8 Virtual Endoscopy and 3-D Reconstruction/Prototyping in Head and Neck Surgeries

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8.1 Introduction

The use and application of the three-dimensional (3-D) reconstructions generated from suitable files Digital Imaging and Communications in Medicine (DICOM) of computed tomography (CT) or magnetic resonance (MR) have been expanding recently. Such reconstructions allow physicians to observe anatomic cavities and structures within our body with an incredible amount of detail in addition to displaying the textures of variety of tissues [1–3]. The applications of such reconstructions have varied from simple illustrations in exams up to the help in the diagnosis and preoperative planning in several ENT procedures. An example of such application is virtual upper airways endoscopies and laryngoscopies. Such application has been practically abandoned due to its complexity and need for computers with high power of graphic processing [4]. However, with the evolution of proper compute softwares for reading and reconstruction of the DICOM files, some applications of such 3-D reconstructions have been recovered for evaluation and preoperative planning in ENT, especially for head and neck surgeries and sinus surgery [5, 6]. Such 3-D reconstructions may offer potentially more usable information than those obtained with 2-D views in the axial, coronal, and sagittal planes. Two-dimensional images are of more difficult comprehension for surgeons [7]. We live in a three-dimensional world, and despite a large part of the endoscopes still do not allow the performance of 3-D stereoscopic surgeries, the images obtained in the traditional endoscopic surgeries allow us

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the creation of 3-D relationships in our mind. These relationships may help in the performance of specific tasks, and the excellent preoperative preparation may sometimes prevent generally challenging complications [8]. Some researchers have studied the utility of the 3-D reconstruction tools for the surgeries of the ear, nose, and throat and of the recess and frontal sinus. Other possible applications include preoperative surgical planning, preoperative measurement for production of prostheses, air flow analysis, and proper teaching to resident doctors [5, 6, 8, 9, 10].

8.2 VE and 3-D in Head and Neck Surgery Planning

Surgical procedures in otolaryngology—head and neck surgery—can be so challenging even to the most experienced surgeons during resection of infiltrative diseases and reconstruction of anatomical structures. These challenges arise from performing excision of lesions within critical and anatomically complex areas in the head and neck region.

Head and neck anatomy is intricately unique in having compact condensation of neuromusculovascular structures. In addition, it is composed of multiple anatomical subsites which are essential for vital functions, namely, breathing, phonation, and swallowing. These structures have different embryological origins and give rise to various disease processes and pathologies. Esthetics is also a unique hallmark in the head and neck region for social acceptance and self-esteem.

Staging workup of head and neck cancers is important for prognosis assesment and for choosing the most appropriate treatment modality. Although there have been advances in nonsurgical treatment options, that is, chemoradiation, adequate surgery is still the mainstay of treatment for many benign and malignant tumors in head and neck region. Performing complete excision while minimizing effects on breathing, phonation, swallowing, and esthetic appearance greatly improves loco-regional control and minimizes short- and long-term complications with improved quality of life scores. Surgical planning for excision and/or reconstruction requires not only surgical expertise but also detailed knowledge of the disease topography in relation to the normal structures surrounding it.

Currently, endoscopic examination in the clinic or operating theatre is a valuable tool for disease mapping and assessing its effects on the upper aerodigestive tract and anticipating the function loss from adequate tumor resections. However, endoscopy is an invasive examination; may cause discomfort, bleeding, and airway compromise; and may often require local or even general anesthesia. In addition, it may yield limited information due to limited views depending on tumor localization and depth of extension and on individual patient's anatomy variations, patient's compliance, body habitus, and comorbidities, which should be taken into consideration. Therefore, reliance on other modes of information gathering is becoming more essential in assessing different head and neck pathologies. The current common modalities utilized in head and neck imaging are US, CT, and MRI, which have their own advantages and limitations in assessing head and neck tumors.

Virtual endoscopy (VE) and 3-D reconstructions have become a more attractive imaging modality concept used in head and neck surgical planning. Virtual endoscopy is the processing of computerized tomography image data to create a virtual environment of the human body to allow diagnosis of disease processes. This technique combines latest imaging techniques with modern computer software to provide interactive reconstruction of the 3-D anatomy and pathology of the head and neck from 2-D images. This mental task usually takes less time of experience to master as a radiologist or a head and neck surgeon. This concept will also be a useful tool for systematic and standardized way to help trainees develop their knowledge in dealing with the complex 3-D anatomy of the head and neck. VE allows the surgeon the opportunity to interact with an image that is artificially generated by the computer that mimics reality.

8.3 Airway Management in Head and Neck Pathology

Managing the airway in head and neck surgery is a shared responsibility between the anesthetist and the surgeon. The surgeon needs to be knowledgeable about how to keep the airway patent.

Traditional approaches to the development of surgical competency and image-guidance technology involve the use of biological specimens in a pre-clinical setting. However, the use of cadaveric specimens requires considerations of resource availability and bio-safety factors. In contrast, animal studies raise ethical issues and may not provide a realistic representation of human anatomy. In both scenarios, there are costs associated with specimen transport and storage.

The development of realistic 3-D reconstruction images and virtual endoscopy for head and neck surgery has the potential to provide a threefold advantage: (1) from an educational perspective, it provides realistic and customizable environments for surgical trainees; (2) from a surgical perspective, it enables the creation of patient-specific models for surgical planning and procedure simulation before starting the actual surgery; and (3) from a research perspective, it facilitates technology development in an environment that mimics clinical practice [2].

8.4 Some Major Problems Solved by VE and 3-D Redemonstration

In this chapter, the current applications and implications/limitations of VE in head and neck surgery are discussed. And processes that create rapid prototype models for VE applications of head and neck surgery are also given.

