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The Research on the Volume of Artificial Structure by the Change of Scan Parameter in CT Inspection

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Abstract

Background/Objectives: The globular and rectangular artificial structures were prepared in order to compare the actually measured volume with the CT image volume obtained by using modified scan parameters, and to compare the errors of these volumes. **Methods/Statistical Analysis**: A plastic with 57.3 Mℓ globular artificial structures and a rectangular artificial structure filled with a 1.9 ℓ contrast medium mixed with distilled water at a ratio of 1:20 were placed on a table. The image data of the following conditions were obtained, namely, 5 mm, 3.75 mm, 2.5 mm, 1.25 mm, and 0.625 mm slice thicknesses; 100 kv and 120 kv tube voltages; 100 mA and 200 mA tube currents; 0% and 50% overlapped slice spaces; standard algorithm; and bone scan parameters. **Findings:** The volume changes in the rectangular artificial structure were less than those in the globular artificial structure. Other than the slice thickness, the effects of slice space, tube voltage, tube current, bone algorithm or standard algorithm on the image quality, and the volumes of the actual model and obtained image were insignificant. The thinner slice of the scan parameter enhanced the volume accuracy of the obtained image, while the thicker slice reduced the image distortion and accuracy. **Application/Improvements:** CT image accuracy and optimization are significantly dependent on the slice space. Therefore, a thin slice is absolutely required to obtain accurate CT images that are used for facial and cranial measurement in forensic medicine and dentistry, tests for restoration, liver transplant, and artificial joint tests.

Keywords: Artificial Structure, CT Inspection, CT Parameter, CT Volume, Slice Thicknesses

1. Introduction

The clinical efficiency of CT has significantly increased due to the developments in CT technologies. Meanwhile, high quality images for accurate diagnoses with low dosage and low radiation dose rates have drawn attention. In particular, the matching accuracy in size and shape between the CT images and actual deformity of the patients is important. Image quality and accuracy can be enhanced with a higher CT dosage; however, the radiation dose rate increases accordingly. If a low-dose CT scan with a lower radiation dose rate is used, the accuracy and quality of the images deteriorate. As a result, it is important to use a minimal dose while accurate diagnoses are still viable[1]. A CT scan has various algorithms depending on the diseases and symptoms, while the radiation dose rates are determined accordingly. Since the dose rate increases with repeated scans on the same site, an optimal algorithm for minimal scans is required[2,3]. In this study, globular and rectangular artificial structures were prepared by using various scan parameters that are highly associated with the CT image quality and accuracy. The image change according to the slice thickness, slice space, tube voltage, tube current, and algorithm, were compared and analyzed by using the actual volume and obtained image volume. Based on the obtained 3D images, changes in the artificial structure volume were measured, and the scan parameters that satisfy the guidelines of the CT scan accuracy, validity, and optimization were suggested.

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2. Materials and Methods

2.1 Experiment Equipment

The Discovery CT750HD, GE Healthcare USA CT hardware and workstation (GE advantage workstation Ver. 4.4) software in a university hospital were used. The Discovery CT750HD uses a new image formation method of advanced statistical iterative reconstruction (ASIR), which realizes 33% increased high-definition images with a lower dosage, as compared with typical CT methods.

2.2 Experiment Methods

A plastic with 57.3 Mℓ globular artificial structures [Figure 1] and a rectangular artificial structure [Figure 2] filled with a 1.9 ℓ contrast medium mixed with distilled water at a ratio of 1:20 were placed on a table. The image data of the following conditions were obtained, namely, 5 mm, 3.75 mm, 2.5 mm, 1.25 mm, and 0.625 mm slice thicknesses; 100 kV and 120 kV tube voltages; 100 mA and 200 mA tube currents; 0% and 50% overlapped slice spaces; standard algorithm; and bone scan parameters. The obtained images were transferred to GE Advantage Workstation Ver. 4.4 to be three dimensionally visualized with a 2,000 high threshold value and a -200 low threshold value. In addition, the images were three dimensionally (3D) edited using the volume rendering technique to compare their volumes with the actual volume according to the artificial structure parameters[4].

