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Study of Volume, Weight and Size of Normal Pancreas, Spleen and Kidney in Adults Autopsies

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Abstract

Aims: 1) To establish the volume, weight and size of a normal pancreas, spleen and kidney in 114 adult male autopsies; 2) To investigate the relationship between the volume, weight, and size of the pancreas, spleen, and kidney with body mass index (BMI), body surface area (BSA), age, height, and weight. Methods: The normal pancreas, spleen, and kidney volume, weight, and size retrospectively gathered from 114 forensic autopsy cases between the ages of 25 and 88 years. The pancreas, spleen, and kidney volume, weight, and size were available. The parameters used for statistical correlation were the age, height, body weight, BMI, and BSA of the deceased. Results: The volume, weight, and size of all the organs were shown in correlation with the deceased's height, body weight, BMI, and BSA but not age. The organ volume, weight, and size showed a better statistical correlation with the BSA, BMI, and body weight than the height. Conclusions: The normal reference ranges for organ volume, weight, and size given in this study can serve as a standard to judge atrophy or hypertrophy of organs in post-mortem diagnosis.

Keywords

Organ Volume, Organ Weight, Autopsy, BMI, BSA

1. Introduction

The volume, size, and weight of abdominal organs bear potential significance. A multitude of medical condi-

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tions are associated with changes in volume and size of these organs. For instance, infectious, hematologic, or metabolic conditions may result in an increase in the size of the spleen [1] [2]. Kidney dimensions may change in correlation with the severity of the renal pathology involved. Pancreatic atrophy is associated with changes in exocrine functions [2] [3]. Also, deviations from the normal ranges of the weight of an organ may indicate the presence of certain pathological changes. Thus, organ weight may play a role in the determination of the cause of death under different pathological conditions, as well as assisting in defining the association between trauma and disease [4]-[6].

Normal anatomic ranges should first be described in order to define pathological conditions. Data from studies examining normal ranges allow a relative comparison of the weight and size of organs. Also, they may help define the degree of atrophy or hypertrophy of a particular organ inflicted by certain diseases [7]. The pancreas, spleen, and kidneys continue to grow until approximately 25 years of age [3] [8] [9]. Thus, only individuals older than 25 years of age were included in this study.

The objective of the present study is to determine the volume, weight, and dimensions of solid abdominal organs in autopsy cases and to explore their association with the weight, height, BMI, and BSA of the individual.

2. Materials and Methods

2.1. Subject Selection

The Scientific Research Committee of the Forensic Medicine Institution approved the study protocol. A total of 114 male autopsy cases between 25 and 88 years of age undergoing a post-mortem autopsy examination within six hours of death were included. Exclusion criteria included death due to trauma, manifest macroscopic disease, or organ anomaly. Forensic medicine specialists measured body weight and height. The body weight measurements were conducted using the same scale (between 0 and 300 kg, with a sensitivity of 100 g) and bodies were naked. Height was defined as the distance between the top of the head and heel in centimetres. Organ weight measurements were made using an electronic weighing scale with a sensitivity of ±0.1 g after the removal of foreign tissues. Length, thickness, and width measurements involved the determination of the two furthest points on the organ's surface. Volume measurements were made based on the Archimedes Principle by submerging the organs in a scaled measuring bowl filled with water. The average measurements were used for kidneys. The removal of organs was performed using standard autopsy protocols and procedures proposed by Ludwig [10].

2.2. Anthropometric Parameters

Anthropometric data includes the body weight, height, BMI, and BSA of each case. BMI was calculated using the formula: $BMI = W/H^2$, where W = weight in kilograms (kg) and H = height in metres (m). BSA was calculated using the Mosteller formula [11] [12]:

$$\text{BSA}\left(\text{m}^2\right) = \left[\frac{\text{height}\left(\text{cm}\right)\times\text{weight}\left(\text{kg}\right)}{3600}\right]1/2$$ should be expressed as an exponential number.

2.3. Statistical Analysis

All statistical analyses were performed using SPSS 17.0 for Windows. Subject characteristics and results are reported as mean ±SD. Correlations between organs measurements including weights, volumes, and sizes, and body height, BMI, BSA, age, and organ sizes, respectively, were studied by performing the Pearson Correlation. We classified the strength of the correlation between organ weight and the parameters in three categories: strongly significant ($P < 0.01$), weak but significant ($0.01 \le P \le 0.05$) and insignificant ($P > 0.05$).

3. Results

The average age of patients was 47.9 ± 17.8 years (between the ages 25 and 88), height 172.2 ± 7.5 cm (between 145 and 190 cm), body weight 78.1 ± 15.2 kg (between 42 and 120 kg), BMI average 26.2 ± 4.7 kg/m^2 (between 17 and 38 kg/m^2) and BSA 1.9 ± 0.2 m^2. The mean, standard deviation and range of the organ measurements including weights, volumes, and size of the studied population are shown in **Table 1**.

