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Surgical effects of various orbital decompression methods in thyroid-associated orbitopathy: Computed tomography-based comparative analysis

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Objectives: To evaluate the surgical effects of orbital fat decompression and bony decompression in each orbital wall using computed tomography (CT) in thyroid-associated orbitopathy (TAO).
Methods: In 27 TAO patients (48 orbits) with exophthalmos who underwent orbital wall decompression combined with fatty decompression, we recorded the resected orbital fat volume intraoperatively and estimated the decompression volume of the orbital wall in the deep lateral, medial and inferior walls using postoperative orbit CT images. Then, the correlation between exophthalmos reduction by Hertel reading and decompression volume in each area was analyzed to validate the surgical predictability, surgical efficiency and contribution level to total exophthalmos reduction.
Results: The decompression volume in orbital fat and the deep lateral wall showed relatively high correlation with exophthalmos reduction (surgical predictability) compared to medial and inferior wall. The surgical efficiency was highest at deep lateral wall (2.704 ± 0.835 mm/cm^3), followed by medial wall (0.892 ± 0.527 mm/cm^3), orbital fat (0.638 ± 0.178 mm/cm^3) and inferior wall (0.405 ± 0.996 mm/cm^3). The actual contribution level to total exophthalmos reduction was highest in fatty decompression, followed by deep lateral decompression.
Conclusion: In TAO patients with exophthalmos, orbital fat and deep lateral orbital wall are more predictable and contributory surgical targets for postsurgical exophthalmos reduction.

1. Introduction

Thyroid-associated orbitopathy (TAO) is the one of the most important extrathyroidal features of dysthyroidism, which can be properly managed by orbital expansion for morpho-aesthetic and functional reasons (Clauser et al., 2012). Orbital decompression, in particular, is a cornerstone in the treatment of TAO with severe exophthalmos (Lyons and Rootman, 1994). Bony decompression in areas such as the lateral wall, inferomedial wall, balanced medial and lateral wall, or the '3-wall' technique has been described as a conventional mainstay in the treatment of exophthalmos (Walsh and Ogura, 1957; Leone et al., 1989; Mourits et al., 1990; Goldberg et al., 1997; Goldberg, 1998). In addition, en bloc resection of the lateral orbital rim and part of the orbital floor had been reported to reduce exophthalmos effectively (Schaaf et al., 2010). However, in practice, it is difficult to determine which wall to decompress and whether the combination technique is necessary or not. Regarding exophthalmos reduction, the maximization of orbital volume expansion should not be the sole focus of therapy. In fact, excessive bony decompression may induce or worsen diplopia, sinusitis, cerebrospinal fluid (CSF) leak, and infraorbital hypoesthesia (Shorr and Seiff, 1986; Warren et al., 1989; Goldberg et al., 2000). The selection of optimal techniques that predictably and efficiently result in exophthalmos reduction is important for a successful operation.

Recently, fatty decompression has been advocated given its lower complication rate and high correlation between the resected orbital fat volume and the reduction in exophthalmos (Wu et al., 2008; Liao and Huang, 2011). Additionally, the deep lateral wall has been reported as a strategic target of decompression due to its ideal location just behind the globe and better retroplacement with lower risk of postoperative diplopia, hypoesthesia, or sinusitis

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(Baldeschi et al., 2005; Mehta and Durrani, 2011). To establish the surgical strategy among these newer techniques and conventional bony decompression methods, the predictability and efficiency of exophthalmos reduction may be an ideal index. To our knowledge, a comparative analysis has not been reported evaluating the contribution of different decompression areas – deep lateral wall, medial wall, inferior wall, or orbital fat – to exophthalmos reduction in TAO patients.

Although the amount of orbital fat removal is easily measurable intraoperatively the actual volume of decompressed orbital bone has to be estimated. We measured the expanded postoperative orbital volume in each site of bony decompression using computed tomography (CT) images, and measured the resected orbital fat volume. We then evaluated the surgical effect including surgical predictability, surgical efficiency and contribution level to exophthalmos reduction at each decompression area based on the ratio of postoperative decrease in exophthalmos measured with a Hertel exophthalmometer to the decompressed orbital volume.

2. Materials and methods

2.1. Patients

A retrospective review of medical records was conducted for all consecutive cases of TAO-associated exophthalmos surgically treated by a single surgeon (Lee JK) at Chung-Ang University Hospital between May 2010 and December 2012. The study protocol and informed consent were approved by the institutional review board of the Chung-Ang University Hospital, and the study conformed to the tenets of the Declaration of Helsinki.

