Non-invasive imaging and diagnostics in the treatment of heart diseases.

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Abstract: The aim of the study is to evaluate the use of new technologies in diagnostic imaging of heart diseases and in modeling heart's structure. Imaging is the key to assessing details of heart disease in modern cardiology.

Materials and Methods: The study was conducted from January 2011 to December 2011 in Poland, at the Department of Cardiology, Regional Hospital of Louis Rydygier in Torun. Patients underwent transthoracic imaging using echocardiography, angiography with angioplasties and coronary angiography. All data were statistically analyzed using the Wilcoxon test.

Results: Imaging is essential for decision-making and treatment planning by cardiologists. The idea of developing medical computer system in cardiology is not to delegate the diagnosis to a machine, but rather that a machine algorithm acts as a support to the cardiologist and point out locations of defects. Computerized systems give new possibilities of imaging in cardiological practices. The drawbacks at present are that there exist a limited selection of software for cardiologists. The staff (health care managers) are also reluctant to implement computerized systems, mainly because of the cost of such systems.

Key words: Healthcare, Imaging, Technology, Treatment, Heart Disease

Introduction:

The health care delivery system has been promoted and shaped by technology advances. Technology also creates new possibilities of medical diagnoses by expanding the range of possibilities of imaging. Electrocardiography and echocardiography allowed the characterization and classification of multiple cardiac conditions, including atrial fibrillation,
heart blocks, and mitral valve prolapse. Before these diagnostic tools were available, life threatening coronary artery compromise and silent myocardial infarctions often went undetected. The promoting technology application in medical care were four indicators that demonstrated inefficiencies in that care. There were: uncertainty, variability, error, and quality
problems. These are eloquent indicators of inherent problems in medical practice. Such inefficiencies are catalyzing an intellectual revolution in medical practice away from the narrow application of raw clinical judgment and qualitative reasoning to a more scientific and quantitative mode of practice [1,2,3]. This new approach will further cement health care delivery's dependence on technology through information systems.

Materials and Methods:

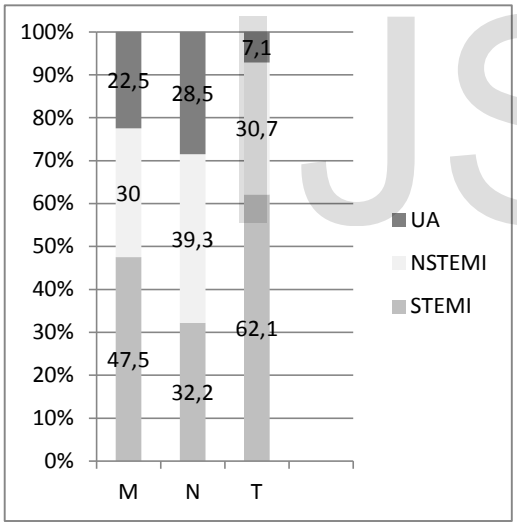
This research was conducted in public surgery clinics in Poland. The research described here was conducted in six healthcare units of Kujavian-Pomeranian province.
The study was conducted from January 2011 to December 2011 in Poland, at the Department of Cardiology, at Regional Hospital of Louis Rydygier in Torun . The analysis included only patients referred urgently (on admission) and classified for invasive diagnostics mode. These criteria are fulfilled for 450 patients. For these patients demographic data, date and time of occurrence of chest pain, time of admission, coronary angiography / angioplasty diagnostic were also collected. Patients underwent transthoracic

imaging using echocardiography and coronary angiography with or without coronary angioplasty. Data were statistically analyzed using the Wilcoxon test.

Results:

Short Patients met the criteria for invasive diagnostics mode were divide into 3 groups:
- Group (T) – 140 patients whose prior to the adoption was transmitted ECG;
- Group (N) -270 patients whose prior to the adoption was not transmitted ECG;
- Group (M) – 40 patients who were executed before the adoption of ECG but has not been transmitted (figure 1)

Figure 1. The Initial Diagnosis in each group studied p < 0.0001



Imaging is the key to assessing details of heart diseases and to studying the lesions and dysfunction of heart. Imaging models are based on reconstruction techniques of echocardiographic or computed tomographic data sets. Thus, imaging is essential for decision-making and treatment planning by cardiologists. Although, the study indicates that unnecessary cardiac involvement workshop was particularly frequent in the treatment of women (who often there was no culprit lesion or significant changes in the coronary arteries), patients with a new block left bundle branch block and after having a heart attack or coronary artery bypass grafting (CABG). Such a situation occurred in 1 of 10 patients referred for imaging studies. In the analysis undertaken, this number represents 27.56% of the total patients (PCI/CBAG) (table I).

