THE ASSESSMENT OF ULTRASONOGRAPHIC ECHOGENICITY IN NORMAL HUMAN PAROTID AND SUBMANDIBULAR GLANDS

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Ⅰ. INTRODUCTION

Diagnostic imaging methods for the diseases of the salivary glands include conventional radiography, sialography, scintigraphy, computed tomography(CT), magnetic resonance imaging (MRI) and ultrasonography. Each technique plays a particular role and is often complementary to each other[1]. Among these, CT and MRI are the methods of choice for the investigation of cysts and tumors of salivary glands[2]. Overall sensitivity of CT in detecting salivary gland tumors approached nearly 100 per cent[3].

Along with CT and MRI, ultrasonography is also highly helpful in differentiating the space-occupying masses such as tumors or cysts from inflammatory swellings of salivary glands. Tumors or cysts are much more hypoechoic in comparison with the echogenicity of the normal glandular parenchyma. Therefore, ultrasonography is highly advantageous in differentiating an intraglandular mass from the extraglandular ones located in superficial regions. The localization of the mass in the salivary glands related to surrounding anatomic structure, except the area obscured by acoustic shadow of the mandible, is as accurate as CT or MRI. It has been claimed that the sensitivity of ultrasonography in detecting parotid tumors is nearly 100 per cent effective and ultrasonography may be more sensitive than CT for the identification of small lesions of less than 1 cm in size[4]. In fact ultrasonography occasionally allows us to identify satellite lesions not seen by other methods of imaging[4]. Moreover, ultrasonography has several advantages over other imaging modalities in

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that it doesn't use ionizing radiation, is non-invasive and is not disturbed by metallic artifacts such as dental restorations.

In inflammatory conditions, sialography is the most effective method of visualizing minute changes of glandular parenchyma, dilatation or obstruction of the ducts and the localization of salivary stones. However, it has several disadvantages as well. Intubation of lacrimal probe into the main duct often causes the patient to feel pain and discomfort. Contrast media may evoke a tissue hypersensitivity or allergic reaction, and the procedure takes much time.

Inflammatory state of glands tends to show hypoechogenic and heterogeneous pattern with or without an enlargement of the salivary gland on ultrasonogram. The portion of the abscess formation can be detected as hypoechoic area. Most salivary stones greater than 2 mm can be detected as high reverberation echo which is accompanied by posterior acoustic shadowing. Of interest is the fact the ultrasonography is especially effective in acute inflammatory conditions, because the clinical evaluation is often limited and the patient's overall condition is much deteriorated[5]. Although ultrasonography is less sensitive than sialography in those regards depicted above, it is a non-invasive, simple, and fast diagnostic technique. Moreover, the ultrasonographic approach is useful in diagnosing of autoimmune diseases of salivary glands such as Sjögren's syndrome[6,7,8].

Recent technical improvements of ultrasound machines have raised the diagnostic accuracy of ultrasound imaging, resulting in a broadened range of glandular diseases that can be diagnosed by ultrasonography. More recently, the color Doppler ultrasonography has shown to enhance the diagnostic capabilities of gray scale ultrasonography in a variety of clinical conditions[9,10].

There have been recent quantitative efforts, using CT to evaluate size[11] and CT number[12] of normal human salivary glands. However, there have been few quantitative studies to this date to evaluate the echogenicity of normal salivary glands, although normal salivary gland is known to show homogenous, relatively hyperechogenic ultrasonographic pattern[13]. It is difficult to diagnose early or mildly advanced inflammatory diseases using ultrasonography because the variability of size and echogenicity among normal salivary glands are considerably larger depending on individuals. These observations present certain limiting factors for further extensive use of ultrasonography of the salivary glands.

The aim of this study was to establish the normal range of echogenicity quantitatively in normal human parotid and submandibular glands with respect to age, sex, and adiposity.

II. MATERIAL AND METHODS

1. Subjects

Ninety healthy subjects, 45 males and 45 females, ranging in age between 20 and 70 years were selected. They had no past history of glandular malfunction or did not present any pathological symptoms of salivary glands. Subjects who had a history of radiation therapy and/or previous operation of major salivary glands were also excluded. The subjects were divided into six groups according to age range and sex(Table I).

