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RHINOLOGY

The role of three-dimensional CT in the evaluation of nasal structures and anomalies

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Abstract Traditionally, computed tomography (CT) is the primary radiographic method to analyze the morphology of the craniofacial bones: Because of the many overlapping anatomical structures, it is difficult and sometimes impossible to evaluate craniofacial bones three-dimensionally (3D) with these images. For this reason, the aim of this paper has been to evaluate and demonstrate the importance of CT scans integrated by three-dimensional reconstructions (3D-CT) volume rendering imaging for the accurate understanding of the nasal pyramid morphology in the evaluation of patients submitted to secondary rhinoseptoplasty. Twenty patients enrolled for a secondary rhinoseptoplasty, underwent a preoperative evaluation through 3D-CT volume rendering imaging. This technique allowed a prefect reconstruction of the nasal structures at the level of the valve, as well as the medial and lateral walls of the nasal fossa in all of its components (bone and cartilage). In our experience, the 3D-CT volume rendering imaging studies improve the preoperative evaluation of structures and anomalies which are hard to evaluate by the anterior rhinoscopy and/or nasal endoscopy: alar and lateral cartilages, interdomal distance, tip morphology, valvular configuration, loss of bone-cartilaginous substance, etc. All of these points are important during the preoperative planning of secondary rhinoseptoplasty.

Keywords 3D-CT · 3D reconstruction · Rhinoseptoplasty · Three-dimensional reconstructions volume rendering

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Introduction

The accurate understanding of morphology and structure of the nasal pyramid and the nasal airways is essential for the preoperative assessment in order to ensure proper planning in primary and/or secondary rhinoseptoplasty. Nasal endoscopy, rhinomanometry, acoustic rhinometry and traditional radiological methods are generally inadequate because they provide incomplete data about the osteocartilaginous elements lining the nasal cavity. These disadvantages are overcome by the integration of imaging examinations: different studies highlight the role of magnetic resonance imaging (MRI) and computed tomography (CT) to provide important elements on the anatomical structures of the nasal valve region, nasal medial and lateral walls and nasal tip [1–4].

The aim of this paper was to show the role of a preoperative evaluation through CT scans integrated by three-dimensional reconstructions "volume rendering" (3D-CT) in patients submitted to secondary rhinoseptoplasty.

Materials and methods

The regional ethics committee approved the study protocol. A total of 20 patients aged between 24 and 57 years (34 years old on average), submitted to secondary

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rhinoseptoplasty, were included. All the patients had undergone primary rhinoplasty and presented nasal obstruction and aesthetic deformities of the nasal pyramid. Objective evaluation of the intranasal findings was performed by anterior rhinoscopy and nasal endoscopy (rigid and flexible).

Exclusion criteria were: genetic and congenital conditions (cystic fibrosis, primary ciliary dyskinesia); nasal polyps; neoplasms; nasal radiotherapy; acute contemporary bacterial, viral and/or allergic rhinosinusitis; middle ear and upper respiratory tract infections; bronchopulmonary disease; recent nasal trauma.

Before surgery, all the patients underwent to 3D-CT volume rendering imaging study. CT images were performed with a dual slice spiral CT (Hi Speed, GE Medical Systems, Milwaukee, USA). To obtain high-resolution images we acquired the coronal images with sequential technique. All examinations were performed by a radiologist, aided by a specialized nurse.

The parameters are the following: 120 kV, 60 mA, collimation 2 mm, range 2 mm, gantry inclination perpendicular to the hard palate using a FOV from the tip of the nose to the posterior wall of the sphenoidal sinus and a filter for bone's reconstruction.

Coronal sections reproduce the visual approach of the surgeon and provide optimal visualization of the ostiomeatal unit and the anatomical structures of the medial and lateral wall of the nose.

Axial sections were acquired with the following parameters: 120 kV, 80 mA, 1 mm collimation, pitch 0.75, FOV including the area from the frontal sinus to the floor of maxillary sinus and using a filter for bone's reconstruction.

Afterward the scans were processed by the J-Vision program to build three-dimensional "volume rendering" images.

The 3D volume rendering images are reproduced in the following views:

- caudo-cranial (Fig. 1a);
- cranio-caudal (Fig. 1b);
- latero-lateral (Fig. 2a);
- oblique (Fig. 2b).