3. Results

3.1 The Volume by Segment Thickness

At the slice thickness of 5 mm, the volume in the globular artificial structure was 55.34 cm^3; at 3.75 mm, 56.13

Figure 1. Globular artificial structure with 57.3 Mℓ volume.

Figure 2. Rectangular artificial structure with 1.9 ℓ volume (contrast medium: distilled water = 1:20).

cm^3; at 2.5 mm, 56.65 cm^3; at 1.2 mm, 57.10 cm^3; and at 0.625 mm, 57.16 cm^3, thereby showing a significant 3% difference from the active volume between 5 mm and 0.625 mm. With the decreasing slice thickness, the artificial structure volume increased in order to approach the actual volume [table 1] [Figure 3]. Meanwhile, at the slice thickness of 5 mm, the volume in the rectangular artificial structure was 1,886.26 cm^3; at 3.75 mm, 1,887.05 cm^3; at 2.5 mm, 1,888.02 cm^3; at 1.2 mm, 1,891.53 cm^3; and at 0.625 mm, 1,892.54 cm^3, thereby showing a 0.4% difference from the active volume between 5 mm and 0.625 mm. With the decreasing slice thickness, the artificial structure volume mildly increased, but the difference was insignificant [table 2] [Figure 4].

3.2 The Volume by the Change of Tube Voltage and Tube Current

Volume changes according to tube voltages and tube currents at 120 kV, 200 mA, 100 kV, and 100 mA were compared. At the slice thickness of 5 mm, the volume in the globular artificial structure was 55.34/55.20 cm^3, and at 0.625 mm, 57.16/57.12 cm^3 [table 3] [Figure 5]. At the slice thickness of 5 mm, the volume in the rectangular artificial structures was 1,886.26/1,886.01 cm^3, and at 0.625 mm, 1892.54/1,890.41 cm^3, thereby showing no significant differences [table 4] [Figure 6].

3.3 The Volume by the Segment Interval

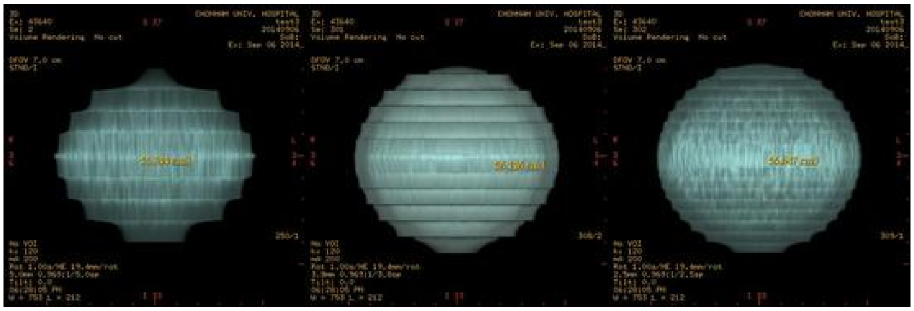
Volume changes according to the slice space in non-overlapped images and 50%-overlapped images are compared. At the slice thickness of 5 mm, the volume in the globular artificial structure was 55.34/54.87 cm^3, at 2.5 mm, 56.65/56.41 cm^3, and at 1.25 mm, 57.10/57.02 cm^3 [table 5] [Figure 7]. At the slice thickness of 5 mm, the volume in the rectangular artificial structure was 1,886.26/1,884.35