2. Ultrasonographic Imaging

Ultramark 4 plus(Advanced Technology Laboratories, U.S.A.), real-time ultrasonic system, was used for the salivary gland imaging. To acquire the image of the depth approximately 4.8 cm from skin surface, high resolution scanner

Table I. Demographic characteristics of the subjects

Sex	Group	Age	Mean Age(±S.D.)	number
Male	Young	20-35	28.0(4.1)	15
	Middle	36-55	43.0(5.9)	15
	Old	56-70	62.0(5.5)	15
Female	Young	20-35	26.0(4.5)	15
	Middle	36-55	44.5(6.2)	15
	Old	56-70	61.3(4.9)	15

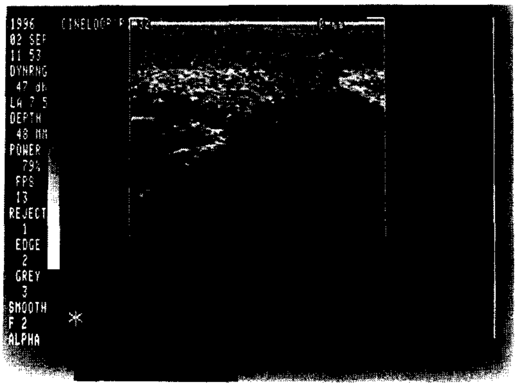

Figure 1. Ultrasonography of parotid gland on heat-sensitive paper

Figure 2. Ultrasonography of submandibular gland on heat-sensitive paper

with 7.5 MHz pulse was used. In all cases, ultrasonographic imagings was obtained with power 79%, edge 2, and gray 3. Compensation for the absorption of ultrasound with respect to the depth was not performed. With the subject lying in supine position and good neck extension, the transverse scans of both glands were done. Transmission gel was applied and the transducer was secured to maintain its close contact with skin, thereby permitting the minimal absorption of ultrasonic energy transmitted through air[14]. During the scanning of the parotid gland, transducer was always positioned just under the ear lobe and perpendicular to the long axis of the mandibular ramus throughout the scanning period. To acquire images of the submandibular gland, transducer was positioned inferior to the mandibular border. The images that showed the most delineated feature of the parotid or submandibular gland were frozen. Frozen images of both glands were printed on heat-sensitive paper of high density by means of videographic printer (UP-890MD, Sony, Japan) (Figure 1, 2). Imaging papers included information on date, instrumental setup environment and the gray scale reference bar which was divided into 16 grades. The first grade, the uppermost part of reference bar, was the darkest and the last grade being the brightest.

3. Scanning

Obtained imaging papers were scanned by flat-bed type scanner(Scantouch, Nikon, Japan) and saved in computer as image files which had the extension name of 'tif'. In all scannings, scanning mode was gray scale with the 1000 DPI(dot per inch) and a resolution of 1024 X 768 pixels. The acquired image file was opened on Adobe Photoshop 3.0. program(Microsoft, U.S.A.).

4. Measurement of the echogenicity of salivary gland

Considering attenuation of ultrasound beam in relation to the depth, the region of interest(ROI) was selected as representing of the partial gland above the depth of 15 mm from the skin surface. The gray scale histogram in Photoshop program reflected the echogenicities of salivary glands measured between 0 to 255. The mean number of gray scale histogram for salivary glands was determined as the mean of the total pixels in the ROI and was called the 'number' in this study. The number for both right and left glands were averaged to obtain the density for an individual case. The number for each grade of gray scale reference bar was measured to compensate for different brightness among ultrasonographic images. These number for salivary glands was always between the 8th grade and 11th grade. The number for 8th grade was regarded as 0, the 9th grade as 100, the 10th grade as 200, and the 11th grade as 300. If the number for echogenicity of the salivary gland was placed between N (N=8,9,10) grade and N+1 grade, the resultant value of the echogenicity was so determined by the following equation.

The value for echogenicity =

$$\frac{\text{number(salivary gland)} - \text{number(N)}}{\text{number(N+1)} - \text{number(N)}} \times 100 + (N-8) \times 100$$

The obtained values were compared between age groups, male and female, right and left side, and parotid and submandibular gland. Also the correlation between the obtained values and body mass index(BMI) was determined. Body mass index is preferable over other indices of relative weight, and simple in calculation, in contrast to the percentage of average weight[15]. BMI was acquired by means of the equation demonstrated below.

$$\text{BMI} = \frac{\text{weight}}{\text{height}^2} \quad \text{(height : m, weight : Kg)}$$

Student's t-test and paired t-test were used for statistical analysis : $p < 0.05$ was considered to be significant. The obtained image, scanning, and the measurements were carried out by one investigator(the author).

