

Ex vivo and in vivo topographic studies of bladder by optical coherence tomography

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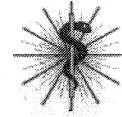
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ABSTRACT

Conventional imaging modalities like CT or ultrasonography have a spatial resolution of 70-1000 μm . OCT is a new method by which light of a certain wavelength is introduced into a fiberglass optic to measure tissue structures of up to 2.5 mm depth with a spatial resolution of up to 10-15 μm . We utilized the Tomograph Sirius 713, developed at the Medical Laser Centre in cooperation with 4-Optics AG, Lübeck, Germany. This apparatus uses a special Super-Luminescence-Diode (SLD) that produces light within the near infrared wavelength, with a central wavelength of 1300 nm. The coherence length is reduced to 15 μm . The light is introduced into a fiberglass optic which is several meters long and is easy to handle. To measure the depth of invasion and position of urothelial bladder tumors, the fiberglass optic is attached to a regular endoscope (Wolf, Knittlingen, Germany) via an OCT adapter. That way, in parallel to the regular endoscopic view of the bladder mucosa with or without pathologic findings, an OCT picture of the superficial as well as the deeper muscle layers is visible online. OCT was used to obtain 945 images from the bladder in vivo und ex vivo of 65 patients. OCT of normal bladder mucosa allows to image a cross section of up to 2.5 mm. It is possible to distinguish transitional epithelium, lamina propria, smooth muscles and capillaries. In cystitis, the thickness of the mucosa is constant, but the distinction between the different layers is blurred. In squamous metaplasia there is thickening of the epithelial layer, with preservation of lamination of the lower layers. In transitional cell carcinoma there is a complete loss of the regular layered structure. It is easily possible to distinguish the border between tumour and normal bladder tissue. OCT is a new high-resolution imaging procedure. It has the potential to improve the diagnostics of the urothelium and its lesions. In conjunction with a highly-sensitive orientating procedure like fluorescence-cystoscopy, intraoperative staging of these changes could be possible in the future.

Keywords: optical coherence tomography, endoscopy, diagnostics, bladder cancer

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Medizinisches Laserzentrum Lübeck

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Introduction

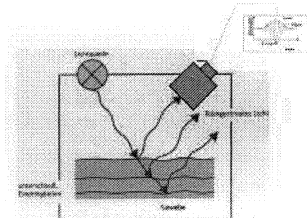
Conventional imaging modalities like CT or ultrasonography have a spatial resolution of 70-1000 μm .

OCT is a new method by which light of a certain wavelength is introduced into a fibreglass optic to measure tissue structures of up to 2.5 mm depth with a spatial resolution of up to 10-15 μm . It takes about 3 sec to generate one 2D-image.

We utilised the Tomograph Sirius 713, which uses a special Super-Luminescence-Diode (SLD) that produces light within the near infrared wavelength (1300 nm).

The fibreglass optic which is a couple of meters long is easy to handle. To measure the depth of invasion and position of urothelial bladder tumours, the fibreglass optic is attached to a regular endoscope via the OCT adapter.

That way, in parallel to the regular endoscopic view of the bladder mucosa with or without pathologic findings, a OCT picture of the superficial as well as the deeper muscle layers is visible online.

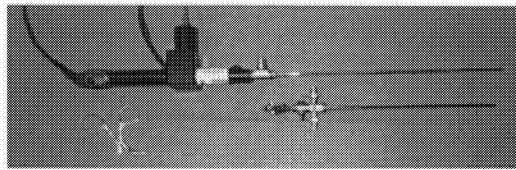
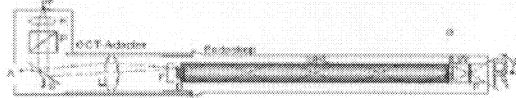
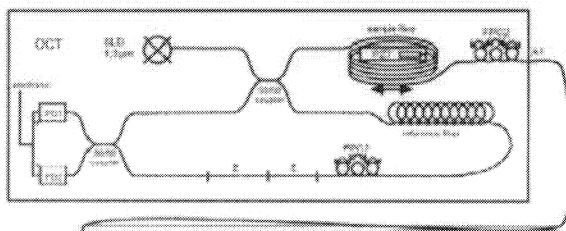


Objectives

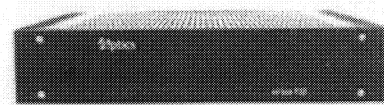
- To test whether OCT is suited for the diagnostic application in conjunction with regular endoscopes.
- OCT measurements of healthy urothelium at various sites of the bladder, urethra or bladder diverticuli.
- To examine OCT measurements of inflammatory, malignant, dysplastic, metaplastic and hyperplastic lesions of the urothelium.
- Analysis of the borders of dysplastic or malignant bladder lesions

Materials:

In 2001-2002 an OCT-endoscope was developed at the Medical Laser Center Lübeck in cooperation with the Richard Wolf Company, (Germany).



