to be used for other areas as well [1–3]. Accelerated partial breast irradiation (APBI) is a technique that promises to overcome the logistical problems created by external beam radiation therapy (EBRT). APBI can be applied interstitial or intracavitary. Common APBI techniques include multicatheter-based brachytherapy (mostly with radioactive wires—gamma emmitting Ir-192 or beta-emitting Y-90), balloon catheter approaches (e.g. balloon filled with radioactive beta-emmitting Co-55) or electronic brachytherapy systems using miniature x-ray sources (at or around 50 kV) [4]. APBI is used for fractionated radiation delivery (total of around 30 Gy) or as a boost treatment (around 10 Gy) in combination with EBRT [5]. While some of these approaches have significantly improved the outcome and the treatment comfort many problems remain, e.g. multi-day treatments, difficult handling for the staff, treatment planning/dose distribution and lack of or inconsistent image guidance and quality control.

Methods

To overcome these problems we propose the use of a newly developed balloon catheter (outer diameter 6 mm, length of lead shielded part 60 mm, total length 150 mm, Ballon diameter inflated 20 mm, with two reservoirs, an inner one containing a non-emitting liquid and an outer one containing high-energy beta-emitting Rhenium-188 liquid (T1/2: 16,98 h—up to 2.12. MeV (4 % of total radiation), with majority (80 %) soft X-rays with only short distance, ITM, Munich) which is indicated for secure therapeutic irradiation of disease sites. Re-188 can be manufactured with an activity of up to 5 GBq/ml, with a remaining radiation of approximately 40 % at 1 mm from the balloon surface, 20 % at 2 mm, 10 % at 3 mm, 5 % at 4 mm. With an assumption that for tumor bed radiation 3 mm should be sufficient an expected radiation time (boost) of around 25 min should be achievable. The Rhenium liquid is filled into the reservoir part of the catheter that is lead protected and is pushed into the balloon once the target site has reached. We combined the stiff catheter with tracking components and injected a radioactive marker close to a simulated tumor site for subsequent 3D handheld SPECT/US imaging (Sentiguide by Surgiceye, Munich) for a feasibility test of an intracavitary radiation delivery approach. In practice the catheter would use the access path that was created by the biopsy needle.

Results

We were able to visualize the simulated target site with a hybrid combination of handheld SPECT and ultrasound and use that to guide the catheter to the radiation delivery area. We were able to use the two reservoir configuration of the balloon catheter to first fill the outer part with the beta-emitting Rhenium-188 und subsequently to push the balloon with the inner reservoir into the simulated tumor area/tumor bed. With this relatively safe handling can be ensured. Intraprocedural imaging confirmed the location of the catheter and the expansion of the balloon.

Conclusions

This first prototype and setup shows that an approach using Rhenium-188 for intracavitary or interstitial radiation therapy delivery combined with hybrid imaging could be feasible (mainly for small tumors) for delivering a radiation boost of around 10 Gy in 3 mm from the balloon surface in an acceptable time (around 30 min). Patient safety, staff safety, device handling, radiation dose distribution (overlaid on the intraprocedural images to register, display, plan, and confirm the radiation delivery) were not really considered and will need to be addressed in the coming development steps. A combination with minimal-invasive surgery removal of the tumor (e.g. through a biospy needle/catheter) and subsequent tumor bed radiation seems very promising however, but needs to be checked with the clinicians.

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AngioPlan: a software assistant to support the treatment of arterio-venous malformations

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Keywords Arterio-venous malformation · Minimally invasive procedure · Vessel segmentation · 3D vessel model

Purpose

Minimally-invasive procedures are considered as the standard treatment for arterio-venous malformations (AVM). The procedure involves the accurate positioning of a catheter within the nidus of the malformation. Subsequently, the catheter delivers coils or toxic sclerosants (e.g. ethanol) in order to close the malformations. Pre-interventional images are supporting the navigation during the procedure. We developed a software assistant that produces pre-interventional 3D planning models from MRI or CT data. The main focus of our software is set to the segmentation of complex vascular structures.

