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Morphotypes and typical locations of the liver and relationship with anthropometry

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Introduction

The liver is one of the most injured organs in road or domestic accidents. To protect or repair it, companies and clinicians rely more and more on numerical finite elements models. It is highly complex owing to its structure, its dual blood supply and its environment. It is located under the diaphragm and partially covered by the thoracic cage and it presents a high variability of its shape.

In order to improve finite element modelling of the liver, an anatomical customization must be done. Three aspects of the liver anatomy have been studied. First, some authors focused on the external shape of the liver [1-3]. Caix and Cubertafond [1] have found two morphotypes according to the subject's morphology. Nagato et al. [2] have divided the liver in six morphotypes depending on the costal and diaphragmatic impressions, or the development of one lobe in relation to the other. Studer et al. [3] have stated on two morphotypes thanks to the ratio of two geometrical characteristics of the liver. Secondly some authors focused on the location of the liver in the thoracic cage [4-5]. The liver's location in different postures has been determined *in vivo* [4] and on cadaveric subjects [5]. Finally, the variability of the internal shape of the liver has been reported. Some authors have described different segments based on the hepatic vessels and particularly the hepatic veins [6-7].

The purpose of our study is a global analysis of the liver anatomy, quantifying at the same time its external shape, its internal vascular structure and its anatomical location, applied to livers reconstructed from 78 CT-scans, in order to identify liver's morphotypes and typical locations in the thoracic cage. Moreover, we analyzed the ability of subject's characteristics to predict these morphotypes and locations.

Materials and methods

Population – This study is based on 78 CT-scans from the Department of Medical Imaging and Interventional Radiology at Hôpital Nord in Marseille. These CT-scans were performed on patients between 17 and 95 years old. with no liver disease nor morphological abnormalities of the abdominal organs or the peritoneum.

Measurement of geometric and anthropometric parameters – The 3D reconstructions of the liver, the associated veins and the thoracic cage were performed manually. A database was created with 53 geometrical characteristics per liver, qualifying its external geometry [8], its internal geometry, the diameters and angles of the veins and their first two bifurcations, and its location in the thoracic cage. Furthermore, anthropometric measurements were measured, such as the xiphoid angle, the abdominal and thoracic perimeters. Lastly, data such as the subject's age and gender were known.

Statistical analysis – To homogenize the data, a transformation in logarithm, logarithm of the cubic root or by the log shape ratio of Mosimann [9] was used. To reduce the number of variables, principal component analysis (PCA) was performed on parameters characterizing the external geometry, the internal geometry, the veins geometry and the location of the liver. The first two dimensions were kept and two new variables by linear combination were created. An ascending hierarchical classification was then produced to determine the number of categories. Then, the partitioning around medoids method was chosen to classify the different individuals into categories. Lastly, ANOVAs followed by post-hoc Tukey (HSD) tests were performed to verify the existence of a relationship between the subject's anthropometry and the liver's morphotypes.

Results and discussion

Four morphotypes were found and described by Fig.1.

The first morphotype corresponds to a liver with a very small volume which presents as a small volume of the right lobe particularly segments 4 to 7. The associated veins globally have small diameters. A small angle between the two lobes can be noted. This kind of morphotype is noticed for subjects with a xiphoid angle under 80° and a thoracic perimeter under 75 cm.

The second morphotype corresponds to a liver with a small volume which manifests as a small volume of the right lobe, and particularly segments 5 to 7. The associated veins globally have small diameters. A large angle between the two lobes can be noted. This kind of morphotype is noticed for subjects with a xiphoid angle under 80° and a thoracic perimeter under 75 cm.

The third morphotype corresponds to a liver with a very large volume which presents as a very large volume of the right lobe, and particularly segments 4 to 6. The associated veins have large diameters. A large angle between the two lobes can be noted. This kind of morphotype is noticed for subjects with a xiphoid angle over 80° and a thoracic perimeter over 75 cm.

The fourth morphotype corresponds to a liver with a large volume which manifests as a large volume of the right lobe, and particularly segments 4, 5 and 7. The associated veins have large diameters. A small angle between the two lobes can be noted. This kind of morphotype is noticed for subjects with a xiphoid angle under 80°, a thoracic perimeter around 75 cm.

No statistical difference can be noted for the position of the liver in the thoracic cage. Only the position of one lobe to the other seems to vary.

Although the volume of the segments varies from one morphotype to another, the proportion of these segments, especially the fifth, seems stable and the volumes of segments are correlated with the hepatic volume ($R^2=0.42$ for segment 5). Moreover, the diameters of the veins seems correlated with the volume ($R^2=0.33$ for the portal vein, but only 0.17 for the vena cava).

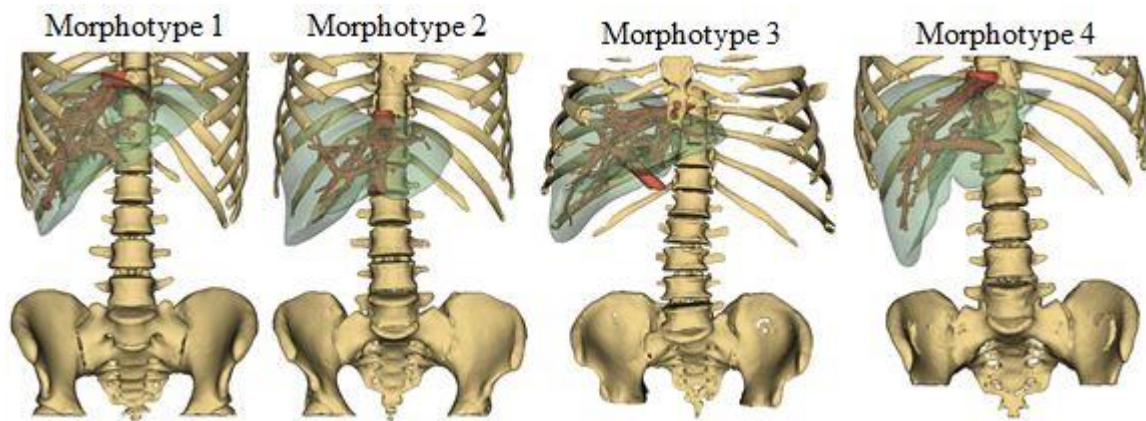


Figure 1 : Presentation of the four morphotypes in anterior view.

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