Implementation scale and other imaging health and social care essay

BME-2636 MEDICAL IMAGE ANALYSIS " ESSAY" RADIONUCLIDE VENTRICULOGRAPHYGroup 17: Aapo Tervonen, 205894Kalle Lehto, 201989Submitted on 14. 4. 2013---------- Page 2----------

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INTRODUCTIONRadionuclide ventriculography (RNV) is a nuclear medicine imaging method used tostudy the condition of a heart, more spesifically the left ventricle. It has many differentnames: equilibrium radionuclide ventriculography (ERNV), multiple-gated cardiacblood pool imaging (MUGA). There are subtle differences between these methods, butthe basic principles

are the same. The main interest in RNV is to measure the left ven -tricule ejection fraction (EF), which describes the hearts ability the contract and thuspump blood. 2 IMPLEMENTATION SCALE AND OTHER IMAGINGMETHODSRadionuclide ventriculography was the first widely used non-invasive method of leftventricular function quantification [1]. Studies from early 80s indicate that RNV is inroutine clinical use [2], but it is nowadays mainly replaced by echocardiography [3]. However, RNV provides a more accurate method of EF determination than echocardio -graphy, but as a drawback it exposes the patient to radiation. Still used for examplewith cancer patients using cardiotoxic drugs or cytostatins. [Pasi Korkola, personalcommunication.]3 IMAGING PROTOCOLThe basic idea of RNV is to inject radiopharmaceuticals into the patient blood streamand image the heart as it pumps the radiolabelled blood with a gamma camera. Firstthing needed for RNV are the radiopharmaceuticals. Usually, Technetium-99m (99mTc)labelled autologous red blood cells are used. Another alternative is 99mTc labeled humanserum albumin. For adults and children, the usual administered activities are 555-1000(700 Mbq in Tampere University Hospital [Pasi Korkola, personal communication]) and70-150 Mbq, respectively. The labelling can be done in vivo, modified in vitro and invitro techniques. [4.] In in vivo method, 99mTc is injected straight to a vein [5]. To en-hance the labeling, pewter can be injected before the injection of 99mTc [Pasi Korkola, personal communication]. In modified in vitro method some blood is withdrawn into asyringe which already contains 99mTc and then the mixture is left to reach equilibrium, after which it is reinjected. In in vitro method, some blood is withdrawn and the mixingwith 99mTc is done completely in vitro, and after equilibrium is reached, the mixture isreinjected

into a vein. The efficiency of the labelling varies between the methods, in---------- Page 4----------2vitro being to most consistent. [5.] In vivo method is the easiest and does not need sterileplace to handle the cells [Pasi Korkola, personal communication]. There are two principle methods for RNV: first pass and gated equilibrium. In firstpass method, the initial passage of the radionuclide bolus through the left ventricle isanalysed by frequent sampling of fluctuations during several cardiac cycles. In gatedequilibrium method, the radionuclide first reaches equilibrium within the blood pool, af-ter which a sequence of images is taken through the cardiac cycle for several hundredheart beats by gating using the R-wave from electrocardiogram. [2.] Minimum of 16frames per R-R interval are taken, as presented in Figure 1 (more accuracy with higherframe rates) [4]. The images of an interval are rejected, if the interval differs too muchfrom the set limits for the normal pulse [Pasi Korkola, personal communication]. 16Figure 1: The gating of the R-wave and the 16 lateral anterioroblique (LAO) imaging acquired [4].---------- Page 5----------3frames are needed to calculate the ejection fraction, and higher rate is needed for de-tailed measurement of diastolic filling parameters [4]. In Tampere University Hospital, the number of frames per R-R interval is 32 [Pasi Korkola, personal communication]. The benefit of the first pass method is that the is little background contribution from theoverlying cardiac chambers, which is a problem in gated equilibrium method. However, due to the averaging over multiple acquisitions, gate equilibrium method produces muchhigher statistical significance than first pass method and thus is more commonly used. Also, the repetition of the imaging with gated equilibrium is easier, as with first passmethod the patient's radiation burden would