Table I Imaging of heart diseases and procedures

	Sum	Group M N=40	Group N N=270	Group T N=140	P <0.0001
Imaging of heart diseases and procedures					
KORO		10 25,00%	87 32,2%	27 19,29%	127 27,56% M vs N vs T: NS

It is 27.56% of all patients participated in the survey, and participating in the coronary. Also in group T for which the earlier recording was made ECG transmission was less unnecessary activation of the catheterization laboratory. Also the duration of chest pain and door to balloon time were the shortest in the group T. The time admission to hospital and start coronary angiography means average 35 minutes and the time admission to the hospital and start coronary angioplasty means average 45 minutes in this group (T). Transthoracic imaging gives a shorter time to initiation of treatment, the reduction in infarct size, improved outcomes, shorter hospital stay and lower hospital costs.

Demographic data:

Place of living: Golub Dobrzyń, Brodnica, Toruń – 241 patients (Toruń area)

Wąbrzeźno, Chełmża, Grudziądz, Chełmno – 207 patients (Grudziądz area)

Lipno, Włocławek – 2 patients (Włocławek area).

Gender: Male: 39% Female: 61%
Age: 46-69 (Average - 57,5)

Patients from the region of Toruń and Grudziądz represent the largest proportion of the patients participating in study and average age of participants was 57,5 years. Also more frequent imagining of heart diseases was treated women.

Discussion

Imaging is the key to assessing details of heart diseases and to studying the lesions and dysfunction of heart and mitral valve according to Carpentier [4]. Imaging models are based on reconstruction techniques of echocardiographic or computed tomographic data sets. Imaging enables assessment of correct and incorrect mitral valve function, especially morphological and dynamic basics throughout the cardiac cycle [4,5]. Thus, imaging is essential for decision making and treatment planning by cardiologists. While multiple modalities exist to assess mitral valve, transthoracic echocardiography (TTE) represents the standard technique to study heart disease and mitral valve [5]. Especially with current advances of 3-dimensional (3D) echocardiography in combination with multi-detector row computed tomography (MDCT) and cardiac magnetic resonance (CMR), characterization and quantification of the mitral valve apparatus and its functional complexity has improved significantly during last years [6,7,8]. Most recently, geometrical and biomechanical models for analysis of mitral valve are undergoing very early clinical evaluation [9,10,11,12], using modern imaging methods. As a result, percentage of defects detected in the early stages of the disease has increased significantly. Automated distinction of medical images is therefore an important preprocessing in Computer-Aided Diagnosis (CAD) systems. Preprocessing of images is essential for reducing the complexity and computation time of the computer aided diagnosis algorithms. The automated clinical decision support system is a software program implemented with the goal of reducing medical errors and of support medical treatment. The software program makes suggestions in the course of diagnosis when patient data are entered into the system. The underlying idea of developing medical computer system in cardiology is not to delegate the diagnosis to a machine, but rather that a machine algorithm acts as a support to the cardiologist and points out locations of suspicious objects (defects). By the same, token the overall sensitivity of computer's systems increases the detection rate of diseases and contributes to better diagnostics and less medical errors. Generally, computer aided diagnosis systems should meet the following objectives:

- integrated analysis of cardiac failure using the computer aided diagnostic results in an improved diagnostic performance,
- improving the quality and accuracy of diagnosis,
- increasing therapy success by early detection of heart failure and fatigue of mitral valve,
- reducing cardiologist's interpretation time.

This systems are useful because they support the doctor's work, but the problem is with the cost of the new technology use in cardiology. Hospital managers do not accept the additional expenses related to the financing of the treatment using new technology. Given the complexity of modern medicine, it is unlikely that quality can be meaningfully improved without creatively applying the powerful capabilities of technological systems, and accepting the additional costs of treatment resulting from technological developments and computer aided diagnosis in modern cardiology. Medical information technology is the science of using system-analytic tools to develop procedures for management, process control, decision making and scientific analysis of medical knowledge. Medical information technology has been making rapid progress, keeping pace with internet and multimedia technology which have shown enormous growth over the recent years [13]. Since

