Biomed Tech 2013; 58 (Suppl. 1) © 2013 by Walter de Gruyter · Berlin · Boston. DOI 10.1515/bmt-2013-4230

Development of a simulation and training system for head and neck tumour diagnosis

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Abstract
The combination of a complex "organ site" head and neck with a demand of a high accuracy and the difficulties with investigator depended examinations are easy to understand.
Measurements of precision and deviations in tumour description and treatment decision of the investigator depended panendoscopy were never performed.
Therefore a simulation system as described is mandatory as neither ethical nor technical limitation allow this investigation in real clinical situations. As side effect a training system is developed, which allows training of procedures in critical situations.

Key Words: head and neck tumour, panendoscopy, simulation system, situation awareness

Introduction
It is estimated that in 2011 52 000 patients will be diagnosed with head and neck squamous cell carcinoma in the United States, which comprises squamous cell carcinomas of the oral cavity, pharynx, and larynx (HNSCC) (1). The outcome is still poor and showed slight improvement in the recent 30 years (Europe 5 years survival in average 42%, (2)).
The medical examination of head and neck cancer is a step-wise process including anamnesis, clinical examination (inspection, palpation, endoscopy, stroboscopy) followed by imaging methods (ultrasonic examination, air-contrast examination, computed tomography, magnetic resonance tomography, and positron emission tomography) followed by panendoscopy under general anesthesia.
The assumption that HNSCC is the most complex "organ site" for a treatment decision is certainly not an overstatement and supports the idea of a best practice model with involvement of a multidisciplinary team (3). The main difficulty lies in the different interpretation of tumour pattern due to the lack of multidimensional information.
In detail, panendoscopy, which includes an epipharyngoscopy, laryngoscopy, pharyngoscopy, bronchoscopy and osophagoscopy, is the optimal and accepted procedure for staging in head and neck cancer, the exclusion of secondary primaries (4) and pathohistological confirmation of the suspected diagnosis. Panendoscopy therefore plays a crucial role in the diagnosis and treatment of head and neck malignancies. The surgeon who has performed the panendoscopy in combination with personal manual transoral palpation of the tumour in the fully relaxated patient under general anaesthesia has a completely different approach for interpretation of the imaging scans as compared to the oncologist or radiation oncologist. He can integrate all tactile, endoscopic and imaging examination results in his personal comprehensive picture of the disease and can clarify imaging related uncertainties like oedemas or inflammatory changes in the adjacent tissue of the tumour.

Question
The combination of the most complex "organ site" with a demand of a high accuracy and the difficulties with investigator depended examinations are easy to understand. Due to the changes on the tumour surface which occur during performing the panendoscopy repeated examinations are not feasible, even when a ethic vote will allow several panendoscopies. Due to this problem, measurements of precision and deviations in tumour description and treatment decision of the investigator depended panendoscopy were never performed. Clinical reality shows unfortunately in several cases differences between the panendoscopy statement and the intraoperative finding. But even if panendoscopy is an investigator depended examination mucosal spread, small tumours, differentiation between tumour surrounding inflammations an tumour or small secondary primaries are not detectable buy computed tomography, magnetic resonance tomography or positron emission tomography. Measurements of variation in tumour description and treatment decision are only feasible in a simulation model.
Secondary effect of a simulation model is training. Panendoscopies are bulk procedures with an overall low morbidity. But in the case of rare problems as esophageal perforation the morbidity is high (5), (6). This creates the sense of competence and the situation awareness might be lower than necessary. Training of procedures in critical situations as narrow esophageal entry or esophageal stenosis is useful to prevent complications.

Technique of panendoscopy
A tracheobrochoscopy with a rigid bronchoscope in combination with 0°, 30° and 70° Hopkins® rods defines the first step of the Leipzig type of panendoscopy. After intubation an osophagoscopy is performed with a rigid esophagoscope in combination with a 0° Hopkins® rod. The examination of the larynx and the hypopharynx is carried out with a video laryngoscope. The examination of the epipharynx is performed by a post rhinoscope. The oropharynx and oral cavity is inspected utilizing a mouth gag. During panendoscopy a number of routine photos are taken: inner surface of the cricoid cartilage, subglottic space, glottis with anterior and posterior commissure, upper sphincter of the oesophagus, the upper part of both piriformis sinuses, vallecula and the epipharynx. All suspicious lesions are of course captured as well.

