Post-congress SATELLITE of the European Congress of Nuclear Medicine at Balatonfüred 28—30, August, 1987

NUCLEAR (stethoscope-like) PROBE SYSTEM

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CONTENTS

THE STAFF OF THE RADIOISOTOPE DIAGNOSTIC LABORATORY OF THE STATE HOSPITAL FOR CARDIOLOGY, BALATONFÜRED

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THE 25 YEARS ACTIVITY OF THE RADIOISOTOPE DIAGNOSTIC AND BIOPHYSICAL LABORATORY OF THE STATE HOSPITAL CARDIOLOGY, BALATONFÜRED

The radioisotope diagnostic laboratory has been instituted here in Balatonfüred in 1961, i. e. in the Hungarian Cardiorehabilitation Center. The activity was directed from the beginning towards to the actual staging of the cardiac patients and to register the effect of the cardiac(drug)-therapy.

According to the actual phase of the technical development the methodology was at first the graphical selective quantitative radiocardiography (RKG), this has been connected later, in the mid sixties with the radiocyclography (RCG). This was initiated first in 1965 in Freiburg by Hoffmann and Kleine as analog version, one year later in Balatonfüred as digital one, both in blood activity equilibrium and averaged by RCG R-wave gating, improving thereby the measuring statistics. This invention made the way towards the combination of the RCG with various type of loads (mostly with bicycle ergometry), persuing them routinously perhaps first in the world in our practice. The RKG—RCG control of the loadings has been carried out from 1970 already with 113m-In-(transferrin) labeling. Our initiation was also verified by the successful IAEA-research contract (1969—72) R-786-F.

At first the clinical aim was the functional nuclear cardiological diagnostics of the aquired and congenital heart failures, we did care, however, already in the sixties for using the radioisotope methods to control the effectiveness of the rehabilitation procedures (including the famous carbondioxid bath cure in Balatonfüred).

Up to day more than 9 thousand graphical investigations have been carried out. Later in 1980 we compared the accuracy of our cardiac output (CO), stroke volume (SV) and left ventricular global ejection fraction (LV—EF) measurements data, with 99m—Tc RBC. rad. ventr.-gr. on Hungarian scintillation gamma camera + dedicated TPA computer and Supersegams program. We published their good correlation in the III. Congress of Nucl. Biol. and Medicine in Paris 1980.

As regards the myocardial perfusion imaging of the ischemic heart diasease patients (IHD) for detecting and localizing the perfusion defect areas, it was our first step the statical and basal 131-CsCl scintigraphy (sgr) in the late seventies, in accordance with the scar or ischaemia qualification of the ECG (Q)-pattern. Later for the sake of security we reproduced the scan with 201—TICl parallel on several patients and their overlap was correct as well. The 201—Tl scan has been

used of course also in our practice as functional tool to select the transitorial ischaemic hypoperfusion from the persistent one, mostly after remote myocardial infarcton, but in several cases also during the acute phase of myocardial necrosis (AMI) after by pass and PTCA as well.

As far as possible, the loadings were submaximal bicycle ergometry, dipyridamole-infusion (steal producing vasodilatator) or both, in a modest series of patients doing them simultaneously of equal value. The 450 201—Tl scan that we have done up to day, has been evaluated by our own circumferential and bar plot spatial and temporal regional wash out program. In the greater part of the (pathologic) cases, the 99m—Tc RBC equilibrium ventriculography (Vgr) has been also completed with acceptable cross talking of the hypoperfused and hypokinetic areas.

For the diagnosis of the left ventricular aneurysm, it proved to be very useful the parametric amplitude and phase-program of the Szeged School of Nuclear Medicine and own regional SV and EF-imaging program as well. It is a pity that because of the limited memory capacity we could control the loading on two steps incl. the maximal tolerable, but the nuclear vgr. supported also in this restricted situation our earlier experience gathered with graphical RKG—RCG, namely that the normal loading reaction trend of the LV—EF is still in old age (between 60-70 years) modestly increasing or without decreasing no alteration. (Of course the pathological decreasing reaction isn't specific for ischaemic heart diasease!) Otherwise on behalf of the great demand we kept the inexpensive graphical RKG—RCG for screening, we performed the drug-experiments also by this way, the GC remained as first step only for regional wall motion studies because the necessity of computing. (During the dipyridamole-infusion and nitrit-test we determined their blood level, too.) In 1983 we began the myocardial fatty acid metabolic studies with 123—J heptadecanoic acid (HDA), nowodays with the Hungarian one.

