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Using Dynamic Maneuvers in the Computed Tomography/Magnetic Resonance Assessment of Lesions of the Head and Neck

İrfan Çelebi, MD[a,*], Aysel Öz, MD[a], Mehdi Sasani, MD[b], Petek Bayındır, MD[c], Esra Sözen, MD[d], Çetin Vural, MD[e], Muzaffer Başak, MD[a]

[a]*Radiology Clinic, Şişli Etfal Training and Research Hospital, İstanbul, Turkey*
[b]*Neurosurgery Clinic, VKV American Hospital, İstanbul, Turkey*
[c]*Department of Radiology, Ege University School of Medicine, İzmir, Turkey*
[d]*Otorhinolaryngologic Clinic, Şişli Etfal Training and Research Hospital, İstanbul, Turkey*
[e]*Department of Otolaryngology, Head and Neck Surgery, Maltepe University School of Medicine, İstanbul, Turkey*

Abstract

Despite advances in technology, the radiologic assessment of certain head and neck lesions may still pose difficulties because of the complex anatomy of this region, the small and mobile structures that this region harbors, and the apposition of mucosal surfaces in the neutral position. Certain maneuvers have been described in the literature to overcome these difficulties. We review the use of the Valsalva and the modified Valsalva maneuver, the puffed-cheek technique, phonation, and inspiration, with possible applications in head and neck imaging.

Résumé

Malgré les avancées technologiques, l'évaluation radiologique de certaines lésions de la tête et du cou soulève encore parfois des difficultés en raison de l'anatomie complexe et des petites structures mobiles que présente cette région et de la superposition des surfaces muqueuses en position neutre. Certaines manœuvres ont été décrites dans la littérature pour résoudre ces difficultés. Nous avons revu l'utilisation des manœuvres de Valsalva et de Valsalva modifiée, de la technique du gonflement des joues, de la phonation et de l'inspiration dans leur possible application en imagerie de la tête et du cou.

Key Words: Dynamic maneuvers; Head; Neck; Lesion; Radiology

Even with the use of currently available fast and high-resolution multidetector computed tomography (CT) devices, it may not always be possible to perform locoregional assessment of gingivobuccal or laryngeal tumours. It can be challenging to confirm a vascular abnormality in the orbita or to demonstrate active cerebrospinal fluid (CSF) leakage with routine CT or magnetic resonance (MR) imaging examinations. In such cases, use of dynamic maneuvers may provide useful information about the lesion. These techniques facilitate providing information concerning lesion size, location, volume, and relationship with surrounding structures to the radiologist and, as well, may aid the surgeon in sharing this information with patients. The effects and possible applications of these maneuvers were listed in Table 1. We reviewed the use of the Valsalva and modified Valsalva maneuvers, the puffed-cheek technique, phonation, and inspiration for their possible applications in head and neck imaging.

Dynamic Maneuvers and Their Diagnostic Contributions

The Valsalva and Modified Valsalva Maneuvers

The Valsalva maneuver is a forced expiratory effort against a closed glottis. The intrathoracic and intracranial pressures rise, the trachea and subglottis are filled with air, and the laryngeal vestibule is collapsed. In the modified Valsalva maneuver, a forced expiration is performed not against the resistance of the closed glottis but against the

* Address for correspondence: İrfan Çelebi, MD, Radiology Clinic, Şişli Etfal Training and Research Hospital, 34377 Şişli, Istanbul, Turkey.

E-mail address: irfancelebi@gmail.com (İ. Çelebi).

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Table 1
Dynamic maneuvers used in the clinical and radiographic evaluation of head and neck lesions

Maneuver	Description	Major effects
Valsalva maneuver	Forced expiration against a closed glottis	Distention of venous malformation (including distensible orbital varix)
		Distention of the entire airway below the vocal cords
		Improved evaluation of the paraglottic fat planes and CSF leakage
Modified Valsalva maneuver	Forced expiration against pursed lips and pursed nose	Distention of the oral cavity and oral vestibule
		Distention of the Rosenmüller fossa
		Distention of the hypopharynx (including the pyriform sinus and postcricoid area)
		Better delineation of the inner cheek wall
		Evaluation of pneumoparotitis
"E" phonation	Vocalization of a high pitched "e"	Arytenoid mobility
		Extension of the laryngeal ventricle, pyriform sinus, and vallecula
		Better delineation of the aryepiglottic fold, epiglottic tip, pre-epiglottic space, and posterior pharyngeal wall
Puffed cheeks	Puffing out the cheeks (the patient may continue respiration)	Evaluation of the gingivobuccal region, retromolar trigone, and tongue via distention of the oral cavity and oral vestibule
Inspiration	Forced inspiration	Evaluation of cord motility and anterior commissure, and superficial extension of the laryngeal carcinoma via expansion of the glottic airway