We included 48 orbits from 27 patients who underwent bony decompression either by deep lateral wall decompression, balanced deep lateral and medial wall decompression, inferomedial wall decompression, or a 3-wall technique in conjunction with orbital fat removal. Exophthalmos less than 18 mm based on the Hertel reading was graded as mild, and as severe if 18 mm or more. The method of bony decompression was selected by the surgeon depending on the severity of exophthalmos: 1-wall decompression (deep lateral wall) in mild exophthalmos, or 2-wall (balancing the deep lateral and medial walls) or 3-wall (deep lateral, medial and inferior wall) decompression in severe exophthalmos. Inferomedial wall decompression was performed for compressive optic neuropathy. Patients with a medical history of orbital or eyelid inflammation, prior orbital surgery, trauma, or re-operation were excluded. None of the selected patients had orbital radiation therapy.

Orbital CT scans (Philips Brilliance 256 Slice iCT, Philips Healthcare Systems, Andover, MA, USA) and Hertel exophthalmometry were conducted routinely less than 2 weeks prior to orbital decompression and 3 months after surgery. The expanded orbital volume in each wall was estimated to determine the contributive and correlative tendency of postoperative exophthalmos reduction.

2.2. Surgical techniques

Decompression of the deep lateral orbital wall was performed through an eyelid crease incision. The greater wing of the sphenoid bone was removed, and additional removal of the anterior department of the inferior orbital fissure was performed in most patients who underwent deep lateral wall decompression. Medial orbital decompression was performed via a transcaruncular incision. After exposure of the medial wall just behind the posterior lacrimal crest, the wall was fractured and an ethmoidectomy was performed using Kerrison rongeurs and Takahashi forceps. The superior limit of the medial wall removal was the ethmoidal vessels, and the inferior limit included the ethmoid–maxillary bony strut. For inferior wall decompression, the orbital floor was approached through the transconjunctival inferior fornix. The osteotomy was carried medially as far as possible, including removal of the inferomedial bony strut, and temporally to the infraorbital neurovascular bundle.

Orbital fat removal was performed in all patients. In cases with deep lateral wall decompression by eyelid crease incision or inferior orbital wall decompression through the inferior fornix, adipose tissue was additionally resected from the inferotemporal intraconal space. The total amount of resected fat (cm^3) was measured using 1 cc or 5 cc syringe, intraoperatively.

2.3. Estimation of decompressed volume of orbital wall on CT images

CT imaging (bone window, 2.5-mm collimation) of all patients was obtained on both of axial and coronal planes. Orbital volume expansion after surgery was calculated using Image J software (National Institutes of Health (NIH); http://rsbweb.nih.gov/ij/) and was sorted into three sections: deep lateral, medial and inferior orbital wall. The expanded area at each orbital slice was marked from the imaginary preoperative wall border to the decompressed bony edge, and the marked areas were calculated with Image J software (Fig. 1). The deep lateral wall was analyzed on axial CT planes. Medial and inferior walls were analyzed on coronal planes in the same manner. The bony strut was used as a landmark on CT image to distinguish medial wall from inferior wall in patients who underwent inferomedial wall or 3-wall decompression. The summation of all surface areas (cm^2) multiplied by 0.25 cm (2.5 mm) was considered as an expanded orbital volume (cm^3) in each orbital wall. All measurements were calculated by three individual readers. To avoid intra-observer variation, the average of three repeated measurements was used in each reader.

2.4. Data analysis

In our study, three indices of surgical effect; 1) surgical predictability, 2) surgical efficiency and 3) degree of contribution to exophthalmos reduction were made in each decompression area.

Partial correlation analysis was used to correlate each decompression volume in the deep lateral wall, medial wall, inferior wall or orbital fat with exophthalmos reduction to determine area-adjusted surgical predictability. A multivariate linear regression model was then constructed to assess individual surgical efficiency in each area, which was derived from exophthalmos reduction (mm) per unit decompression volume (cm^3). The contribution level of orbital decompression to exophthalmos reduction in each area was compared each other by standardized coefficient value of multivariate linear regression to validate the actual contributory proportion to total exophthalmos reduction. SPSS software version 19.0 (SPSS, Chicago, IL, USA) was used for all statistical analyses, and $P < 0.05$ indicated statistical significance. Values shown represent the mean $\pm$ standard deviation (SD).

3. Results

In 48 orbits the following procedures were performed: 3-wall decompression (deep lateral orbital wall, medial orbital wall, and inferior orbital wall) was performed in 27 orbits (56.3%), balanced deep lateral and medial wall decompression in 16 orbits (33.3%), deep lateral wall decompression in 2 orbits (4.2%), and inferomedial wall decompression in 3 orbits (6.3%). Orbital fat removal was done in all cases. The mean age of patients was 39.3 $\pm$ 14.7 years, and 39 orbits (81.3%) were from women (Table 1). The intraoperatively-

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