

# DIAGNOSTIC POTENTIALITIES OF THREE-DIMENSIONAL NLS-GRAPHY

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*This publication contains modern principles of three-dimensional images rendering in accordance with NLS-graphy data. Also it gives overall evaluation of three-dimensional NLS graphy diagnostic value for revealing of various diseases in comparison with other methods of hardware diagnostics, such as roentgenography, computerized tomography and magnetic resonance imaging. Special attention is paid to advantages and disadvantages of various techniques of three-dimensional images rendering.*

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Three-dimensional pictures of human's internal organs became a part of general practice in early 90's after computer tomographic scanners were equipped with powerful computing systems capable of controlled processing of two-dimensional crosscuts. Nowadays three-dimensional representation of elements of diagnostically interesting zone is an everyday reality in leading clinics of the world.

Method of three-dimensional representation of diagnostic data is generally related to powerful hardware resources, i.e. acquiring of parallel (or placed at previously specified angles) magnetic-resonance, roentgen or NLS-graphic images with their following integration into single visual array where an operator can separately visualize bones, muscles, soft tissues, vessels, nerves etc. highlighting them with color while other tissues are shown in gray semitransparent tone.

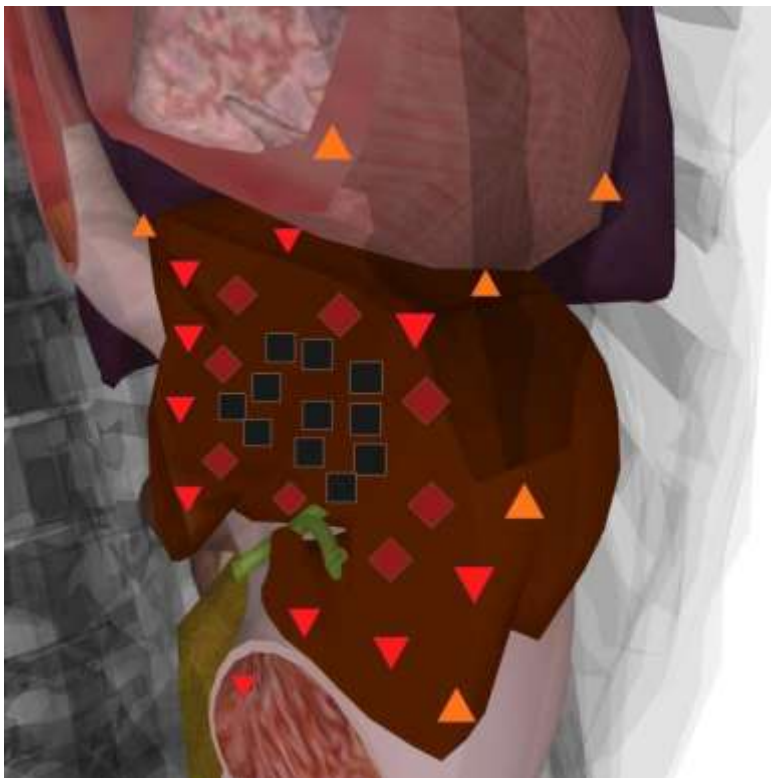
Rendering of three-dimensional NLS-graphic images of abdominal cavity organs is considered nowadays to be an experimental task mainly. Rarely used due to its low information value method of creating of separate two-dimensional images of abdominal cavity organs by means of NLS-visualization is much more interesting for rendering three-dimensional diagnostic images.

In addition to solving of usual objectives on the basis of two-dimensional NLS-graphy of abdominal cavity organs data many parallel diagnostic tasks are solved by means of non-linear algorithms and massive calculations application.

Maybe that is how should be explained so accurate results described in one of the first reports about three-dimensional reconstruction on the basis of transabdominal NLS-data (T.G. Kuznetsova, R.A. Sorokina).

We place our great hopes on three-dimensional NLS-graphy, first of all related to its application in endoscopy. In 2010 V.I. Melushko theoretically justified an opinion that application of three-dimensional NLS-research in laparoendoscopic surgery will allow to "look beyond the horizon" and see anatomic structures which cannot be visualized when using laparoscope. He believed that NLS-graphy is diagnostically efficient, safe and affordable procedure.

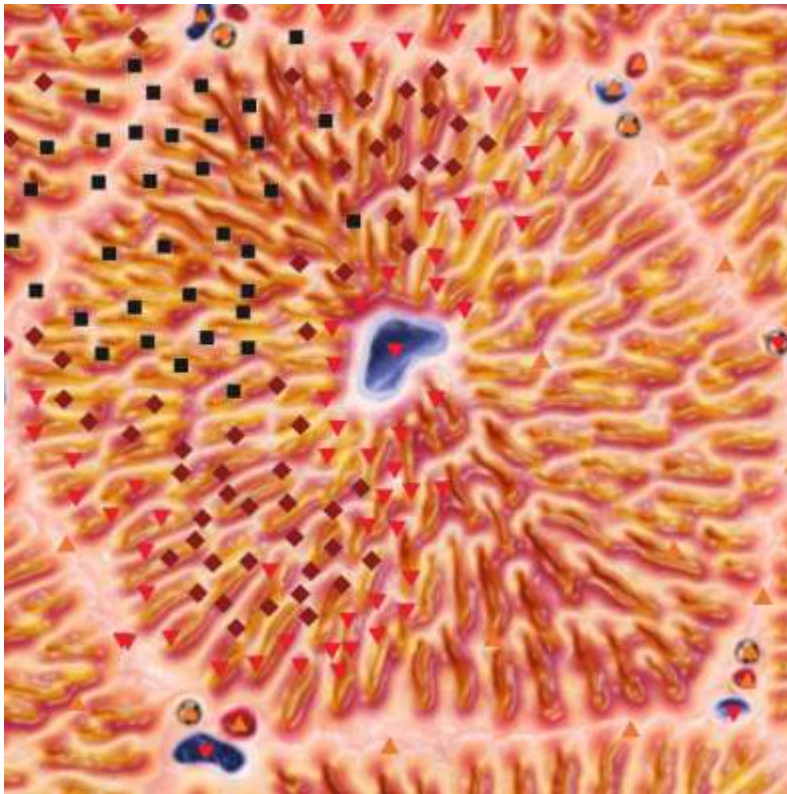
A.Y. Shvack and L.P. Goltsova (*Pic.1*) found out that at size changing of hepatic focal formations two- and three-dimensional NLS-graphy are equally precise when shape of neoplasms is relatively simple - close to roundish or oval. However, the authors state that if shape of neoplasms is complex, results of two-dimensional NLS-graphy matched in 65% of cases only, when at three-dimensional visualization – in 92% of cases.