CSF = cerebrospinal fluid.

resistance of pursed lips or a pursed nose. The major effects of the modified Valsalva maneuver are to open the Rosenmüller fossa and to distend the laryngeal ventricle and the pyriform sinuses [1]. The Valsalva and modified Valsalva maneuvers increase the flow rate of CSF leakage by increasing the intracranial pressure and, therefore, ease the radiologic diagnosis of rhinorrhea or otorrhea.

During a Valsalva maneuver, the true and false vocal cords approach to midline and the true vocal cords come into contact, the laryngeal vestibule is collapsed, and the entire airway below the cords becomes distended with air. In this state, distinguishing the margins of the true cords from each other may be difficult. Visualization of the paraglottic region is improved [2]. When a modified Valsalva maneuver is performed, the glottis opens and the pyriform sinuses are slightly distended, the mucosal surfaces of the hypopharynx are separated, and assessment of tumour extension into the postcricoid area and evaluation of hypopharyngeal region tumours are facilitated.

Puffed-Cheek Technique

The puffed-cheek technique has recently been described by Weissman and Carrau [3] and Bredesen et al [4]. The maneuver is easy to understand and perform for the patient. The patient is asked to close the mouth and fully puff the cheeks. The entire oral cavity, from the hard palate to the mandible, is scanned with a continuous spiral scan, after contrast material administration. By puffing the cheeks, the oral vestibule is filled with air, which, by creating a negative contrast, separates the buccal and labial mucosa from the gingival mucosa, which allows both mucosal surfaces to be assessed separately. The buccinator muscle, the pterygomandibular raphe, and the retromolar trigone can be better delineated. Assessment of the loss of mucosal pliability due to accompanying submucosal fibrosis, which is commonly observed in oral cavity cancers, is also facilitated. Another technique to eliminate artifacts caused by dental fillings is the open mouth technique described by Henrot et al [5] in which a device, such as a syringe, is placed between the teeth to keep the mouth open, with images being obtained during quiet respiration.

Phonation and Respiration Maneuvers

On routine scans obtained during quiet respiration or apnea, early stage laryngeal tumours can be overlooked or their margins may not be depictable. The laryngeal ventricle and the pyriform sinuses may not be clearly visualized. In such cases, scans obtained during phonation, inspiration, and the Valsalva maneuver might be helpful to overcome these difficulties. In laryngeal CT scanning performed by having the patient produce a high pitched "e" sound for 10 seconds (phonation maneuver), the vocal cords approach each other, the laryngeal ventricle and the pyriform sinuses expand, fill with air, and become more visible. The phonation maneuver facilitates in determination of supraglottic and infraglottic extension of tumours by demonstrating the laryngeal ventricle on the coronal plane images. Lesions located on the true or false cords are easier to depict.

For scans during inspiration, the patient is asked to slowly inhale, preferably through the nose, a single breath throughout the scan, this is facilitated by a prior forced expiration. During inspiration, the vocal cords are slightly drawn away from the midline but are not completely effaced against the lateral laryngeal wall; visualization of the true vocal cords and the laryngeal ventricle is weak. However, as the glottic airway expands and the cords are drawn away, assessment of endoluminal superficial lesions is facilitated, and craniocaudal and anteroposterior extension throughout the mucosal surface can be better demonstrated.

Parotid Space

Recurrent parotid gland swelling can have various etiologies (eg, recurrent sialadenitis, sialolithiasis, autoimmune diseases, pneumoparotitis). In suspected sialolithiasis, ultrasound is usually the first modality used. Plain radiographs have little role, because the majority of parotid sialoliths (67%) have been reported to be radiolucent [6]. CT is very sensitive in detecting even small deposits of calcium and can demonstrate coexisting diseases [7]. However, artifacts due to dental fillings may obscure small, semicalcified, or distally located stones. Important features of which clinicians may want to be aware when assessing sialolithiasis of the Stensen duct are the status of the parotid gland, the size of the sialolith, and the distance between the sialolith and ductal orifice. Advanced damage to the parotid gland may require removal of the gland. The size and location of the sialolith determines the treatment options, which may vary from institution to institution [6,7].

