R/F

The Effectiveness of Tomosynthesis for the Diagnosis of Atlantoaxial Vertical Subluxation
—The 46th Annual Meeting of the Japanese Society for Spine Surgery and Related Research

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Ryo Tamaki, M.D., Ph.D. of Tokyo Women's Medical University presented the study on the effectiveness of tomosynthesis for the diagnosis of atlantoaxial vertical subluxation, which featured Shimadzu SONIALVISION series R/F system, at the 46th Annual Meeting of the Japanese Society for Spine Surgery and Related Research, which was held in Sapporo, Japan between April 13 and 15, 2017. This article describes an outline of his presentation.

1. Introduction

Radiographs of the upper cervical spine are usually clear enough to evaluate the detailed morphological structures. CT images are normally acquired with patients in the decubitus posture, so they do not reflect the effects of gravity in the vertical axis of the body. Tomosynthesis (TOMOS), a contraction of the words "tomography" and "synthesis," allows us to obtain high-definition tomographic images in sitting and standing postures.

2. Purpose

The purpose of this study was to evaluate the effectiveness of TOMOS about an influence of the weight of patient’s head on atlantoaxial vertical subluxation (VS) by comparing measurements using TOMOS, CT, and radiography.

3. Materials and Methods

TOMOS, CT, and radiography images were taken of 26 patients with suspected VS, and we measured the distance from the apex of the odontoid process to the McGregor's line. TOMOS, CT and radiography images were all taken within a 3-month period in each patient. Patients were diagnosed with VS when the measurements were 2.5 mm or more with TOMOS or CT images.
The TOMOS, CT, and radiography images were loaded onto a 3D workstation and we measured the value by plotting fixed points shown in Fig. 1. The

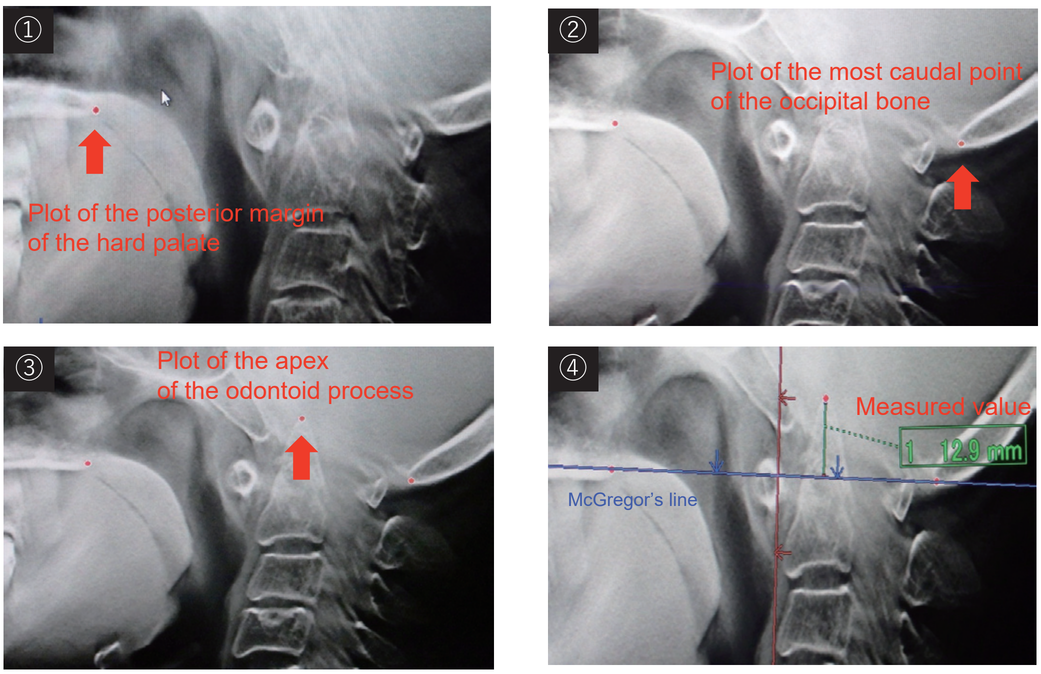


Fig.1 The Method for Evaluating VS with TOMOS (The identical method was used for measurements with CT.)

radiographs were measured in two-dimensional domain. We selected the appropriate slices of TOMOS and CT, and drew a line from the posterior margin of the hard palate to the most caudal point of the occipital (McGregor's line) **(Fig. 1)**.
We used a Shimadzu SONIALVISION safire series R/F system for TOMOS and radiography, and an AZE 3D workstation for measurements.