Results

The anterior rhinoscopy and nasal endoscopy showed a normal objective examination in six patients; turbino-septal sinechiae narrowing the nasal valve region in seven patients; asymmetries of the nasal pyramid with a depressed area in the nasal valvular region in five patients; septal deviation obstructing the nasal fossa in two patients (Table 1).

In all the patients the 3D volume rendering images showed an open roof and lateral osteotomies' outcomes of previous rhinoplasty as a defect of the lateral cartilages, cause of the sidewall and valve collapse, and a resorption of the cranial part of the lateral crura and the domes, with increased interdomale distance with asymmetry of the nasal tip (Figs. 3, 4; Table 1).

Furthermore, the 3D volume rendering images highlighted turbino-septal sinechiae narrowing the nasal valve region in eight patients, septal deviation obstructing the nasal fossa in two patients and bulky concha bullosa in one patient (Table 1).

Discussion

Nasal profile is relatively variable, owing to underlying soft tissue, which can change for quantity and distribution over different conditions: individual characteristics, nutrition, age, previous surgery, over all. On the other hand, bone is much more stable over time, but its minor modifications, can lead to major changes in nasal appearance [5]. For

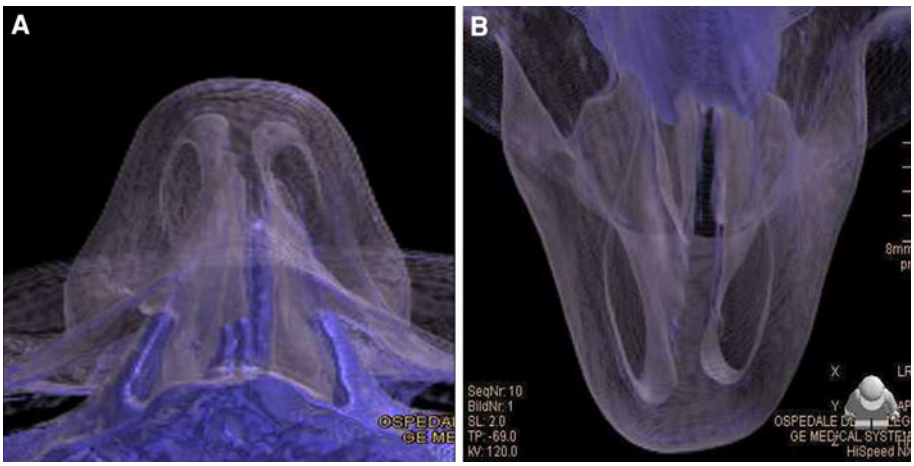

Fig. 1 **a** Control case—3D volume rendering image for cartilage: caudo-cranial view. **b** Control case—3D volume rendering image for cartilage: cranio-caudal view

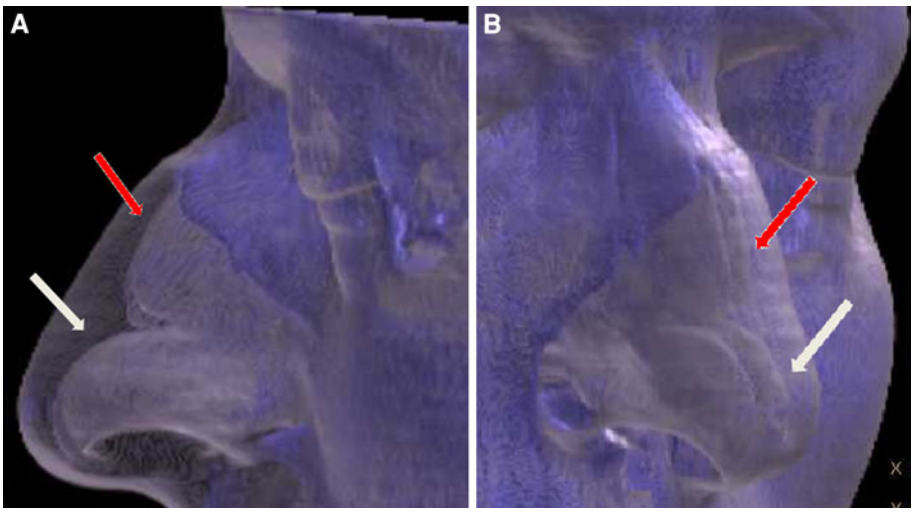

Fig. 2 **a** Control case—3D volume rendering image for cartilage: lateral view. The *white arrow* indicates the left alar cartilage; the *red arrow* shows the left upper lateral cartilage. **b** Control case—3D volume rendering image for cartilage: oblique view. The *white arrow* indicates the nasal dome; the *red arrow* shoes the cartilaginous dorsum of the nasal pyramid