The puffed-cheek technique is useful in detecting small, distally located sialoliths. Even stones lucent to standard radiography contain a minimal number of calcific deposits that can be successfully imaged with CTs obtained by using this technique. The visualization of small sialoliths can be further improved by hyperflexion of the neck, which eliminates artifacts due to dental restorations (Figure 1). The puffed-cheek technique recently has been reported to be effective in the radiologic diagnosis of pneumoparotitis [8]. The surfaces of the oral cavity that are often in contact are the buccal (cheek) mucosa more posteriorly or the labial (lip) mucosa more anteriorly, and the alveolar (gingival) mucosa of the mandible and maxilla. In puffed-cheek CTs of the oral cavity, the patient is asked to purse the lips and puff out the cheeks, and the air separates these mucosal surfaces [3]. The modified Valsalva maneuver is also suited for this purpose. The difference is that the modified Valsalva maneuver causes a greater increase in intraoral pressure. The increase of pressure in the oral vestibule facilitates retrograde passage of air into the Stensen duct (Figure 2).

Pneumoparotitis is a rare cause of recurrent unilateral or bilateral parotid swelling and consists of the accumulation of air in the ductal system and glandular acini due to an increase in intraoral pressure, accompanied or not by an inflammatory process. Patients present with tender or nontender recurrent parotid swelling, accompanied by subcutaneous emphysema in severe cases. Reported causes are increases in intraoral pressures, as seen in wind instrument musicians, in glass blowers, in divers working under high pressure; after intubation with positive pressure; after the application of odontologic devices; and in association with hypertrophy of the masseter muscle or hypotonia of the buccinator muscle, as well as self-induced cases in adolescents with psychological problems [9]. Visualization of air in the Stensen duct, together with air in the gland itself, establishes the diagnosis of pneumoparotitis.

Oral Cavity and Gingivobuccal Space

The oral cavity extends from the skin-vermillion junction of the lips to the junction of the hard and soft palate anteriorly and to the line of the circumvallate papillae posteriorly. It is divided into the following specific areas, which are important in describing the spread of superficial mucosal-based lesions: the mucosal lip, buccal mucosa, lower and upper alveolar ridges, retromolar trigone, floor of the mouth, hard palate, and anterior two-thirds of the tongue [10]. In the radiologic assessment of oral cavity lesions, it is important to determine the space from which the pathology is originating, the tumour size, and whether there is trans-spatial extension or invasion of deep structures. Due to the apposition of the mucosal surfaces in the neutral position, small lesions may be missed or a tumour's origin or its deep extension may not be clearly delineated. Air and water have been proposed as contrast agents to enable separate evaluation of the mucosal surfaces [11]. Lesions of the oral vestibule, retromolar trigone, and tongue can be better delineated with the puffed-cheek technique (Figure 3). Demonstration of invasion of the buccinator muscle and pterygomandibular raphe and assessment of the loss of mucosal pliability due to accompanying submucosal fibrosis, commonly observed in oral cavity cancers, is facilitated. With the puffed-cheek technique, the lesions located periorally is apparent: these lesions are usually overlooked due to artifacts caused by dental occlusal restoration materials. The puffed-cheek technique also can be used in selected cases with MR