4. Results

4-1 Measured Results

Table 1 shows the results of measurements. Because the apex of the odontoid process were not be clearly observed in radiographs for 9 of the 26 cases (35 %, indicated with red ×), we were unable to measure the value. The measured values were 2.5 mm or more in 19 of the 26 cases (cases 1 to 19, enclosed by the blue frame) in CT or TOMOS, and we diagnosed them as VS.

Table 1 Measurement Results for 26 Cases, and 19 Cases Diagnosed with VS (enclosed by the blue frame)
The measured values were 2.5 mm or more in 19 of the 26 cases in CT or TOMOS, and we diagnosed them as VS.

Case	CT	TOMOS	Radiography	Case	CT	TOMOS	Radiography
Case 1	4.0	4.2	7.0	Case 14	11.3	13.9	14.3
Case 2	3.6	3.7	4.0	Case 15	0	2.8	0
Case 3	2.1	6.7	×	Case 16	9.7	8.2	8.3
Case 4	9.3	9.6	×	Case 17	11.8	12.6	×
Case 5	18.0	15.3	×	Case 18	6.7	7.6	6.7
Case 6	10.5	11.4	10.5	Case 19	5.1	5.2	×
Case 7	6.1	6.4	×	Case 20	2.1	1.8	2.3
Case 8	3.9	4.9	6.8	Case 21	2.0	0.2	×
Case 9	8.7	7.2	×	Case 22	0	0	0
Case 10	2.2	2.9	4.7	Case 23	0	0	0
Case 11	5.8	6.8	7.7	Case 24	0	0	0
Case 12	17.2	17.7	20.6	Case 25	−0.3	−1.6	−1.1
Case 13	3.4	5.3	6.7	Case 26	−5.2	−6.3	×

(Unit: mm)

4-2 Comparison of Results between CT and TOMOS

As shown in **Table 2**, in the comparison of results between CT and TOMOS, the measurements of TOMOS in 10 (indicated in red) of the 19 VS cases

Table 2 Comparisons of Measurements by CT and TS
The increased VS measurements were observed in TOMOS in 10 of 19 cases. (Wilcoxon p-value = 0.040)

Case	CT	TOMOS	Case	CT	TOMOS
Case 1	4.0	4.2	Case 11	5.8	6.8
Case 2	3.6	3.7	Case 12	17.2	17.7
Case 3	2.1	6.7	Case 13	3.4	5.3
Case 4	9.3	9.6	Case 14	11.3	13.9
Case 5	18.0	15.3	Case 15	0	2.8
Case 7	10.5	11.4	Case 16	9.7	8.2
Case 7	6.1	6.4	Case 17	11.8	12.6
Case 8	3.9	4.9	Case 18	6.7	7.6
Case 9	8.7	7.2	Case 19	5.1	5.2
Case 10	2.2	2.9			

(Unit: mm)

exceeded those of CT by 0.5 mm or more, and this difference was statistically significant (p = 0.040). We determined that the weights of patient's heads increased the measurements of TOMOS. Although CT of cases 3, 10 and 15 (indicated in blue) showed normal values, TOMOS showed abnormal values.

4-3 Comparing Results between TOMOS and Radiography

In 7 of the 17 cases which we were able to measure the value with radiography (**Table 3, indicated in red**), there were 1 mm or more differences between TOMOS and radiography, and the mean difference was 2.1 mm. The difference between measurements with radiography and TOMOS were randomly distributed. No statistically significant correlation was observed between measurements of the two methods in the same 17 cases, and considered that radiography possibly produced more measurement errors.

Table 3 Comparisons of Measurements by TOMOS and Radiography
In 7 of the 17 cases which we were able to measure the values with radiography, there were 1 mm or more differences (average: 2.1 mm) between TOMOS and radiography.

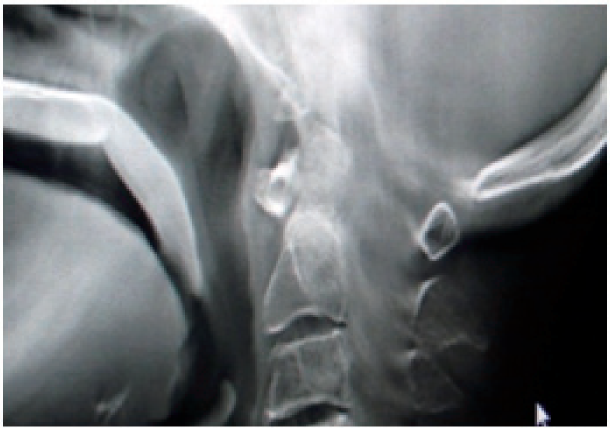
Case	TOMOS	Radiography	Case	TOMOS	Radiography
Case 1	4.2	7.0	Case 15	2.8	0
Case 2	3.7	4.0	Case 16	8.2	8.3
Case 6	11.4	10.5	Case 18	7.6	6.7
Case 8	4.9	6.8	Case 20	1.8	2.3
Case 10	2.9	4.7	Case 22	0	0
Case 11	6.8	7.7	Case 23	0	0
Case 12	17.7	20.6	Case 24	0	0
Case 13	5.3	6.7	Case 25	−1.6	−1.1
Case 14	13.9	14.3			

