Combining Training and Computer-assisted Planning of Oncologic Liver Surgery

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Abstract. We present a framework for liver surgery training with the focus on therapy decision making, tumor resection and ablation planning based on patient individual data. In this framework we combine state of the art planning facilities with components for training of oncologic liver surgery planning. *Guide'n'Support* , *Intervention-Strategy-Sets*, and *Comparison-to-Experts-Plan* functionality are implemented to enable guided training for young surgeons as well as open but on demand supported training for senior visceral surgeons.

1 Introduction

Inspired by [1], surgical education can be seen as mainly build upon two pillars: (1) *clinical surgery* including declarative and factual knowledge about etiology, pathology, differential diagnosis, and therapeutic alternatives as well as procedural knowledge about therapy decision-making and planning; and (2) *practical surgery* including declarative, factual, procedural and senso-/motorical knowledge about operation techniques and strategies.

While surgery simulation systems focus on the training of senso-/motorical skills, our system focus on declarative, factual, and procedural knowledge about therapy decision-making and planning. Our work extends the system described in [2] by combining training and actual planning facilities.

Due to the combination of an enhanced system that provides state of the art liver surgery and ablation planning [3, 4, 5, 6] and the functionality of the widespread digital media publishing system Macromedia Director we are able to enrich state of the art liver surgery planning by interactive, multimedial content, educational guidance and training support. Furthermore, the presented flexible *Guide'n'Support* system enables computer based education of young and senior visceral surgeons (and avoids spoon-feeding).

2 Training of Computer-assisted Liver Surgery Planning

Computer-assisted risk analysis and virtual tumor resection has become a nearly standard procedure for oncologic liver surgery planning. Today, enhanced liver surgery planning and risk analysis systems provide preoperative decision support on a detailed level. As one consequence, new therapy and planning strategies had been developed due to the new planning facilities [7].

However, training of therapy decisions by means of the new tools was not considered as a necessary task. The training of liver resection planning as well as of tumor ablation planning on patient individual data is not available yet.

The presented training system for liver surgery planning aims to (1) enable training of liver surgery decision-making and surgery planning for liver tumor resection and ablation on patient individual data, (2) publish and spread novel findings about liver tumor therapy options and planning as well as (3) to familiarize surgeons with the complex handling of surgery planning.

To accomplish these goals we identified the following two main tasks:

1. combining state of the art facilities for liver surgery planning with facilities of common media rich publishing tools, and
2. developing an educational environment for surgeons that supports and not spoon-feeds them (as common training systems for students would do).

Inspired by [8] fundamental necessary educational facilities in computer based training (CBT) are guidance, tutorial, and feedback in general. Experience without these training features will only increases confidence not competence [9].

3 State of the Art

For liver surgery some computer based training (CBT) systems are available that focus on declarative facts [10] and on procedural knowledge about operation techniques [11].

We did neither find any system that enables training of liver surgery planning nor training systems for planning of other abdominal interventions. Only one publication with a title that implies CBT for liver surgery planning [12] can be found. But the described system in [12] is a pure planning system that neither provides any educational facilities (e.g. tutorial, guidance or help systems) nor feedback mechanisms (e.g. criticising, correcting or confirming). For educational purposes and training, such mechanisms are crucial as established CBT systems (e.g. CASUS [13] and CAMPUS [14]) demonstrate. Nevertheless, with these systems it is not possible to interactively train liver surgery planning and virtual tumor resection.

In contrast there exist some enhanced and well elaborated systems for liver surgery and ablation planning [3, 15, 16, 4, 5, 6]. Unfortunately, they do not provide educational facilities, since they do not focus on CBT.

4 Concept and Implementation

We extended the Liver Surgery Trainer [2] (implemented in Macromedia Director) by integrating MeVisLab [5] via Active-X [17, 18]. The Active-X interface enables the seamless display and interactive usage of MeVisLab in the learning environment. This is used for example to remotely load patient data, to render and display 3d and 2d scenes, to calculate and simulate resection volumes and ablation results as well as to interactively define a resection plane and to place applicators.

For educational purposes, we split the planning procedure in the learning environment in successive steps that can also be accessed in arbitrary order. After the introduction of the current case and the presentation of information about diagnosis and operability, the following main steps are: (1) tumor resectability or ablation eligibility assessment and (2) resection/ablation planning.

In the first step, 2d slices and a 3d reconstruction of the data set can be explored and measurement tools are provided to assess the resectability and/or ablation eligibility. It is also possible to define an initial resection plane if it is needed by the user.