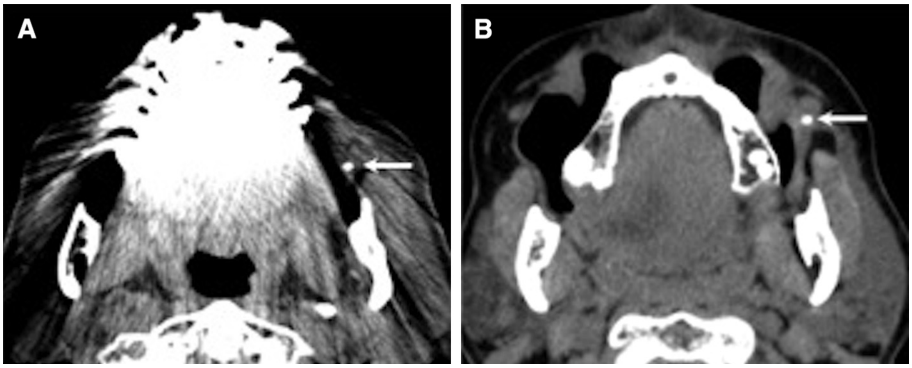

Figure 1. Contrast-enhanced computed tomography images of a 36-year-old man with episodes of painful left parotid swelling associated with eating. (A) A small sialolith (arrow) can be identified at the level of the left distal parotid duct. (B) After a repeated scan with the head in hyperflexion and with puffed cheeks, the sialolith (arrow) can now be visualized much more clearly; artifacts related to dental restoration materials are eliminated, and the distance to the ductal orifice can be measured as well.

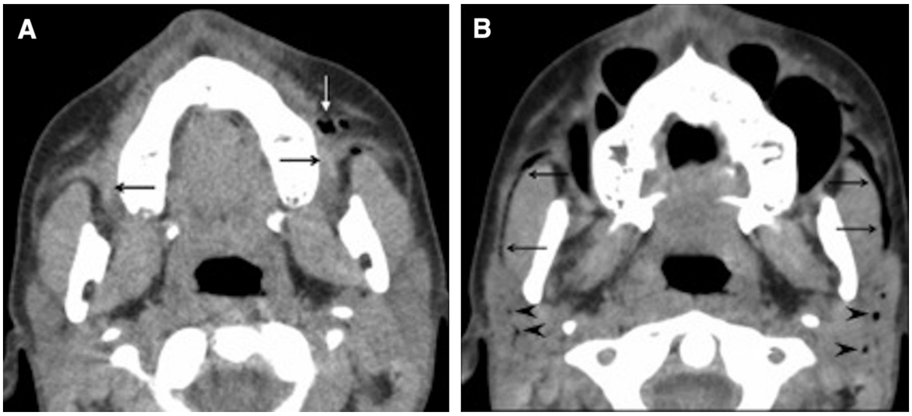

Figure 2. (A) Unenhanced computed tomography images of a 15-year-old girl evaluated for recurrent painless left cheek swelling and a suspected calculus in the Stensen duct. A calculus is not identified, but small, distal pericanalicular-located air bubbles (white arrow) are noted in the left buccal region, which suggests pneumoparotitis. Note the ampullar region and Stensen ducts (black arrows). (B) Images obtained with the patient performing a modified Valsalva maneuver resulted in air being visualized in both Stensen ducts (black arrows), in the parotid glands (arrowheads), and in the buccal soft tissues, which established the diagnosis of pneumoparotitis.

imaging. However, keeping the buccal vestibule properly open may be relatively difficult for patients, even with fast pulse sequences. In such cases, materials such as cotton or sponges can be used to keep the apposed mucosa apart without the risk of unwanted motion artifacts.

Larynx and Hypopharynx

Lesions of the larynx and hypopharynx are primarily evaluated by laryngoscopic examination. The laryngoscopic visualization of the laryngeal ventricle, the subglottic region, and the hypopharynx is restricted. Clinical suspicion of submucosal spread or lesion extension into deeper tissues mandates radiologic imaging. The accurate assessment of tumour extensions enables the otolaryngologist to select the most effective treatment alternative, with the goal of preserving respiratory and phonatory functions. Use of the Valsalva and modified Valsalva maneuvers, phonation, and inspiration has been described for radiographic studies and has been adopted in sectional imaging with advances in technology [2,12,13].

‘‘E’’ phonation, performed by causing distention of the pharynx, allows better visualization of the tonsillar fossa, base of the tongue, epiglottic tip and aryepiglottic folds, and pharyngeal mucosa from the inferior surface of the soft palate to the superior border of the cricoid cartilage. The true and false vocal cords approach in midline to within a distance of approximately 1 mm [13]. The laryngeal ventricle and the pyriform sinuses distend and become clearly visible on CTs (the former on the coronal plane and the latter on the axial plane) when obtained during ‘‘e’’ phonation. Small lesions located on the true or false cords are easier to depict. Tumoural involvement of the pyriform sinus apices and lateral walls, as well as the hypopharynx posterior wall, can be clearly seen (Figure 4). Forward movement of the tongue expands the valleculae and separates the epiglottis from the base of the tongue and the pre-epiglottic space from the hyoid bone [2,12]. Tumoural invasion of the tongue base or the hyoid bone is an important finding in the preoperative assessment of supraglottic tumours because a more extended surgical procedure is required in these cases.