Table 1 Comparison of the results obtained with the objective evaluation of the intranasal findings (anterior rhinoscopy and nasal endoscopy) versus 3D volume rendering images, in the 20 patients (*n*: number of patients)

	Anterior rhinoscopy nasal endoscopy (*n*)	3D volume rending images (*n*)
Normal	6	0
Turbino-septal sinechiae narrowing the nasal valve region	7	8
Depressed area in the nasal valvular region	5	20
Open roof and defect of the lateral cartilages	0	20
Septal deviation obstructing the nasal fossa	2	2
Bulky concha bullosa	0	1

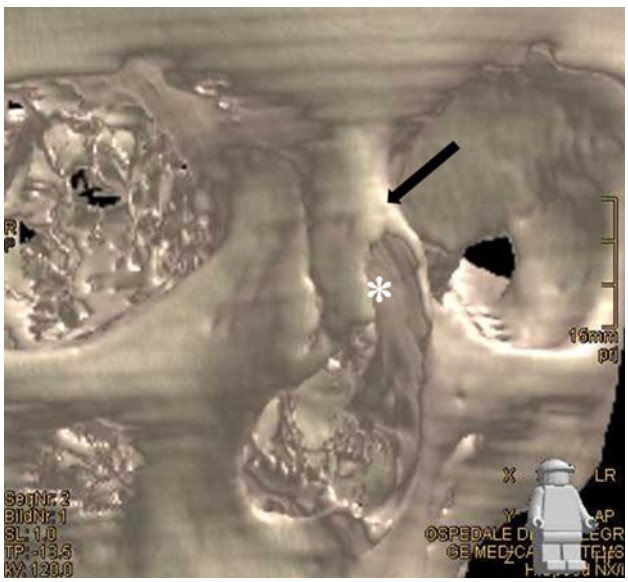

Fig. 3 3D volume rendering image for bone: open roof with increased interdomale distance with asymmetry of the nasal tip (*white asterisk*). The *black arrow* indicates the nasal bone

Fig. 4 3D volume rendering image for cartilage: lateral right view. Wide defect of the lateral cartilages, largest on the right. Reabsorption of the cranial part of the lateral crura and domes of the alar cartilages, greater on the right (*red arrow*); increased interdomale distance with asymmetry of the nasal tip (*white asterisk*)

these reasons, the nose is the most difficult facial feature to aesthetically manipulate; rhinoplasty is one of the most technically challenging plastic surgical procedure

performed; revision rhinoplasty is clearly more difficult than a primary (first time) rhinoplasty [6].

It's evident as in revision rhinoplasty an accuracy of preoperative computer imaging is necessary [7]. Ultrasound is considered to be quite reliable, but the pressure of the probe and its inclination can introduce a relevant bias [8]. The key to accurate diagnosis of small craniofacial abnormalities has been the use of axial CT slices in narrow-width technique of preferably not more than 1 mm [9]. Although the spiral CT technique using 1 mm slice thickness by 1 mm of reconstruction interval allows high 2D imaging quality and represents a clinically effective way of craniofacial abnormalities detection [10], this technique is subject to methodological errors [5]. Another problem is that some nasal skeletal abnormalities can lead to pathological conditions not always detected by spiral CT [5]. Furthermore, 2D-CT presents limitations in the localization of bone fragments and the direction of bone displacement [5].

Different authors observed that 3D images provide an easy detection of specific characteristics of facial asymmetries and defects in the middle portion of the face and in the skull vault, and a clear localization of fractures associated with extensive bone displacement [11, 12]. In our experience, CT scans and 3D volume rendering images reconstructed for bone and cartilage demonstrate preoperatively anatomical defects and pathological conditions underestimated during the clinical examination, performed through traditional methods and fiber-optic endoscopy. Often the clinical examination does not allow to define the anatomical components responsible for the functional and aesthetic alterations [13, 14].