Table 1. Globular artificial structure information according to slice thickness

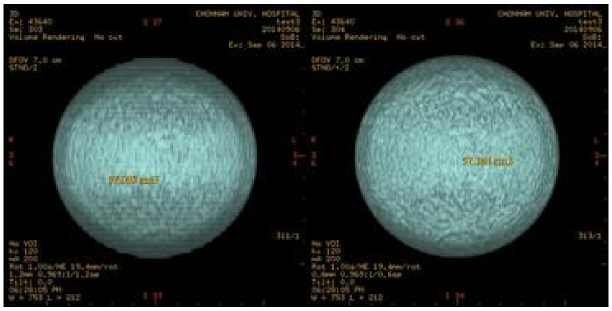
Slice Thickness (mm)	Volume (mℓ)	Volume Differences (%)	Average (%)
5.00	55.34	3.42	1.44
3.75	56.13	2.04	
2.50	56.65	1.13	
1.25	57.10	0.35	
0.63	57.10	0.24	

Table 2. Rectangular artificial structure information according to slice thickness

Slice Thickness (mm)	Volume (mℓ)	Volume Differences (%)	Average (%)
5.00	1886.26	0.72	0.57
3.75	1887.05	0.68	
2.50	1888.02	0.63	
1.25	1891.53	0.45	
0.63	1982.54	0.39	

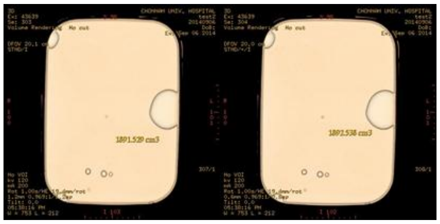


slice thickness 5.00 ㎜ slice thickness 3.75 ㎜ slice thickness 2.50 ㎜



slice thickness 1.25 ㎜ slice thickness 0.625 ㎜

Figure 3. Globular artificial structure images according to slice thickness.



slice thickness 5.00 ㎜ slice thickness 3.75 ㎜ slice thickness 2.50 ㎜ slice thickness 1.25 ㎜ slice thickness 0.625 ㎜

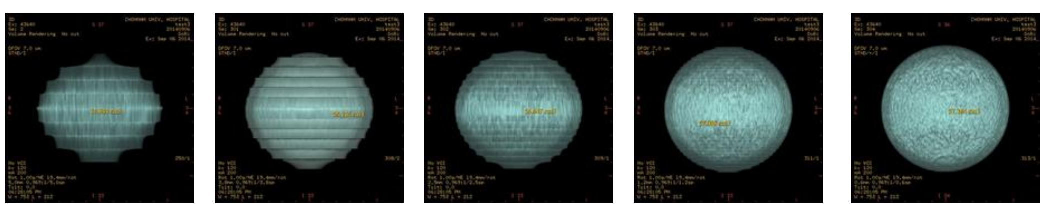
Figure 4. Rectangular artificial structure images according to slice thickness.

Table 3. Globular artificial structure information according to kV and mA changes

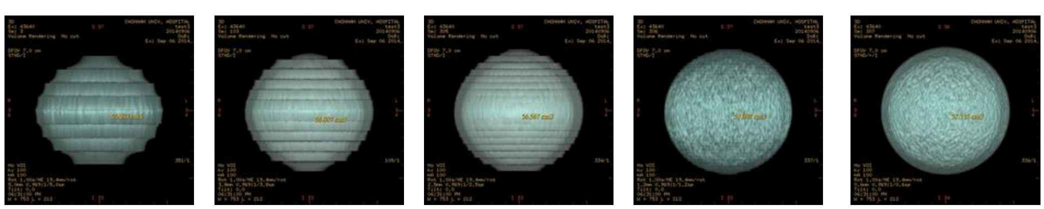
Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
120 kV 200 mA	5.00	55.34	3.42	1.44
	3.75	56.13	2.04	
	2.50	56.65	1.13	
	1.25	57.10	0.35	
	0.63	57.16	0.24	
100 kV 100 mA	5.00	55.20	3.66	1.59
	3.75	56.01	2.25	
	2.50	56.57	1.27	
	1.25	57.05	0.44	
	0.63	57.12	0.31	

Table 4. Rectangular artificial structure information according to kV and mA changes

Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
120 kV 200 mA	5.00	1886.26	0.75	0.57
	3.75	1887.05	0.68	
	2.50	1888.02	0.63	
	1.25	1892.54	0.45	
	0.63	1886.54	0.39	
100 kV 100 mA	5.00	1886.04	0.74	0.65
	3.75	1886.24	0.72	
	2.50	1886.49	0.71	
	1.25	1889.47	0.55	
	0.63	1890.41	0.50	



120 kV, 200 mA slice thickness 5.00 mm | 120 kV, 200 mA slice thickness 3.75 mm | 120 kV, 200 mA slice thickness 2.50 mm | 120 kV, 200 mA slice thickness 1.25 mm | 120 kV, 200 mA slice thickness 0.625 mm



100 kV, 100 mA slice thickness 5.00 mm | 100 kV, 100 mA slice thickness 3.75 mm | 100 kV, 100 mA slice thickness 2.50 mm | 100 kV, 100 mA slice thickness 1.25 mm | 100 kV, 100 mA slice thickness 0.625 mm

Figure 5. Globular artificial structure images according to kV and mA change.

120 kV, 200 ㎃ slice thickness 5.00 ㎜ | 120 kV, 200 ㎃ slice thickness 3.75 ㎜ | 120 kV, 200 ㎃ slice thickness 2.50 ㎜ | 120 kV, 200 ㎃ slice thickness 1.25 ㎜ | 120 kV, 200 ㎃ slice thickness 0.625 ㎜

100 kV, 100 ㎃ slice thickness 5.00 ㎜ | 100 kV, 100 ㎃ slice thickness 3.75 ㎜ | 100 kV, 100 ㎃ slice thickness 2.50 ㎜ | 100 kV, 100 ㎃ slice thickness 1.25 ㎜ | 100 kV, 100 ㎃ slice thickness 0.625 ㎜

Figure 6. Rectangular artificial structure images according to kV and mA changes.

Table 5. Globular artificial structure information according to slice space change

Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
0% overlapped	5.00	55.34	3.42	1.63
	2.50	56.65	1.13	
	1.25	57.10	0.35	
5% overlapped	5.00	54.87	4.24	2.09
	2.50	56.41	1.55	
	1.52	57.02	0.49	

Table 6. Rectangular artificial structure information according to slice space change

Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
0% overlapped	5.00	1886.26	0.72	0.60
	2.50	1888.02	0.63	
	1.25	1891.53	0.45	
5% overlapped	5.00	1884.35	0.82	0.65
	2.50	1887.58	0.65	
	1.52	1890.59	0.48	