*Pic.1. 3D-image of hepatic neoplasms foci*

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In 2010 S.A. Volkova and A.V. Zaitsev reported about results of three-dimensional transabdominal NLS-graphy application in diagnostics of hepatobiliary system, in particular for specifying diagnostics of previously revealed neoplasms. The objective of their research was accuracy evaluation of three-dimensional NLS-graphy method with application of spectral-entropic analysis (SEA). Acquired results were compared with information gathered by computed tomographic portal venography carried out on spiral tomograph. Altogether 62 cases were analyzed including those with hepatic neoplasms sized from 1.5 cm to 12.3 cm. The researches showed that three-dimensional model built on the basis of NLS-data (*Pic.2*) contains more precise and valuable diagnostic information in comparison with usual two-dimensional NLS-graphy or data acquired with CT. The authors believe that three-dimensional NLS-graphy is financially affordable procedure for diagnostic of tumor affections.



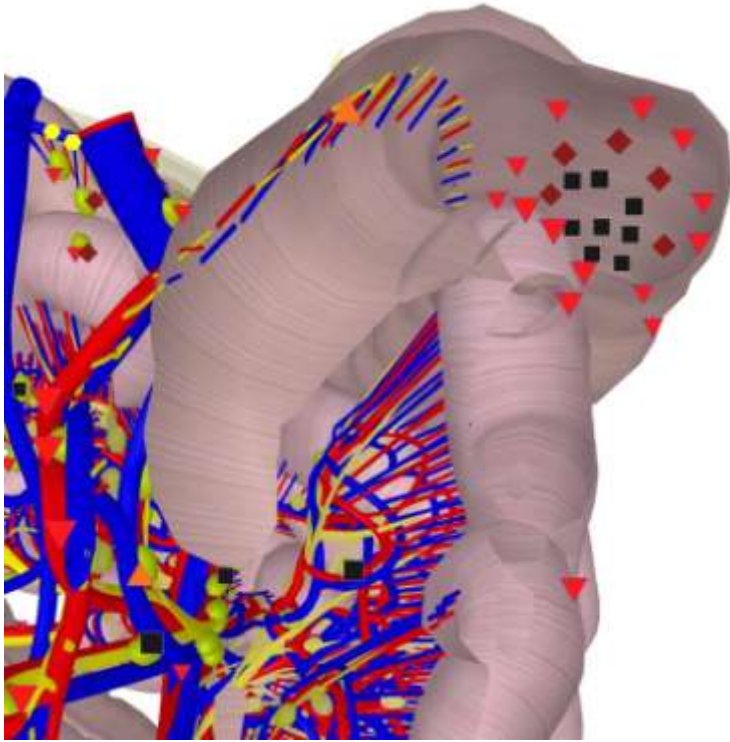
*Pic.2. Ultramicroscanning of hepatic tubules at liver cancer*

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Above mentioned studies (except single publications about diagnostics of stomach and gall bladder pathologies) are almost everything we have in sphere of systematized studies about three-dimensional reconstruction of organs and neoplasms in abdominal cavity based on data acquired with transabdominal NLS-studies which were ever mentioned in periodic scientific literature.

Mentioned difficulties of methodological and computing character are leveled in a great measure by endoscopic and intraoperational NLS-research of abdominal cavity and small pelvis organs, when the most difficult stage of three-dimensional visualization becomes textural segmentation of acquired two-dimensional picture.

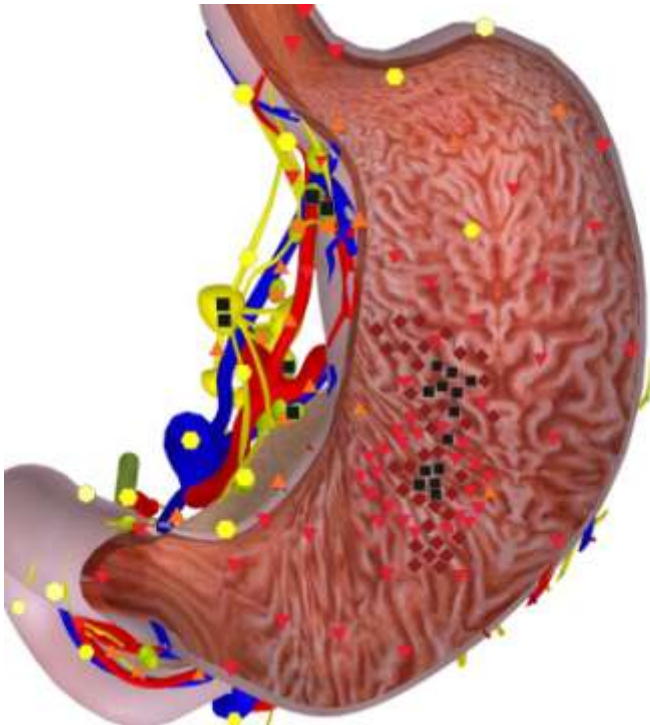
Hishimura T. et al. (*Pic.3*) compared results of endoscopic ultrasonography of gastrointestinal neoplasms with data acquired with NLS-scanning.



*Pic.3. 3D NLS-image of large intestine cancer*

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In two cases of esophagus cancer, in two cases of rectum cancer and in 7 of 10 cases (*Pic.4*) of stomach cancer results of three-dimensional reconstruction made on the basis of NLS-graphy were accurate in relation to depth of tumorous invasion.