8.4.1 VE and 3-D in Head and Neck Foreign Body Diagnosis

8.4.1.1 Deceiving Duck Bone Which Turned Out to be a Needle

Foreign body ingestion is a very common presentation in ENT practice and can have different sequelae. It can arrest anywhere in the pharynx, or it can continue further down either taking the airway tract to end up in the bronchus, or the digestive tract up to the intestines. A young female patient presented with possible ingestion of duck bone. CT imaging and 3-D reconstruction are shown in Figs. 8.1 and 8.2 (Movie 8.1). The characteristics of FB determined to be more of metallic in nature. The FB was traversing the sternocleidomastoid muscale and peircing the internal jugular vein; it was removed and it was actually an injection needle with a bore, and with a pinged proximal end suggestive of a break-off from its base. Although she didn't not know how she ingested the needle, she recalled a dental procedure where she received a local anesthetic. The bottom line is that 3-D reconstruction and VE were helpful in localizing the FB and in surgical planning as well.

8.4.1.2 Fish Bone as a Diagnostic Tool

VE and 3-D reconstruction play a very important role in the diagnosis of foreign body ingestion like fish bone, and to see how the diagnosis becomes easy and accurate please refer to Movies 8.2, 8.3 and 8.4.

Please refer to Chap. 12, Challenge case discussion.

8.4.2 3-D and VE in Tracheo-Esophageal (TEF)

Tracheo-esophageal fistula is an abnormal communication between the trachea and the esophagus. Causes of TEF are numerous and could be classified into congenital and acquired. The acquired could be further subclassified into being benign (commonest is iatrogenic causes) or malignant. Although benign acquired TEF is uncommon, the incidence seems to be rising due to increase in long term intubations and tracheos-

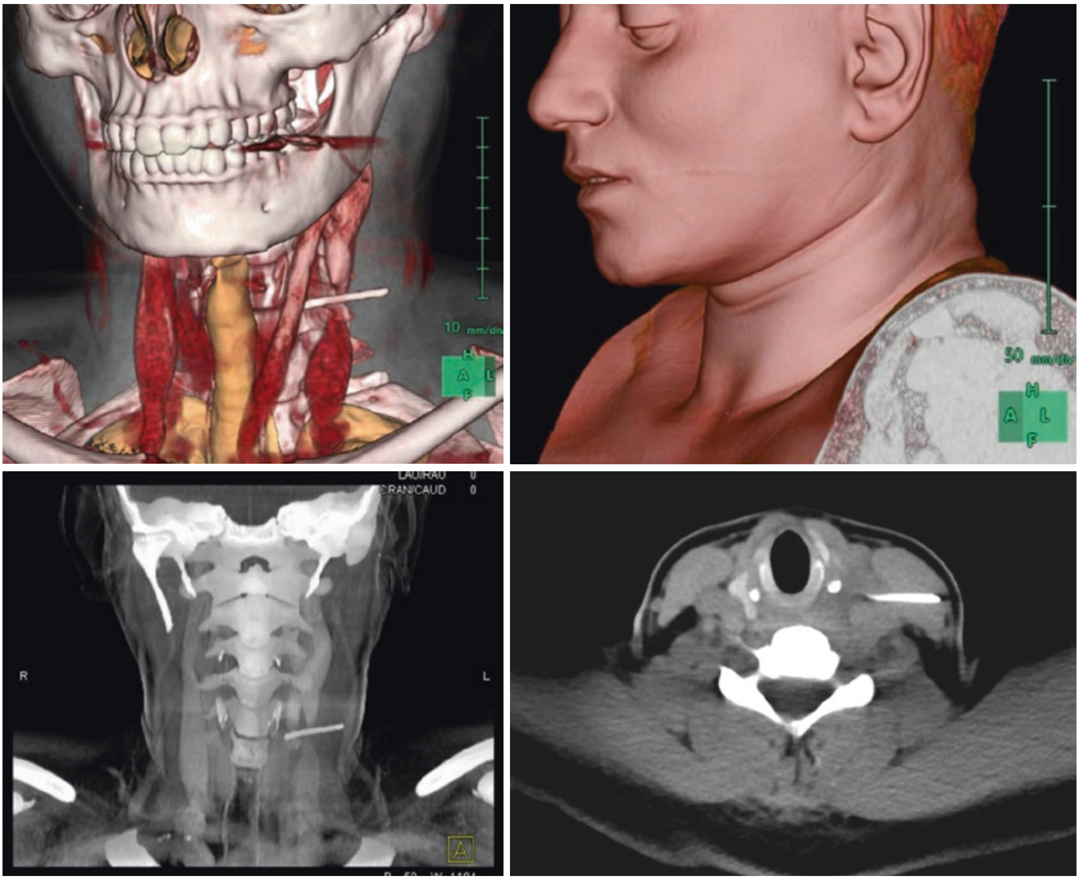

Fig. 8.1 FB needle transversely oriented with metallic density F.B. is noted as traversing and embedded within the left sternocleidomastoid muscle abutting the apparently intact left carotid sheath vessels with partial compression/effacement of the left IJV. The subcutaneous region showed subtle bulge which was the guide for easy surgical intervention (arrow).

tomies.) Patients typically present with cough after deglutition and/or recurrent chest infections/aspiration pneumonia. The latter is a reason for increased morbidity and mortality of TEF. Therefore, early detection and appropriate management is vital. Esophagoscopy and bronchoscopy are currently the gold standard for diagnosis. Radiological studies using VE and 3-D are important to plan surgical intervention. Size, location, and depth of the fistula are important factors to consider when planning the best approach for surgical closure or to plan the use of regional flaps (Fig. 8.3). Please refer to Chap. 12, Challenge case discussion.

Clinical scenario of one of our patient: a 60-year-old female patient who was intubated for 2 months with viral meningoencephalitis complained of recurrent cough while eating soon after extubation. Bronchoscopy and esophagoscopy aided to identify a small tracheoesophageal fistula in the cervical esophagus. The patient was initially managed conservatively with NPO and NG feeding. However, several months later, the fistula persisted and the patient presented to the ED with collapse due to septic shock secondary to aspiration pneumonia. Full recovery was made after 2-week course of intravenous (IV) total parenteral nutrition (TPN) feeding. VE was utilized in this frail patient to assess the size and location of the TEF and also the integrity of the posterior wall of the trachea/anterior wall of the esophagus. Please refer to Chap. 12, Challenge case discussion (Fig. 8.4).