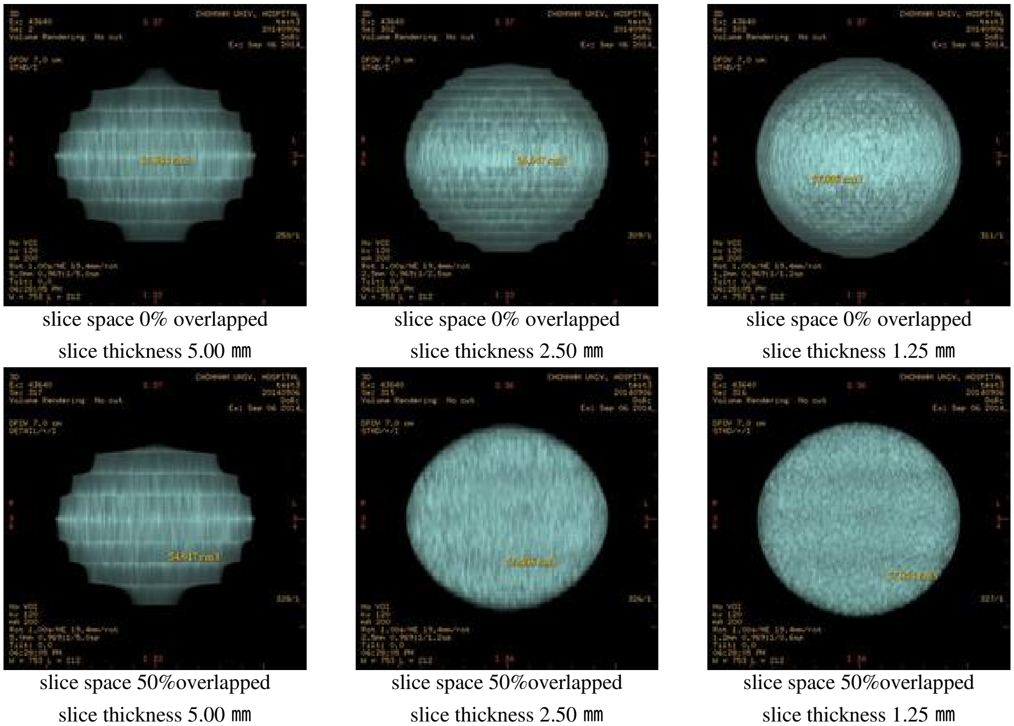


Figure 7. Globular artificial structure images according to slice space change.

