Comparison of exophthalmos measurements: Hertel exophthalmometer versus orbital parameters in 2-dimensional computed tomography

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ABSTRACT •

Objective: To compare the reliability of orbital parameters calculated using 2-dimensional computed tomography (CT) and Hertel exophthalmometry when measuring exophthalmos in normal subjects and in patients with thyroid-associated orbitopathy (TAO).

Design: Retrospective, observational case series.

Participants: CT images of 33 normal orbits and 69 orbits with TAO were included.

Methods: In central axial CT scans, globe area (GA), orbital area (OA), and GA/OA ratio were calculated by 2 observers using ImageJ. Interobserver agreement was analyzed for Hertel exophthalmometer and CT parameters. In patients with TAO, the association with activity and severity of TAO were also evaluated.

Results: GA and the GA/OA ratio measurements showed excellent interobserver agreement, whereas OA and the Hertel exophthalmometry measurements showed moderate agreement between the 2 observers. GA and the GA/OA ratio were significantly correlated with Hertel exophthalmometry measurements ($r = -0.740$, $r = -0.706$, respectively; all $p < 0.001$). GA and the GA/OA ratio were significantly correlated with the activity and severity of TAO (all $p < 0.01$).

Conclusions: GA and the GA/OA ratio were reliable CT parameters with a high intraclass correlation coefficient compared with Hertel exophthalmometer.

Proptosis is determined by the relationship between the volume of orbital contents and the morphologic characteristics of the bony orbit and is affected by the tightness of the septum and the vascular flow of the orbit. Measurement of proptosis is among the basic clinical examinations that are essential to diagnose orbital disease and evaluate the results of treatment. Proptosis is a particularly critical sign for grading the severity of disease and for assessing the course of thyroid-associated orbitopathy (TAO).[1–3] Traditionally, the most widely used instrument is the Hertel exophthalmometer (Oculus International, Berlin, Germany), which measures the distance from the frontal process of the zygoma to the vertex of the cornea.[4–6]

Hertel exophthalmometry is simple, rapid, and easy to perform, but it has been shown to have low accuracy and poor reproducibility.[5,7,8] The reproducibility of Hertel exophthalmometry can be improved with a standard protocol such as keeping the same base between measurements and using the same exophthalmometer, as shown in a recent multicenter study.[9] However, selection of a proper base may require skill and clinical experience and can act a factor of disagreement between clinicians.

For this reason, there have been some attempts to use computed tomography (CT) to measure orbital area (OA) or proptosis quantitatively. Three-dimensional CT imaging may be an ideal tool to evaluate proptosis because it can accurately reflect complex orbital morphology and enables volumetric analysis.[10] However, the clinical application of 3-dimensional CT is very limited because of the need for specific software, the intricate nature of the procedure, and the length of time it takes to perform. In contrast, 2-dimensional CT (2D-CT) is a relatively rapid, simple, and easily assessable procedure and has been used to measure orbital volume and to characterize orbital morphology, but there has been no unified standard or easily available tool to measure proptosis using 2D-CT.[11–13] Campi et al.[14] recently introduced a novel method to calculate the degree of proptosis with 2D-CT images. They measured the area ratio of the buried eyeball orbit to orbit and reported that it showed good performance for measurement of proptosis in patients with TAO. However, the reliability and clinical usefulness of this method for measuring proptosis has not been proven yet, and it is technically complex in that it involves manual drawing and complicated calculations.

Herein, we modified the measurement protocol using the ImageJ program (version 1.47; National Institutes of Health, Bethesda, Md.) and simplified the calculation. We aimed to compare the reliability of Hertel exophthalmometry and CT parameters. Two observers carried out both examinations in a blinded manner, and intraclass correlation coefficients (ICCs) were analyzed. In addition, we analyzed the correlation between Hertel exophthalmometry and CT parameters as measured by a single

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oculoplasty specialist and the association between CT parameters and the activity and severity of TAO.

METHODS

This retrospective observational study was performed at the Hallym University Sacred Heart Hospital from August 1, 2011, to December 31, 2013, in accordance with the tenets of the Declaration of Helsinki. Ethics approval to conduct the study was obtained from the Institutional Review Board committee of Hallym University Sacred Heart Hospital (IRB No. 2016-I132). Due to the retrospective nature of this study, the exemption from written consent was approved by the ethics committee, and all clinical records were anonymized and de-identified before analysis.