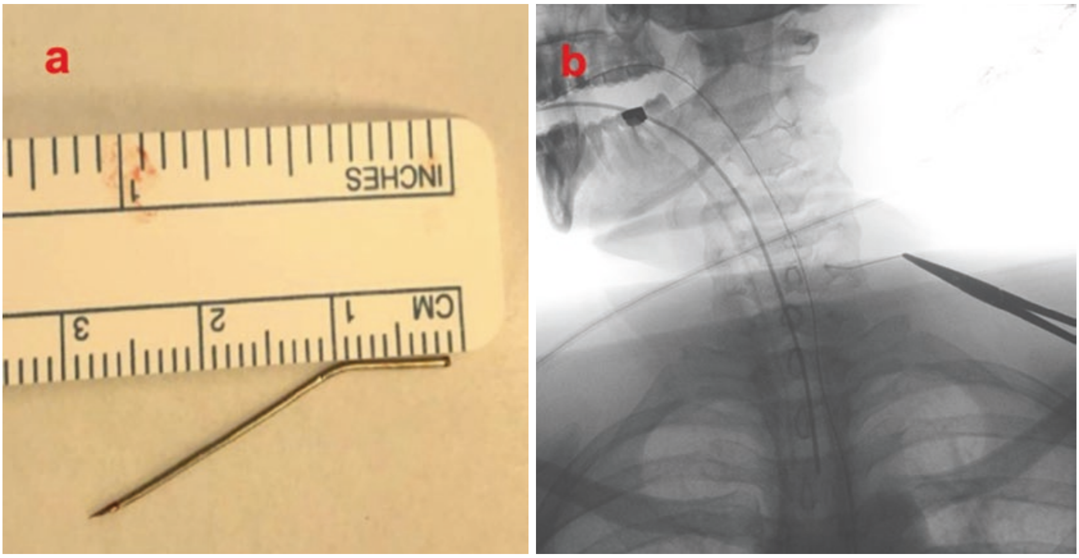

Fig. 8.2 (**a**) Curved metallic needle averaging about 3 cm in length with one beveled end. (**b**) The X-ray image showed the forceps caption of the needle during its extraction

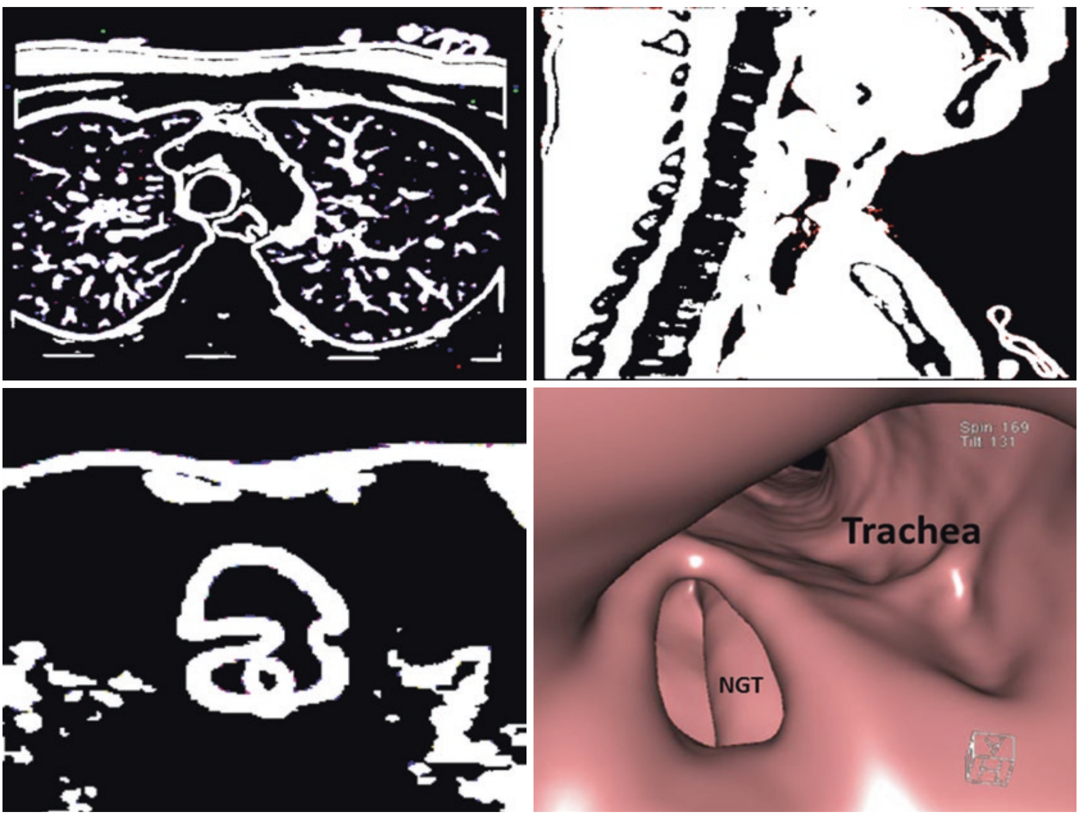

Fig. 8.3 Patient with TEF diagnosed after nondiagnostic several contrast studies; CT was carried out using modified Valsalva maneuver with nice demonstration of the fistula tract