Tomograph Sirius 713

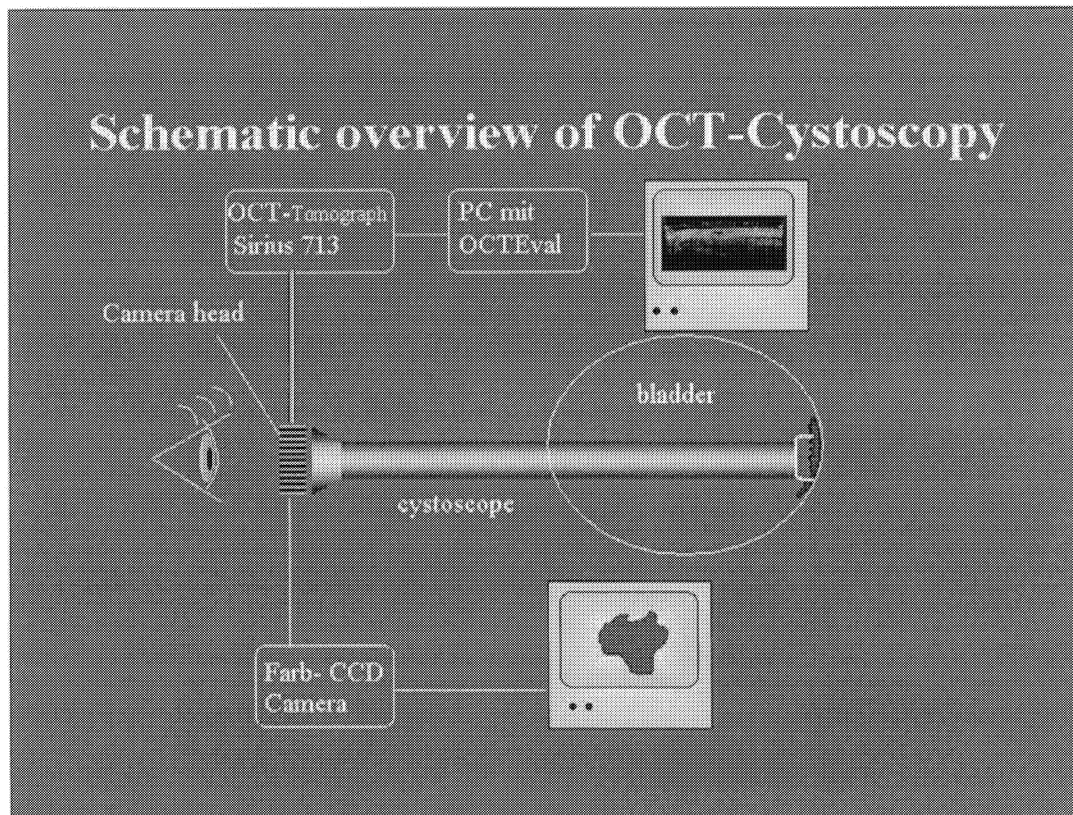


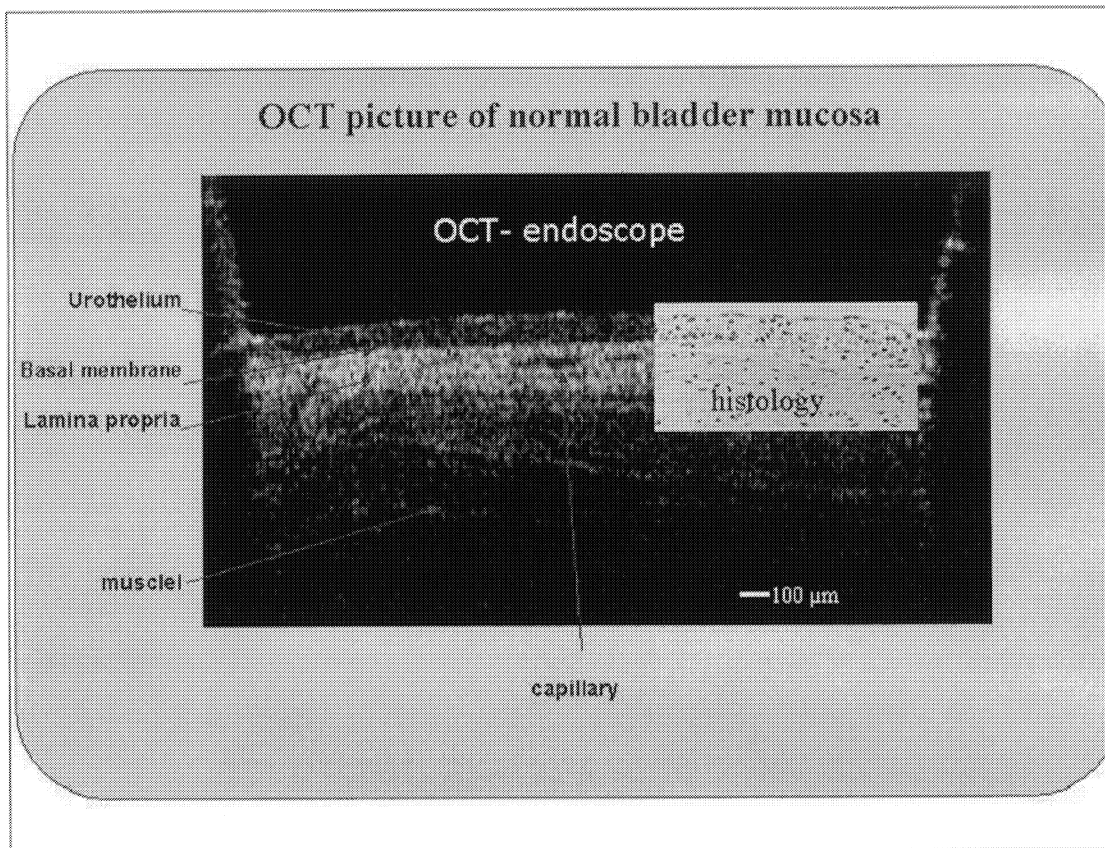
OCT-Endoscope

Methods:

65 patients (50 women, 15 men, age 45-81 years) with suspected bladder cancer were endoscopically examined for a primary or recurrent tumor. 945 OCT measurements were carried out in 545 areas of the bladder in vivo and ex vivo. These were then compared with histology slides.

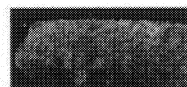
To prevent the introduction of errors by mechanical pressure of the OCT device onto the mucosa, we use a special adapter that keeps a 2 mm distance of the fibre optic from the surface.



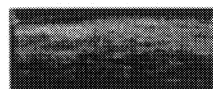


Results:

- OCT of normal bladder mucosa allows to image a cross section of up to 2.5 mm.
- It is possible to distinguish transitional epithelium, lamina propria, smooth muscles and capillaries.
- In cystitis the thickness of the mucosa is constant, but the distinction between the different layers is blurred.
- In squamous metaplasia there is thickening of the epithelial layer, with preservation of lamination of the lower layers.
- In transitional cell carcinoma there is a complete loss of the regular layered structure.
- It is easily possible to distinguish the border between tumour and normal bladder tissue.



papillary transitional cell carcinoma



cystitis



Squamous metaplasia



invasive transitional cell carcinoma



Carcinoma in situ

Conclusion:

OCT is a new and promising method for diagnosing different conditions in the human urothelial bladder.

This method can provide valuable information on tumour invasion and extension in real time and therefore influence therapeutic strategies.

In conjunction with a highly-sensitive orientating procedure like fluorescence-cystoscopy intraoperative staging of these changes could be possible in the future.

REFERENCES

1. E. Lkenau, M. chumacher, P. Koch, F. Koenig, D. Daniltchenko, D. Schnorr, G. Huettmann, "Dispersion compensation for proximal scanning rigid OCT endoscopes", *Proc SPIE* **5316**, pp. 172-177, 2004
2. F. König, S.A. Loening, "Strategien in der bildgebenden Diagnostik des Harnblasenkarzinoms," *Der Urologe B.* **39(4)**, pp. 303-306, 1999.
3. E.V. Zagaynova, O.S. Streltsova, N. Gladkova, "In vivo optical coherence tomography feasibility for bladder disease," *J. Urol.* **167(3)**, pp.1492-1496, 2002.