Intelligent epidural needle placement by fiber-probe OCT

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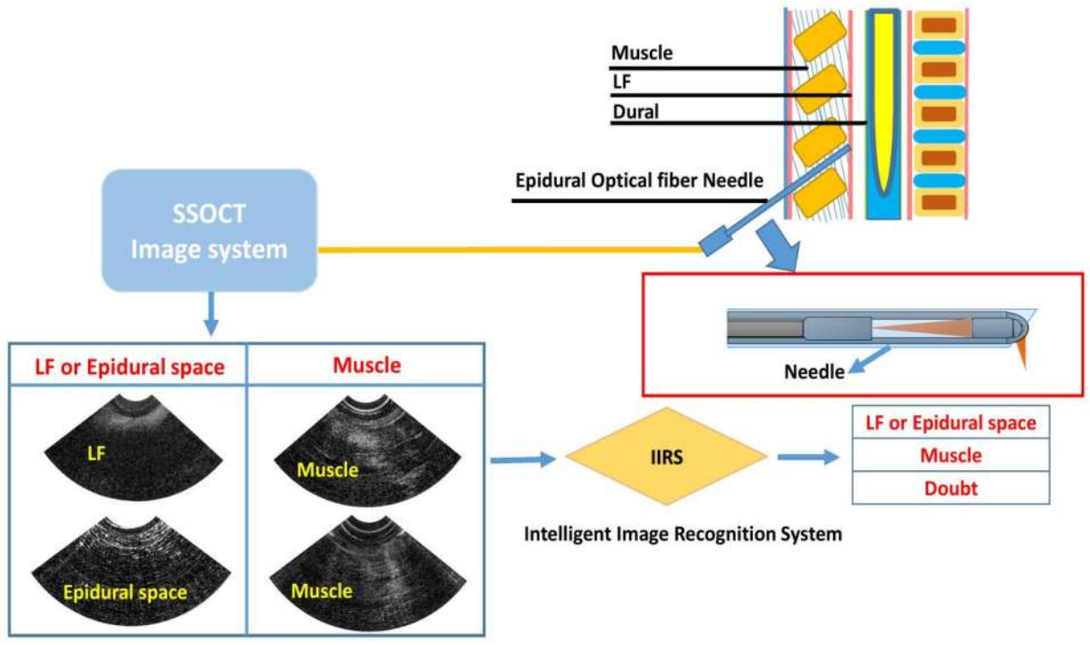

Fig. 1 Schematic layout of epidural needle placement by intelligent fiber-probe SSOCT system.

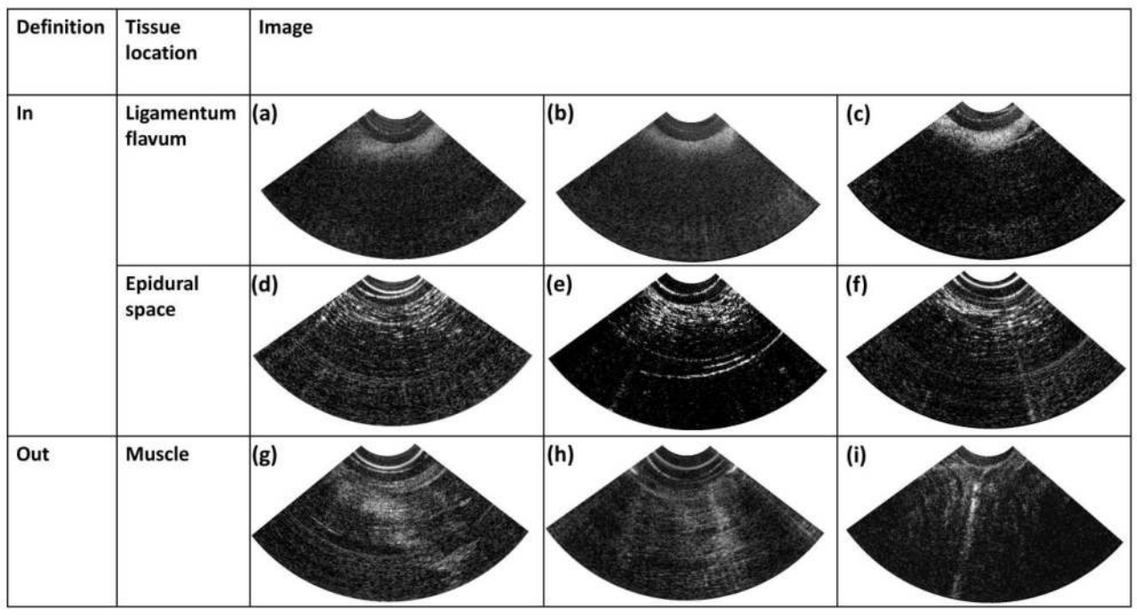

Fig.2 Representative OCT images showing inside and outside of the ES. Images of the LF are considered to show the needle inside the EF and are shown in (a), (b) and (c). The epidural space is shown in (d), (e), and (f). Muscle tissues considered outside the ES are shown in (g), (h) and (i).

Background: Incorrect placement of the needle causes medical complications in the epidural block, such as dural puncture or spinal cord injury. This study proposes a system which combines an optical coherence tomography (OCT) imaging probe with an automatic identification algorithm to objectively identify the position of the epidural needle tip and thus reduce the complication rate of epidural needle insertion.

Methods: Three quantitative features were continuously extracted from each two-dimensional (2D) OCT image as the needle tip was progressively inserted from the skin surface toward the epidural space (ES). The differentiation of the needle tip inside of the ES or outside of the ES was automatically evaluated by using three classifiers: k nearest neighbor (KNN), linear discriminant analysis (LDA), and support vector machine (SVM). Sensitivity, specificity, and accuracy of each testing data set were then evaluated using the receiver operating characteristic (ROC) curve.

Results: 200 in vivo OCT images were obtained from 4 anesthetized piglets. Half of these images were obtained from inside of the ES and half from outside of the ES. The combination of all image features, including the mean value of intensity, gray level ratio, and limited range of depth gray level ratio, showed the highest differentiating performance. SVM classification was found to yield the highest sensitivity (95%), specificity (93%), and accuracy (94%) among the three classifiers.

Conclusions: We provide an intelligent method for objective identification of the ES, which can increase the success rate of epidural needle insertion.

Table 1. Validation of quantitative features extracted from *in vivo* OCT images for ES identification by 3 different classifiers.

Feature	Classifier	Sensitivity (%)	Specificity (%)	Accuracy (%)
Graythreth	KNN	98.0	16.0	57.0
	LDA	64.0	94.0	79.0
	SVM	92.0	88.0	90.0
Graythreth (1-2 mm)	KNN	98.0	76.0	87.0
	LDA	88.0	76.0	82.0
	SVM	82.0	94.0	88.0
Mean	KNN	72.0	86.0	79.0
	LDA	98.0	64.0	81.0
	SVM	76.0	94.0	85.0
All	SVM	92.0	98.0	95.0
	SVM (Leave one out)	93.0	95.0	94.0

KNN: K nearest neighbor, LDA: linear discriminant analysis, SVM: Support vector machine, ALL: includes all three image features

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