Inspiration causes the true and false vocal cords to be abducted against the laryngeal wall. Abduction of the true cords, by eliminating any excessive soft tissue, causes clear demarcation of the anterior commissure (Figure 5).

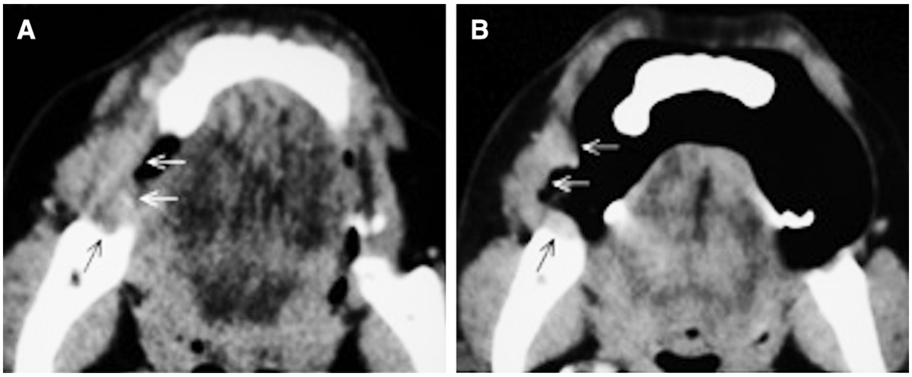

Figure 3. Contrast-enhanced computed tomography images of a 55-year-old woman, referred for a painful, bleeding buccal lesion. (A) Although the mass (black and white arrows) can be identified on the images obtained during a routine scan, it is not possible to determine from which mucosa the mass is arising. (B) On images obtained with the puffed-cheek technique, the tumour is seen to originate from the right buccal mucosa (white arrows), with invasion into the retromolar trigone (black arrow). There is a remarkable loss of pliability due to peritumoural fibrosis and infiltration of the buccinator muscle.

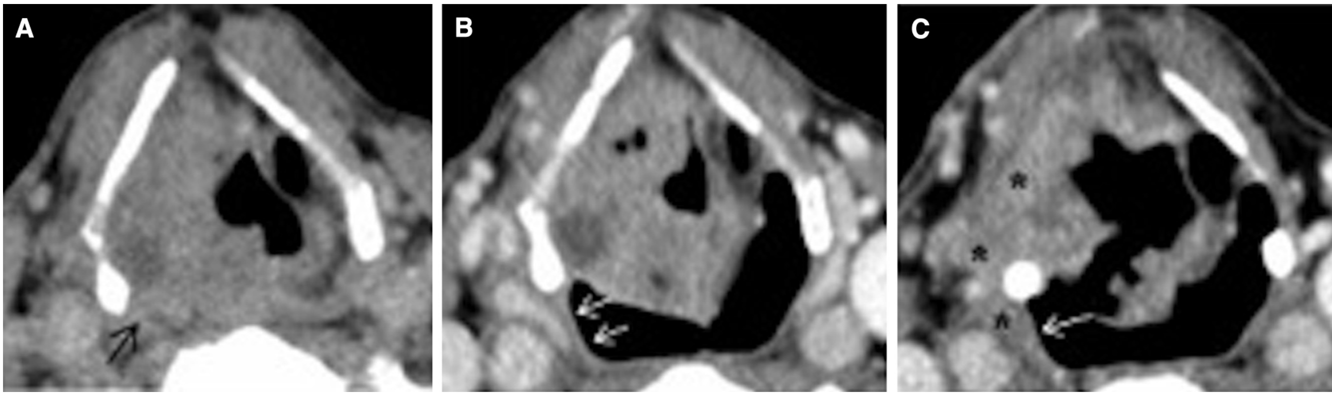

Figure 4. Contrast-enhanced axial plane computed tomography images of a 66-year-old man evaluated for laryngeal carcinoma. (A) There is suspicious invasion of the right pyriform sinus (black arrow) on images obtained during a routine scan. (B, C) Images obtained during ''e'' phonation clearly demonstrate submucosal involvement of the lateral sinus, as well as the posterior pharynx wall (asterisks in C), with extension through the thyrohyoid membrane. Note the intact mucosa (white arrows in B and C). There is loss of mucosal pliability with reduced distention of the right pyriform sinus.