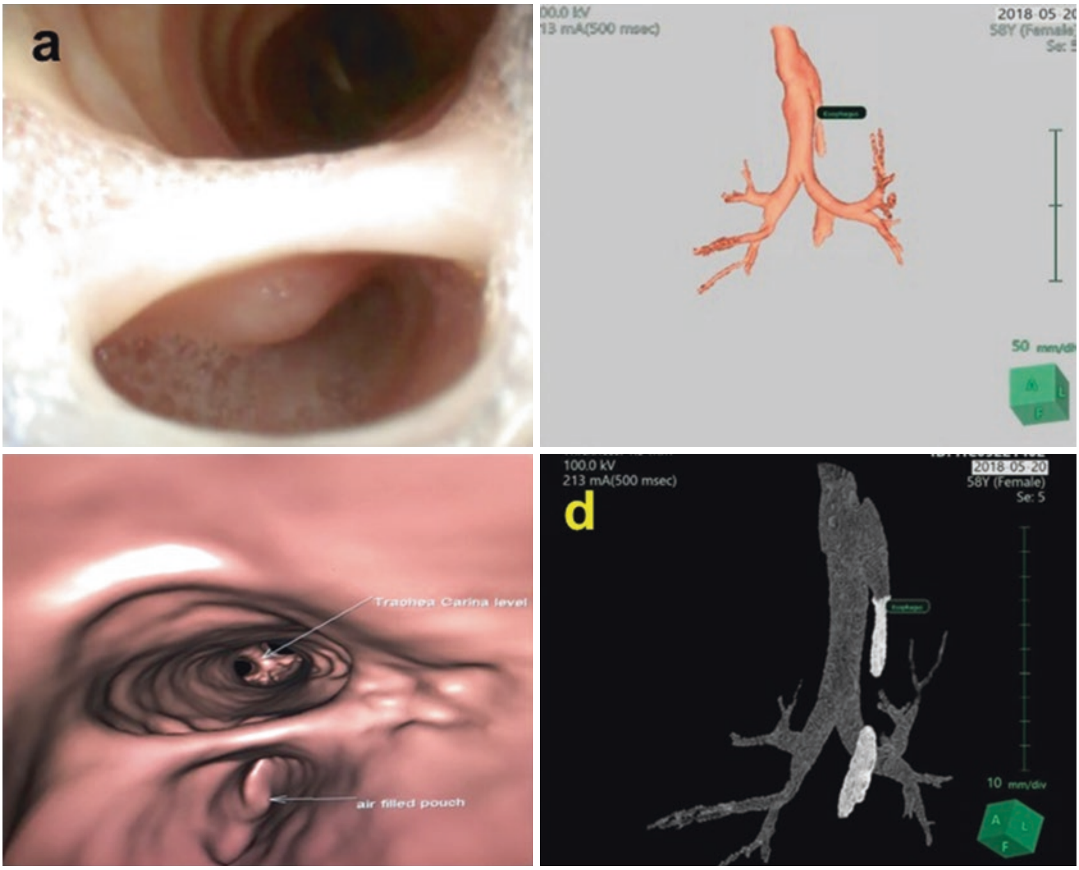

Fig. 8.4 TOF nicely demonstrated by virtual endoscopy and VRT and SSD techniques. The virtual endoscopy images and findings were identical and in accordance with the conventional endoscopy images, however, without the need for a local anesthetic and risk of aspiration, which is considered a breakthrough in safe patient management

8.4.3 VE and 3-D in Abnormal Hyoid Bone Diagnosis

8.4.3.1 Circular Hyoid Bone

Hyoid bone is a free-floating horseshoe-shaped, single bone located in the anterior neck. The hyoid bone consists of a central body and two horns (cornuas) on each side, a greater horn and a lesser horn. The hyoid bone is embryologically derived from the second (greater horns) and third (lesser horns) pharyngeal arches. Developmental abnormalities of the hyoid bone can be seen in clinical conditions such as Pierre Robin syndrome and cleft lip and palate. Only a few cases were reported on abnormal hyoid bone [11].

Circular hyoid bone with subsequent narrowing of airway in a 32-year-old male patient presenting to the clinic with dysphagia and having the feeling of pinprick sensation in the neck all the time for the past 1.5 years. Fiber optic examination revealed prominent corniculate cartilages and prominent hyoid bone horns protruding into the pharyngeal lumen.

CT imaging and 3-D reconstruction show abnormal thick and abnormal configuration of the hyoid bone causing mild oropharyngeal airway narrowing and indenting posterior upper hypopharyngeal wall. With the use of VE, the diameter of the airway was determined, and surgical, as well as anesthesia, planning was done accordingly. Microlaryngoscopy was done with a CO_2 laser and mucosa over the abnormal part of the bone and the abnormal part of the bone was exposed and removed. Please refer to Chap. 12, Challenge case discussion (Fig. 8.5), and kindly refer to Chap. 12, Movies 12.1 and 12.2.

8.4.3.2 Displaced Hyoid Bone

Our second patient presented earlier with a recent diagnosis of thyroid carcinoma for preoperative anesthesiology assessment for which clinical evaluation was carried out, and preoperative naso-endoscopic evaluation revealed the presence of abnormal mucosal lined drumstick-shaped structure of odd presentation, yet with no signs of malignancy or hyper-vascularity (Movie 8.5).

Its exact etiology origin was unclear till this point. Subsequently, 3-D reconstruction was carried out which solves this mystery as the etiology was due to displaced blade of the hypoid bone, in which the thyroid mass lesion was clearly visualized. Please refer to Fig. 8.6 and Movie 8.6.

For more details, please refer to Chap. 12, Challenge case discussion.

8.4.4 Tracheal Stenosis (Please Do Referencing)

A 40-year-old lady presented with chief complaints of difficulty in breathing when she walks for 300 meters or more or during any form of exercise.

She had a past history of an acquired tracheal stenosis for which she was treated by balloon dilatation, after which she had improved.

Her presenting history is otherwise unremarkable.

Examinations are all within normal.

Laboratory workup including complete blood count, serum urea, and electrolytes is within normal limits.