III. RESULTS

The mean value and standard deviation of the

Table II. The values of the echogenicity of parotid glands

Age Group	Mean (± S.D.)	
	Male	Female
Young	133.9 (41.5)	123.9 (31.3)
Middle	150.0 (49.7)	165.0 (47.0)
Old	187.2 (41.2)	192.4 (35.5)
Total	157.0 (48.7)	160.4 (47.0)

Table Ⅲ. The values of the echogenicity of submandibular glands

Age Group	Mean (± S.D.)	
	Male	Female
Young	146.2 (50.9)	145.7 (55.3)
Middle	168.3 (58.4)	161.9 (44.8)
Old	202.1 (58.8)	198.6 (40.6)
Total	172.3 (58.8)	172.1 (50.6)

Table Ⅳ. Statistical comparison of the average values of the echogenicity according to sex and gland (student's t-test and paired t-test)

Gland	Mean(±S.D.)		Significance
	Male	Female	
Parotid gland	157.0(48.7)	160.4(47.0)	N.S.
Submandibular gland.	172.3(58.8)	172.1(50.6)	N.S.
Significance	*	N.S.	

* : p < 0.05, N.S. : not significant

echogenicity for the parotid glands is shown in Table Ⅱ. There was an age-dependent increase in the mean value, for both male and female, although the standard deviation was large ($p<0.05$). But the difference between middle and old age group in male and young and middle age group in female were not significant. The difference in mean value of the echogenicity between male and female was small.

Table Ⅲ depicts the mean values and standard deviation of the echogenicity for the submandibular glands. As in the parotid gland, there was an increase in the mean values with increasing age in male, except between young and middle group($p<0.05$). But in case of female, there was significant difference only between young and old age group. The difference in mean value between male and female was also small.

Statistical comparison of the echogenicity of parotid and submandibular glands according to sex and gland is shown in Table Ⅳ. There was no sex difference in the average values for all age groups in both types of salivary glands. The average values were higher in the submandibular than parotid gland of both sex. But there was significant difference only in male ($p< 0.05$).

Mean absolute difference between the values of echogenicity for the right and left glands is recorded in Table V. There was no significant difference between the values of echogenicity of right and left glands. And there was no significant sex difference between the mean absolute difference of right and left glands in both glands. But the mean absolute difference was higher in female than in male($p< 0.05$).

There was moderate positive correlation between the mean values of the echogenicity in the parotid and the submandibular glands (Table Ⅵ).

Correlation coefficient between the mean value echogenicity and body mass index(BMI) are presented in Table Ⅶ. There was close correla

Table V. The mean absolute difference between the values of the echogenicity for right and left glands.

Gland	Mean (± S.D.)	
	Male	Female
Parotid gland	25.4(21.8)	32.9(33.0)
Submandibular gland	28.8(21.5)	38.9(33.8)

Table VI. Correlation coefficient between mean values of the echogenicity in the parotid gland and the submandibular glands.

Age Group	Correlation coefficient	
	Male	Female
Young	0.32	0.67
Middle	0.53	0.26
Old	0.54	0.39
Total	0.56	0.54

Table VII. Correlation coefficient between the mean values of the echogenicity and body mass index.

Age Group	Correlation coefficient			
	Parotid gland		Submandibular gland	
	Male	Female	Male	Female
Young	-0.11	0.19	0.23	0.07
Middle	0.61	0.14	0.76	-0.01
Old	0.39	0.45	0.39	0.09
Total	0.26	0.23	0.36	0.10

tion only in the both types of salivary glands of male middle age group.

IV. DISCUSSION

Echogenicity of the normal major salivary glands have not received much attention, although past workers have made limited investigations. CT number is expressed by X-ray attenuation coefficient of tissues. Ultrasonic beam is reflected or scattered[16] at the interface between impedance. (The ultrasound beam reflected or scattered is picked up by the transducer and is called echos). Echo intensity, i.e., echogenicity is influenced by the average size and the number of interfaces of a partcular gland. Normal salivary glands have both hyperechogenic and homogenous pattern because of their multiple, evenly distributed fibrous septae that appear as large interfaces to the ultrasonic beam. This studies demonstrated a grossly age-dependent increase of the echogenicity of major salivary glands except the sublingual gland. The subligual gland was excluded because of its location and size.