Extension of a vocal cord tumour to the anterior commissure does not change the T-staging but may affect survival and choice of treatment method because surgical exposure of this region with endoscopic tools may be challenging and vertical laryngectomies would require a more extended approach [14]. Assessment of anteroposterior and craniocaudal extensions of mucosa-based lesions is improved [2]. The modified Valsalva maneuver causes distention of the hypopharynx, especially the pyriform sinuses and postcricoid region [15]. In the Valsalva maneuver, the entire airway above the glottis is collapsed. In laryngeal imaging, the Valsalva maneuver can be used to exclude tumour invasion into the adjacent cartilage and bone by delineating a clear strip of intermittent fat planes and as an adjunct in the assessment of vocal cord mobility (Figure 6) [2].

Skull Base

CSF leakage occurs as a result of communication of the subarachnoid space with the extracranial regions in the presence of an osseous and dural defect in the skull base. Most cases are posttraumatic, with iatrogenic cases due to previous otorhinolaryngologic or neurosurgical procedures being common [16]. Most traumatic CSF fistulas heal spontaneously. CSF leakage is associated with the risk of intracranial hypotension and meningitis, which has been reported in up to 50% of initial studies [17]. Some patients experience recurrent episodes of meningitis without the presence of nasal discharge. This complication indicates the presence of an occult CSF fistula, which can be a challenging problem and requires careful imaging to determine the precise location of the defect. Plain thin-section coronal CTs are generally used to show bony defects. MR or CT cisternography can be used to identify the site of CSF leakage; however, because of the superior geometrical resolution of MR imaging in depicting brain tissue and its lack of radiation, MR cisternography is usually the method of choice. Because the radiation dose that results from high-resolution CT is significant, MR cisternography is usually the first technique used. The reported sensitivity of MR cisternography in the diagnosis of CSF fistulas ranges from 87%-100%. If this examination does not provide adequate information, then high-resolution CT may be used. The sensitivity of high-resolution CT reportedly ranges from 71%-92% [18].

For CT cisternography, approximately 3-10 mL of nonionic low-osmolar contrast material and, for MR

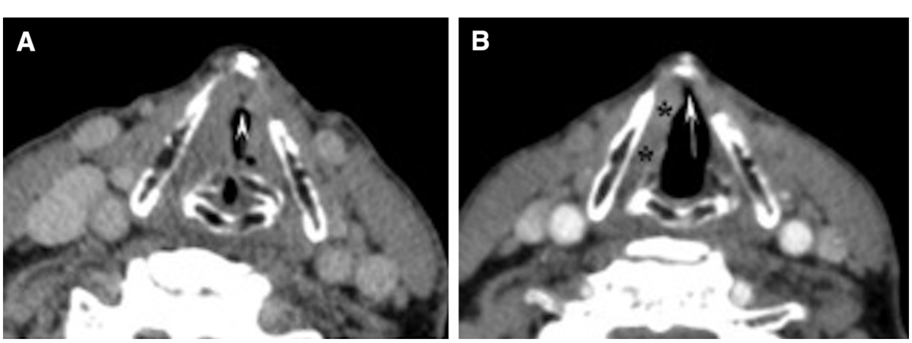

Figure 5. Contrast-enhanced axial plane computed tomography images of a 59-year-old man evaluated for glottic carcinoma. (A) On the images obtained in a neutral position, neither the limits nor the original side of the glottic mass is identifiable. Involvement of the anterior commissure cannot be assessed (arrowhead in center). (B) On images obtained during inspiration, the mass is seen involving the right vocal cord (asterisks), with no extension to the anterior commissure (white arrow).