The 3D volume rendering images allowed to identify precisely specific anatomical details of both, the bone and the cartilage, in important nasal regions such as the nasal valve, the alar and lateral nasal cartilages, the nasal tip, defining the interdomal space and the divergence angle, essential parameters to the planning of the functional and aesthetic nasal surgery. These abnormalities are particularly evident when you compare the reported case with images relating to a control subject with a normal representation of the nasal pyramid structure.

The 3D volume rendering images allowed to define the anatomical different districts through various colors in relation to its hounsfield densitometric values. It was possible to represent both nasal structural components (bone and cartilage) and to assess accurately the structure, shape, orientation and symmetry of the different anatomical elements examined.

CT scans and 3D volume rendering images are used as imaging method supplying information regarding not only abnormalities of the bone components but also the ones of the cartilage, not well assessed by the clinical and endoscopic examination, allowing to perform a specific project to rebuild the reported defects and eliminate structural anomalies so identified.

Coronal and axial CT scan projections, without 3D volume rendering elaboration, allow an optimal viewing of only anatomical bone structures (nasal bones, vomer, etc.). These images do not reproduce the anatomic details of the nasal cartilaginous component.

According to our results, CT scans and 3D volume rendering images enables the radiologist to visualize and manipulate volumetric data quickly, permitting ready application of advanced imaging to the nasal region. This enables to evaluate the thickness, morphology and degree of structural integrity of the nasal cartilaginous component. The ability to view the nasal pyramid from every angle allows a detailed analysis of a critical region as nasal tip, evaluating the effects of a previous trauma or rhinoplasty on the alar and triangular cartilages. For these reasons, a precise evaluation of cartilaginous defects, nasal pyramid deformities, etc. is possible, adding important information to the final preoperative evaluation of patients.

The outcomes of aesthetic and functional nasal surgery are difficult to assess objectively because of the intricate balance between nasal form and function. Despite historical emphasis on patient-reported subjective measures, objective measures are gaining importance in both research and the current outcomes-driven health care environment. [15]. Objective measures currently available have several shortcomings that limit their routine clinical use; in particular, the low correlation between objective and subjective measures poses a major challenge [15].

CT scans and 3D volume rendering images applications for surgical planning has been reported for facial and laryngeal surgery [16]; in our experience CT scans and 3D volume rendering images demonstrated nasal external cosmetic, soft tissue and bony abnormalities. The key to safe treatment of these lesions is accurate preoperative imaging in order to determine the diagnosis, the extent of the lesion and the more appropriate surgical approach in the performance of delicate surgical times as nasal tip correction, lateral osteotomies, etc. Fractured bone fragments and result of a previous rhinoplasty are better evaluated using CT scans and 3D volume rendering images as they can be viewed from innumerable angles and be compared to the normal contralateral side. Sometimes subtle rotational abnormalities can only be appreciated on 3D images. The exact amount of gap between the ends of the bone, the precise localization of the bone segments and the relationship of these fragments to the bone of origin, to each other and with the cartilaginous structures can be accurately assessed.

CT scans and 3D volume rendering images is also able to compensate for streak artifacts due to the presence of

metallic implants such as plates, pins and prostheses, in the mouth of the patient. Also, because the time of examination, acquisition and elaboration of the images is about 40 min, the faster scanning speeds appear to have an impact on the accuracy of 3D images in patients, reducing motion artefacts and without additional radiation exposure to the patient.

The cost effectiveness is not a limit of this specific technique. All modern CT scanners possess some form of 3D reconstruction imaging capability, and manufacturers now offer a wide range of products. The computer graphics methods that serve as the basis for 3D reconstruction imaging have evolved rapidly, and dramatic improvements in image quality, efficiency, versatility, ease of use, and reduction in the cost of systems have been realized.

In conclusion, our experience highlights the assessment of nasal form before aesthetic surgery, by 3D volume rendering images; it is an applicable tool that provides secure items in planning the nasal revision surgery.

Conflict of interest None of the authors have a financial relationship with any organization that sponsored the research.

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