Methods

The AngioPlan prototype was developed using the software platform MeVisLab. For semi-automatic segmentation of vascular structures, vesselness filters are combined with an adaptive region growing algorithm. The user initializes the algorithm by setting seedpoints. Afterwards, the segmentation result can be incrementally improved in the following manner: setting of further seedpoints or deleting unwanted seedpoints, threshold adaption or manual post-processing by means of eraser and brush tools. Eraser and brush tools are part of every simple image processing software and are thus intuitively known to every user. After obtaining the segmentation, a 3D model is generated on the basis of the segmentation's skeleton. For spatial orientation, 3D surface models of bones and skin are generated additionally. The models either base on simple threshold segmentation or—in case of bone segmentation in MRI datasets - on live wire segmentation. If multiple datasets for one patient exist, they need to be aligned accordingly. A manual registration tool allowing for affine transformation enables the alignment. After the registration and segmentation is completed, a virtual trajectory can be defined within the 3D viewer. For this purpose, the user selects an entry point on the skin model and a target point on the vascular model.

Results

An example result for a vessel and venous malformation segmentation can be seen in Fig. 1 where veins are illustrated in blue and arteries illustrated in red. We evaluated the developed software assistant using MRI and CT datasets from different body regions. In general, the vessels could be well segmented. Problems only occurred

with some CT datasets where the intensity range of the vessels was not high enough to be distinguished from the other tissue by the region growing approach. The software assistant was already used for the planning of a real interventional procedure. The physicians considered the vessel segmentation as very helpful for the spatial location and orientation of the malformation.

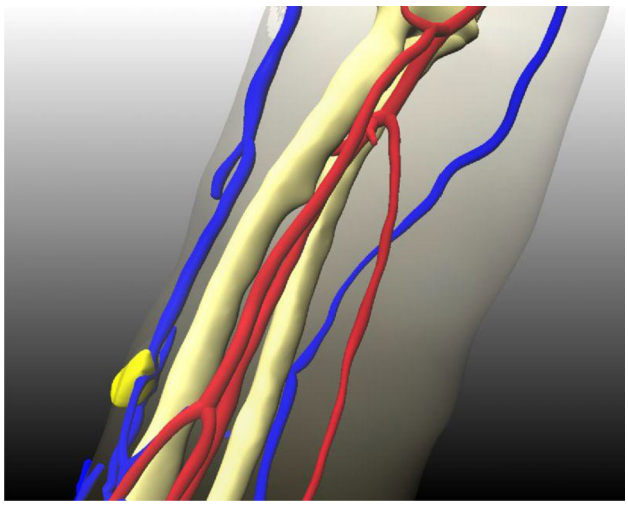

Fig. 1 Example result for a vessel and venous malformation segmentation

Conclusions

We presented AngioPlan, a software assistant for the planning of minimally invasive interventions of arterio-venous malformations. The location of the malformation in a 3D model consisting of the main veins and arteries, bones and skin, is considered as a significant support for physicians. Because our preliminary results indicate that AngioPlan facilitates a better understanding of target and risk structures, it might improve the minimally invasive treatment of arterio-venous malformations in the future.

Clinical decision support system for prediction of infected pancreatic necrosis

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Keywords Clinical decision support system · Artificial neural networks · Prediction · Infected pancreatic necrosis

Purpose

Infected pancreatic necrosis is associated with high morbidity and mortality and is mandatory for surgical or minimally invasive intervention.

The aim of this study was to construct and validate the clinical decision support system (CDSS) [1–5] to predict infected pancreatic necrosis (IPN).

Methods

All patients who presented with severe acute pancreatitis from January 1998 to December 2011 were reviewed. The study included 398 patients: age (median, range)—49 (23–77); sex males/females (n)—302/96; BMI, kg/m^2 (median, range)—28 (24–33); SAPS II at admission, grades—12.9 ± 3.8; pancreatic necrosis etiology, %: alcohol induced 62.6 %, biliary 20.6 %, idiopathic 12.2 %, trauma induced 4.6 %.