Patients

The study included 69 eyes of 41 patients who had clinically confirmed TAO and available CT scans (TAO group: 28 patients with bilateral TAO, 13 with unilateral TAO), and 31 eyes of 31 patients who underwent orbital CT for unilateral benign orbital disease other than TAO and had unaffected normal orbits (control group). All patients in the TAO group and control group received comprehensive ophthalmic and orbital examinations at the initial visit. Patients with other conditions that could change the morphology of the orbit, such as blow-out fracture or a history of any orbital surgery, were excluded. Patients with a history of ocular surgery other than cataract surgery were also excluded. The treatment modalities used for thyroid disease, smoking history, diabetes, hypertension, and presence of other autoimmune disease were also reviewed in the TAO group.

Clinical Examination

Ophthalmic examination data included best-corrected visual acuity, intraocular pressure, spherical equivalent, slit-lamp biomicroscopy, and fundus examination. Orbital examination, including margin reflex distance 1, measurement of proptosis by Hertel exophthalmometry, and extraocular muscle movement (EOM), was also performed. When a patient visited the oculoplasty clinic, orbital examinations were usually performed twice: once by a designated resident (K.J.C., examiner 2) for screening and again by a faculty member of the oculoplasty division (M.J.L., examiner 1). The degree of exophthalmos measured by the 2 ophthalmologists using the Hertel exophthalmometer was recorded. The 2 observers used same exophthalmometer. All examinations were performed separately, and the examiners did not refer to each other's test results; the base of exophthalmometry did not always coincide between the 2 observers. For patients with TAO, clinical activity and severity were assessed by the clinical activity score (CAS) and a modified NOSPECS classification.[2,15] Out of 10 points, patients with CAS scores ≥3 were considered to have active TAO. The modified NOSPECS classification included 3 categories (signs of soft tissue involvement, proptosis measured by Hertel exophthalmometry, and EOM involvement) that were each graded 0, 1, 2, or 3 and then added together to give a total eye score.

Measurement of CT Parameters

All patients were examined with a 2D-CT scan (Philips Medical Systems, Cleveland, Ohio) within 7 days of the clinical examination. The general orbital CT scanning protocols included both the axial and coronal planes with 2 mm sections. We used the concept of Campi et al.[14] to assess orbital parameters and modified the protocol using ImageJ 1.47 as follows. First, we chose an axial CT image with a soft tissue window at a midglobe level and set the reference length using the scale bar. Next, we chose 3 orbital landmarks: the anterior lacrimal crest, the orbital apex (the centre of the optic nerve at the level of entrance into the optic canal), and the point of emergence of the anterior zygomatic arch. A triangle was then drawn connecting these 3 points using the basic tool of ImageJ,

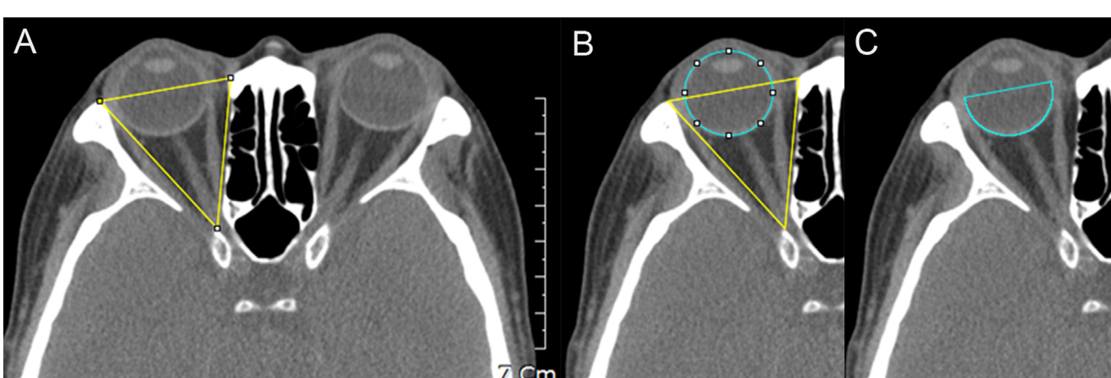

Fig. 1—Measurement of the orbital parameters. A triangle connecting the anterior zygomatic eminence, anterior end of medial orbital wall, and centre of optic nerve was defined as the orbital area (OA, yellow triangle) (A). An oval was drawn to fit the posterior scleral curvature (B). The overlapped area between the triangle and the oval was defined as the globe area (GA, blue sector), representing the area of eyeball buried in the orbit (C).