Development of Ultrasound Phantom for Volume Calibration

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The purpose of this study was to design and construct an ultrasound phantom for volume calibration and evaluate the volume measurement accuracy of a 2 dimensional ultrasonic system. Ultrasound phantom was designed, constructed and tested. The phantom consisted of a background material and a target. The background was made by mixing agarose gel with water. A target, made with an elastic material, was filled with water to vary its volume and shape and inserted into background material. To evaluate accuracy of a 2 dimensional ultrasonic system (128XP, ACUSON), three different shapes of targets (a sphere, 2 ellipsoids and a triangular prism) were constructed. In case of ellipsoid shape, two targets, one with same size length and width (ellipsoid 1) and another with the length 2 times longer than width (ellipsoid 2) were examined. The target volumes of each shape were varied from 94cc to 450cc and measurement accuracy was examined. The volume difference between the real and measured target of the sphere shape ranged between 6.7 and 11%. For the ellipsoid targets, the differences ranged from 9.2 to 10.5% with ellipsoid 1 and 25.7% with ellipsoid 2. The volume difference of the triangular prism target ranged between 20.8 and 35%. An easy and simple method of constructing an ultrasound phantom was introduced and it was possible to check the volume measurement accuracy of an ultrasound system.

Key Words: Ultrasound phantom, Volume calibration

INTRODUCTION

There have been many publications on the effects of bladder volume on the prostate position change during radiotherapy[1-5] and techniques were introduced to maintain the bladder volume. One of the methods is to instruct the patients to empty the bladder and drink a certain amount water prior to daily treatment.[6-10] This method was found to be useful in reducing bladder volume variation between the treatments. Ultrasound is a good candidate for soft tissue imaging and it has been used for many years to measure ovarian, prostate, and urine volumes.[11-13] The volume of an organ measured with a two dimensional ultrasonic system is calculated by estimating certain shape such as ellipsoid or cylinder. In case of ellipsoid, a simple formula (width×length×thickness×0.523) is used.[12] On the other hand, three dimensional ultrasound systems use various calculation algorithms and calculations are performed by dedicated computer software. The volume calculation accuracy of 2 and 3 dimensional ultrasound system has been studied[14-17] and showed good agreement in both system. However, the effects of shape and volume on measurement accuracy have not been studied yet. In the present study, we aimed to construct an ultrasound phantom for volume calibration and the phantom is used to evaluate the accuracy of volume measured using 2 dimensional ultrasonic system.

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MATERIALS AND METHODS

An ultrasound phantom was designed and constructed to evaluate the volume measurement accuracy of a two dimensional ultrasound system. It is consisted of a background material and a target (Fig. 1). The background material was made by mixing high strength agrose gel (1.5% by weigh: iNtRON Biotechnology) with water. The background material was then heated in microwave oven for 5∼10 minutes to make a gel type solution. The target was designed such that the volume and shapes can be changed. Three shapes of targets were constructed. These include sphere, 2 ellipsoids (one with equal length and width and another with longer length), and triangular prism. The sphere target was made out of balloon and filled with 94, 150, 200, 300, 400, and 450 cc of water. The ellipsoid target was made out of condom and the volumes were 100 and 150 cc. The triangular prism target was made out of a plastic mold and it was filled with 235 cc of water. The melted background material was poured into a flat glass container and left at room temperature for about 1 hour. After the gel became little hard, the targets were located in the middle of the container and the container was filled with melted agarose gel and dried for 1 day.

The volumes of phantoms were measured using 2 dimensional ultrasonic system by a radiation medical specialist. The observer had no knowledge of volume information. The phantom was scanned in two directions (anterior-to posterior direction, and lateral direction) using ultrasound probe. From the acquired ultrasound images of the target, two points on each image were identified as shown in the Figure (Fig. 2). Then the system calculated target volume automatically. Five to six measurements were performed for each target except the triangular prism. The measurements were repeated 14 times for the triangular prism target because there was large difference between measured and actual volume. The volume differences between actual and measure volumes were calculated for accuracy evaluation.

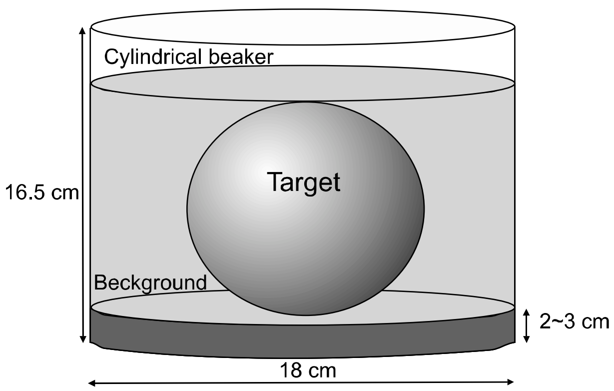

Fig. 1. Schematic diagram of an ultrasound phantom.

RESULTS AND DISCUSSION

The target images taken using the 2D ultrasound system are shown in Fig. 2. The target volumes were calculated if the

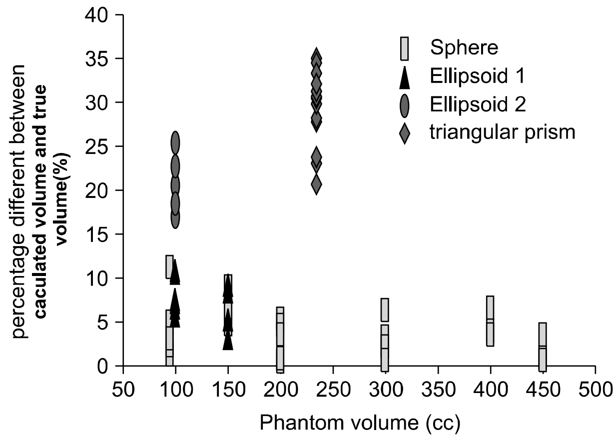

Fig. 3. Percentage difference between the real volume and measured volume measured by the 2 dimensional ultrasonic image.

