Evaluation of a Training System for the Computer-based Planning of Liver Surgery

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Abstract:
We present the results of a formative evaluation of the LiverSurgeryTrainer. The LiverSurgeryTrainer is a system for the training of preoperative decisions which have to be made during the therapy of liver tumors and living liver donor transplantations respectively. Therefore, radiological image data, image analysis results and interactive 3D visualizations of the patient anatomy are used. A functional prototype served as background for the evaluation of acceptance and usability with experts of the liver surgery domain. The results provide important clues for the future development of our software as well as general insights for the design of surgical training software.

Keywords: evaluation, operation planning, training, liver, surgery

1. Motivation

Medical training in surgery is strongly dependent on available experts and the existing case spectrum. The selection of the ideal treatment strategy and the training of surgery and treatment strategies play a major role. Up to now, the established method for the planning of interventions is the selection of the most effective therapy on the basis of clinical data and 2D slice data. However, this is complicated since spatial conditions, especially the location of a tumor in relation to the complex vessel trees, are difficult to evaluate. Thus, computer-based planning systems are applied more frequently. Especially for the planning of treatments concerning the liver, 3D models of the liver, its vessels and pathological structures are reconstructed from the slice data [1]. Based on these models, different treatment possibilities, e.g. regarding the resulting volume and supply of the vessels can be assessed. The usefulness of computer-assisted planning in liver surgery has been validated for tumor surgery [2] and living donor liver transplantations [3]. To introduce the use of such planning systems, a training system is essential. By contrast to the planning process, we have to consider learning surgeons. To provide adequate information for them, we include expert comments and videos and relate the learners planning decision to expert recommendations.

Therefore we developed the LiverSurgeryTrainer. It enables the training of the required workflow, pre-operative decisions and interaction techniques for the planning of interventions (e.g. drawing of virtual surgical resection planes, see Fig.1) on the basis of 2D slice data and 3D models. We do not aim at a simulation of the actual intervention. The training with the system aims at enhancing surgical competencies and acceptance of computer based planning. The conceptual design is based on the following pillars:

1. We analyzed the clinical workflow in conversations with surgeons and by observations (see Fig. 2).
2. The didactical design of the system was done by means of the Four-Component-Instructional-Design-Model [4].
3. To be able to involve future users of the system into the design process, we furthermore decided on a scenario-based conception of the system [5].
4. General principles of the user interface design [6] were realized in an iterative process.

This paper presents the first evaluation of the LiverSurgeryTrainer with prospective users. The basis for this evaluation was a prototype of the training software, which had been sent to experts of liver surgery and living donor liver transplantation throughout the world. Usability and acceptance should be evaluated.