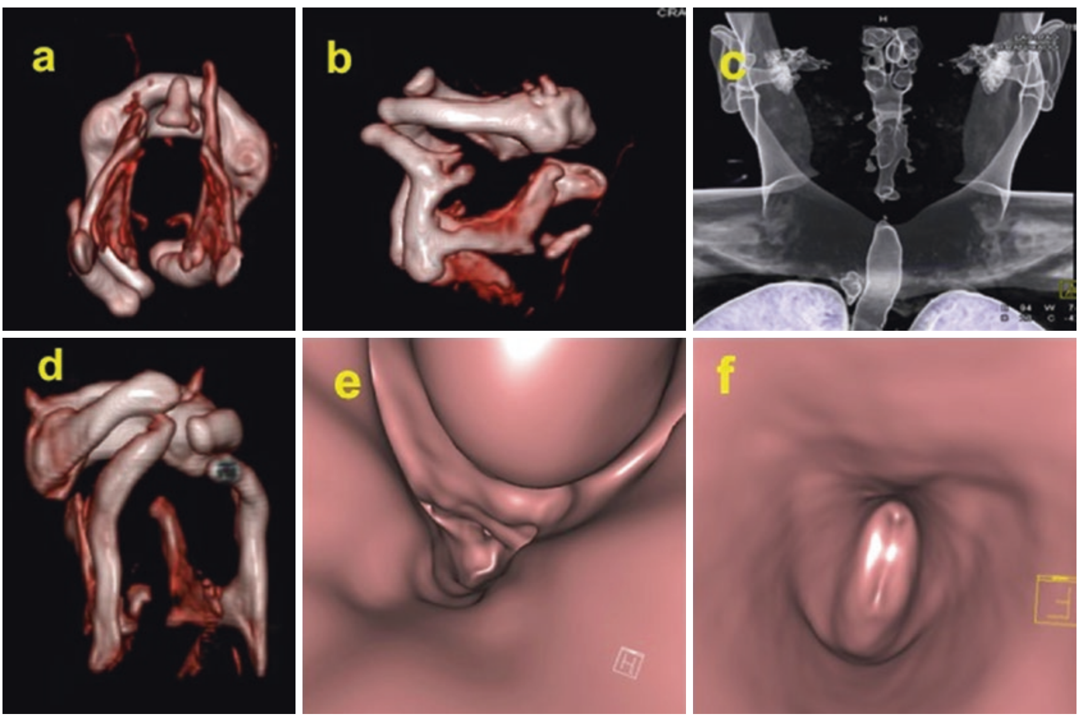

Fig. 8.5 Extremely rare anomaly (circular hyoid bone) with over-riding of its posterior aspect forming incomplete ring; the thyroid cartilages' superior conu share in the same process with subsequent signal encroachment on the related airway column. The 3-D images: (**a**) caudocranial, (**b**) right lateral, (**c**) TTP for the airway column with a narrow segment, (**d**) posterior aspect of the 3-D model, (**e**) VRT of the severely compromised airway, and (**f**) unique caudocranial view of the subglottic region

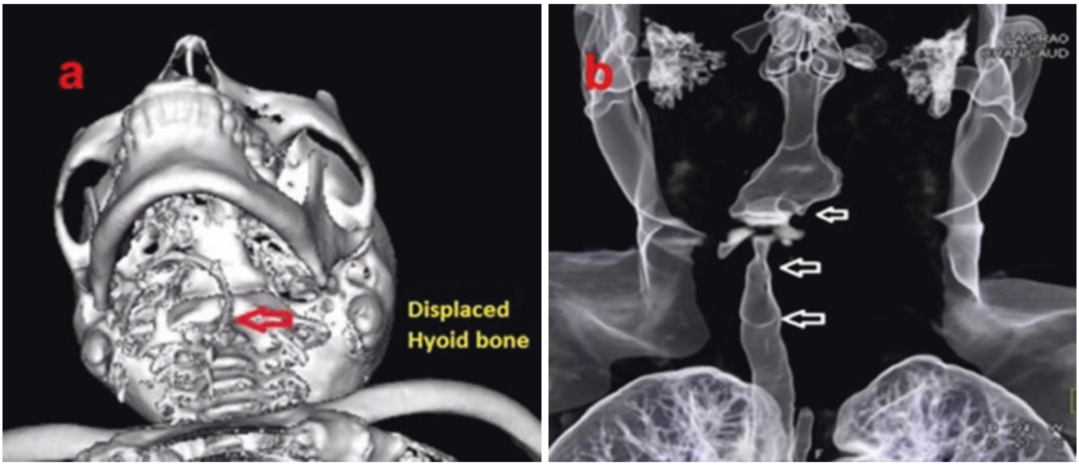

Fig. 8.6 Displaced and rotated hyoid bone (red arrow) with significant encroachment upon the airway, which is violated and replaced by a soft tissue mass lesion (white arrows)

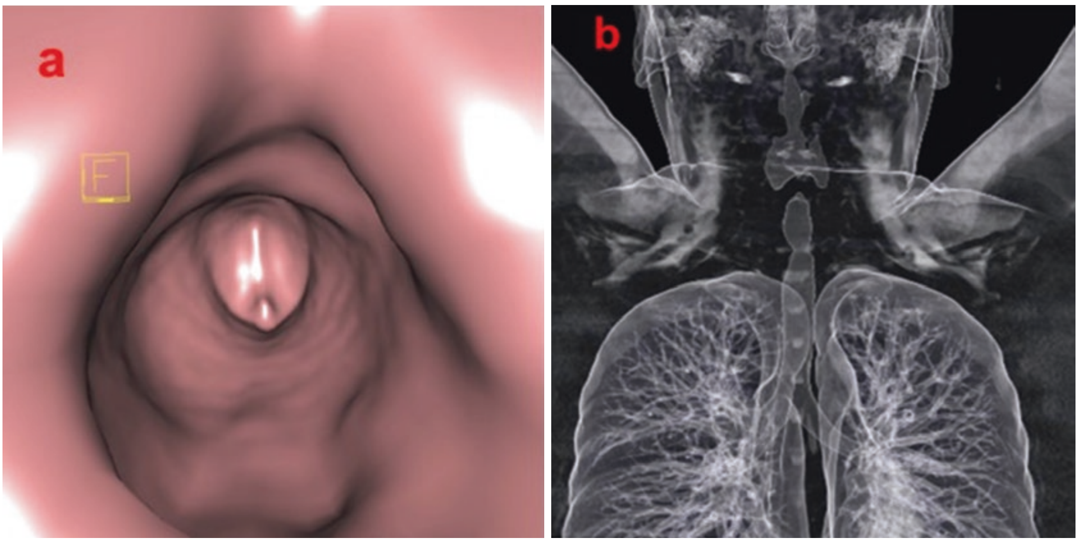

Fig. 8.7 Virtual endoscopy and TTP of the airway showing significant encroachment and subtotal occlusion, narrowing

CT of the neck and thorax was done (Fig. 8.7), which showed the severity and extent of stenosis:

A 1.5 cm short segment tracheal luminal narrowing of around 50% at the level of the thyroid gland and opposite to C5 vertebral body, corresponding to the previous tracheostomy site.