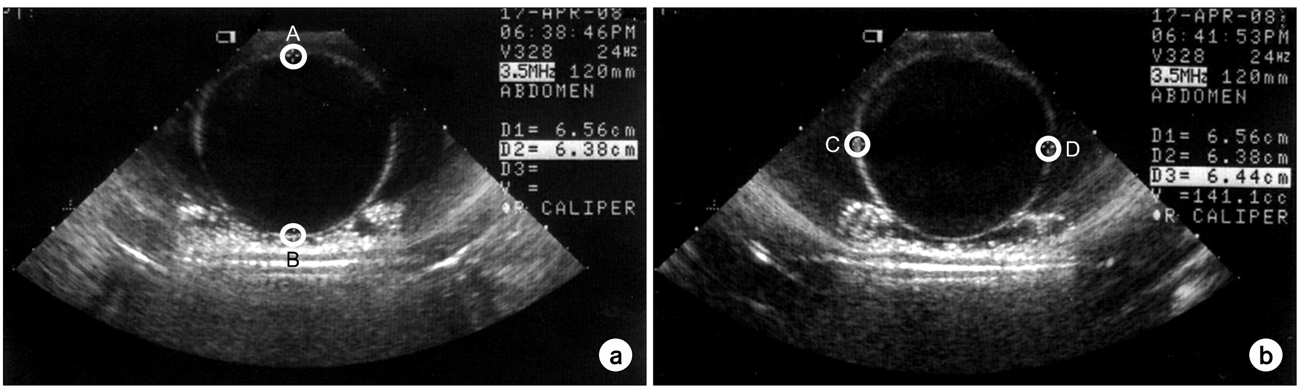

Fig. 2. Ultrasound images of a sphere phantom. (a) AP images (b) Lateral images.

Table 1. Accuracy result measured according to the volume and form of phantom.

Shape	Real Volume (cc)	The number of measurements	Error limits (cc)	Percentage differences (%)
Sphere	94	6	−10.4∼+2.6	1.0∼11.05
	150	5	−13.4∼−7.3	5.13∼8.93
	200	7	−0.4∼+4.9	0.05∼4.90
	300	4	−17.5∼+0.2	0.07∼5.83
	400	6	+15∼+26.7	3.75∼6.68
	450	6	−4.2∼+14.9	0.8∼3.73
Ellipsoid 1	100	6	−5.48∼−10.4	5.48∼10.4
	150	6	−5.1∼−13.8	3.4∼9.2
Ellipsoid 2	100	6	−17.3∼+25.7	17.3∼25.7
triangular prism	235	14	−82.2∼−70	20.8∼35.0

points A and B from AP image and C and D from lateral image were determined. The percentage volume differences between the real and measured volumes of the targets are shown in Fig. 3. The volume differences were correlated with changes in target size and shape. For the sphere target, the difference in volume between measured and true volume was 11, 9, and 6.7% when the size of target was 100, 150, and between 200 and 450 cc, respectively. In case of ellipsoid target, the differences were 10.5, and 9.2% when the size were 100 and 150 cc for ellipsoid 1 and 25.7% when the target volume was 100 cc. The difference ranged between 20.8 to 35.0% when the target was the triangular prism shape (Table 1).

CONCLUSION

In the present study, we designed and constructed an ultrasound phantom for volume calibration. By using the designed ultrasound phantom, it was possible to check the volume measurement accuracy of an ultrasound system. Using 2 dimensional ultrasonic system, the volume measurement accuracy was investigated by varying target volume and shape. The accuracy was unacceptable if the target is either in ellipsoid 2 or triangular prism shape. Since the volume measurement accuracy depends on target shape and size, it is recommended to calibrate an ultrasound system if it is going to be used for volume measurements of an organ.

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부피 측정을 위한 초음파 팬텀 개발

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본 연구에서는 2차원 초음파 시스템의 체적 측정 정확성을 측정하기 위한 초음파 팬텀을 설계 및 제작하였다. 팬텀은 체적 측정용 타겟과 백그라운드 물질로 구성되었다. 백그라운드 물질은 agarose gel과 물을 혼합하여 만들었다. 타켓은 모양과 부피를 변화시키기 위하여 신축성 있는 물질로 선택하였고 타겟에 물을 채운 후 백그라운드 물질에 삽입하였다. 2차원 초음파 시스템의 정확성을 평가하기 위하여 세가지 형태의 타겟(구형, 2가지 형태의 타원형, 삼각 기둥형)을 제작하였다. 타원형의 경우, 하나는 길이와 폭의 크기가 비슷하도록 제작하였고(타원 1) 다른 하나는 길이가 폭보다 2배 이상인 모양(타원 2)으로 제작하였다. 각각 형태의 타겟 부피는 94 cc에서 450 cc까지 변화하였고 2차원 초음파 장비(128XP, ACUSON)를 이용하여 정확성을 측정하였다. 구 모양의 타겟에 삽입된 물의 실제 체적과 측정된 체적 간의 차는 6.7에서 11% 이다. 타원형 타겟의 경우 타원 1은 9.2에서 10.5% 사이의 차이를 보이는데 타원 2의 경우는 25.7%의 오차가 있다. 삼각기둥 형태의 경우는 실제체적과 측정체적간 20.8에서 35%의 차이를 보였다. 쉽고 간편한 방법의 초음파 팬텀의 제작 방법을 소개하였고 제작된 팬텀을 이용할 경우 초음파 시스템의 부피 측정 정확성을 평가할 수 있음을 입증하였다.

중심단어: 초음파 팬텀, 부피 측정