Some remarks about geometry in medicine

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Summary

Geometry has been present in medicine in various aspects for many years. Information on geometrical form of particular anatomic structures should not be underestimated since it is both basic and key information in many clinical cases, beginning from fractures to radiotherapy. Technical apparatuses and devices used in doctors' practice also require comprehension of technical documentation in necessary range. The knowledge of some geometrical issues can help in doctors' work although it is necessary to a certain group of doctors.

Keywords: geometry, engineer graphic, medicine

1 Historical background

Medicine has always developed basing on new technological and technical solutions. This medical knowledge, gained sometimes with difficulty, had to be recorded and the easiest way of

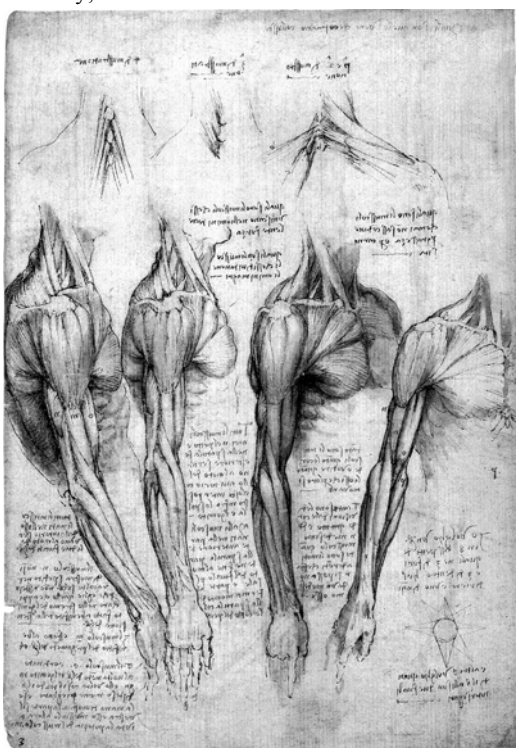

Fig. 1 Leonardo Da Vinci sketches

recording was description in a form of a text and a drawing. In nature it is very rare to come across exactly the same animals or plants and thus it can be even stated that they do not exist. This remark refers to humans too. Therefore, the oral description can

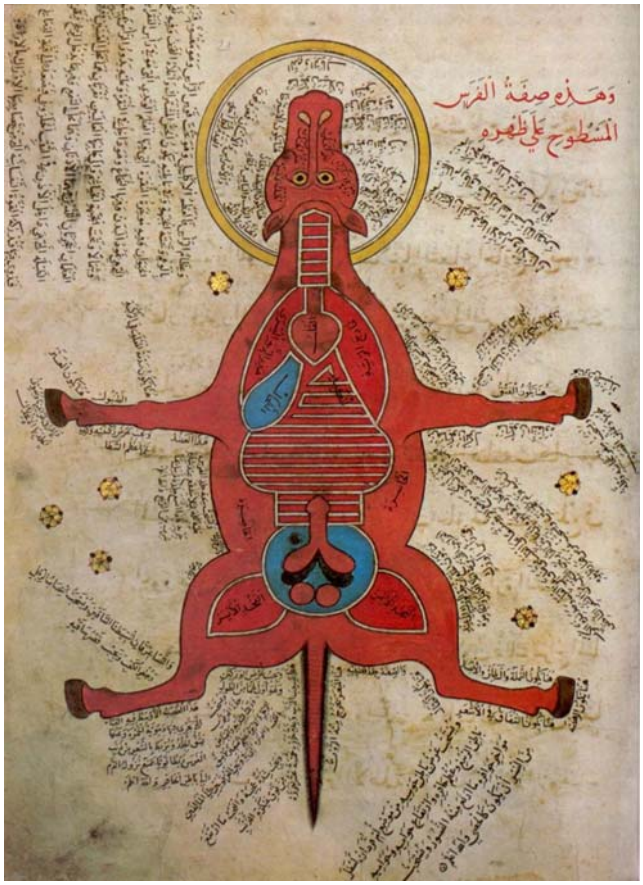

Fig. 2 15th century Egyptian anatomy of horse

refer to the description of symptoms and the way of clinical conduct. It is difficult to imagine the description of e.g. spinal bones and so, since the very beginning of medicine as science, picture is used for presenting typical shape of organs (bones, circulatory system etc.). In many regions of the world and in many historical epochs this method of reaching knowledge was opposed by authority, in many cases caused by religious motives as well. Many scientists and artists gained knowledge on inner organs exposing themselves to danger. The share of painters and sculptors in the development of that method should be stressed. As it can be seen in Leonardo Da Vinci sketches (Fig.1), such a precision could have been made only based on autopsy.