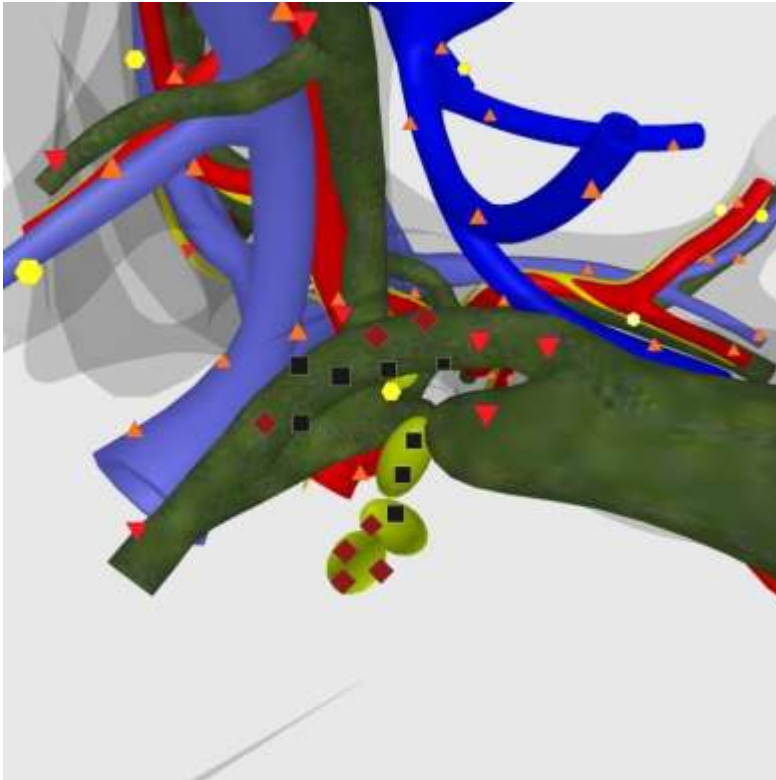


*Pic.4. 3D-image of stomach cancer*

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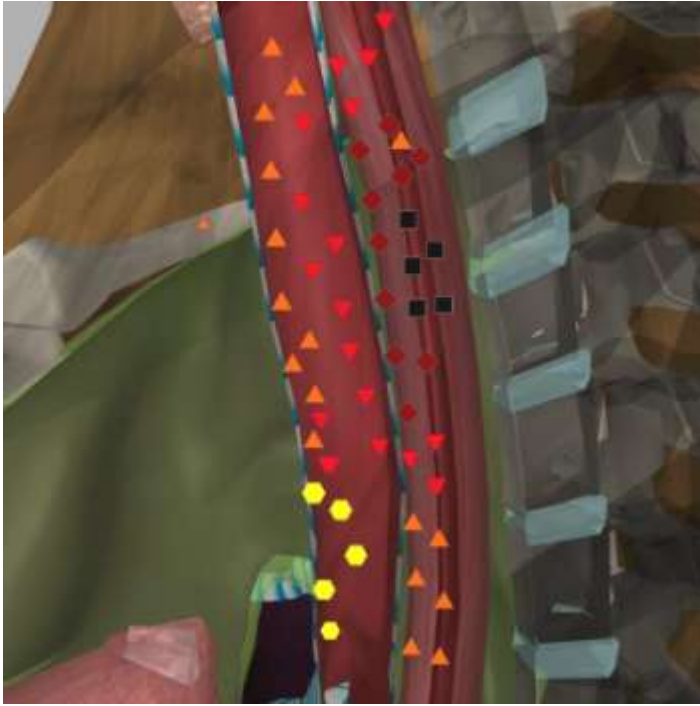
Japanese scientists Katamaki S. et al. (*Pic.5*) reported in 2011 about preliminary results of three-dimensional NLS-graphy application in 26 patients. Three-dimensional reconstruction made on the basis of three-dimensional pictures allowed to define presence of metastatic affection of surrounding organs and in 4 of 6 cases of bile duct cancer – to define volume of tumorous tissue.



*Pic.5. 3D NLS-picture of common bile duct cancer with affection of regional lymph nodes*

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Fox P. et al. (*Pic.6*) used NLS-study for three-dimensional reconstruction of esophagus picture in 5 patients suffering from esophagus cancer. The research was carried out with sensor's frequency of 4.9 GHz. Three-dimensional pictures were reconstructed on the basis of series of cross-cut pictures. Precise three-dimensional visualization of tumor's structure and surrounding tissues were acquired in all cases. In this study proper determining of tumorous process stage was achieved in three of four cases. The authors note special diagnostic value of pictures showing longitudinal sections of tumor which allow to define precisely its length and connection with mediastinal structures.

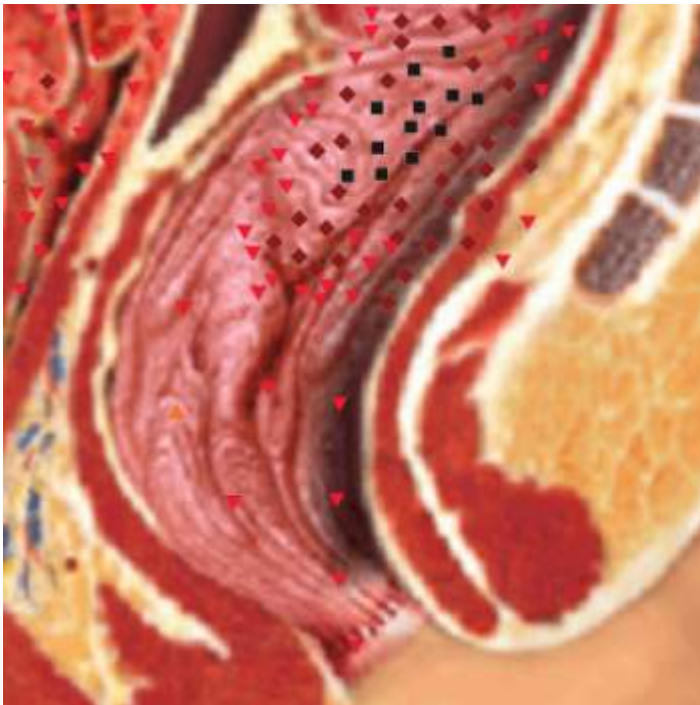


*Pic.6. Longitudinal 3D NLS-image of esophagus cancer*

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Among of the most standardized methods of research are three-dimensional NLS-graphy of rectum and NLS-scanning of prostate.