The correlations (p and r values) volume and the weight of the pancreas with height, weight, BMI, and BSA

Table 1. The mean, standard deviation and range of the organs measurements of the studied population.

Measurements of the organs			
		Mean ± S.D.	Range
Pancreas volume	(mL)	88.6 ± 31.5	40 - 185
weight	(g)	87.3 ± 30.6	41 - 174
Spleen volume	(mL)	201.3 ± 108.4	45 - 575
weight	(g)	209 ± 111.7	48 - 720
length	(cm)	12.8 ± 2.1	8.5 - 20
depth	(cm)	3.7 ± 1.2	2 - 6
width	(cm)	8.2 ± 1.2	5 - 10.5
Kidney volume	(mL)	149.7 ± 48.1	85 - 320
weight	(g)	150.7 ± 45.4	85 - 309
length	(cm)	11.3 ± 1.1	7.5 - 15
depth	(cm)	3.8 ± 1	2 - 6
width	(cm)	6 ± 0.8	4.5 - 9

are shown in **Table 2**. For the pancreas, organ volume and weight were strongly and positively correlated with body height, weight, BMI, and BSA. When there was a correlation, the organ weight and volume increased with BSA and/or body weight. In general, organ weight and volume were more correlated with BSA and body weight than BMI and body height. There was no significant correlation for organ weight and volume with age in the pancreas.

The correlations (p and r values) volume, weight, and sizes of the kidney with height, weight, BMI, and BSA are shown in **Table 3**. For the kidney, organ volume and weight were strongly and positively correlated with body height, weight, BMI, and BSA. Organ weight and volume were more correlated with BSA and body weight than BMI and body height. No correlation was found with age for kidney volume and weight. Kidney sizes were positively correlated with body height, weight, BMI, and BSA.

The volume and weight of the spleen correlated positively to height, body weight, BMI, and BSA as shown in **Table 4**. For the spleen, organ volume and weight were strongly and positively correlated with body height, weight, BMI, and BSA. When there was a correlation, organ weight and volume increased with BSA and/or body weight. In general, organ weight and volume was more correlated with BSA and body weight than BMI and body height. Spleen sizes were positively correlated with body height, weight, BMI, and BSA. There was no significant correlation for organ weight and volume with age in the spleen.

4. Discussion

Many conditions are known to influence the volume, weight, and size of organs. Some diseases enlarge organs while some may diminish their volume, weight, and size [13]. Even normal organs seem to show great variation. Meanwhile, the volume, weight, and size of organ reference tables are only valid over a limited period of time and may vary among different populations.

Thus, the values of an organ's volume, weight, and size achieved by autopsy should not be compared with out-dated reference tables or with data obtained from other parts of the world. Indeed, the use of uncertain tables may lead to a wrong judgment on the pathological or non-pathological features of the organ, especially in forensic cases in which histology is not always performed. This means it is necessary to establish updated reference tables from appropriate autopsy material.

Previous reports [9] [14] [15] have demonstrated differences in the pancreatic volume in CT, MRI and autopsy. We found that the mean pancreas volume of 114 male individuals was 88.6 mL. Lohr *et al*. [16] reported that pancreas volume was 86.5 ± 33 cm^3. Geraghty *et al*. [2] reported an average pancreas volume of 87.4 cm^3 in 57 male individuals (the mean 48 years of age). Our results are very similar to those in literature mentioned above.

Differences in the literature on pancreas volume may be due to differences of the number, mean age, and

Table 2. Relationship between the parameters used and pancreas volume and weight.

	The parameters			
	Weight (kg)	Height (cm)	BMI (kg/m^2)	BSA (cm^2)
Pancreas volume				
r	0.486	0.288	0.418	0.499
p	<0.001	0.002	<0.001	<0.001
Pancreas weight				
r	0.518	0.298	0.448	0.531
p	<0.001	0.001	<0.001	<0.001

r: value is the correlation coefficient, p: value is the probability.

Table 3. Relationship between the parameters used and kidney volume, weight and size.

	The parameters			
	Weight (kg)	Height (cm)	BMI (kg/m^2)	BSA (cm^2)
Kidney volume				
r	0.586	0.264	0.521	0.575
p	<0.001	0.005	<0.001	<0.001
Kidney weight				
r	0.613	0.276	0.545	0.603
p	<0.001	0.003	<0.001	<0.001
Kidney length				
r	0.323	0.286	0.222	0.358
p	<0.001	0.002	0.018	<0.001
Kidney depth				
r	0.621	NS	0.608	0.588
p	<0.001		<0.001	<0.001
Kidney width				
r	0.369	0.308	0.268	0.394
p	<0.001	0.001	<0.001	<0.001

r: value is the correlation coefficient, p: value is the probability.