We initiated early in the mid seventies, first in Hungary to monitor of the CO, SV and LV—EF of the critically ill pateints in the coronary care unit, including also the possibility of the 133-Xenon right RKG and of the radiospirometry through a bored scintillation crystal. Good inverse negative correlation has been determined on our AMI-patients between the actual LV—EF, SV and their serum myoglobin level.

For qualification and staging of the patients we used of course the RCG, the echo-mechano-CG and the X-ray information, contrast vgr.- and selective coronarogr.

Our old wish is to extend our nuclear stethoscope-like technique in mobile version, with semiconductor detector on the chest surface for detecting the EF and SV-pattern during the daily activity SV and during ergometric exercise stress load. This is now in progress.

В г. Балатонфюреде, в кардиологическом реабилитационном Центре ВНР в 1961 году была создана диагностическая радиоизотопная лаборатория, деятельность которой уже с самого начала была направлена на определение состояния больных сердцем и влияния кардиологических лекарств. В начале техникой — в соответствии с уровнем того времени — была селективная квантитативная графическая радиокардиография. К этой технике была добавлена радиоциклография — осуществленная в середине шестидесятых годов в Фрейбурге аналоговой техникой, затем на один год поздже в Балатонфюреде цифровой техникой, — с выполнением путем аверагинг от Р волны ЭКГ при эквилибрации активности в крови. Этим открывалась дорога к обследованиям при нагрузке (главным образом посредством эргометрии), которую с конца шестидесятых годов, быть может, первыми в мире мы применяли на практике рутинным образом, а уже с начала семидесятых годов осуществляя трансферином 113 м — Ин.Эту нашу инициативу также подтверждает и итоговый отчет об успешно выполненном нашем договоре об исследовательской работе с Международным Агенством по Атомной энергии (ИАЕА — Р — 786 — Ф).

В начале в качестве клинической проблематики была главным образом функциональная диагностика приобретенных и врожденных пороков сердечных клапанов, но уже в шестидесятых годах мы занимались — у ишемических сердечных больных, перенесших инфаркт — также и реабилитацией, которую можно достичь путем научного реабилитационного курса лечения (среди лечебных факторов был также и курс лечения водами Балатонфюреда). До конца семидесятых годов мы проводили семь тысячи обследований, а затем, когда в 1980 году мы приобрели отечественного производства гамма-камеру с компютером, мы сопоставляли наши результаты по минутному объему и ударному объему, а также и фракции выброса левого желудочка с теми результатами, которые были получены с помощью ядерной вентрикулографии. Об установленном хорошем совпадении мы дали информацию в 1982 году в Париже на III-ем Всемирном Конгрессе по Ядерной Биологии и Медицине.

Мы рано внедрили в интенсивном терапевтическом отделении монитор минутного объема, ударного объема и глобальной функции выброса левого желудочка, но есть в нем и 133-Хе РКГ правой половины сердца, или эксшпирограм. Мы рассматривали сердечно-легочные обследования как единый комплекс, и естественно используем информации по эхо-, механо КГ и ЭКГ. У больных с острым инфарктом миокарда мы наблюдали хорошую инверсную

корреляцию между актуальным ударным объемом и функцией выброса и уровнем сывороточного миоглобина.