German oncoproctologists Operbein K. et al. (*Pic.7*) have studied more than 100 patients suffering from rectum tumors with three-dimensional NLS-graphy.



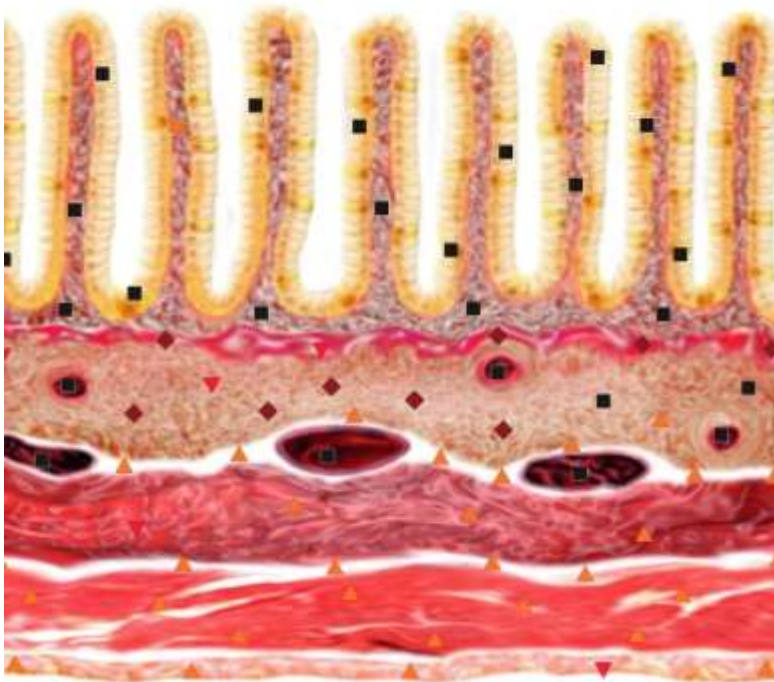
*Pic.7. 3D NLS-image of rectum cancer*

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Diagnostic accuracy of three-dimensional ultrasound research in this group was 89%, at the same time accuracy of two-dimensional NLS-graphy in the same group of patients was 76%. Accuracy of these methods in defining of pararectal lymph nodes affection was 85% at three-dimensional visualization and 71% in accordance with two-dimensional data. The authors believe that three-dimensional NLS-graphy allows to overcome well known limitations of two-dimensional NLS-study which are usually faced at obstructing tumor and in revealing of recurrent cancer of rectum.

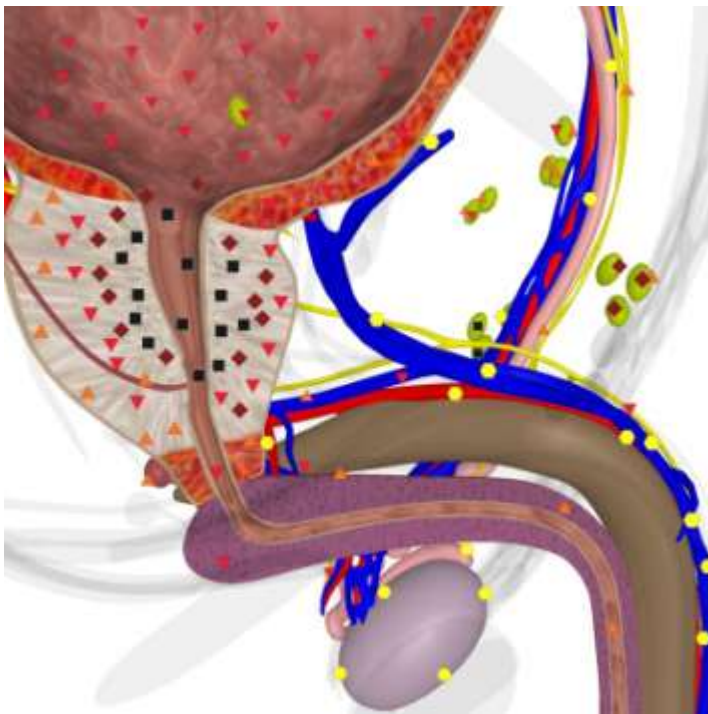
Operbein K. et al. also used three-dimensional NLS-graphy to detect recurrent malignization of rectum in patients after surgical treatment of rectum cancer. Possibilities of two-dimensional NLS-study in these cases are strictly limited due to massive growth of fibrous tissue. Data for three-dimensional reconstruction was acquired by Operbein K. and Schmidt A. who used non-linear scanner co-manufactured by IPP (Omsk, Russia) and the firm's Clinic Tech Inc. (USA) with operating frequency of 9.6 GHz. Three-dimensional NLS-graphy have helped to find pararectal neoplasms in 28 of 163 patients. Spectral-entropic analysis confirmed recurrent cancer in 7 patients and metastatic affection of lymph nodes in 2 patients correspondingly.

Therapists of pediatric surgery department Stubdreier H. et al. (*Pic.8*) of Tübingen University (Germany) used three-dimensional NLS-graphy of pelvic floor as an auxiliary diagnostic instrument for determining of surgical tactics for treatment of children suffering from stool incontinence. The study included visualization of sphincter muscles and rectum walls; results of the study were confirmed by data acquired with spiral computed tomography. A distinctive feature of this study was using of interactive tissue segmentation of organs and tissues by means of 4D TISSUE mode application during their three-dimensional visualization.



*Pic.8. 3D-ultramicroscanning of rectum cancer*

Chun L.G. et al. (*Pic.9*) carried out three-dimensional NLS-graphy of malignant prostate gland in 46 patients. In accordance with gathered diagnostic data cryoablation of prostate gland was fulfilled.



