Computer Assisted Surgery Planning for Neck Dissections

AUTHORS

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INTRODUCTION

To support the preoperative planning of neck dissections, 3d visualizations are intended to explore and to quantify anatomic and pathologic structures. Neck dissections are carried out for patients with malignant tumors in the head and neck region. These surgical procedures are necessary because the majority of the patients develop lymph node metastases in the neck region. The extent of the intervention depends on the occurrence and location of enlarged (and probably) malignant lesions. To ensure the decision about operability and the surgical procedure of the neck dissection, the occurrence and number of enlarged lymph nodes, as well as their location in relation to risk structures have to be assessed and visualized. In particular, the infiltration of the M. sternocleidomastoideus, the main blood vessels of the neck (A. carotis, V. jugularis) and several nerves is of relevance to the surgeon.

Therefore, two subtasks have to be handled: The identification and segmentation of all relevant anatomical structures from the datasets and their visualization and exploration with respect to the surgical question.

A variety of elementary segmentation techniques are known, which can be used for the segmentation of blood vessels, bones and air-filled organs, e.g. Region Growing or the marker-based Watershed Transformation. For the lymph nodes segmentation, as well as for the segmentation of other soft tissue, Live-Wire [1] can be used as a semiautomatic method, but results in high segmentation times and interaction effort. It has been pointed out, that a fixed order of segmentation of the individual structures can be beneficial to the segmentatio of the various neck structures [2].

In many areas of intervention planning, there are visualization techniques solving similar problems. Visualization techniques for planning neck dissections have not been published so far. Some of the methods described in this paper have been applied to other areas, e.g. the use of silhouettes or local transparencies. In general, emphasis techniques in interactive medical environments are described in [3].

METHODS

For the segmentation of the required anatomic structures, three elementary methods without shape knowledge were tested: Region Growing, the marker-based Watershed Transformation and Live-Wire. The demands on the analyzed methods were a sufficient quality of the segmentation results, coupled with low time and interaction effort, as well as the ability of automation.

Besides, several visualization and interaction techniques were analyzed with respect to their suitability for supporting the decision process on an appropriate surgery strategy. We focussed on the following problems:

- Exploration of enlarged lymph nodes (up to 30 nodes)
- Estimation of infiltrations into risk structures (and therefore of the patient's operability)

All structures were colored according to medical textbooks. Different degrees of transparency were used to differentiate between focus and context. In a next step, after a preparation of 13 CT datasets, an evaluation of the used visualization techniques was carried out. Based on this evaluation, the colors and transparency of the individual objects were adjusted to obtain a higher contrast between focus and context structures, as well as an enhanced discrimination between the context structures. It became apparent that applying one transparency value per object is not sufficient to visualize complex structures. When showing several transparent objects at a time, the spatial alignments are barely recognizable. Using less transparency for the focus objects did not solve this problem.

For that reason, other visualization techniques were developed. E.g., the application of silhouettes to highly transparent objects increases the recognizability [4]. The use of local transparency was also promising. Therefore, only regions of structures located in front of a focus object, e.g. a tumor, were depicted transparently. For that purpose, a cylindrical region is defined, bordering the object to be emphasized. All geometry inside thise cylinder is then rendered transparent.

To aid the decision about operability, the risk organs are colored due to their distance to the closest lymph node metastasis. Using a discrete color scale for distances of 0, 2 and 5 mm, the spatial alignment between two structures can be estimated more clearly. The exploration of many lymph nodes at a time requires an appropriate interaction technique. Well suited is the selection of whole lymph node levels or according to measurement results [5]. Thereto, the nodes' extent or their minimal distance to risk structures is used.

RESULTS

The segmentation and visualization are realized as a service for the surgical partners. The segmentation effort ranges from 50 to 150 minutes per dataset, depending to the quality and the number of slices of the dataset. The results were presented via the WWW by showing screenshots and short videos. The contents of the resulting videos and images were standardized and radiologically verified.

DISCUSSION

The quality of the segmentation was denoted as satisfying or better by the surgical partners. To adopt the methods to clinical routine, the time and interaction effort for the segmentation has to be reduced to 10 minutes of maximum interaction effort. For this purpose, a model based segmentation is being worked on.

The surgeons certified a high degree of recognition between the visualizations and the ususal experiences during interventions. In some cases, the computer-assisted planning seems to be essential for the surgical decisions. To support this subjective appraisal, a clinical survey is in progress.

The use of videos for conveying the final results is intended as a temporary solution. At present, an interactive 3d tool for manipulating and measuring the datasets is being developed. This "ENT InterventionPlanner" will conclude all visualization and interaction techniques, to enable a straightforward intervention planning.

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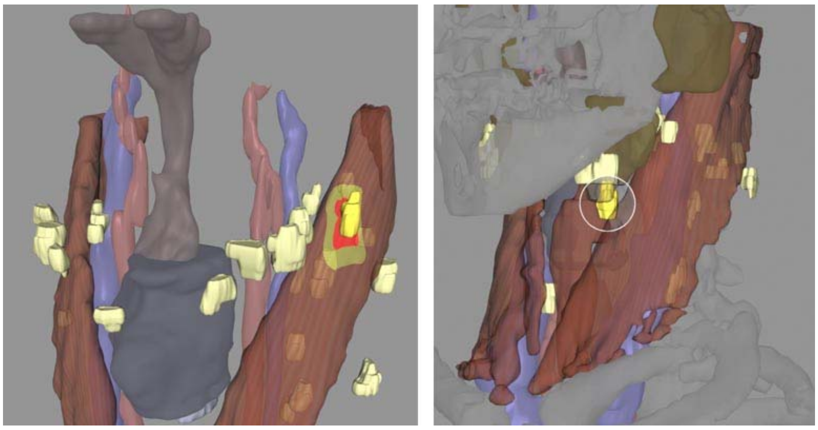

Left Figure: Color coded distance of a lymph node to the M. sternocleidomastoideus. The 2 mm distance is coded in red, 5 mm in yellow. Right Figure: Lymph node behind the M. sternocleidomastoideus and the Gl. submandibularis.