Что касается сцинтиграфии миокард-перфузии ишемических сердечных больных, то в начале для локализации и выявления размера рубцов после инфаркта, мы проводили с отечественным 131—Cs статическую сцинтиграфию, и на основе патологической Q волны ЭКГ мы получили убедительное соответствие. В дальнейшем в отношении статического положения, на тех же больных 201—Tl сопоставляемость также доказывалась. Однако, 201 — Tl мы использовали, конечно, как функциональную пробу для отделения временной ишемической гипо-перфузии и постоянного перманентного дефицита циркуляции по-возможности в случае после инфаркта, в некоторых случаях также и в связи с острым инфарктом. В качестве нагрузки была суб.-макс. эргометрия, или дипиридамол инфузия, и эти мы нашли одинаковыми при параллельных обследованиях, проведенных на тех же больных. До сих пор мы провели более чем 450 T1 перфузионных обследований, оценка была выполнена по круговой своим программе и по программе столбец, в отношении распределения в пространстве и вымывания во времени 201—Tl. Дополнительно, меченными 99м — Tc собственными красными кровяными тельцами мы проводили также и ядерную вентрикулографию, в большинстве случаев методом эквилибрации и с уверенным перекрытием гипо-акинетических зон. Для диагностики аневризма левого желудочка весьма полезными оказались параметрический амплитудный скэн, и частично наша карта по ударному объему и региональной функции выброса. Нагрузочную функцию выброса мы обследовали в нескольких толерантних, ступених, но ядерной вентрикографией и так была подтверждена та наша постановка, полученная нами ранее графическими исследованиями, согласно которой при нормальных условиях в связи с нагрузкой не поступит глобальное уменьшение фракции выброса левого желудочка даже в старом возрасте. Впрочем, учитывая потребность в большом числе обследований, мы сохраняли графический метод в качестве проверочного способа, и большинство экспериментов по влиянию лекарств мы проводили именно так, а на гамма камере мы изучаем только возможность улучшения движения стенки. В связи дипиридамол инфузии и нитрит пробы мы определили также и уровень крови. Мы начали исследование обмена веществ в миокарда с помощью 123—I гептадекан кислоты.

ESTIMATION OF CARDIAC FUNCTION BY MEANS OF RADIOCARDIOGRAPHIC FUNCTION ANALYSIS

G. Hoffmann, E. Lösel, N. Kleine

The radiocardiographic function analysis by "gated blood pool investigation" provides comprehensive hemodynamic parameters. After equilibration of an intravenously administered radionuclide the precordially recorded count rate depends on the volume of blood in the cardiac chambers.

The cyclic volume alterations of the ventricle can be followed by changes in the count rate.
For a statistically correct data aquisition it is necessary to store several cardiac cycles without phase lag. The scintillation data collection is triggered by the R-wave of the ECG as had been proposed by Hoffmann and Kleine (1)

^{51}Cr or ^{99m}Tc were used as radioisotopes. Autologous red blood cells are labeled with one of these isotopes and administered intravenously to the patient. Labeling of red blood cells with radioisotopes is of great advantage compared with labeled proteins because there is no loss of radioactivity from the circulation during the investigation. This is of great importance for investigations during physical exercise. The curves of total cardiac radioactivity are recorded by a precordially placed scintillation detector.

The advantage of this method is to register non-invasively changes in cardiac dynamics at rest and during exercise: continuous registration of enddiastolic volume, and registration of time interval e g. ejection time and filling time, permits the calculation of mean ejection velocity (stroke volume divided by ejection time), the maximal ejection velocity and the velocity of ejection related to the enddiastolic volume (stroke volume divided) by the product of ejection time and enddiastolic volume) (Table 1).

Registration of several steps of increasing physical load delivers optimal regression lines, simplifying the analysis of pathological findings under conditions of physical load.

Table 1: Haemodynamic parameters (mean value of 100 heart cycles)

	EDV*	HF	EJT (msec)	DT (msec)	work per heart beat
rest	100%	66	370	450	100% (88,4 cm^2)
50 watt	98%	109	250	280	131% (116 cm^2)
100 watt	94%	126	230	260	151% (133,6 cm^2)
150 watt	88%	152	210	200	182% (160,8 cm^2)

EDV* = enddiastolic volume (radioactive)
HF = heart frequency
EJT = ejection time
DT = diastolie time
work = area of the pressure-volume-equivalent-diagram (PVE)

After insertion of a cardiac catheter, it is possible to record the corresponding pressure pulse in the right ventricle or in the pulmonary vessels simultaneously (3).

The pressure pulse of the cardiac cycle is summed up likewise with the above-mentioned trigger device during the measuring period. The coordination of the pressure pulse of the ventricle with the tracer-generated volume curve delivers an exact information concerning the change of cardiac performance ($\int P \times dV$) (Table 1).
Calibration of the data in ml or mm Hg enables the computation of absolute values whereas this is not absolutely necessary for the interpretation of the dynamic variations under physical exercise; ml and Hg are constant values - representing a constant factor of calibration - on every step of physical load and may therefore be neglected.