*Pic.9. 3D NLS-graphy of malignant prostate gland*

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Possible diagnostic value of three-dimensional NLS-graphy is most clearly seen during examination of small pelvis organs in women, where conventional diagnostic methods allow to see advantages and disadvantages of each of them.

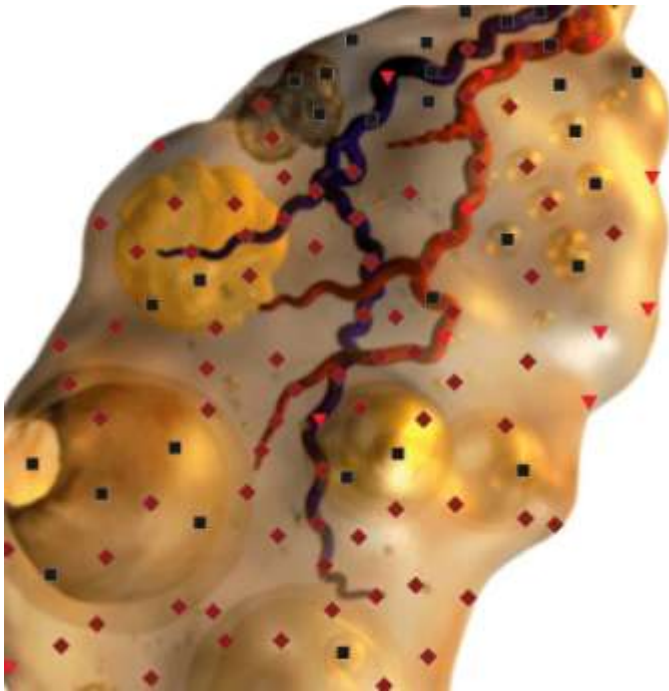
Akuda T. et al. have not got any additional information using three-dimensional NLS-graphy in comparison with usual two-dimensional NLS-study which revealed uterine cavity septa in one woman, fibroid foci in three women and endometrial polyp in one woman of five examined patients.

Spanish gynecologists Brisoles H. et al. have studied possibilities of three-dimensional NLS-graphy, transvaginal sonography, transvaginal Doppler sonography, hysteroscopy and usual hysterosonography in diagnostics of endometrial tumors and defining of endometrium thickness during hormonal treatment in 16 patients. Three-dimensional NLS-study was found the most accurate diagnostic method of all methods studied.

Chun L.G. et al., a group of gynecologists of Temple University (Philadelphia) in 2011 reported about results of comparative study of diagnostic efficiency of three-dimensional and two-dimensional NLS-graphy. Altogether 8 women (*Pic.10*) suffering from surgical diseases of ovaries were examined. Later on all patients were subjected to explorative laparotomy or diagnostic laparoscopy. NLS-graphy data was compared with intraoperational findings and results of macroscopic and histological studies. In all eight cases three-dimensional NLS-graphy managed to define correct diagnosis before surgical intervention. It is especially important that in absence of difference in diagnostic accuracy of three-dimensional and two-dimensional study of



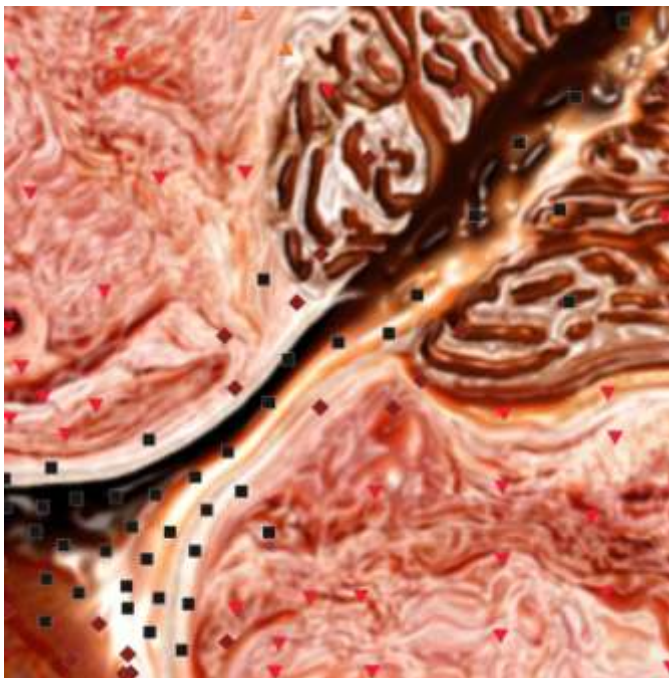
cysts and benign neoplasms, two-dimensional NLS-graphy turned out to be less accurate in detecting of malignant tissues, giving both false-positive and false-negative results.



*Pic.10. 3D-ultramicroscanning of ovarian cancer*

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Spoun N. et al. (*Pic.11*) have carried out comparative evaluation of two-dimensional and three-dimensional NLS-graphy accuracy in specifying diagnostics of uterine neck cancer. The study was carried out in 61 women one day before surgical intervention; accuracy of three-dimensional examination was in range of +6.68 to -6.1 ml, two-dimensional – from +12.46 to -10.98 ml.



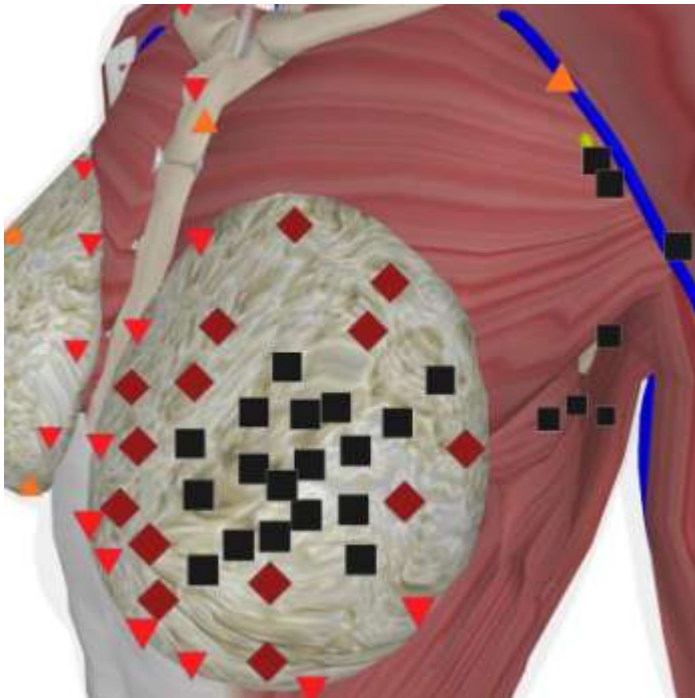
*Pic.11. 3D-ultramicroscanning of uterus cervix cancer*

