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Volumetric three-dimensional computed tomographic evaluation of the upper airway in patients with obstructive sleep apnoea syndrome treated by maxillomandibular advancement

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Abstract

Obstructive sleep apnoea syndrome is the periodic reduction or cessation of airflow during sleep together with daytime sleepiness. Its diagnosis requires polysomnographic evidence of 5 or more episodes of apnoea or hypopnoea/hour of sleep (apnoea/hypopnoea index, AHI). Volumetric 3-dimensional computed tomographic (CT) reconstruction enables the accurate measurement of the volume of the airway. Nasal continuous positive airway pressure (CPAP) is the conventional non-surgical treatment for patients with severe disease. Operations on the soft tissues that are currently available give success rates of only 40%-60%. Maxillomandibular advancement is currently the most effective craniofacial surgical technique for the treatment of obstructive sleep apnoea in adults. However, the appropriate distance for advancement has not been established. Expansion of the air-flow column volume did not result in an additional reduction in AHI, which raises the important issue of how much the maxillomandibular complex should be advanced to obtain an adequate reduction in AHI while avoiding the risks of overexpansion or underexpansion. We have shown that there is a significant linear relation between increased absolute upper airway volume after advancement and improvement in the AHI ($p=0.013$). However, increases in upper airway volume of 70% or more achieved no further reduction in the AHI, which suggests that the clinical improvement in AHI reaches a plateau, and renders further expansion unnecessary. This gives a new perspective to treatment based on the prediction of changes in volume, so the amount of sagittal advancement can be tailored in each case, which replaces the current standard of 1 cm.

Keywords: OSAS; Sleep disorders; Maxillomandibular advancement

Introduction

Obstructive sleep apnoea syndrome is defined as the periodic reduction or cessation of airflow during sleep together with daytime sleepiness. It is characterised by repetitive episodes

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of pharyngeal collapse with increased airflow resistance during sleep. The diagnosis requires the polysomnographic evidence of 5 or more or more episodes of apnoea or hypopnea/hour of sleep (apnoea/hypopnea index (AHI)) together with physical complaints during the day.

Risk factors include obesity, male sex, advancing age, and anatomical factors such as craniofacial abnormalities, macroglossia, hypotonia of the oropharyngeal soft tissues, retropositioning of the base of the tongue, mandibular hypoplasia and retropositioning related to posterior positioning of the hyoid and geniohyoid muscle, and maxillary retrusion. Patients with craniofacial stenosis or severe mandibular retrusion have coarctation of the 3-dimensional airway as a result of retrusion of the craniofacial complex.[1]

Obstructive sleep apnoea is associated with high cardiovascular and cerebrovascular morbidity and mortality, as well as excessive daytime sleepiness, fatigue, and neurocognitive deficits. When left untreated, the 15-year mortality approaches 30%. [2,3] Nasal continuous positive airway pressure (CPAP) is the conventional non-surgical treatment. [4] Several operations can now be done on the soft tissues to increase the posterior airway space and treat the apnoea in the 50% of patients who cannot tolerate CPAP. However, the reported success rates of these procedures are only about 40%–60%. [5]

In the early 1980s there were several reports of improved polysomnographic measures in patients having mandibular osteotomy with advancement.[6,7] However, maxillomandibular advancement (MMA) was championed over mandibular osteotomy alone to treat non-syndromic patients with sleep apnoea by the mid-1980s because it preserves the maxillomandibular relations and acknowledges the common involvement of mandibular and maxillary deficiency in the aetiology of obstructive sleep apnoea. [8,9] The operation results in enlargement of the pharyngeal space by expanding the skeletal framework to which the pharyngeal soft tissue and tongue are attached. This results in reduced pharyngeal collapsibility during negative pressure inspiration. [10,11] Enlargement of the airway after MMA has been shown by lateral cephalometric radiography, three-dimensional computed tomography (CT), and magnetic resonance imaging (MRI).[10,12–15] MMA is currently the most effective surgical technique for the treatment of obstructive sleep apnoea in adults. [16,17] Criteria used to evaluate surgical success include an AHI of 20 or less, and 50% or moe reduction in the AHI postoperatively.[5] Three-dimensional geometrical reconstruction and computational fluid-dynamic simulations have been used to predict the amount of surgical movement needed to achieve adequate upper airway volume.[18]

However, the appropriate amount of advancement has not been established, which leaves many issues unresolved, such as whether the maxillomandibular unit should be advanced as much as possible, whether it should be done in the same way in every patient, and whether it should be done independently of preoperative anatomical conditions. The objective of this retrospective study was therefore to analyse volumetric changes in the upper airway after MMA in patients with obstructive sleep apnoea using 3-dimensional CT and to examine the relation between these changes and reductions in AHI.

Material and methods

Patients

This retrospective study involved 10 consecutive men (mean (SD) age 45 (14), range 16–59 years) with obstructive sleep apnoea who had MMA at the Maxillofacial Surgery Unit of S. Orsola-Malpighi Hospital, Bologna, Italy, between July 2008 and January 2011. They all had moderate or severe disease diagnosed by polysomnography according to established variables. [1]

Examinations

All patients had routine preoperative examinations, polysomnography, Muller's manoeuvre, sleep endoscopy, and CT with cephalometric analysis.

Polysomnography was done to calculate AHI preoperatively and 6 months postoperatively during standard, overnight sessions. Muller's manoeuvre, in which the patient attempts to inhale with the mouth closed and the nostrils plugged, induced airway collapse, and was designed to identify collapsed sections of airway such as the trachea and upper airways with a flexible fibreoptic endoscope inserted into the hypopharynx. This was used to help find out the cause of the sleep apnoea. Sleep endoscopy, which enables dynamic evaluation of the upper airway, was used to ascertain the site(s) of collapse during respiratory events. CT was done preoperatively and 6 months postoperatively to evaluate the anatomy of the upper airway. Images were acquired with a high-speed CT scanning station (General Electric; 3.0-mm slice interval, 1.5-mm overlap) while patients were awake supine and in a neutral position (including standard head position) during one breath hold at the end of a normal inspiration, as proposed by many authors. [9]

The following limits for upper airway volume were adopted in accordance with Ogawa et al:[19] cephalad=hard palate plane; caudad=inferior margin of the hyoid; ventral=junction of the superior adenoid tissue and nasopharynx; dorsal=posterior pharyngeal wall; and lateral=right and left lateral pharyngeal walls. The range of upper airway volumes was extrapolated postoperatively using 3-dimensional CT images and reconstruction software (Simplant View; Materialise, Leuven, Belgium).

Operation

All patients were operated on under general anaesthesia with nasopharyngeal intubation. The operation was undertaken through a Le Fort I osteotomy with a standard advancement