Fig. 3 Acupuncture chart from Hua Shou (Ming Dynasty)

Sketches with such precision could not have been made without with genius of the author, especially when autopsy could be done only at night. Graphical record of gathered information does not refer solely to European culture but also to other cultures e.g. Arabic anatomy of a horse (Fig.2) and Acupuncture chart from

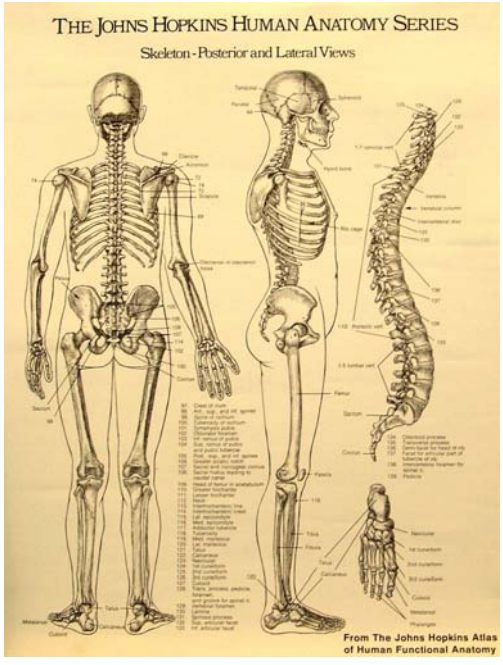

Fig. 4 The Johns Hopkins Atlas of Human Anatomy

Hua Shou (fl. 1340s, Ming Dynasty) (Fig.3). Anatomy atlases have always been made with greatest precision. Since organs are located in some 3D space, the way inner organs were presented varies. The atlas must have been prepared in such a way that a person without special preparation could use it. It was true specially when doctors and doctors-to-be were not prepared as far as geometry was concerned. One of the ways of presenting which was used in many atlases was to show consecutive layers with organs as well as picturing from different sides e.g. front and rear (Fig.4) or models in scale or natural size were made.

2 Processed picture as a base for doctor's conduct in real time

In case of classical operation of inner organs a doctor must first have access to the place which is to be operated on, so that it can be seen and tools can be used freely. Due to these actions big wounds appear. A doctor can directly see operating area and thanks to that he can see some incorrectness or damages which were not included in the process of procedure. Currently a doctor can carry operation without such wounds but a drawback of such solution is the fact that he bases his decisions on a picture obtained by intermediary devices (e.g. camera- screen) and not on what he actually sees. The picture can be distorted owing to optical intermediary devices and therefore knowing about that one can evaluate the situation correctly and carry the operation. Consequently, such practices require training connected with the skills of operating a device which is controlled by man and is not directly in his hand. Similarly, the same situation happens when distant operations are carried and problems appear connected with constant uninterrupted communication between a doctor, operating theatre and a patient.

3 Picture and diagnostics

Another issue worth discussing is interpretation of obtained graphical information from X-rays via ultrasonography and Computed Tomography (*CT*) and finally magnetic resonance