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French gynecologists Sarida M. et al. used three-dimensional NLS-graphy for diagnostics of atropic pregnancy in 12 women with amenorrhea period above 6 weeks. Laparoscopy detected atropic pregnancy in 9 cases, only in 2 of them it was found on NLS-pictures. Hence the authors believe that this diagnostic method is ineffective, especially for early non-invasive detection of gestational sac development in fallopian tube.

Other methodologically valuable results for evaluation of advantages of three-dimensional representation of NLS-graphic data were results acquired at NLS-study of mammary glands.

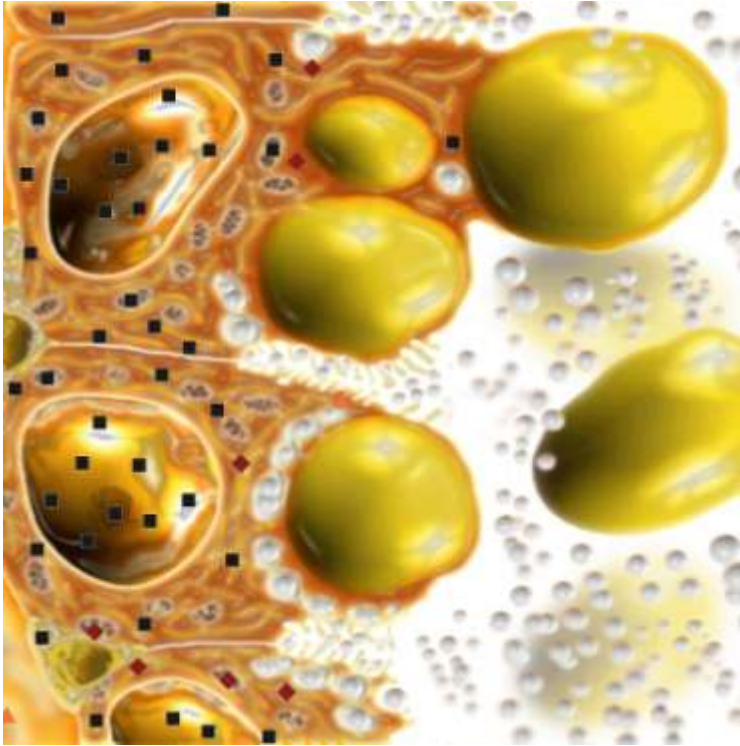
Bluhmberg S.O. et al. (*Pic.12*) have used three-dimensional NLS-graphy of mammary gland in study of 48 women, 18 of which had malignant neoplasms of mammary gland. The therapists reported about 4 false-positive mammary gland cancer diagnoses against two cases of false-positive diagnoses when two-dimensional NLS-graphy was used. At the same time the authors note that three-dimensional NLS-graphy has advantages in evaluation of edge zones and shape of pathological nidus and also at multifocal affection of mammary gland.



*Pic.12. 3D-image of mammary gland cancer*

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English breast physicians Havies L. et al. (*Pic.13*) of Bristol University used three-dimensional NLS-graphy of mammary gland and in some cases managed to reveal and detect internal structure of intraductal carcinoma by means of spectral-entropic analysis, and neoplasms simulating microinvasive carcinoma. Such outstanding diagnostic results authors achieved using non-linear sensor of 9.6 GHz frequency that allowed to get resolution of 30 microns.

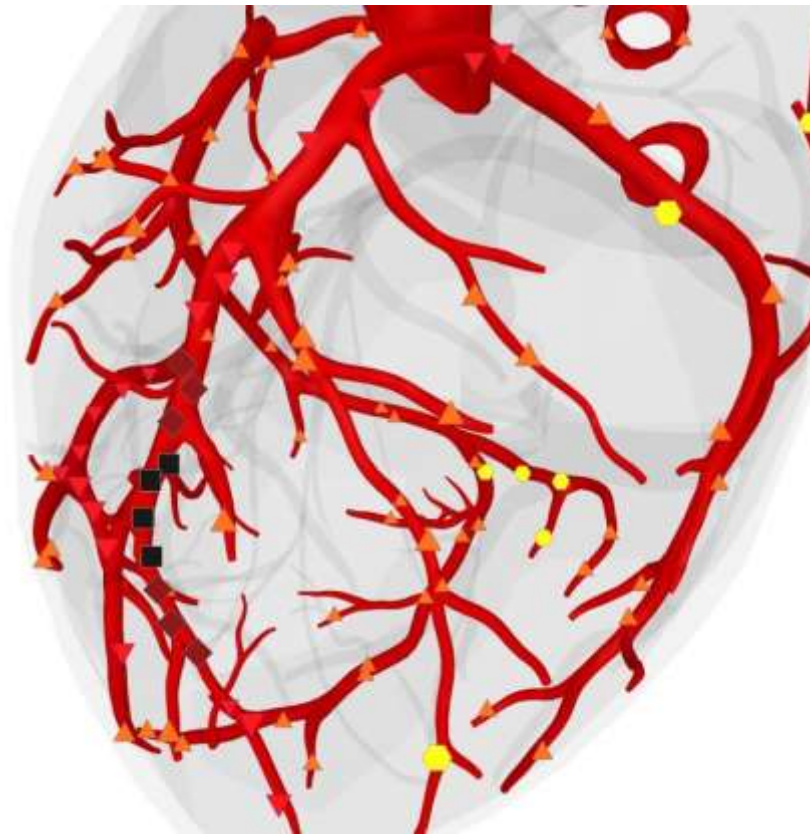


*Pic.13. 3D-ultramicroscanning of mammary gland cancer*

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A peculiar etalon test of diagnostic efficiency of three-dimensional reconstruction at complex configuration of source two-dimensional data is considered NLS-scanning of bloodstream, results of which are compared with similar data acquired by traditional and well known radiographic contrast study.