According to Ariji et al.[12], age-dependent decrease in CT number has been noted for the parotid and submandibular gland. The decrease can be attributed to that the CT numbers of salivary gland are thought to reflect the adipose tissue content[17] and the parenchyma of human major salivary glands is replaced by fat with increasing age[18]. Since the CT number for adipose tissue is lower, the adipose tissue content infiltrating into salivary gland parenchyma results in the decrease of the CT number.

However, it is not clear how much the adipose tissue can influence on the echogenicity of the parenchyma of salivary glands. Generally, the fibrous tissue is believed to be more important contributing factor that produces echogenicitiy than the adipose tissue in salivary glands. We need more substantial studies of evaluating tissues with histological techniques before one could be absolutely certain of the meaning of echogenic changes by fatty infiltration in glandular parenchymal tissue. The increase of the echogenicity in the old age group should also be integrated in concert with histological changes that may modulate the number and size of interfaces in the salivary gland under study.

It is well known that secretory portion atrophies with aging[19,20], and the fibro-adipose tissue replaces the reduced portion[21,22]. Throughout all salivary glands, there is a fine network of supporting connective tissues extending from the capsule to interlobular septae and intralobularly surrounding the individual parenchymal unit element. The main collecting ducts are also ensheathed in fibrous tissue which is continuous with fine intralobular fibrillar network. In salivary glands, there is an age-related increase in the amount and density of this fibrous skeletal component surrounding the ducts and in septae[23]. Collagenous fibers become denser, more fragmented and less evenly regularly oriented. And elastic fibers are more numerous, thicker, and fragmented with aging. Because fibrous skeleton composed of collagenous fibers are major source of the echogenicity, it is natural that the increase of echogenicity with respect to age groups for salivary glands.

According to Ida et al[17], the CT number of parotid gland in female was lower than that in male, however there was no significant difference. Although there was a trend towards a greater adipose proportional volume in female, the difference between the sexes did not achieve statistical significance in the histological study[19]. The result of histological study was roughly compatible with the study of CT number mentioned above. However, there was no sex difference in the values of echogenicity for both parotid and submandibular glands in this study. Conclusively, the content of adipose tissue may not have a direct relation with the echogenicity of salivary glands.

The mean value of the echogenicity of the submandibular gland was higher than that of the parotid gland in all age groups. Additionally there was significant difference between the parotid and submandibular gland in male. The fibrous skeletal component around the ducts is also expected to contributing to echogenicity. There is an age-dependent increase in the amount and density of this fibrous skeleton around the duct. These changes are particulary well developed in man and particularly in aging submandibular gland[23,24]. The proportional volume of duct of submandibular glands is higher than that of parotid gland which is largely due to the relatively abundant of intralobular ducts. Although fibrous ducts account for only a small fraction of whole gland fibrous skeleton, it can be surmised to influence on echogenicity of salivary glands, particularly the submandibular gland. The fact that the echogenicity of submandibular gland is higher than that of parotid gland is reasonably understood. However future investigation of, using different methodology, relationship between fibrous skeleton from ducts and echogenicity is needed.

The mean absolute difference of right and left glands in both glands was somewhat large, but was not significant. This result is similar to the result of Ariji et al [12] using CT number. They concluded there was no difference between the mean CT number of right and left glands in both glands. In this study the difference was higher in females than in males for both salivary glands.

There was moderate positive correlation between the mean values of the echogenicty in parotid and submandibular gland. There was wide individual difference in the values of echogenicity inspite of the same age group. But in an individual, the salivary gland with high echogenicity tend to show that high echogenicity for the other salivary gland. Both salivary glands may resemble together in respect to aging process and histological proportion of fibrous tissue.

There was weak correlation between the value of echogenicity and body mass index(BMI). Undoubtedly, there is an increase in the level of adiposity with increasing age in salivary glands. But the amount of adipose tissue, which is widely variable from gland to gland in any age group, has been shown to be independent of the general adiposity of the individual[15]. Moreover the effect of adipose tissue on echogenicity is lower than that of fibrous tissue.