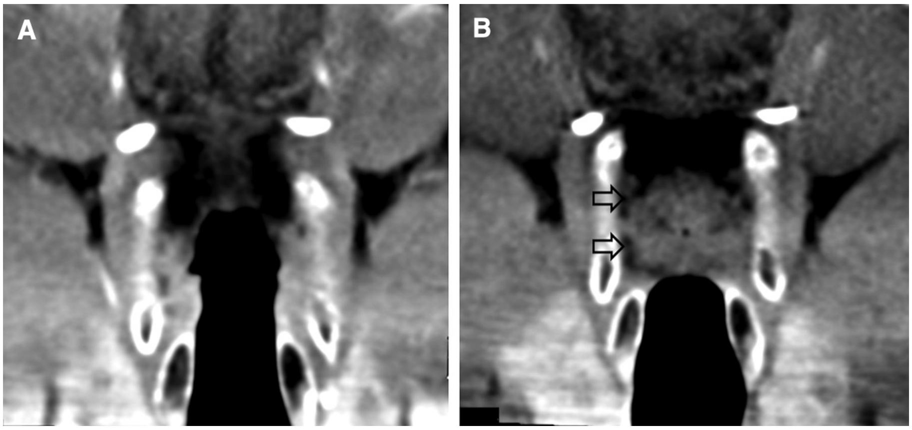

Figure 6. Coronal reformatted computed tomography (CT) images in a patient with right-sided vocal cord tumour, which is diagnosed endoscopically. (A) Inspiratory phase CT is not enabling clear visualization of the mass. (B) Valsalva phase CT, however, reveals the intact paraglottic fat planes as a thin hypodense line (open arrows).

cisternography, 0.5-1 mL of gadopentetate-based contrast material, diluted with 4 mL saline solution, are administered intrathecally by lumbar puncture, and the patient is kept in the Trendelenburg position until the contrast material reaches the basal cisterns. In cases of slow flow rhinorrhea, cisternography is carried out after provocative maneuvers, such as sneezing or the Valsalva maneuver. These maneuvers should not be used in conditions with increased intracranial pressure, such as trauma or an intracranial mass. The demonstration of contrast material in the sinonasal cavities or the middle ear, together with the presence of a skull base defect, is diagnostic (Figures 7 and 8). In CT cisternography, Hounsfield unit (HU) measurements can be used in inconclusive cases; an increase of >50% in HU value is considered positive for a CSF fistula [19].

Orbita

Orbital venous malformations (OVM) are categorized into distensible and nondistensible OVMs. The histopathologic structures of distensible and nondistensible lesions do not differ from each other. Distensible OVMs have rich communication with the venous circulation and increased

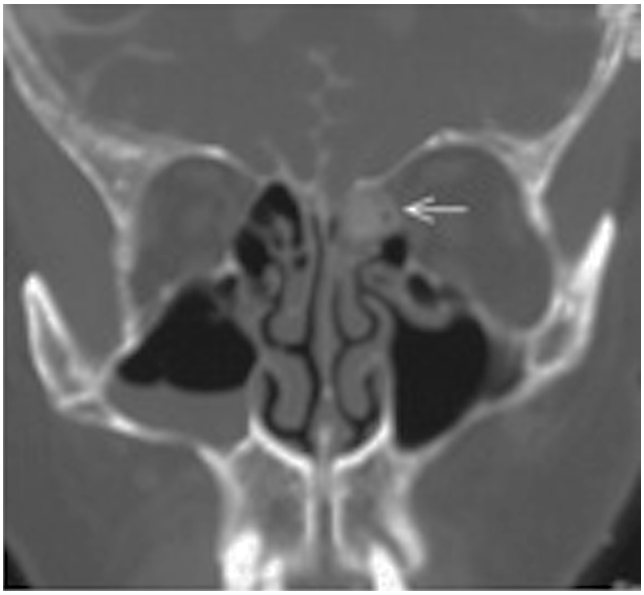

Figure 7. Direct coronal computed tomography (CT) cisternography image of a 25-year-old woman with postoperative rhinorrhea, demonstrating leakage into the ethmoid sinus (arrow). Because a Valsalva maneuver was contraindicated in this patient with accompanying meningoceles, images were obtained after keeping the patient in the Trendelenburg position for 30 minutes. Note the lower attenuation of the contrast-enhanced subarachnoid spaces on the left when compared with the right side, due to washout and leaking of the contrast material and cerebrospinal fluid.