Diagnosis: Recurrent subglottic and tracheal stenosis.

Treatment planned: Microlaryngoscopy and balloon dilatation of the stenotic segment.

8.5 Traumatic Supraglottic Stenosis

This is the case of a patient with hoarsness of voice and exertional dyspnea. ENT clinical evaluation based on clinical and naso-endoscopy assessment revealed a web formation at the level of the glottis extending from the anterior commissure to the junction between the anterior two-thirds and posterior one-third of the vocal cord (glottic area) (Movie 8.3).

Virtual endoscopic evaluation was done which showed the web to be at a supraglottic region, 8 while the glottic region was clear) (Movies 8.7, 8.8, and 8.9).

The anesthesiologist's decision based on the VE findings was to give the patient light sedation in addition to topical surface spray airway anesthesia (Fig. 8.8).

8.6 Eagle Syndrome

Eagle syndrome is a rare disease due to elongation of the styloid process. Patients with this syndrome present with odynophagia, sensation of a foreign body in the throat, pain in the neck, and other nonspecific symptoms such as otalgia and tinnitus. In most cases, elongation is an acquired condition, often occurring as a result of a traumatic incident, including tonsillectomy. Diagnosis is usually made through clinical symptoms, physical examination, and radiological findings (Fig. 8.9).

8.6.1 First Case

We describe the case of a 57-year-old man who experienced unremitting right neck pain for several years following an accidental fall. A multidisciplinary investigation identified an elongated

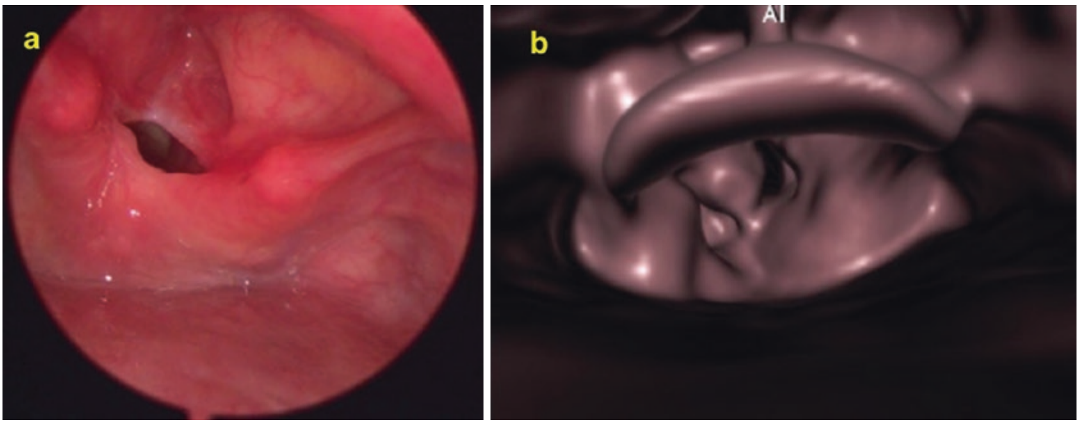

Fig. 8.8 Web formation at the level of the glottis extending from the anterior commissure to the junction between the anterior two-thirds and posterior one-third of the vocal cord (glottic area). The (**a**) image is for the conventional endoscopic evaluation, while the (**b**) image is the virtual endoscopy view [12]

Fig. 8.9 Cropped view of the VRT model nicely demonstrated the elongated styloid process with partial calcification and ossification of the stylohyoid ligament in a case of Eagle syndrome

styloid process. Surgical shortening of the structure provided definitive relief of the patient's symptoms. We review the anatomy of the peristyloid structures and discuss the etiology, diagnosis, and treatment of Eagle syndrome.

8.6.2 Second Case

A 35-year-old male patient had tonsillectomy 5 years ago for chronic tonsillitis. One year later, he started to complain of pricking sensation in his throat upon swallowing along with severe pain during swallowing with significant weight loss because of fear of eating-related pain.

3-D reconstruction and virtual endoscopy were helpful in measuring the length and the relation with carotid artery because the plane of the styloid process is not pure in the coronal and sagittal planes.

8.7 Laryngocele

Laryngoceles are uncommon cystic lesions of the larynx, which may be internal type, external type, or combined. Laryngoceles are usually filled with air but could also be filled with mucus (laryngomucocele) or pus (laryngopyocele). They may be congenital or acquired mostly arising in the sixth decade of life. The association between acquired laryngoceles and squamous cell carcinoma is well established in the literature.

A 73-year-old had a 1-year history of anterior neck swelling which was slowly increasing in size, and 6-month history of dysphonia and dysphagia. Naso-pharyngo-laryngoscopic examination revealed a large left supraglottic cystic lesion with a normal overlying mucosa overhanging the glottic opening. CT showed a mixed fluid-filled laryngocele/laryngomucocele. VE reconstruction was helpful to navigate the upper airway to intubate the patient and avoid an upfront tracheostomy. Both components of the lesion were completely excised through a combined approach with airway reconstruction [13] (Fig. 8.10).

8.8 Blunt Neck Trauma

Blunt neck trauma is not common in children, but these injuries can be potentially life-threatening. The presentation could be vague and nonspecific. Voice change and stridor may not be evident early and could be life threatening when occurring late; imaging is very important for diagnosis and management.

We present a 6-year-old female child, previously healthy, presented with a history of falling down at the edge of the bed (wooden part); after that she had some little change in the voice. She also reported coughing a small amount of blood soon after trauma. With mild degree of odynophagia, no dysphagia, and no stridor, flexible fiberoptic laryngoscope revealed left aryepiglottic fold edema, a small hematoma above the posterior third of the left vocal cord, left vocal cord almost in the midline with sluggish movement, suspected thyroid cartilage fracture on the left side above the left vocal cord, mild to moderate airway compromise, no external injuries seen on the neck, she had mild to moderate tenderness on the neck at the level of thyroid cartilage. CT of the neck showed tiny air loculi at the level of the hyoid bone and thyroid cartilage on the left side and suspected upper airway injury with the help of 3-D reconstruction and VE; it was determined that we proceed with conservative management. The child did well and was discharged after full recovery and improvement in her voice and the above findings.

