1, *b*) of organs (prostheses of heart valves, explanted organs);

3) The absence of any findings while anticipating them by clinicians (the absence of a tumor in the gross specimen during the anatomicopathological examination of the surgical material sent for tumor removal); gross specimens with disruption of continuity (Fig. 1, *c*) of anatomical structures
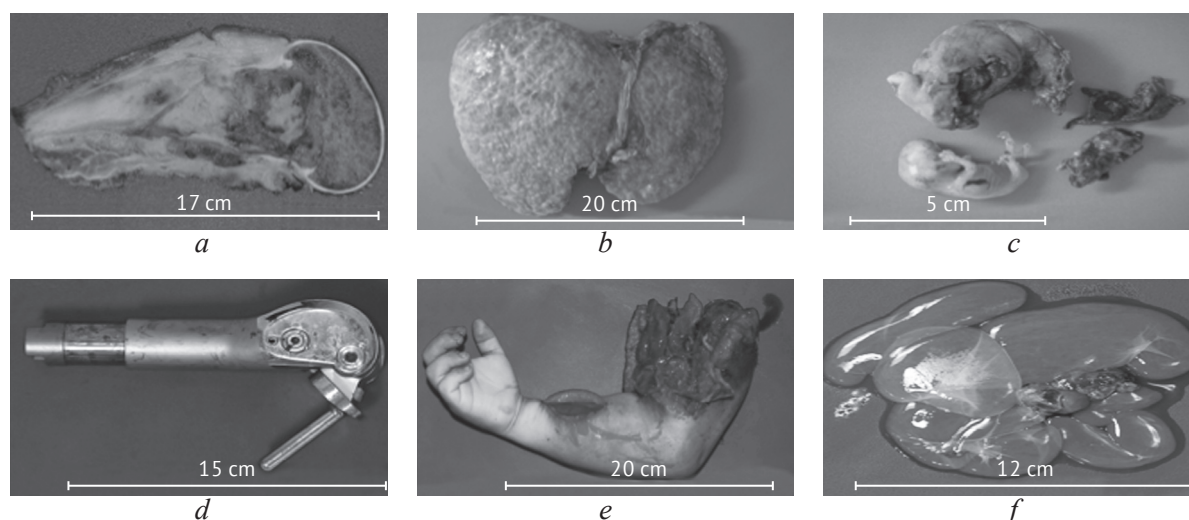
Fig. 1. A macroscopic photograph: *a* – the right femoral segmental resection specimen for osteosarcoma. The central slab of the bone is longitudinally sectioned in the sagittal plane. The macroscopic photograph demonstrates a tumor with massive structure-less areas of necrosis and hemorrhagic infiltration. The tumor involves the diaphysis, metaphysis, intramedullary space, cortical bone, and partially soft tissue. There is no gross evidence of tumor at the inked margins; *b* – an external view of the explanted native liver due to cirrhosis specimen; *c* – a specimen composed of fragmented parts of the fallopian tube and fetus due to disrupted ectopic pregnancy; *d* – a total femoral prosthesis hardware removed due to being worn out. The specimen is for gross examination only and photo documentation; *e* – a specimen resulting from an above elbow amputation of the right upper extremity. The skin, soft tissue, and bone margins are irregularly-shaped and hemorrhagic consistent with traumatic amputation. There is a previously opened defect of skin and underlying soft tissue consistent with a surgical incision on the anterior aspect of the forearm; *f* – a macroscopic photograph of a rare mesothelial cyst of the abdominal cavity

Рис. 1. Макропрепараты: *а* — сегментарная резекция правого бедра по поводу остеосаркомы. Центральная костная пластина, выпиленная в сагиттальной плоскости. На фотографии видна опухоль с массивным бесструктурным участком некроза и геморрагической инфильтрации. Опухоль захватывает диафиз, метафиз, интрамедуллярное пространство, кортикальную часть кости и частично мягкие ткани. Маркированные края резекции без видимого опухолевого роста; *b* — макропрепарат удаленного нативного органа с выраженным циррозом при операции по трансплантации печени; *с* — фрагментированные части маточной трубы и плод при прервавшейся эктопической беременности; *d* — дистальный феморальный протез, извлеченный вследствие износа. Препарат доставлен для макроскопического исследования и фотодокументации; *е* — макропрепарат травматической ампутации правой верхней конечности на уровне средней трети плеча при автомобильной травме. Края кожи на уровне ампутации неровные, мягкие ткани размозжены, отмечается геморрагическая инфильтрация. Визуализируется оскольчатый перелом плечевой кости. На внутренней поверхности предплечья послеоперационная рана; *f* — препарат мезотелиальной кисты брюшной полости

(fragmented organs, preparations in the presence of hemorrhages, ruptures);

4) Gross specimens that require only a macroscopic examination (Fig. 1, *d*) without subsequent histological analysis (excised Phyto- or trichobezoars, medical devices, endoprostheses);

5) Gross specimens of cases (Fig. 1, *e*) that may be the cause of court proceedings (foreign bodies, traumatic organ amputations); unusual findings (Fig. 1, *f*) and rare cases (mesothelial, fetus in fetu, others).

When working, a simple rule must be borne in mind. A set of macro photographs for a given case should form a single picture that enables answering the questions raised by the clinician and leads to the correct clinical and morphological conclusion.

In the daily practice of a pathoanatomist, many different models of digital cameras can be used for photography. If a camera is not available, subject to patient data confidentiality, a mobile telephone can also be used. Several practical recommendations that will help improve the imaging quality of gross specimens are provided below.