(Unit: mm)

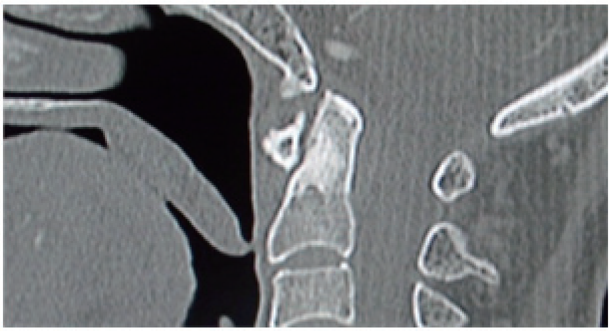
5. Discussion

As a result of comparison among 3 diagnostic imaging methods **(Fig. 2)**, it tends to be difficult to evaluate morphological fine details with radiography because all of X-ray shadows are projected and superimposed into two-dimensional domain. TOMOS provides multiple slices, and it allows us to select appropriate slices for measurements. Therefore, we can obtain morphological information clearer with TOMOS than that with radiography. Although, CT can reconstruct thinner slices than TOMOS and allow clearer observation than TOMOS, it usually requires the patient to be in the decubitus posture.
In comparison of VS diagnosis by CT and TOMOS, significant higher values were measured with

XP



TOMOS



CT

Fig.2 Comparison among Radiography, TOMOS, and CT Images

TOMOS in 10 of the 19 cases. Three of them were normal value with CT but they were abnormal with TOMOS. Based on these observations, we determined that their VS were aggravated by weights of their heads, and determined that diagnosis of VS by only CT was difficult. As the apex of the odontoid process was indistinct in 9 radiographs of the 26 cases, we were unable to measure the value. There was no statistically significant correlation between any of TOMOS and radiography measurements, and the mean difference was 2.1 mm in the 7 cases in which we observed 1 mm or more differences. This indicates that radiography may lead a bigger measurement errors than TOMOS does.

It is reported that the X-ray dose of TOMOS is approximately twice the dose of radiography **(Table 4)**. It is also reported that the X-ray dose of TOMOS is approximately 1/10th of the dose of CT **(Table 5)**.

Table 4 Comparison of the X-ray Dose of TOMS and Radiography

	Reduction Target Dose for Radiography (A)	Entrance Surface Dose of TOMOS (B)	B/A	TOMOS X-ray Parameters
Head (front)	3mGy	2.7mGy	0.9	90kV,0.9mAs
Cervical spine (front)	0.9mGy	1.7mGy	1.9	85kV,0.8mAs
Hand and fingers	0.1mGy	0.2mGy	2.0	47kV,1.25mAs Fast
Knee joint	0.4mGy	0.9mGy	2.3	70kV,0.8mAs
Hip joint (front)	4mGy	4.1mGy	1.0	85kV,1.4mAs

(A): JART 2006 Guideline for Medical X-ray Dose

Table 5 Comparison of X-ray Dose of TOMOS and CT

	TOMOS	MDCT
Chest	0.92mSv	15.0mSv
Abdomen	1.12mSv	12.9mSv
Hip joint	0.82mSv	10.5mSv

Koyama S et al:Radiation dose evaluation in tomosynthesis and C-arm cone-beam CT examinations with an anthropomorphic phantom.Med.Phys.37(8),4298-4306,August 2010

6. Conclusion

TOMOS produces a number of tomographic images in a single scan, and with the use of a 3D workstation, we can select appropriate slices for the posterior margin of the hard palate, the most caudal point of the occipital bone, and the apex of the odontoid process. By plotting these fixed points, we were able to conduct accurate measurements of the upper cervical spine.

It was difficult to diagnose abnormalities in the upper cervical spine by radiography alone. For the VS evaluation, as we determined that the VS conditions were aggravated by the weights of the heads, and the X-ray dose of CT was evaluated much higher than that of TOMOS, the diagnostic method using TOMOS in standing posture was considered to be more effective than that using CT.