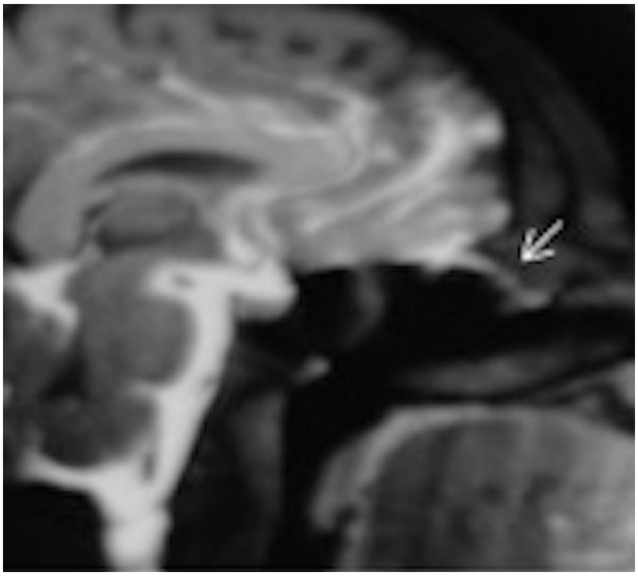

Figure 8. Sagittal plane magnetic resonance cisternography image of a 48-year-old man with postoperative clinical signs of a cerebrospinal fluid (CSF) fistula and positive laboratory findings. An obvious bony defect was not identified on the high-resolution coronal computed tomography (not shown). In this patient, the leakage of contrast-enhanced CSF through the cribriform plate (arrow) could only be visualized on scans repeated after 12 hours, after a Valsalva maneuver.

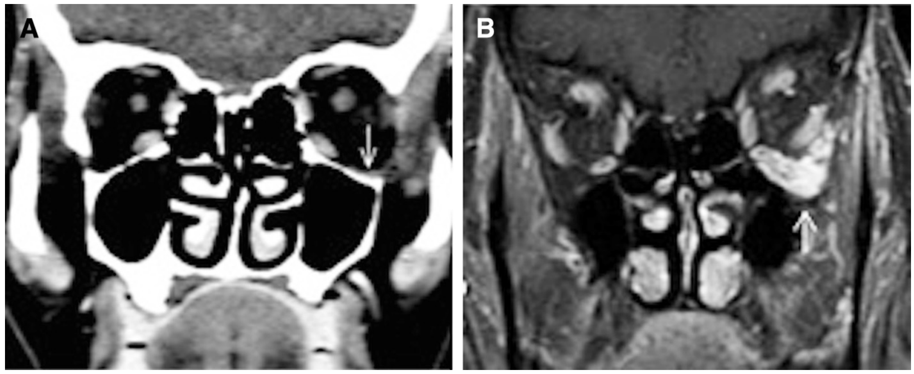

Figure 9. (A) Contrast-enhanced coronal plane reformatted image, obtained with the patient in the supine position, of a 43-year-old woman with left orbital pain and proptosis when bending forward. Careful examination revealed an indistinct, dense, soft-tissue lesion in the inferior aspect of the left orbit (arrow). (B) A coronal plane contrast-enhanced magnetic resonance image of the same patient, obtained with the patient in the prone position during a Valsalva maneuver, clearly demonstrating the orbital varix (arrow).

venous pressure, whereas nondistensible OVMs have minimal communication. The increase in venous pressure required to produce distension is achieved by coughing, forward flexion, jugular vein compression, or a Valsalva maneuver. The distensibility of an OVM affects its clinical and radiologic behavior. Nondistensible OVMs more often present with thrombosis and hemorrhage [20]. Most lesions are diagnosed clinically, and radiologic documentation of orbital varices is uncommon.

Contrast-enhanced orbital CT and MR imaging are reported to be reliable in demonstrating OVMs [20]. MR imaging provides a more detailed visualization of the orbital and intracranial structures. OVMs have the tendency to collapse due to low venous pressure and may be observed only as minimal dilatations of the involved veins, or they may not be detected at all with routine CT or MR imaging. Images, particularly those obtained during a Valsalva maneuver, can help in revealing more subtle abnormal venous structures (Figure 9).

Conclusion

The use dynamic maneuvers, which are the Valsalva and modified Valsalva maneuvers, the puffed-cheek technique, phonation, and inspiration, improve lesion detection, overcome blind spots, and add value to the pretherapeutic evaluation of head and neck lesions during radiologic assessment.

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