8.9 3-D Printing and Its Applications in Otorhinolaryngology and Head and Neck (for More Details Please Refer to Chap. 11)

8.9.1 Splints and Stents for Trachea

Recently, researchers and clinicians are investigating the use of 3-D printing for more delicate and critical implants such as tracheobronchial splint for pediatric patients, where the challenge

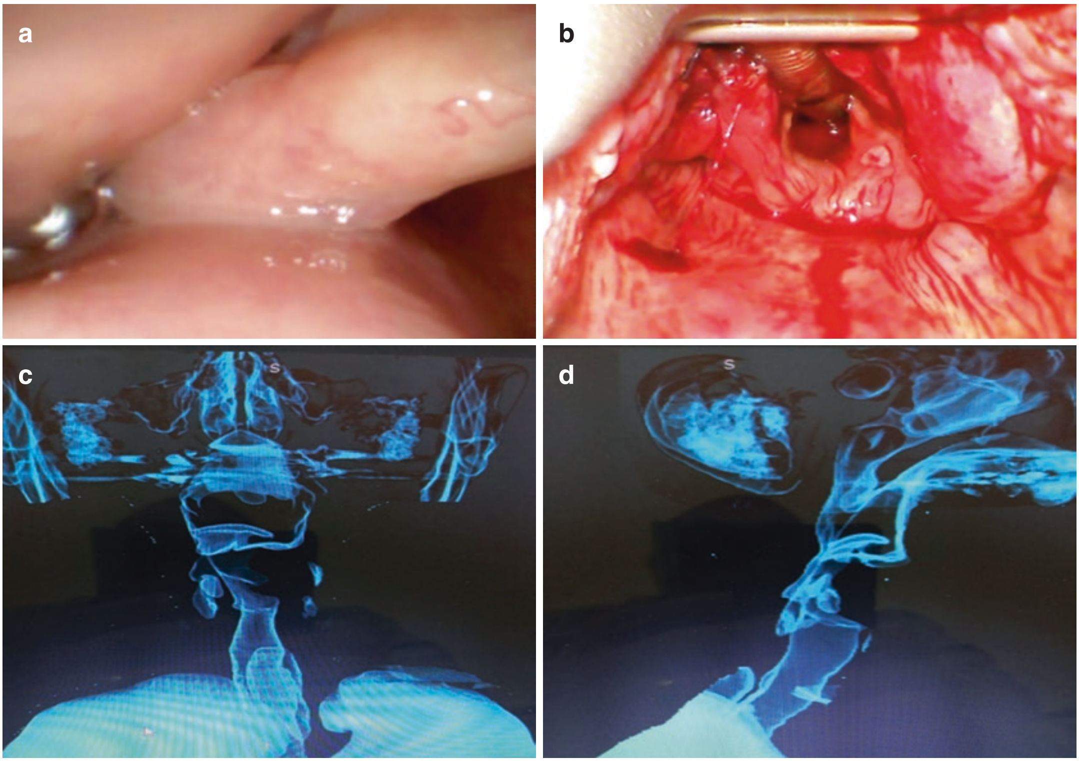

Fig. 8.10 A sizable combined internal and external laryngocele encroaching significatly upon the aerodigestive tract: (**a**) laryngoscopic view, (**b**). intraoperative photo, (**c**, **d**) airway reconstruction for the airway frontal and right lateral projections

is to create an external splint responsive to geometry changes. The case proves that 3-D printing can be useful to accommodate physiological behavior of the patients over time, in what many started to coin as four-dimensional (4-D) printing, in which materials with thermomechanical properties have shape-morphing behavior.

Surgeons succeeded in treating airway stenosis with customizable 3-D printed airway stent [14]. 3-D printing proved useful in this case due to the complexity of the geometry of the stenosis. In this case, the patient suffering from a complex case of a complete stenosis of the bronchus intermedius (BI) with partial dehiscence of the bronchial anastomosis after lung transplantation [15]. The complexity of the case excluded the use of conventional airway stents (Figs. 8.11 and 8.12).

By using computer-assisted segmentation and by conducting a virtual operation, the stenosis and dehiscence were treated and a 3-D stent was designed.

8.9.2 Bio-absorbable Polymer Vascular Stents in Head and Neck Area

Currently, most vascular stents, which are used as flow diverters or to treat stenosis, are manufactured using multi-step manufacturing processes that include, but not limited to, LASER precision micro sheet and tube machining and micro wire braiding. Essential post processing includes heat treatment to dispose internal stresses and manufacturing defects as well as surface electrochemical treatments. Materials used for stent manufacturing include nickel titanium (NiTi) and cobalt chromium (CoCr) [16]. 3-D printing seemed to be unsuccessful to present any added value to the clean room manufacturing of stents. However, many are investigating 3-D printing for direct digital manufacturing of stents that can better fit with complex geometries of critical vessels in head and neck, thus reducing the probability of failure. Furthermore, 3-D printed flexible, biodegradable polymer stents, which are customized to patient-specific geometries, can be coated with drugs that aim to reduce complications and expedite the healing process [16].

Fig. 8.11 3-D printed tracheal model shows mass effect on the wall of the trachea due to pressure from outside

8.9.3 3-D Printing for Design and Manufacture of Implantable Devices

Advances in 3-D printing now allow for the creation of biocompatible structures with impressive complexity. 3-D printed implantable models of auricle can be used for reconstruction of patients with microtia or arrhinia.

Researchers have begun exploring the feasibility of printing multi-material biomimetic tympanic membrane (TM) grafts that could be implanted into a patient.

The goal is to overcome the limitations of current graft materials to improve the outcomes following tympanoplasty. If we could design a graft material from the ground up and include optimized features, this would be a huge step forward. I think 3-D printing may now offer the means to produce such a graft.

Currently, physicians use materials such as temporalis fascia, perichondrium, and cartilage for TM grafts. The problem with these materials is that they do not possess similar structural features as those of the native TM, and this can leave the patient susceptible to chronic otitis media, a long-standing infection of the middle ear. 3-D printers can fabricate biomimetic TM grafts.