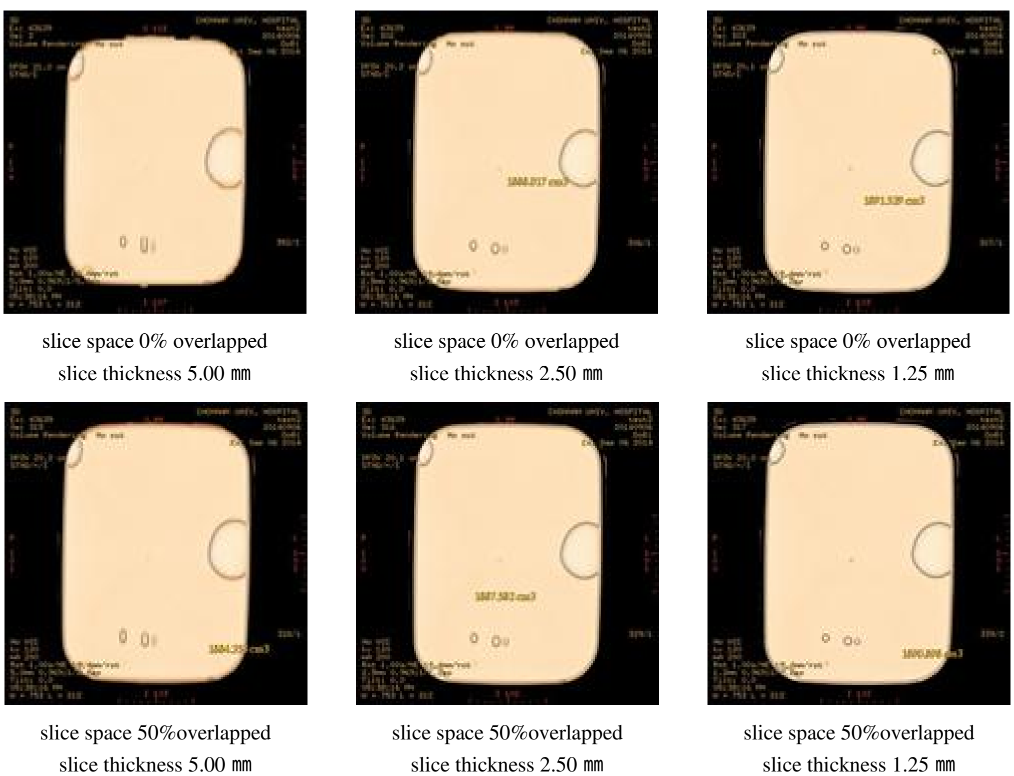


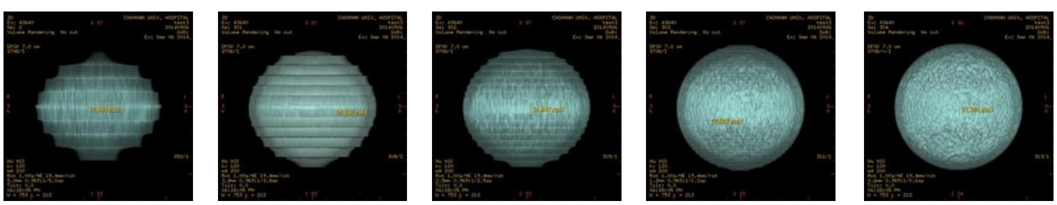
Figure 8. Rectangular artificial structure images according to slice space change.

Table 7. Globular artificial structure information according to algorithm change

Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
Standard	5.00	55.34	3.42	1.43
	3.75	56.16	2.04	
	2.50	56.65	1.13	
	1.25	57.10	0.34	
	0.63	57.16	0.24	
Bone	5.00	55.61	2.95	0.76
	3.75	56.41	1.55	
	2.50	56.96	0.59	
	1.25	57.57	-0.47	
	0.63	57.77	-0.82	

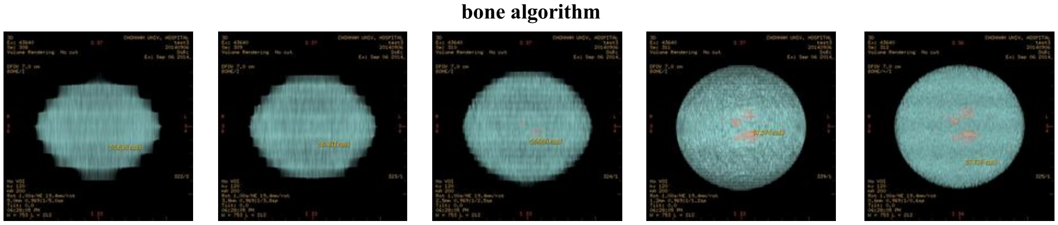
Table 8. Rectangular artificial structure information according to algorithm change

Classification	Slice Thickness (mm)	Volume (Mℓ)	Volume Differences (%)	Average (%)
Standard	5.00	1886.26	0.72	0.57
	3.75	1887.05	0.68	
	2.50	1888.02	0.63	
	1.25	1891.53	0.45	
	0.63	1892.54	0.39	
Bone	5.00	1892.76	0.39	0.11
	3.75	1895.85	0.22	
	2.50	1897.46	0.13	
	1.25	1901.46	-0.07	
	0.63	1902.48	-0.13	



slice thickness 5.00 ㎜ | slice thickness 5.00 ㎜ | slice thickness 2.50 ㎜ | slice thickness 2.50 ㎜ | slice thickness 0.625 ㎜

bone algorithm



slice thickness 5.00 ㎜ | slice thickness 3.75 ㎜ | slice thickness 2.50 ㎜ | slice thickness 1.25 ㎜ | slice thickness 0.625 ㎜

Figure 9. Globular artificial structure images according to algorithm change.