the quality of the images in diagnostic imaging depends on patients and CT imaging sequences, there is much variability in the pixel value range, noise level and background level and also personal skill to use technology. Therefore, the normalization of pixel values, some smoothing filters for reducing noise, background correction, etc., should be performed prior to input into the feature extraction [14], because the bad quality of images increases probabilities of medical errors. However, applying all those software corrective features allows for better and clearer according reading and analysis of the medical documentation. In the recent years computer aided diagnosis (CAD) has become one of the major research topics in medical imaging, and has been applied to various medical imaging modalities including computed tomography (CT), magnetic resonance imaging (MRI), ultrasound imaging, and also nuclear medicine [15,16,17,18]. One of the most important applications of computer aided diagnosis is the detection and characterization of heart diseases, as they are the leading cause of deaths and diseases in civilizations throughout the world. In fact, the total number of deaths caused by heart attach is greater than that resulting from other diseases such as: colon, breast, and prostate cancers combined [19]. Survival from heart attach is directly related to how quickly the attach is detected and diagnosed. The earlier the detection of many of heart diseases is, the higher the chances of successful treatment are. Although cardiovascular surgery, has been used in the treatment of heart diseases, the five-year survival rate for all stages combined is only 25%. This tendency has not changed in the past three decades [20]. Studies show that case interpretation time is 10-40 minutes, even with expert cardiologist and abdominal radiologists [21]. Thus, the current need of the market is to substantially reduce the interpretation time before ultrasound imaging, angiography and other procedures can make the transition from research to routine clinical practice, especially as a screening tool. Hence, it can be visualized that this area of medical informatics has great research potential and excessive research is needed, but sometimes meet difficulties because of the cost of implementation of this new technology in hospital practices. We must also remember that the creation of computer models and imaging of the heart muscle in cardiovascular and cardiology medicine requires close collaboration between physicians, computer scientists and engineers. In cardiovascular and cardiology medicine one can distinguish between different types of computational models such as geometric models, biomechanical models and multi-scale generic models. All models are based on the reconstruction of the image of actual anatomic structure and are developed to fulfill very special requirements. Past studies have shown that these models are suitable for the description of complex morphological and biomechanical changes of the heart and great vessels. Computational models were used for accurate analysis of left and right ventricular contraction, flow simulation through artificial heart valves or shear stress analysis of the aorta with aortic aneurysms [22,23,24,25,26,27]. Exact modeling of mitral valve function has not been realized in the past due to the lack of imaging techniques that enable detection of the 3D structures and their respective function. With the development of real-time 3D echocardiography and 4 - dimensional computed tomography (4DCT), however, the technical capabilities have been introduced to create substantial and well-defined heart images and mitral valve models with a high probability for implementation into clinical practice (10). Within the technological advances the quality of diagnosis can be meaningfully improved, but without creatively applying the powerful capabilities of computer systems in medical practice it will not be possible [1,28,29,30].

Conclusion

The results of this study indicate, that the complex structure of the cardiac cycle can be analyzed with different types of computational models and imaging systems. These represent substantial progress in the diagnosis of structural heart disease. Also, modeling will contribute to a deeper understanding of how the computer aid system helps the doctors in their daily work and improves the comfort of patient's life. Computerized systems give new possibilities to cardiologist practices, but there exist a limited selection of software for cardiologists. As it was noted before, the health care managers are not eager to implement computerized systems, mainly because of the cost of these systems.

References

1. Slack, W. Cybermedicine: *How Computing Empowers Doctors and Patients for Better Health Care*. San Francisco: Jossey-Bass, 1997.

2. Eddy, D.M. Money, *Medicine and Mathematics. Bulletin of the American College of Surgeons* 77(6):**36-49** (1992).

3. Millenson, M.L. *Demanding Medical Excellence: Doctors and Accountability in the information Age*. Chicago: University of Chicago Press, 1997

4. Carpentier A. *Cardiac valve surgery--the "French correction"*. J Thorac Cardiovasc Surg;86:323-37 (1983).

5. Debonnaire P, Palmen M, Marsan NA, et al. *Contemporary imaging of normal mitral valve anatomy and function*. Curr Opin Cardiol. 27:455-64 (2012).

6. Delgado V, Tops LF, Schuijf JD, et al. *Assessment of mitral valve anatomy and geometry with multislice computed tomography*. JACC Cardiovasc Imaging, 2:556-565 (2009).

7. Kaplan SR, Bashein G, Sheehan FH, et al. *Three-dimensional echocardiographic assessment of annular shape changes in the normal and regurgitant mitral valve*. Am Heart J 139:378-87 (2000).

8. Morris MF, Williamson EE, Topilsky Y, et al. *Multi-imaging assessment of the congenital mitral arcade.* J Am Coll Cardiol 57:1856 (2011).

9. Ionasec RI, Voigt I, Georgescu B, et al. *Personalized modeling and assessment of the aortic-mitral coupling from 4D TEE and CT.* Med Image Comput Comput Assist Interv 12:767-775 (2009).

10. Ionasec RI, Voigt I, Georgescu B, et al. *Patient-specific modeling and quantification of the aortic and mitral valves from 4-D cardiac CT and TEE*. IEEE Trans Med Imaging 29:1636-1651 (2010).