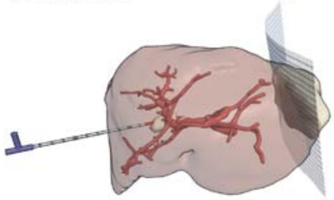
In the second step, a resection can be planned by defining a resection plane in the 2d slices and by adjusting it in 3d views [4] or models of RF applicators can be positioned and parameterized respectively [6]. To enable comparative therapy decision making (crucial for young surgeons or difficult cases), the learning environment provides the ability to save the current resection/ablation plan in *Sets* and to define another resection or ablation. Switching through these *Intervention-Strategy-Sets* can then be used to compare different resection or ablation strategies as well as to assess a resection plan compared to an ablation. This enables surgeons to try out, compare and learn to assess different therapy decisions in different situations.

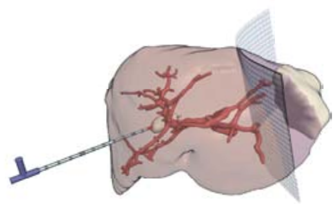
At the end of this procedure, the learner has the possibility to assess and compare the planned resection/ablation to a resection/ablation plan provided by an expert (see Fig. 1). In this *Comparison-to-Experts-Plan* step differences between the learners decisions and the experts recommended therapy plan are highlighted. Comments of the expert, explaining and illustrating his/her decision-making process and further possible therapy alternatives endorse the training feedback for the learners.

To guide and support users during the learning process without spoon-feeding and restricting them, the learning environment presents a tripartite *Guide'n'Support* functionality that consists of (1) *Guided Tour* that guides new users through all steps in the learning environment, introduces all available functionality and demonstrates its usage; (2) *Automatic Support* that gives automatically hints for the usage of complex features as well as for appropriate next steps to do and that also premonitions serious mistakes of the learner if it is selected; and last but not least (3) *Support on Demand* is accessible at any stage in the training procedure that presents automatic selected information about the current planning step and usage of available functionality. Hypermedial navigation (like in Windows-Help) allows the free access to the whole content of the *Guide'n'Support* system at any time.

Fig. 1. Comparison-to-Experts-Plan: Example of the printable tabular comparison of a planned resection/ablation by an user to a resection/ablation plan by an expert.

User		Expert	
Number of Resection Meshes:	1	Number of Resection Meshes:	1
Number of Ablations:	1	Number of Ablations:	1
Resection:		Resection:	
Remnant volume:	1492 ml (93,5%)	Remnant volume:	1429 ml (89,6%)
Resection volume:	103 ml (6,5%)	Resection volume:	166 ml (10,4%)
Reached safety margin:	**0 mm (R2)**	Reached safety margin:	12 mm (R0)
Ablation:		Ablation:	
Ablation volume:	47 ml	Ablation volume:	45 ml
Reached safety margin:	**1 mm**	Reached safety margin:	10 mm
Ablation access:	exposed	Ablation access:	exposed
Ablation power:	20 mV	Ablation power:	20 mV
Ablation time:	20 min	Ablation time:	20 min
Distance to expert's applicator:			
Center of active zone:	1 mm		
Shaft orientation:	**15°**		





Additional comments and explanations:
In this case a combined therapy is recommended in order to resect the tumor in liver seg-

5 Results and Discussion

The presented training system for liver surgery planning (Liver Surgery Trainer) presents a framework for training of surgery decision making with respect to liver tumor resection and ablation on patient individual data. The design of the system and the presented *Guide'n'Support*, *Intervention-Strategy-Sets*, and *Comparison-to-Experts-Plan* functionality enables: (1) guided training for young surgeons to gather declarative, factual, and procedural knowledge as well as (2) open but on demand supported training for senior visceral surgeons to gather deeper contextual knowledge or to get familiar with new findings in the domain.

Due to the used Active-X connection to MeVisLab, advances in resection and ablation planning as well as in computer-assisted risk analysis and ablation simulation will be automatically available in the learning environment. To enable visceral surgeons to integrate there cases and planning results into the system an authoring system will be part of future work.

Currently we are working on a representative set of learning scenarios that for example include living donor transplantations as well. Furthermore, we are investigating adaptive animations of patient individual data for 3d visualization and navigation support in the learning environment [19]. One major task left open for future work is the evaluation of the learning effects which are achieved with the Liver Surgery Trainer.

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