Table 4. Relationship between the parameters used and spleen volume, weight and size.

	The parameters			
	Weight (kg)	Height (cm)	BMI (kg/m^2)	BSA (cm^2)
Spleen volume				
r	0.512	0.324	0.416	0.519
p	<0.001	<0.001	<0.001	<0.001
Spleen weight				
r	0.504	0.348	0.395	0.517
p	<0.001	<0.001	<0.001	<0.001
Spleen length				
r	0.284	0.364	NS	0.331
p	0.002	<0.001		<0.001
Spleen depth				
r	0.403	0.265	0.324	0.413
p	<0.001	0.004	<0.001	<0.001
Spleen width				
r	0.480	0.434	0.335	0.528
p	<0.001	0.001	<0.001	<0.001

r: value is the correlation coefficient, p: value is the probability.

gender of individuals enrolled in the study and regional differences between populations. Our study found that pancreatic volume and weight values are positively correlated with body height, weight, BMI, and BSA. The results are in line with previous studies [9] [14].

We found that the mean spleen volume and weight of 114 male individuals were 201.3 mL and 209 g, respectively. With regards to the values for splenic volume and weight, our study found that spleen volume and weight are positively correlated with body height, weight, BMI, and BSA. Henderson *et al*. [17] found in 11 normal subjects a mean spleen volume of 209 mL. Hoefs *et al*. [18] used a CT scan and found a normal spleen volume of 201 mL in normal patients. Prassopoulos *et al*. [1] reported a mean spleen volume of 215 mL for 140 patients. Geraghty *et al*. [2] found the mean spleen volume of 209 cm^3 in 149 individuals. Ehimwenma and Tagbo [19] reported that the average spleen volume was 202 cm^3 in 91 male individuals (mean age of 32 years). Our results are very similar to those in literature mentioned above.

Land [20] reported an average spleen weight of 163 g in 440 autopsies (in the 35 - 59 age range) and spleen weight increased with increasing body weight, height, and surface area. Garby *et al*. [21] reported an average spleen weight of 167 g for males. Organ weight was found to be positively correlated with BMI and body height. Sprogoe-Jakobsen [13] and Grandmaison [22] did not find a correlation between the weight and age and BM, but instead body weight and height. Shekzadi *et al*. [23] reported found no correlation between spleen weight with body height. Ehimwenma and Tagbo *et al*. [19] reported that there was no statistically significant correlation between age of subjects and spleen length, weight, or volume. We found no correlation between spleen volume, weight, and size with age in this study. We found a significant correlation between spleen size and subject height, weight, BSA, and BMI.

As noted earlier, while comparing our data with other studies in the literature, we must consider the different characteristics of the population from one study to another. Quantitative assessment of splenic volume and weight in autopsy might be of value in clinical or research applications.

Kidney volume and weight were correlated to body height, weight, BMI, and BSA but not to age. These results were in concordance with those of Shekzadi *et al*. [6], who found that kidney weight correlated with body weight, height, and BMI but not to age. Rasmussen *et al*. [23] found by ultrasound that kidney volume correlated with body weight. There is also a previous article that concludes renal volume is closely related with body weight [24] [25], and our results were consistent with this observation as well.

Kidney size was correlated to body height, weight, BMI, and BSA but not to age. Many studies have shown that height correlates best with kidney length [25] [26]. In our study, kidney length and width correlated best with BSA, but kidney depth correlates best with body weight. We found much weaker correlations between renal length and height or BMI compared with that of BSA and body weight. This suggests that BMI and height might not be a significant confounder in estimating renal sizes. Kidney volume and weight were correlated to body height, weight, BMI, and BSA.

We must consider that normal values of organ volume, weight, and size change with time probably under the influence of genetic factors and environmental factors such as dietary habits, daily water intake and regional differences between populations [6] [22]. Nevertheless we think that organ volume, weight, and size remain a good diagnostic criterion for autopsy only if normality is accurately and regularly defined.

5. Conclusion

The volume, weight, and size of organs were strongly and positively correlated with BSA, BMI, and weight. Therefore, these parameters can be used to estimate the volume, weight, and size of organs. Moreover, the normal reference ranges for organs' volume, weight, and size given in this study can serve as a standard to judge whether atrophy or hypertrophy of organs in post-mortem diagnosis.

Conflict of Interest

The authors declare that they have no conflict of interest.

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