increase. [2.]Furthermore, the gated equilibrium RNV can be done as rest or stress study. In stressstudy the images are acquired on a bicycle ergometer in a supine, semi upright or up-right position. Also pharmacologic stress with an inotropic agents or vasodilators can beused if the patient is unable to do the normal stress test. [4.]Images are usually acquired in the left anterior oblique (LAO) direction. Sometimesalso anterior (Ant) and left lateral (LL) are taken. The angle of LAO projection is ad-justed so that the maximum separation of right and left ventricules is seen, and usuallyan angle of 45° is used. [5] The different acquisitions are presented in Figure 2. The images acquired with RNV are usually planar, but also single-photon emissioncomputed tomography (SPECT) can be used. This creates three dimensional images, from which it is easier to separate the atriums from the ventricules. SPECT and planarRNV function similarly to each other when calculating left ventricle EF and volume, butSPECT shows better the abnormalities in wall motion and more localized behavior. [6.]The collimators used in RNV can be either a low-energy, all-purpose or high-resolution, parallel hole collimators [4]. Figure 2: The three different acquitions: anterior (Ant), leftlateral (LL) and left anterior oblique (LAO) [5].---------- Page 6----------44 IMAGE PROCESSING AND ANALYSISThe digital image processing is a combination of the methods used for improving theimage quality in chain where the input picture is edited by mathematical algorithmsachieving sufficient quality of the output picture. Image analysis is detection of funda-mental information from the image. The techniques for image processing and analysisare usually highly automatic and pre-set, hence, user makes only crucial choices. Thereare several factors that have an effect on quality of the medical picture e. g. amount ofthe adipose tissue,

object movements and used radioactive labeled tracer. The tracer de-fines the resolution of the picture with the gamma camera detector properties. The rawimage is usually very noisy and blurry, consequently, the image require post-processing. Following chapters contain methods for image processing and analysis. 4. 1 Image enhancementImage enhancement is considered as a process focusing more appropriate image thatoriginal image was. Several factors affect on medical image quality and the processesare highly application dependent. The high imaging quality ensures that the diagnosis isobjective and the patient is treated by appropriate therapy in the future prospect. Themethods in this chapter are illustrated very briefly, because we assumed that the basictheory behind the digital image processing is foreknowledge in this specific BMEcourse. The image enhancement technique is divided roughly in two main categories: spa-tial- and frequency domain operations. In the spatial domain the pixel values (e. g. greylevels) are edited. Basic spatial domain operations are gamma correction, contraststretching, histogram equalization, histogram manipulation, histogram matching, localhistogram enhancement, logical operations, filtering operations (smoothing, sharpening(Sobel, High-boost, Lap-Lace)). In the frequency domain the image is Fourier Trans-formed and filtered. Typical frequency domain filters are: low-pass/high-pass filter(smoothing, sharpening), combined with Butterworth and Gaussian filters. [7.]In Tampere University Hospital there is special software for the equilibrium ra-dionuclide ventriculography (ERNV) developed by Hermes Medical Solutions. Inter-viewed Hospital Physicist Pasi Korkola emphasizes that the image can be degraded bynoise (low number of the counts), attenuation or scattering. Hence, the filtering ismandatory for compensating

these artefacts. The filter choice is a compromise betweennoise reduction and fine detail restriction. In practice, the Hermes software consist ofbasic above mentioned image processing tools, but according to Hospital Physicist val-ues are usually pre-set. [Pasi Korkola, personal communication.]Hermes Medical Solutions have wide category of software used for cardiology e. g. QGS Gated SPECT Ejection Fraction Analysis (Figure 3), QPS Quantitative PerfusionSPECT, Blood Pool Gated SPECT Analysis and First Pass Shunt Analysis. [8.]---------- Page 7----------5Figure 3: Quantitative Gated SPECT (QGS) interface [8]. 4. 2 Image segmentationIn image segmentation the basic idea is to separate region(s) of interest and highlightthem. There are huge variability of segmentation tools in medical imaging, thus, themethod is application/manufacture related. Nevertheless, the segmentation methods usu-ally involve some of following: local filtering, classification, regional methods, or activecontours. Local filtering consists of low-pass filtering, which reduce the noise and causessmoothening when the high-frequency components are removed. Edge detecting filtersare also used when the original image is not sufficient. Edge detection can be executede. g. by the threshold method that is a tool for separate objects from the background. It isdivided in several classes: local, spatial, object attribute based, histogram shape based, clustering based, and entropy based method [9]. In complete classification method pix-els/voxels are detected in pre-defined clusters. Classification itself is a field of the pat-tern recognition and measured features can be relevant characters: intensity, edges ortexture. Regional methods consist of region growing, where the seed pixel is grown, andregion merging. Active contours are elastic and simultaneously rigid that reshapes itselfiteratively. [10.]In the isotope department of the Tampere