11. Jassar AS, Brinster CJ, Vergnat M, et al. *Quantitative mitral valve modeling using realtime three-dimensional echocardiography: technique and repeatability*. Ann Thorac Surg 91:165-171 (2011).

12. Mahmood F, Karthik S, Subramaniam B, et al. *Intraoperative application of geometric three-dimensional mitral valve assessment package: a feasibility study*. J Cardiothorac Vasc Anesth. 22:292-298 (2008).

13. Lee, J., Kim, J., Lee, J., Hwang, S., Lee, B., Jeong, K., Cho, C. and Lee, M. (2004*) The Study on the Web-Based Clinical Database Management System of Oriental Pulse Waveform*, Journal of Medical Systems, Springer Netherlans, Vol. 25, No. 5, Pp. 274-284.

14. Arimura, H., Magome, T., Yamashita, Y. and Yamamoto, D. (2009) *Computer-Aided Diagnosis Systems for Brain Diseases in Magnetic Resonance Images*, Algorithms, Vol. 2, Pp. 925-952; doi:10.3390/a2030925

15. Doi, K. (2004) *Overview on research and development of computer-aided diagnostic schemes, Seminars in Ultrasound, CT, and MRI,*.Vol. 25, Pp.404-410.

16. Giger, M.L. (2004) *Computerized analysis of images in the detection and diagnosis of breast cancer, Seminars in Ultrasound, CT, and MRI*, Vol. 25, Pp. 411-418.

17. Li, Q., Li, F., Suzuki, K., Shiraishi, J., Abe, H., Engelmann, R., Nie, Y.K., MacMahon, H. and Doi, K (2004) *Computer-Aided Diagnosis in Thoracic CT, Seminars in US, CT, and MRI*, Vol. 26, Pp.357-363.

18. Yoshida, H. and Dachman, A.H. (2004) *Computer-aided diagnosis for CT colonography, Seminars in Ultrasound, CT, and MRI*, Vol. 25, Pp.419-431.

19. Greenlee, R.T., Murray, T., Bolden, S. and Wingo, P.A. (2000) *Cancer statistics, 2000*. CA Cancer Journal of Clinicians, Vol. 50, Pp. 7-33.

20. Sammouda, R., Hassan, J.A. and Sammouda, M. (2005) *Computer Aided Diagnosis System for Early Detection of Lung Cancer Using Chest Computer Tomography Images*, GVIP 05 Conference, CICC, Cairo, Egypt, Pp. 1-8.

21. Johnson, C.D., Dachman, A.H. (2000) *CT colonography: the next colon screening examination?* Radiolog, Vol.216, Pp. 331-341.

22. Grewal J, Suri R, Mankad S, et al. *Mitral annular dynamics in myxomatous valve disease: new insights with real-time 3-dimensional echocardiography*. Circulation 121:***1423-1431*** (2010).

23. Calleja A, Thavendiranathan P, Ionasec RI, et al. *Automated quantitative 3-dimensional modeling of the aortic valve and root by 3-dimensional transesophageal echocardiography in normals, aortic regurgitation, and aortic stenosis: comparison to computed tomography in normals and clinical implications*. Circ Cardiovasc Imaging 6:***99-108*** (2013).

24. Chandra S, Salgo IS, Sugeng L, et al. *Characterization of degenerative mitral Valle disease using morphologic analysis of real-time three-dimensional echocardiographic images: objective insight into complexity and planning of mitral valve repair*. Circ Cardiovasc Imaging 4:***24-32*** (2011).

25. Mihalef V, Ionasec RI, Sharma P, et al. *Patient-specific modelling of whole heart anatomy, dynamics and haemodynamics from four-dimensional cardiac CT images*. Interface Focus 1:***286-296*** (2011).

26. Dwyer HA, Matthews PB, Azadani A, et al. *Computational fluid dynamics simulation of transcatheter aortic valve degeneration*. Interact Cardiovasc Thorac Surg; 9:***301-308*** (2009).

27. Nicosia MA, Cochran RP, Einstein DR, et al. *A coupled fluid-structure finite element model of the aortic valve and root.* J Heart Valve Dis 12:**781-789** (2003).

28. Berwick, D.M., Godfrey, A.B., Roessner. J. *Curing Health Care: New Strategies for Quality Improvement*. San Francisco: Jossey-Bass, 1990.

29. Chassin, M.R., Galvin, R.W. *The Urgent Need to Improve Health Care Quality*. Journal of the American Medical Association. 280(11):**1000-1005** (1998).

30. Classen, D.C., Pestotnik, S.L., Evans, R.S., Lloyd, J.F., Burke, J.P. *Adverse Drug Events in Hospitalized Patients: Excess Length of Stay, Extra Costs, and Attributable Mortality*. Journal of the American Medical Association, 277(4): **301-306** (1997).

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