All patients in our study (n = 398) our divided randomly into three groups.

The first group consisted of 234 patients randomly selected from all study patients and was used to train an Artificial Neural Network. The second group consisted of 65 randomly selected patients and allowed us to conduct a verification of the ANN model, 99 randomly assigned patients comprised a control (test) group and verify accuracy and prognostic values of the artificial neural network. The random assignment of the patients was done to overcome bias in the study related to different personal approaches of the surgeons in our hospital, use of different surgical and diagnostic equipment, and other factor potentially influencing the results in the span of the years of study (1998–2011).

Presenting data on admission and at 48 h were collected. SAPS II and Glasgow severity (GS) score were calculated. CDSS (Artificial neural networks (ANNs) were created and trained to predict development of IPN and mortality from AP; 25 % of the data set was withheld from training and was used to evaluate the accuracy of the CDSS. Accuracy of the CDSS in predicting infected pancreatic necrosis was compared with SAPS II scores.

Studied parameters: (1) Parameters at admission: Age, sex, BMI, Ranson criteria, GS; (2) Consequently studied parameters: SAPS II score, multiple organ system failure, systemic inflammatory response syndrome, respiratory rate, intra-abdominal hypertension, hemoglobin, hematocrit, platelet count, prothrombin, fibrinogen, glucose, BUN, creatinine, albumin, bilirubin, ALT, AST, calcium, C-reactive protein, LDH, pO2/ fiO2, base excess et al.

Since ANN is a computer model based on a binary number data entry and computation, we coded clinical and laboratory data and introduced it into the system as coded values of 1 and 0. Normal laboratory results were coded as 0 and pathological results were assigned the value of 1. In data which didn't have normal or pathological values, such as sex or age, we used codes 0 or 1. All results (studied parameters) were coded in a binary data mode and introduced to ANN for training and data analysis.

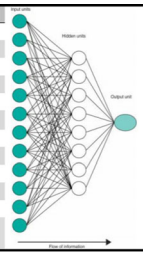
Artificial neural network design: a three-layered back-error propagation forward data flow ANN. Back propagation of error allowed minimization of error by adjusting weights connected to ANN units, which was used in system's training to improve predicting values of the method.

Results

A total of 1690 patients with acute pancreatitis were identified of whom 398 (23.6 %) fulfilled the clinical and radiological criteria for severe acute pancreatitis and 98 patients died (5.8 %). Median SAPS II score at 48 h was 6 (range 0–23). Our CDSS with 12 criteria (Table 1) was more accurate than SAPS II scoring systems at predicting infected pancreatic necrosis ($P < 0.05$, respectively) (Table 2).

Table 1 Input variables used to develop the artificial neural network model for IPN prediction

Variable	Data format	Error	Sensitivity (%)
Early surgery (days 0-14)*	Yes / No	0.52%	2.38%
Duration of treatment in ICU (days)	Continuous variable	0.38%	1.75%
Duration of in-hospital stay (days)	Continuous variable	0.37%	1.71%
Clinical deterioration§	Yes / No	0.36%	1.67%
Serum glucose level‡	Continuous variable	0.34%	1.56%
Temperature	Continuous variable	0.33%	1.52%
Heart rate	Continuous variable	0.25%	1.15%
Serum blood urea nitrogen	Continuous variable	0.24%	1.10%
Leukocyte count	Continuous variable	0.24%	1.08%
Respiratory rate	Continuous variable	0.23%	1.06%
CRP	Continuous variable	0.22%	1.00%
Paresis (intra-abdominal hypertension)	Yes / No	0.21%	1.00%



*Early surgery was conducted in some cases before IPN developed
§Clinical deterioration represented a "second wave" of the disease and was based on interpretation either APACHEII or SAPSII scores
‡Serum glucose level in non-diabetic patients