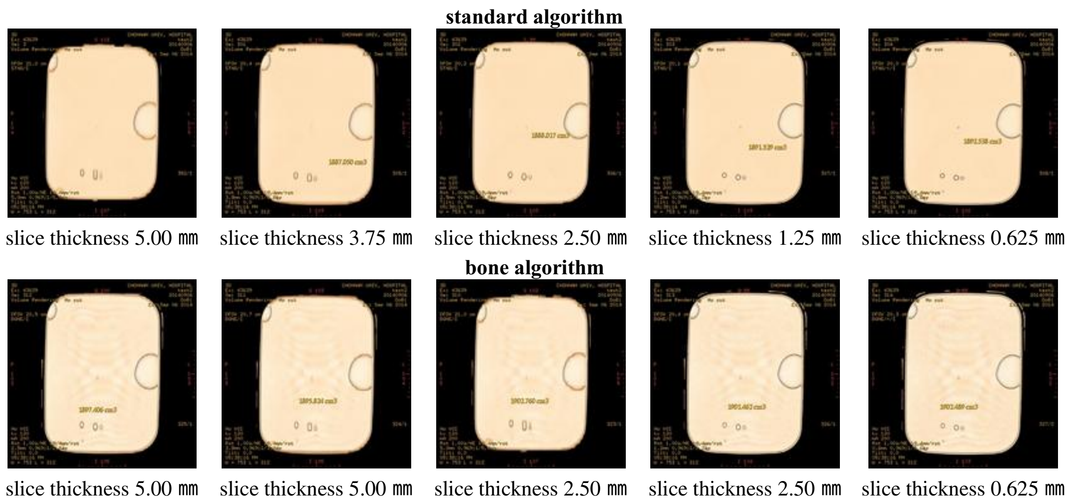


Figure 10. Rectangular artificial structure images accoding to algorithm change.

cm³, at 2.5 mm, 1,888.02/1,887.58 cm³, and at 0.625 mm, 1,891.54/1,890.89 cm³, thereby showing no significant difference in the volume change [table 6] [Figure 8].

3.4 The Volume by Algorithm

Volume changes, according to the standard and bone algorithms, were compared. At the slice thickness of 5 mm, the volume in the globular artificial structure was 55.34/55.61 cm³; at 3.75 mm, 56.13/56.41 cm³; at 2.5 mm, 56.65/56.96 cm³; at 1.2 mm, 57.10/57.57 cm³; and at 0.625 mm, 57.16/57.77 cm³ [Table 7] [Figure 9]. At the slice thickness of 5 mm, the volume in the rectangular artificial structure was 1,886.26/1,902.76 cm³; at 3.75 mm, 1887.05/1895.82 cm³; at 2.5 mm, 1,888.02/1,897.46 cm³; at 1.2 mm, 1,891.53/1,901.46 cm³; and at 0.625 mm, 1,892.54/1,902.48 cm³, thereby showing no significant differences in volume change [Table 8] [Figure 10].

4. Conclusions

The diagnostic X-ray equipment, including the CT, is used to obtain accurate images of minute lesions with minimal dosage[5]. CT images can be used for measuring the accurate volume of lesions these days. They are used not only for liver transplant surgery, artificial joints, facial deformities, and mock corrective-orthognathic surgery, but they are also used for interpreting anatomical structures, explanations to patients, and fixtures on the model. Accuracy is an important issue[6]. According to Matteson et al. on the volume accuracy and image errors, the errors of a dry 3D cranial bone image model were 0.19 mm (0.28%) in length and 0.38˚ (1.39%) in degrees[7-10]. While obtaining the CT images, many factors can produce discrepancies between the actual patient data and obtained image data. Scan parameters that are particularly associated with the image quality can significantly affect the image accuracy. Parameters, such as slice space, slice thickness, tube current, tube voltage, and algorithm, must be enhanced in order to obtain highly accurate images, and improve the signal to noise ratio and image quality. However, this may cause an increase in the patients' radiation dose rate. In this study, the difference in the volume between the actual model and CT images was compared at various scan parameters. Image changes according to the scan parameters, such as tube current, slice thickness, pitch, and 3D image reformation thresholds were measured. With the increasing helical pitch and slice thickness, the volume and diameter of the artificial structure decreased. With the lower 3D reformation threshold, the volume and diameter of the artificial structure decreased. Scan parameters that can be allowed in low-dose chest CT, parameters of HQ-mode helical pitch, 100 mA tube current, and 5 mm slice thickness were selected to decrease the radiation dose rate and to minimize the deterioration in image quality[4]. To reduce the radiation dose rate according to the principle of "As Low As Reasonably Achievable (ALARA), studies on the CT image accuracy according to scan parameters have been conducted. In this study, the accuracy between the actual model and CT images were compared according to scan parameter changes. Both the globular artificial structure and rectangular artificial structure showed the same patterns according to the scan parameter change, but the globular artificial structure showed more difference in volume from the actual volume than the rectangular one. Other than the slice thickness, all the scan parameters significantly affected the volume difference. With the thinner slice, the CT image volume approached to the actual volume, and with the thicker slice, the volume difference increased. According to [Figure 6, 8], the thicker slice showed a staircase phenomenon particularly in the globular artificial structure. Partial volume averaging is inevitable because the digital image pixel has a constant size. An increase in the slice thickness can cause an uneven mean volume that will deteriorate the image resolution and show a staircase phenomenon[6]. According to this study, the effects of the CT scan parameter change were confirmed, and the scan parameters for accurate and optimal images were suggested. Further studies with various sizes of artificial structures other than the globular and rectangular ones may be necessary in the future.