Using nonabsorbable materials, as well as biologics, such as collagen and fibrin, they have created tympanic membrane grafts with acoustic properties that can be tuned to correct the sound-induced motion patterns of the human TM.

Fig. 8.12 3-D printed tracheal model, right and left main bronchus, and printed tracheal stent

3-D printed grafts can be reliably produced and have structural features that are more consistent with temporalis fascia. Such grafts have promising implications for clinical applications. With 3-D printing, we can rapidly create constructs with varying structural features and then answer these questions in a systematic way. It should help us generate a TM structure with the ideal features—a design that may one day be implanted into patients—and hopefully result in better outcomes.

8.9.4 Maxillofacial 3-D Printing

3-D design tools have enabled the virtual construction of 3-D-specific models to construct implants and guides to facilitate surgical procedures such as drilling and implant placement. The main applications of maxillofacial 3-D printing are dental implant surgery, mandibular reconstruction, mandibular pathology, orthognathic surgery, and midface reconstruction.

Please refer to Chap. 7 for more details.

8.9.5 3-D Printing in Preoperative Surgical Planning

The level of personalized care achieved through 3-D printing has been influential in increasing accuracy and efficiency in procedures, cutting down operating room time, and improving surgical outcomes. Working with patients who have cancer or radiation damage involving the mandible, we can use 3-D models to help prepare for and implement their surgical resections and reconstructions. We can use 3-D models for two reasons: to help plan where we will make our bone cuts around the tumor and to help streamline and optimize the reconstruction.

It starts with a CT scan that is turned into a 3-D image of the patient's face to determine where the bone cuts around the tumor will be and at what angles. Often times, there is a need to take part of the patient's fibula to create a new jawbone, and 3-D imaging is used to determine where fibula osteotomies will be. Once all of the cuts have been mapped out, the 3-D model is printed. These models are used to bend a titanium plate customized to the patient's native mandible, which is implanted during surgery. In some instances, the models are also shared with patients to give them a better understanding of what the surgery will look like.

Improved cosmetic outcomes have been another advantage to 3-D printing. Patients who have mandibles that are excessively deformed are now able to achieve a result that is much more symmetric than before. We can use the 3-D images to view the opposite side of the mandible, invert it, and make it an exact mirror image of the other side of the jaw.

From a point-of-view of bone reconstruction anywhere in the head and neck region, using 3-D models is going to become the standard way to go.

8.9.6 Reductions in Operation Room Time

Operating room time has usually been one of the huge debates for health care 3-D printing. Of the 227 articles, 42 explained the precise effect of utilizing 3-D printing innovation on OR time. For a large number of applications, 3-D printing resulted in time-saving. The outcomes are given in applications such as operative guides for maxillofacial surgical operation, models for vertebral and maxillofacial surgical preparation, and designs for forming implants utilized in maxillofacial surgery appear to benefit the more from the modern 3-D technology [17] (Fig. 8.13).

8.9.7 Resident Training

Quick prototyping is a developing innovation that has the possibility to transform health care learning. As plastic cosmetic surgeons, we are anticipated to recognize the touches of comprehensive human anatomical designs and their spatial relationship with one another. 3-D printing can enable an in-depth awareness of human anatomy that was generally obtained from text illustrations and years of operative expertise doing complex dissections. The future of plastic surgery learning is interesting because of the capability to take a

Fig. 8.13 3-D model print as a rehearsal and accurate measurement of the metallic plate and screws in a patient going to have right-sided hemimandibulectomy

Fig. 8.14 3-D print model of the skull

2-dimensional (2-D) picture and carry it to way of life with a full-scale design (Fig. 8.14).

8.9.8 Patient Education of Head and Neck Surgery

Throughout (ENT) subspecialty, a somewhat minimal portion of patients follow through with elective procedures to fix ailments such as oral, head and neck tumors, or pathology. Patient awareness of their medical diagnosis and therapy plan is integral to compliance, which essentially generates enhanced health care results and far better quality of life. Here we report the usage of advanced, polyjet 3-D printing options to develop a multimaterial reproduction of human nasal sinus anatomy, derived from clinical X-ray computed tomography (CT) data, to be used as an educational aid during doctor assessment. The last patient education model was developed over several models to optimize material properties, anatomical reliability, and overall performance [18].

8.10 Future Applications

Incredible advances have been gained from 3-D reconstruction and printing; however, there is some concern that such claims may be exaggerated. There has been major dramatic and important discovery in tissue scaffolds and bio-printing in the last few years; however, many of these technologies, including organ printing, are in their primitive stage.

Three 3-D printed implantable models of auricular and nasal scaffolding have been assessed.

In such models, anatomic structure has been persevered and histologic appearance revealed cartilaginous growth within the territories of these scaffolds. The need to develop and present a vascular network to deliver oxygen and remove waste remains a considerable challenge to organ printing. Vascular structures could be constructed from biomaterials, using three-dimensional printing, which, thereafter, can be incorporated with endothelial cells. Vessel-like microfluidic channels flanked by tissue spheroids have also been proposed and may be a viable option in the future. The organ production steps also include separation and differentiation of stem cells, culturing the cells in support medium, checking for markers, and organogenesis in a bioreactor. Correcting congenital anomalies, reconstructing defects from resecting large tumors, and rebuilding traumatic injuries can be achieved from complex tissue and organ production. Vascular pathologies such as arteriovenous malformations can be created as well.

Ossicular reconstruction, cochlear and vestibular structures, turbinates, and laryngeal subunit reconstructing defects arising from large head and neck tumor resection can be some important future applications in the field of otolaryngology.

8.11 Conclusion

Surgical procedures in otolaryngology-head and neck surgery can be so challenging even to the most experienced surgeons during resection of infiltrative diseases and reconstruction of anatomical structures. These challenges arise from performing excision of lesions within critical and anatomically complex structures in the head and neck region. Virtual endoscopy (VE) and 3-D reconstructions have become more attractive imaging modalities used in head and neck surgical planning. 3-D reconstruction images and virtual endoscopy images have the potential to provide realistic and customizable environments for surgical trainees, enable the creation of patient-specific models for surgical planning and procedure simulation before starting the actual surgery, and facilitate technology development in an environment that mimics clinical practice.

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