In 2011 Bljger K. et al. (*Pic.14*) reported about results of a study than have been carried out in University hospital of Antwerp and were devoted for “reconstruction of bloodstream’s geometry” in accordance with data of radiographic contrast angiography and intracoronary NLS-study. After evaluation of reconstruction precision of studies performed on special phantoms, the authors agreed to consider acquired results “very realistic” and offered a number of criteria for comparative evaluation of three-dimensional bloodstream reconstruction precision. Clinical part of the study contained comparison of reconstructed three-dimensional images of coronary arteries with data acquired with usual angiograms. The difference was less than 5%.



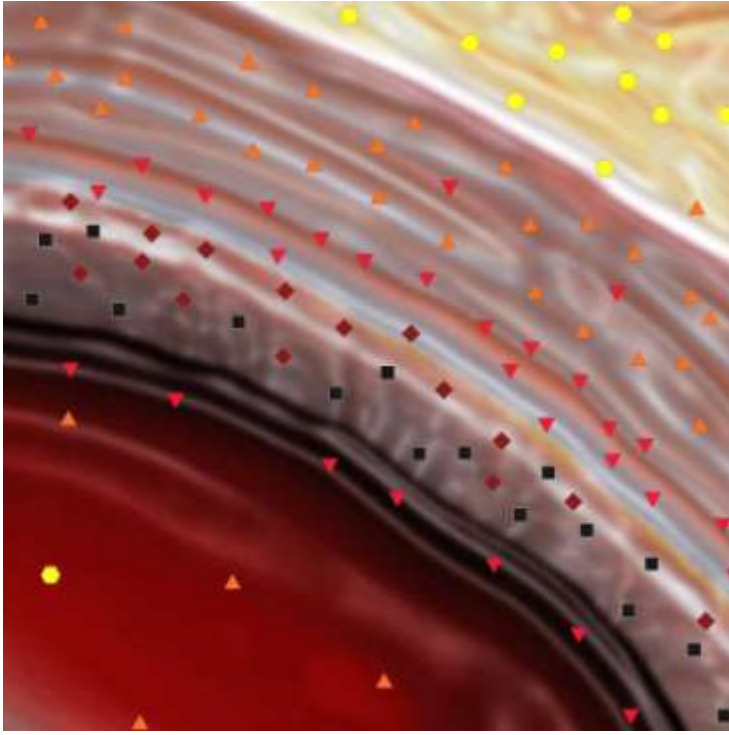
*Pic.14. 3D-image of coronary artery*

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Prust G.J. et al. note the following advantages of reconstructed images of arteries, acquired with intravascular NLS-study: 1) a vessel may be seen from different sides and angles, 2) its direction may be seen, 3) changes of vessel's diameter are clearly visible, 4) a possibility to get a cross-section of a vessel in any plane of scanning, 5) condition and location of intravascular stent may be found with high precision.

Kogan S. et al. (*Pic.15*) have determined high diagnostic efficiency of three-dimensional intravascular NLS-graphy in visualization of arterial wall structure and its pathological changing. The authors believe that intravascular NLS-graphy with following three-dimensional reconstruction significantly excels coronary angiography, because it have better resolution and allow to reveal many hidden neoplasms; that is why it is irreplaceable at study of coronary arteries condition after heart transplantation.





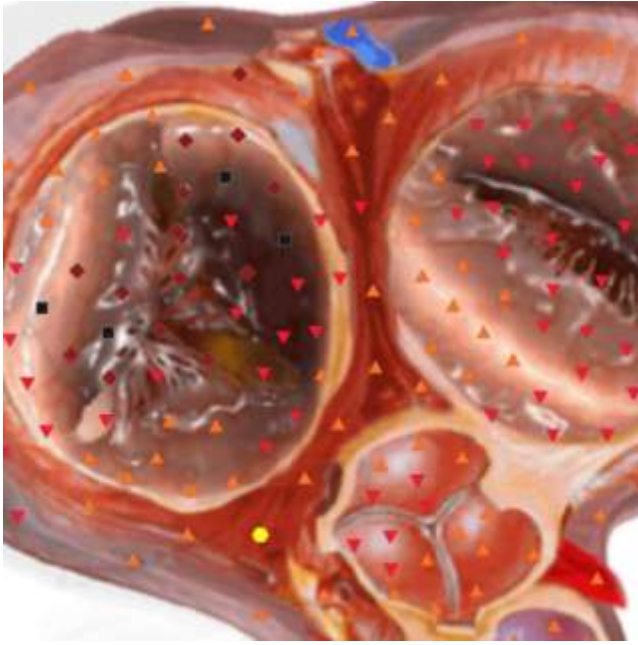
*Pic.15. 3D-ultramicroscanning of vascular wall*

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The most impressive was using of three-dimensional NLS-study data for intraoperative navigation and computed modeling of surgical manipulations.

Serbia S. – a head of obstetrics and gynecology department of Washington University reasonably stated that three-dimensional NLS-study is a potential diagnostic instrument which in near future will become the main source of data for preoperative surgical training which uses individual diagnostic data.

Three-dimensional NLS-graphy may be widely used in cardiosurgery as a method of intraoperational navigation. Quite character in this relation is a study of cardiothoracic surgeons from North Carolina Abrams O.H. et al. (*Pic.16*) who presented in 2011 a detailed report about wide clinical application of intraoperational three-dimensional NLS-graphy during replacement of cardiac valves. The authors say that this diagnostic method helped them to get important intraoperational data when they used spectral-entropic analysis about morphological peculiarities of valves, which weren't revealed by echocardiography and Doppler sonography.