Volume changes in the rectangular artificial structure were less than in the globular artificial structure. Other than the slice thickness, the effects of the parameters, including slice space, tube voltage and tube current, and algorithm (bone and standard algorithms) on the obtained image volume, were less than that of the image quality and actual model. The thinner slice resulted in a higher accuracy of obtained image volume than that of the actual model, as well as less image distortion and accuracy. CT image accuracy and optimization are significantly dependent on the slice space. Therefore, a thin slice is absolutely required to obtain accurate CT images that are used for facial and cranial measurement in forensic medicine and dentistry, tests for restoration, liver transplant, and artificial joint tests.

5. References

1. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), report to the General Assembly, annex on medical exposures. New York. Available from: www.unscear.org/unscear/publications.html, Data accessed: 2010.
2. Dougeni E, Faulkner K, Panayiotakis G. A review of patient dose and optimisation methods in adult and pediatric CT scanning. European Journal Radiology. 2012 Apr; 81(4):665–83.
3. Payne JT. CT radiation dose and image quality. Radiol Clin North Am. 2005 Nov; 43(6):953–62.
4. Cho SD. Developing Optimized the Computed Tomography (CT) Scan Protocols to the Reduction in CT Radiation Exposure Dose: Evaluated the Image Quality by using an AAPM Performance Phantom. Dept of Biomedical Health Science, Graduate School of Dong-eui University. 2015; 47(10):27–40.
5. International Commission on Radiological Protection, recommendations of the International Commission on Radiological Protection. ICRP publication. Available from: www.icrp.org/.../ICRP_Publication_103-Annals_of_the_ICRP, Data accessed: 1990.
6. UM KD, Lee BD . Influence of Slice thickness of Computed Tomography and type of Rapid Prototyping on the Accuracy of a 3 dimensional medical model. Korean J Oral Maxillofac Radiol. 2004 Mar; 34(1):13–8.
7. Asaumi J, Kawai N, Honda Y, Shigehara H, Wakasa T, Kishi K. Comparison of three dimensional computed tomography with rapid prototype models in the management of coronoid hyperplasia. Dentomaxillofacial Radiology. 2001 Aug; 30(1):330–5.
8. Matteson SR, Bechtold W, Phillips C, Staab EV. A Method for Three-dimensional Image Reformation for Quantitative Cephalometric Analysis. Journal of Oral and Maxillofacial Surgery. 1989 Oct; 47 (10):1053–61.
9. Kragskov J, Sindet Pedersen S, Gyldensted C, Jensen KL. A Comparison of Three-dimensional Computed Tomography Scans and Stereolithographic Models for Evaluation of Craniofacial Anomalies. Journal of Oral and Maxillofacial Surgery. 1996 Apr; 54 (4):402–11.
10. Kim KD, Kim HJ, Han SH, Park CS. Anthropologic study of Korean mandible using three-dimensional computed tomography-evaluation of the accuracy of a three-dimensional image. Korean J phys Anthropol. 1999 Jun; 12(1):13–22.