The obtained results were discussed based on the previous studies that have evaluated the CT number of human salivary gland according to age, sex and gland. The authors of these studies have came to several logical arguments which have been drawned deduction from the other histological studies about the salivary glands. They have explained the role of the adipose tissue in lowering the CT number of salivary glands with aging, because histological studies have indicated that aged person had more fatty salivary gland than younger person. The way that we make conclusions were the same as the above. Indirect explanation for the obtained results can be accepted logically, but can not be regarded as distinctive and clear conclusion. The previous histological studies will be kept for future reference. And histological study connected with the echogenicity of salivary glands is absolutely needed for the elucidation of relation between histological elements and the echogenicity of salivary glands. This thesis must be a starting point for clarifying the relationship between age-related echogenic change and histological change in normal salivary glands.

V. CONCLUSION

The ninety healthy volunteers, 45 males and 45 females, served as subjects in this experiment to evaluate normal range of the echogenicity of ultrasonography in healthy salivary gland. After obtaining sonographic imaging papers and scanning of imaging papers, the number for gray scale histogram of ultrasonography was measured by Photoshop program and the value of echogenicity was calculated from the measured number. The correlation of the echogenicity with age, the difference between the echogenicity of male and female, parotid and submandibular gland, right and left glands, and the correlation of the echogenicity with BMI were investigated

After having received the results of the study, the author came to the following conclusions.

1. There was increasing pattern of echogenicity according to aging in both parotid and submandibular glands and there was significant difference between the young groups and the

old age groups($p<0.05$).

2. There was no significant sex difference in echogenicity of both parotid and submandibular glands.
3. The echogenicity of submandibular gland was higher than that of parotid gland regardless to sex and there was significant difference between parotid and submandibular gland in male.
4. There was no significant difference between the mean absolute difference of right and left glands.
5. There was moderate positive correlation between the echogenicity of parotid gland and submandibular gland(male : $r = 0.56$, female : $r = 0.54$).
6. There was a weak positive correlation between the echogenicity of salivary gland and BMI.

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국문초록

정상 이하선과 악하선에 대한 초음파영상의 반향성 평가

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타액선 병변의 일반적인 영상진단법으로는 타액선조영술, 전산화단층촬영술, 자기공명영상, 타액선 스캔, 초음파촬영술이 있다. 이중 초음파촬영술은 타액선내 종양의 유무를 평가하는데 있어서 매우 우수하여, 전산화단층촬영이나 자기공명영상과 더불어 이용되고 있으나, 염증을 진단하는데 있어서는 타액선조영술보다 민감도가 떨어지는 단점이 있다.

일반적으로 타액선의 염증반응시 초음파상은 반향이 정상보다 낮아지며, 내부의 균질성이 떨어지는 양상을 보여 이를 진단의 기준으로 이용해왔으나 정상타액선에서도 반향이 편차가 심할뿐만 아니라 연령에 따른 정상 타액선의 반향성에 대한 연구가 부족하여 진단에 어려움이 있었다. 이에 저자는 우선적으로 타액선에 병적인 증상이 없는 남녀 90명을 연령별(20~35세 : 청년군, 36~55세 : 중년군, 55~70세 : 노년군), 성별에 따라 분류하여 정상 타액선의 초음파상을 얻었다. 이의 반향을 측정하고, 비만한 정도를 나타내는 체격지수를 구하여 다음과 같은 결과를 얻었다.

1. 이하선과 악하선 모두에서 연령군에 따라 반향성이 증가하는 양상을 보였으며, 청년군과 노년군 사이에는 유의한 차이가 있었다($p < 0.05$).
2. 이하선과 악하선 모두에서 성에 따른 반향성의 유의한 차이는 없었다.
3. 성에 관계없이 악하선의 반향성이 이하선의 반향성보다 높았으며, 남자에 있어서는 유의한 차이가 있었다($p < 0.05$).
4. 동일한 타액선에서 좌우측 타액선의 반향성의 평균 차이값은 유의한 차이가 없었다.
5. 이하선과 악하선의 반향성은 중등도의 양의 상관관계를 보였다(남자 : $r = 0.56$, 여자 : $r = 0.54$).
6. 체격지수와 타액선의 반향성은 약한 양의 상관관계를 보였다.

주요어 : 타액선, 이하선, 악하선, 초음파영상, 반향성