Methods
As a first step a segmentation process based on individual radiological data was performed using Dornheim Segmenter Software (fig. 1) (7), (8) to build up a virtual model consisting of a a generic patient anatomy on the left side and of an individual tumour on the right side of a median axis. The segmented anatomic and pathologic structures included the

mandible, the maxilla, the soft and hard palate, the tongue and base of tongue, the pharyngeal space, the hyoid bone, the thyroid and cricoids as well as the arytaenoid cartilages, the trachea and the esophagus. Furthermore we segmented the Mm. sternocleidomastoidei and suprahyoid muscels as structures needed to support the stability and outer appearance of the model.

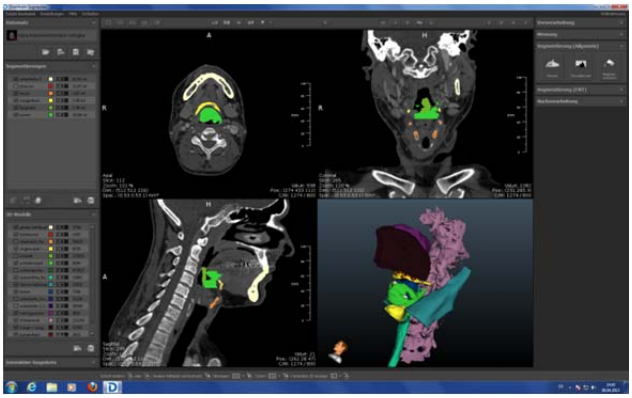

Fig. 1 Screenshot of the CT-data segmentation process using Dornheim Segmenter software including a 3-D reconstruction of the segmented structures

The segmented data was exported in STL file format (Surface Tesselation Language) and modified using Geomagic Freeform Modelling (fig. 2).

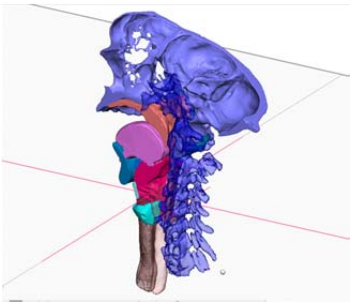

Fig. 2 Geomagic Freeform Modelling was used to design the prototype of the panendoscopy model. The skull and the spine were used as spatial reference.

For economic and didactic reasons the decision was taken to design a model showing the neoplastic structures on one hand side and the regular anatomy on the other hand side, therefore it was necessary to create a symmetric model using the median as axis of reflection. Needless to mention that no human being is symmetric so we had to make certain modifications to the shape of the segmented structures patterning a symmetric anatomy. The positioning of the facial skull and mandible was designed to represent a standard mouth opening of an adult. This circumstance along with the symmetry of the model proofed to be of advantage concerning the manufacturing engineering. The boundaries of the components of the model were chosen according to the haptic requirements, e.g. various soft to hard parts as well as to the requirements of the casting technique and the fixation points. The archetype was created by using layer manufacturing technology also known as rapid prototyping.

Although our aim was to focus on the realistic anatomic and haptic representation of the inner life of the model, a silicone based skin of the head and neck was designed as well. As the exact positioning of the upper part of the patient, especially the neck is, too, a challenge in performing panendoscopy; we were looking for an already available training torso to integrate our model of the upper airways and digestive system into a pre-existing system in order to save money and time.

Conclusion

Regarding the annual total sum of 450 to 500 panendoscopies performed in the ENT-Department of the University Hospital Leipzig, quality control of an investigator depended examination, which plays a key role in the diagnostic pathway from head and neck tumour patients is crucial. Therefore a simulation system as described is mandatory as neither ethical nor technical limitation allow this investigation in real clinical situations. As side effect a training system is developed, which allows training of procedures in critical situations for head and neck surgeons and for anesthesiologists.

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