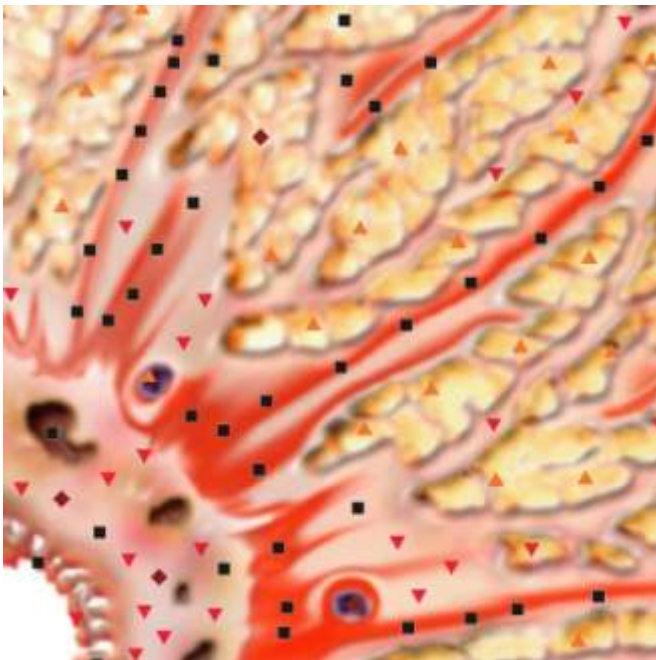


*Pic.16. 3D NLS-picture of cardiac valves*

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Going beyond the most optimistic ways of possible application of three-dimensional NLS-graphy, Parris D. et al. (*Pic.17*) use data about prostate gland structure acquired by this method for computerized control of robot (!) movement during fulfillment of transrectal resection.



*Pic.17. 3D-ultramicroscanning of prostate gland*

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An unique and apparently having no equals in efficiency navigation algorithm was offered by Hatayama T. et al. – scientists of Tokio University in 2012. They reported about possibility of precise matching of three-dimensional pictures acquired by CT and MRI in preoperational period with data of three-dimensional NLS-research acquired during neurosurgical intervention. NLS scanner of 4.9 GHz frequency was an integral part of a system and had built-in positioning device. The authors report about successful clinical application of a system in three cases and note good complementarity of NLS-graphic pictures and MRI and CT data. On the one hand, not visualized on NLS-picture parts of surgical intervention zone were filled by pictures got during preoperational period; on the other hand precise intraoperational positioning of various anatomic objects on NLS-sonogram allowed to identify them without any doubts. According to the authors, even preliminary results of this study allow to think about beginning of a new stage in intraoperational navigation based on NLS-graphic three-dimensional pictures of human body, which was not possible at separate application of above mentioned methods or inaccurate matching of pictures acquired with this method.

On the whole in comparing of diagnostic efficiency of indirect visualization various methods, NLS-graphy, significantly pressed in surgical room by such hardware titans as CT and MRI, in 2 recent years started to get new significance because of improving of both visualization method itself and results of three-dimensional reconstruction on the basis of NLS-graphy data.

### **Improving of diagnostic equipment**

Thanks to a number of qualitative changes of NLS-diagnostic devices, NLS-graphy potentials were widened to extent unthinkable even few years ago, when CT and MRI had obviously growing advantage in surgical gastroenterology.

Application of high-frequency sensors during NLS-studies in gastroenterology allowed to move early diagnostics of pathology to a qualitatively new and higher level. By means of spectral-entropic analysis and ultramicroscanning it is possible to diagnose superficial carcinoma of esophagus or stomach, when cancerous cells infiltrate mucous and sub-mucous levels only and initial manifestations of metastases in periesophageal and periogastric lymph nodes. It is considered that application of high-frequency sensors at three-dimensional visualization ensures determining of depth and length of tumorous infiltration into stomach walls in 93.6% of cases. Besides using of high-frequency sensors allows to excel all known methods of polyps and bile papilla cancer diagnostic, at the same time specificity of the method at preoperational diagnostic of choledocholithiasis reaches 94%. And finally, there is information that application of high-frequency sensors allows to visualize concrements not visible even at intraoperational cholangiography.

### **Conclusion**

Even now when methods of three-dimensional NLS-diagnostics are in stage of formation and standardization, it is possible to conjecture direction of their further development in relation to mutual competence and complementarity.

In 2011 Dupla D. and Supuy X.E. while noting that for the last 5 years significant difference in visualization methods at acute abdominal pathology was related to CT mainly, stated that at the present time, thanks to technological improvement of NLS-scanners, NLS-graphy must become the first diagnostic instrument for patients suffering from acute stomach pain and women suffering from acute pain in right lower quadrant of stomach and small pelvis. The authors believe that computed tomography is necessary only when NLS-graphy turned out to be diagnostically inefficient. According to the authors place of MRI in diagnostic sequence at acute surgical diseases of abdominal cavity organs is uncertain due to absence of its wide application.

Sun K., Bergman P. and Flager W. of Cambridge University have developed an algorithm of “wire” model of organs building on the basis of their frequency characteristics, acquired by various methods of medical registration. The most demonstrative result of this algorithm application is its application of liver model reconstruction on the basis of three-dimensional NLS-study, the authors say.

Thus role of three-dimensional NLS-research in combined diagnostics is constantly growing and becoming quite unique. At the same time in modern high-quality representation of diagnostic data, in particular in surgical gastroenterology, two-dimensional models in many cases are insufficient for acquiring of comprehensive diagnostic information.

Other important aspect is improving of applied methods of three-dimensional diagnostic data presentation, which will help to implement numerous possibilities of efficient visualization of researched objects and use their graphic images for computer training simulators and real intraoperational navigation.

Solving of these problems is the most efficient way to improve quality of preoperational diagnostics and boosting of surgical accuracy.

Achieved hardware-software level of ultramicroscanning and spectral-entropic analysis, gathered positive experience of topological and tissue segmentation of organ’s virtual pictures, rapid development of three-dimensional animation software available for average personal computer allow to put a reasonable question about need in development and clinical approval of practically acceptable and unified methods of three-dimensional parametric animation on the basis of NLS-data.