1. The choice of imaging mode (manual or automatic) depends on the experience and skills of the camera user. For indoor photography, a ring flash is useful, the design of which provides uniform illumination of small objects and is ideal for shooting gross specimens. At the start of shooting, the gross specimen is photographed in the form it was delivered for research. Then, its sectional view is photographed. If serial sections are made in the form of a "book." then the picture should be taken before parts of the sample have been displaced relative to each other. This is necessary to recreate the integral anatomical structure of the sample and see the contact boundaries of its parts. If separate serial cuts are made, then the plates should be laid out sequentially. All parts must be included entirely while ensuring that no cut edges of one or another fragment are in the frame. When shooting, it is recommended to take several pictures at different magnifications. This practice can be useful in further work for drawing up the so-called schematic map for the layout of tissue fragments of the sample in cassettes and macro-microscopic comparisons [1].

2. It is essential to choose the background for macro photography. It must be clean and have a suitable color. For example, black is not preferable when photographing dark brown and dark red specimens. Yellow, red, and brown are not very good backgrounds for photography of gross specimens, while light blue and green are the most suitable colors.

3. A digital photograph of a gross specimen is a legal document. A lack of scaling and labeling can ultimately devalue all the efforts and diagnostic value of this image. Therefore, macrophotography must necessarily contain labeling with the identification number of the sample and a scale bar with the units of measurement. It is better to place the scale bar closer to the sample, and labeling should be in the corner of the frame. They should not be located on the specimen or overlap its parts. This arrangement enables removing the photo identification number and using the photo for a conference, training, or scientific presentation. All objects in one photo (gross specimen, scale bar, and labeling) must be in focus.

4. When shooting, it is recommended to avoid getting your hands in the frame. A metal probe or tweezers can be used to point to a specific area in the sample.

5. After photographing, the quality of the photographs should be checked to ensure that they fully meet the requirements of the researcher and are saved. The most common file format for saving digital images is JPEG (Joint Photographic Experts Group). However, it has a disadvantage manifested as the deletion of part of the information during the shooting process; when an image is opened in the editing program and saved as a JPEG, part is deleted. The RAW format is the optimal format since it preserves the maximum image quality [6].

6. The creative approach of this specialty enables obtaining an image with a greater depth of field from a series of conventional macro photographs and software for merging focal digital planes (z-stacking) [12]. Such digital images will illustrate the anatomic pathology report and be used in the educational process.

Several studies have already demonstrated success with using digital photographs of gross specimens for in-depth learning of neural networks and the use of neural network analysis in the future for recognizing various organs [9].

The next step is using neural network analysis of digital images of gross specimens for macroscopic differential diagnostics of pathological processes. Today, creating a high-quality and well-annotated digital image repository of gross specimens and their metadata should be considered. This endeavor is a time-consuming and labor-intensive process. Such annotations in our work were created using the publicly available software QuPath. This pro-
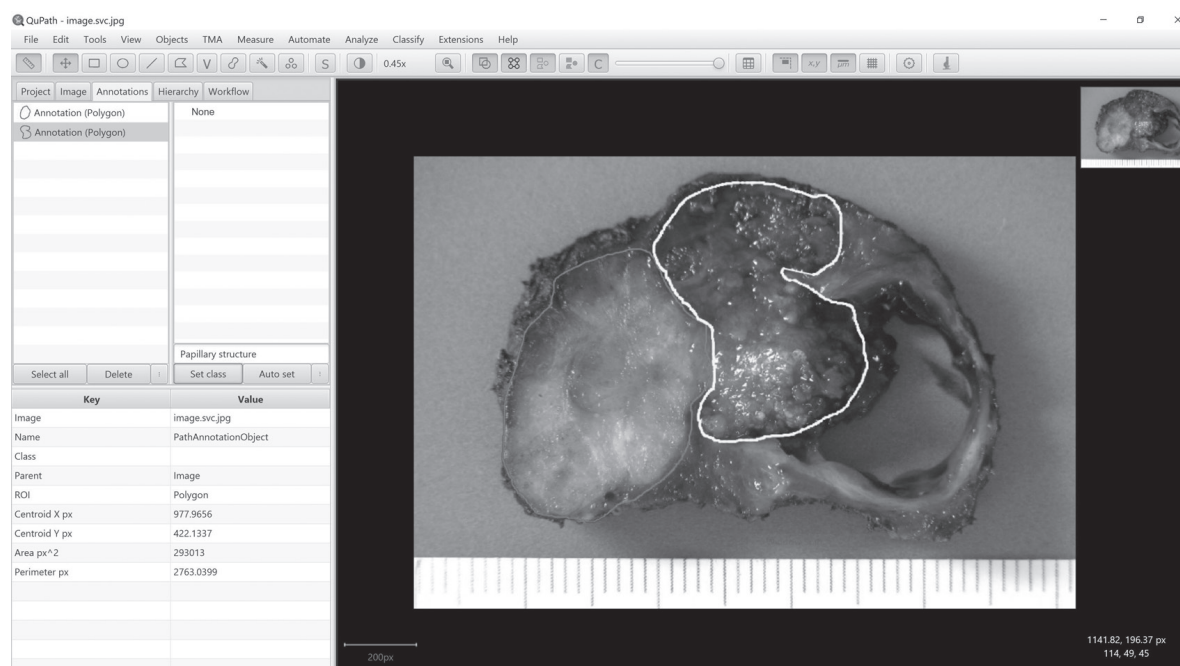
Fig. 2. An example of work with QuPath software for annotation digital gross photograph of the thyroid gland tumor
Рис. 2. Пример работы с программным обеспечением QuPath для аннотации цифрового изображения макропрепарата опухоли щитовидной железы

gram allows for object detection, classification, and image segmentation (Fig. 2).

Thus, even today, with a minimum expenditure of material resources and having certain knowledge of and skills in digital photography, a pathoanatomist can significantly improve the quality of the anatomic pathology report and create the necessary base for conducting computer-assisted differential diagnostics based on digital images.

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