University Hospital in ERNV, the main in-terest is in the ejection fraction of the heart (EF). The planar image contains sufficientinformation about the volumetric fraction of blood pumped out from ventricles in car-diac cycle. In the clinical ERNV studies the focus is the EF of the left ventricle. TheHermes software has a semi-automated tool for left ventricle segmentation . Since userhas defined the region of interest (ROI), the endocardium edges of the heart are detectedautomatically by software in systole and diastole states (Figure 4) Automatic edge de-tection tool (active contours) is not as accurate as human eye, hence, the user identifyand edit edges more accurately after the automation. Consequently, the segmentation---------- Page 8----------6process is quite simple for the user and overall not time consuming method in practice.[Pasi Korkola, personal communication.]Figure 4: Schematic picture of the ROIareas [11]. 4. 3 Quantitative parameters and normal valuesThe diagnostic isotope cardiac imaging procedures rely significantly on quantitativetechniques. There are also similarities in quantitative techniques between differentimaging modalities. Therefore, for instance heart's EF can be measured by ultrasound orradionuclide ventriculogram. Because the heart’s purpose is to push mechanically bloodthrough the circulation system, naturally quantitative analyses focus on hemodynamicperformance estimation. [11 .]Dynamic cardiac images reflect the hemodynamic performance and the wall motionof the ventricles. Cardiac output values are evaluated by global parameters. The heartdetection programs such as Hermes displays for example heart rate, EF (normal range55-70%), cardiac output (CO, normal range 4-8L/min), end-diastolic volume (EDV, nor-mal range 65-240mL), end systolic volume (ESV, normal range 16-143mL), and strokevolume (SV normal range 55-100mL). The

heart's left ventricular volume might be themost common volume measurement of the heart, because its clinical relevancy. The ba-sic idea of the technique is edge detection of the ventricular cavities. Additionally, over-lapping structures can be removed by subtracting a mask ECG-gated image. The vol-ume of the measurement can be solved by the area length method, that models ventricleas a 3D ellipsoid. Furthermore, volume of the ventricle can be calculated also by den -sitometric method, where the contrast material is proportional to the volume of theblood in certain cavity. The ejection fraction can be studied also regional (REF), that isproportional to local EF values. REF evaluates the functions of apex to septum and ven-tricles. Phase analyse of the ventricular wall motion is also typically detected by thesoftware. Asynchrony of the wall motion causes disorder in the blood flow, thus, thephase of the ventricles and atrium is important to evaluate. [11 ; 12.]4. 4 Measurement analysisInterviewed Hospital Physicist Pasi Korkola illustrated how the differences in segmen -tation have an effect on the results. The edge detection of the left ventricle was carried---------- Page 9----------7out by a semi-automatic " snake" (active contours). We used one specific left ventricleERNV picture and compared how many units the EF value changes if the edges aredrawn with approx. 1-3mm difference in the display. The final result was that the differ-ence is not significant. Even the differences were quite huge in the screen the result inthe EF was approximately +/- 2 %, that has not impact on the final diagnose. We alsocompared EF valuess between healthy heart (EF > 55 %) and the patient who was in thequeue of heart transplant (EF < 19 %). The differences were considerable. [Pasi Ko-rkola, personal communication.]5 REQUIREMENTS OF IMAGING CONDITIONS ANDDIAGNOSIS CRITERIA FOR

PATIENT SELECTIONThe patient has to remain still during the imaging process (approximately 15 minutes). This may be a problem with young patients. Also, overweight and cardiac dysrhythmiaare problems. If the heart rate varies a lot, the gating will reject most of the images.[Pasi Korkola, personal communication.]The patients have usually problems with their heart. RNV provides an easy way tomonitor the functionality of the heart. As already mentioned, it is also used to monitorthe heart of cancer patients during medication. [Pasi Korkola, personal communication.]6 DURATION AND COST OF THE PROCESSIn Tampere University Hospital, the imaging process takes around 45 minutes. At first, pewter is injected into the vein, followed by a wait of 15 minutes. Then, in vivo methodis used to label the red blood cells with 99mTc. Then again 15 minutes are waited to letthe label reach equilibrium in the blood pool. Then, the imaging is done, and it takesaround 15 minutes, depending on the heart rate. The cost of RNV in Tampere UniversityHospital is 414 €. [Pasi Korkola, personal communication.]---------- Page 10----------8