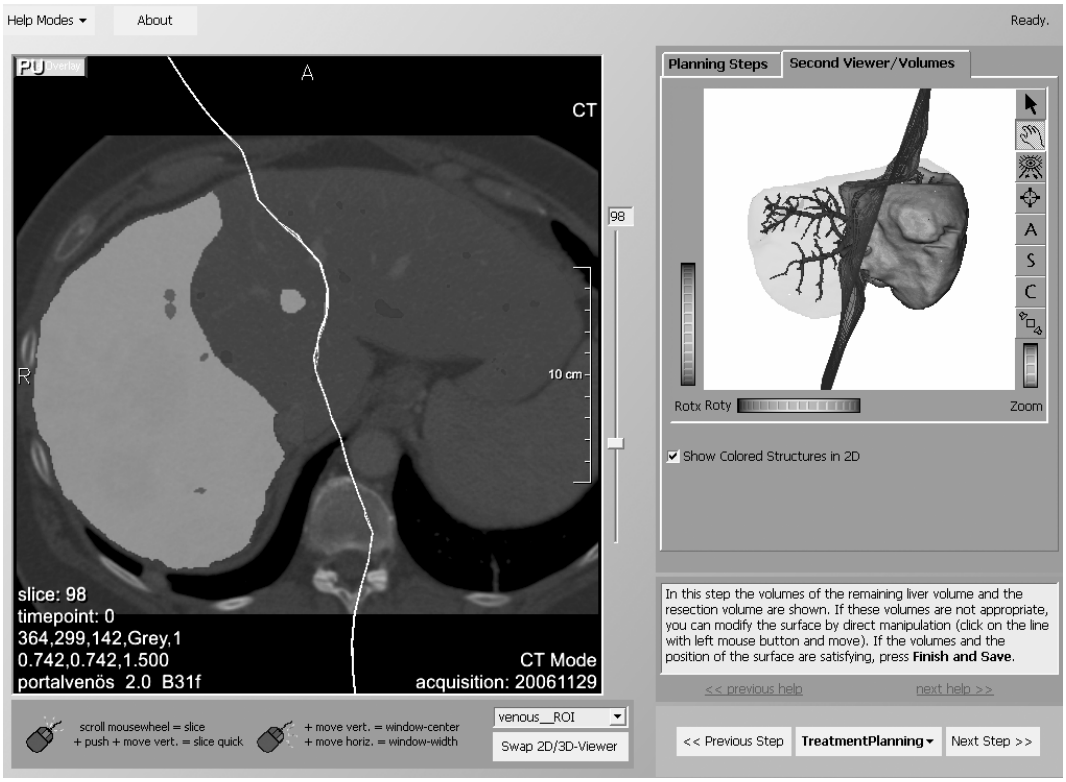

Abb.1: LIVERSURGERYTRAINER resection planning. In the 2D (left) and 3D presentation (right) liver, tumor, vessels and resection surface are visible.

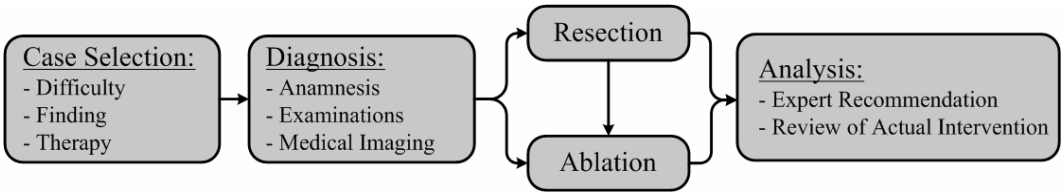

Abb. 2: Schematic Workflow of the Training with the LiverSurgeryTrainer.

2. Methods

The goal of the first evaluation was to identify flaws that should be corrected in future development. 32 surgeons agreed to participate in the test. They received a DVD containing the system and two training cases, as well as detailed instructions for the installation, handling and processing of the two cases (one oncological case with a cholangiocellular carcinoma in the right lobe of the liver and an evaluation of a donor for a child living donor liver transplantation).

After processing the cases, the surgeons were asked to assess the program in different categories. The design of the developed questionnaires was oriented on respective guidelines [6]. Personal data, and experiences in liver surgery as well as with computers and 3D models were acquired. Afterwards the test persons were asked about their attitude towards the computer-based planning and its use in the clinics. Thereafter an assessment of the used terminology, the suitability for the training, the given feedback, waiting times, occurred errors and learnability followed. Finally the test persons should evaluate new ideas for the future development of the LiverSurgeryTrainer, e.g. the integration of structure annotations in the 2D slice data and the 3D model. For each question it was possible to write down optional comments.

Test persons could call up the questionnaire online. As an alternative they received an additional paper form via mail. All answers were stored and managed in a MySQL database.

3. Results

The number of test persons (13) (rate of return 41%) did not allow a meaningful statistical analysis, but the evaluation provided interesting hints to necessary changes within the workflow, layout and functionality of the system.

3.1. Analysis of test persons

11 male and 2 female surgeons with an average age of 32 years (min. 28, max. 44 years) participated in the test. 10 of 13 surgeons have more than 5 years experience in surgery. The experiences in liver surgery were more heterogeneous: experiences of <2 years, 2-5 years and >5 years were equally distributed. Except for one, all test persons evaluated their experience in handling computers as well and very well. Their experiences in interacting with 3D models were diverse. A few test persons indicated much experience with 3D models, but most of them had only medium knowledge. The familiarity with computer-based treatment planning was moderate: three-quarter of the questioned people used computer-based surgery planning. The majority of them conveyed that they do the planning in the clinic, the others use it as a service. Cases planned with the computer include complex liver resections and living donor liver transplantations. Two-thirds of the participating surgeons were sure that the support of computers has a huge benefit. The need to train the computer aided planning was classified high and almost always higher as the planning need.