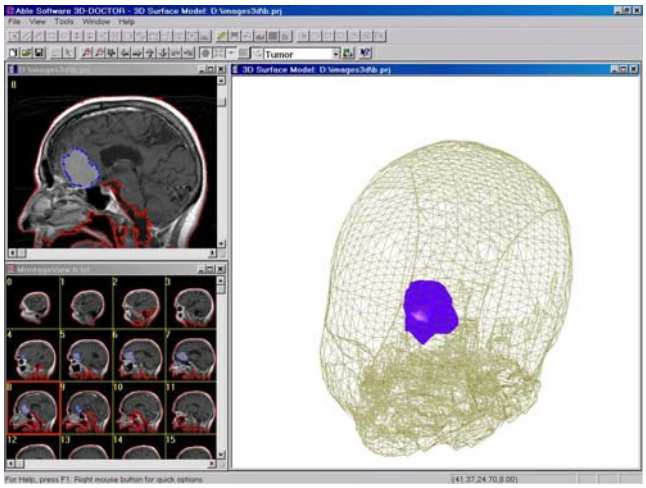

Fig. 5 Skull - 3D model

imaging (***MRI***) (Fig.5). Each of these methods despite engineers' efforts requires interpretation of picture. This interpretation is made by reading geometrical form of a given anatomic structure based on medical knowledge. Computer with its software facilitate the task of creating 3D model of a treated organ greatly. However, each method can be error burdened or have some inaccuracies, which may result from the way information is

collected or algorithms generating 3D model as well as the way of model representation. The engineers' task is to prepare the process in such a way that a model is as close to natural organ as possible. In preplanned processes there is time and possibilities for engineers to check and correct the model so that it is useful for a doctor. Nevertheless, in emergency cases there can be no time for checking and verification. This is the main reason why a doctor who knows at least the outline of model creation and information collection about organ's geometry, can in case of errors (resulting from information collection or model generation algorithm) manage himself.
Creation of 3D model can lead to diagnosis of future complications or susceptibility to injuries e.g. fractures. Such a model can be used for research on e.g. strength [Rychlik et. al. 2004] and verification of different theories.
For the sake of cognitive research the whole library of human body sections have been created with 1mm precision, which can be used for 3D model creation in didactics.

4 3D space in doctors' practice

In some situations operations have been made based on documentations prepared on the basis of 3D model, which truly