Half of the test users performed the evaluation training with the oncological scenario or both scenarios. Their preference for the oncological case seems plausible, since oncological resections are performed more often than transplantations.

3.2. General statements and assessment of user interface

Considering the low number of test persons and the choice of test persons out of the project environment (to find other liver surgeons for tests is difficult, because the majority of them participated the project), the results of this evaluation have to be carefully interpreted.

On a scale (very good) 1-7 (very bad) the LiverSurgeryTrainer was assessed with good/satisfying (2.6) and its suitability for the training of the planning was confirmed. Therefore, the actual prototype of the system represents a good basis for further developments. The usability was also assessed as satisfying, but it showed huge potential for enhancements in future development: test persons wished a stronger guidance through the training and a more manageable user interface where most of the information and functionality appears on demand. Errors, which occurred during the use of the system, were declared as minor errors which could be easily corrected.

Another important aspect to increase the acceptance of the system relates to the enhancement of performance and feedback. The waiting time that arises during the training was considered as too long. There occurred long waiting times when loading the CT data and during calculation of the resection volume. Feedback of the system during long loading and calculation processes has to be enhanced as well.

3.3. Assessment of learning effort

The expenditure of time for learning to handle the training was evaluated as justifiable (3.3; scale (low) 1-7 (very high)) and it was not difficult to learn (2.4). But in both fields, effort for learning and learnability, a demand of improvement exists. However, the statements of the testing people confirmed the underlying concept of the program. Defining the virtual resection surface [7] was the most challenging interaction technique for the surgeons. To some extent the used method is not intuitive and therefore it is not very suitable for a training system. In particular, for virtual resection of tumors in the periphery of the liver, the resection method turned out to be cumbersome. New and better methods for the virtual resection shall be developed and integrated in future versions of the LiverSurgeryTrainer.

3.4. Assessment of new ideas for future developments

The simulated intraoperative ultrasound was determined as limited supportive and not essential. In contrast to this the optional annotations in the slice data and 3D model were assessed as very helpful, but the opinions concerning the need of this technique are divers as well. Some test persons uttered that annotations in 3D are very helpful because it is more difficult to figure out anatomy in 3D, but another person stated that 3D anatomy is clear. The reason for the different notions may be the different level of experience with radiological image data and 3D models.

The test persons proposed to integrate the analysis of vascular supply into the planning. This functionality is already intended and shall be available in the next versions of the LiverSurgeryTrainer. On the basis of the resection surface the supply and outflow within the liver parenchyma is analyzed. Thus, it is possible to identify areas that contain disrupted vessels and are not fully functional anymore.

Furthermore, the test persons required a simulated radiofrequency ablation for the training. This type of therapy is also planned to be realized in the future.

4. Conclusion and Discussion

According to this evaluation, first of all the virtual planning in the LiverSurgeryTrainer will be revised. The training will be divided into smaller steps to offer a stronger guidance and, as far as possible, a self-explanatory system. Further optimizations have to be made to shorten the waiting times.

In the future development phase, an additional alternative of therapy, the ablation of tumors, as well as the annotation of the slice data and the 3D models shall be integrated into the training system. Moreover, the users will get the possibility to adjust the parameters of the visualization individually (e.g. color, transparency). Appropriate parameter combinations will be defined in presets, which shall provide fast visualization options to the user.

To use the LiverSurgeryTrainer in surgical courses, it is necessary to develop strategies for integrating the system into the conventional curriculum. Furthermore, it is essential to assess the learning outcome and inform the users about their learning progress. Therefore, the relevant parameters have to be identified and learning curves have to be determined and analyzed. Finally, the learning outcome of the training shall be tested in a before and after comparison.

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