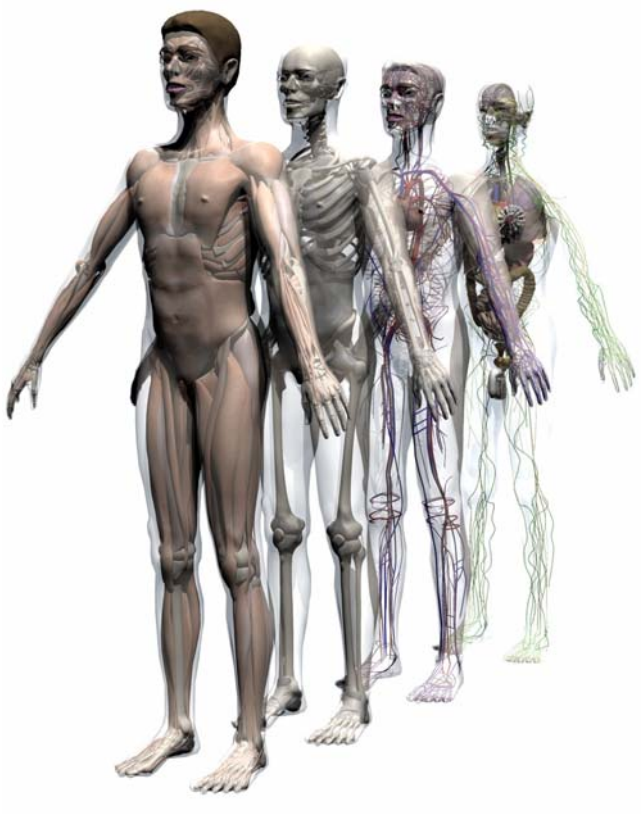

Fig. 5 3D models

represented a patient. Simulation of the way tool is used is necessary especially in case of operations which require great precision e.g. scull operations when tiny error or inaccuracy can lead to damages of brain which are difficult to predict. Preparation of such operation requires first preparation of data for precise creation of 3D model (Fig. 5). Next problem which engineers have to face is preparation of such software which will allow a doctor to get to know operation area. Operation theatre has its own rules and thus everything should be prepared and foreseen. Firstly, a doctor or his assistant must have a possibility to change the location of the observed model and tools in a possibly simple way. Static picture does not guarantee the full control of tool's location. Before operation patient must be precisely positioned as regards tools. It is also necessary to secure patient against relocation or rotation before operation so that coordinates of a patient and tool do not differ.
Another area where the knowledge of geometry is very important are techniques connected with radiation [Wagner et al. 2002]. In this case engineers can help in the possible correctness of results. Also in this situation a patient must be placed in precisely determined place so that a beam of radiation gets to the planned area. In order to reduce side effects of radiation of neighboring tissues the source of radiation must be in motion and it must be adjusted in a way that proper effect is achieved. In this case we talk about geometry and time in 3D space. Similar situation is with teeth X-rays [Stachel 1998] panoramic views.

5 Doctor - picture - patient

In many patient- doctor contacts it is necessary to explain to a

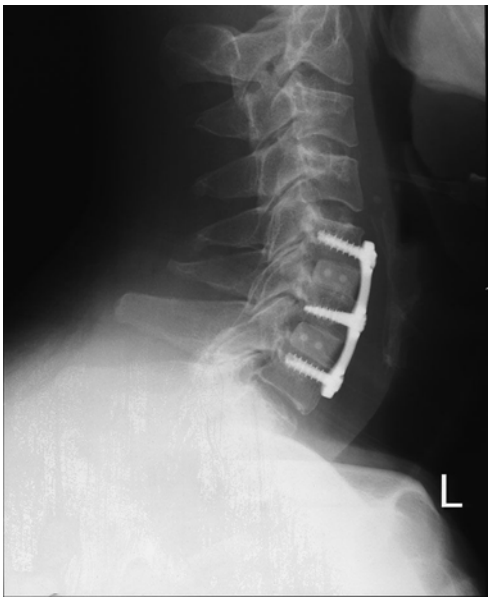

Fig. 6 X-ray vertebral column

patient what his procedure will be like. Naturally, already existing illustrations concerning similar cases can be used. However, in

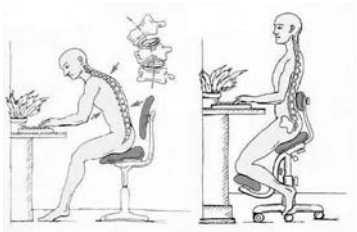

Fig. 7 Sitting position - vertebral column

case of e.g. fractions each case is different and thus the way of joining is different. Detailed information for patients is also important during rehabilitation. When a patient knows what e.g. stiff spine is (Fig.6,7) he can undergo proper rehabilitation easier. Based on 3D models didactic movies for patients and people under rehabilitation can be made.

6 Simulators

The development of technology enables the usage of different simulators, which based on computer systems generate pictures that can be adapted for one viewer (e.g. such a system with goggles as an element). Then generated picture can be exactly the same as in reality. Different situation appears when there are a few people and one picture for them. It is impossible to have it shown correctly for all viewers and therefore being aware of the distortions it is easier to take part in simulation. This remark refers also to presentations with 3D techniques when being aware of possible distortions observer can understand the picture better. Another aspect is the fact that such distorted picture can lead to faster tiredness of viewer, and in consequence incorrect decisions. The error is then not the effect of lack of knowledge but the result of used simulator.

7 What to teach the students of medicine

The important information at Polish medical universities does not teach the students of geometry, computer graphic.
Topics should differ from regular geometry course which is offered at the technical universities, definitely it should include:

- reading of technical documentation
- axonometry (3D models)
- central projection (also from cameras)
- methods of generation of 3D models
- generation of digital picture

8 Conclusions

There are a number of prerequisites to introduce geometry to doctors' education and training.
The following issues should be considered:

- the range of topics depending on the specialization
- the way of realization

9 Acknowledgement

I would like to express my gratitude to MD, PhD Wiesław Rycerski from Upper Silesian Rehabilitation Center "Repty" in Tarnowskie Góry, Łukasz Talarek from Municipal Hospital no 1 in Gliwice and Stanisław Sulwiński, PhD for all the inspiring discussions and MSc Barbara Skarka for help in preparing English version of the paper.

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