Fig. 1. shows the volume change of radioactivity, the pressure pulse and the $\int P \times dV$ under a physical load of work load have been dropped for reasons of a more informative demonstration. Fig. 2 shows the changes of the "pressure volume-equivalent" curve (expressed in count rates) under physical exercise.

Fig. 3. delineates the change of recorded data after reduction of blood volume. After reinjection of the previously taken blood all the changes have totally normalized.

This example illustrates that the recorded data - changes of stroke volume, enddiastolic volume and cardiac output - have not been induced by changes of myocardial contractility since the behaviour of the velocity of myocardial contraction (SV/EJT x EDV) cannot be interpreted by a reduction of carciac dynamics but, on the contrary, must be interpreted as an increase in cardiac dynamics under these conditions caused by regulative symphathetic influences.
Finally it must be emphasized that the relation SV/EJT x EDV represents an equivalent expression for the efficiency of the cardiac muscle.

$$\eta \sim \frac{1}{1 + \frac{\alpha \, EDV \, . \, t \, . \, K}{SV}}$$

The radiocardiographic function analysis represents a relatively simple procedure for the clinician to collect information concerning the changes of cardiac dynamics, cardiac performance and cardiac efficiency.

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(3) Lösel, E., G. Hoffmann, I. Gaede, R. Seiler: Messung der Arbeit des rechten Herzens durch simultan registrierte Druck und Volumenäquivalentkurven. Vortrag. 13. Jahrestagung der Gesellschaft f. Nuklearmedizin, Koppenhagen. Schattauer Verlag, Stuttgart 1975, S. 520-521.

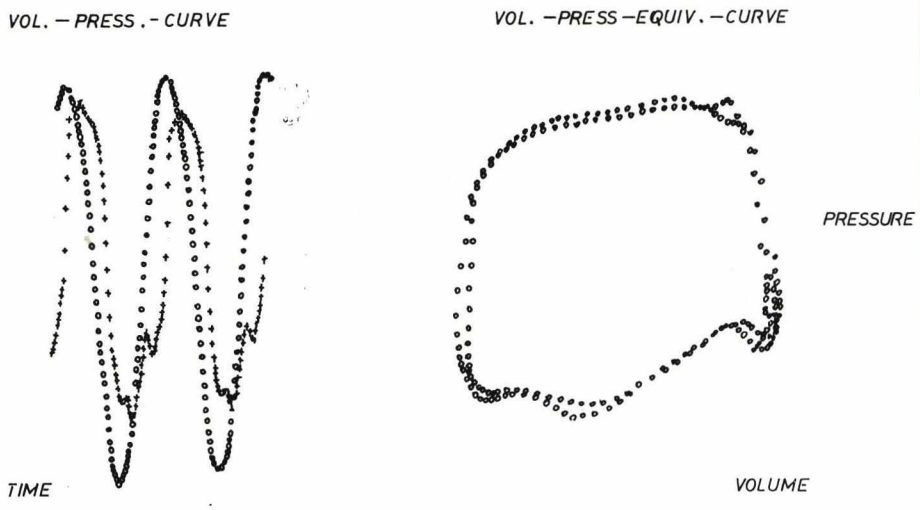


Fig. 1. Pressure-, volume-, pressure volume equivalent curve under physical exercise (150 watt) o = volume + pressure

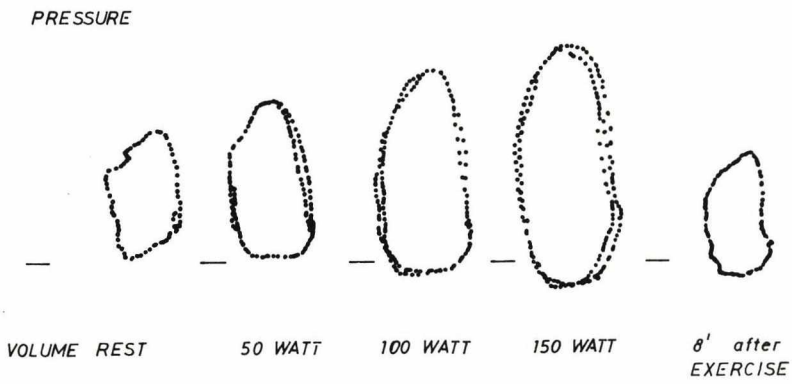


Fig.2. Pressure volume equivalent curve under physical exercise (right ventricle).

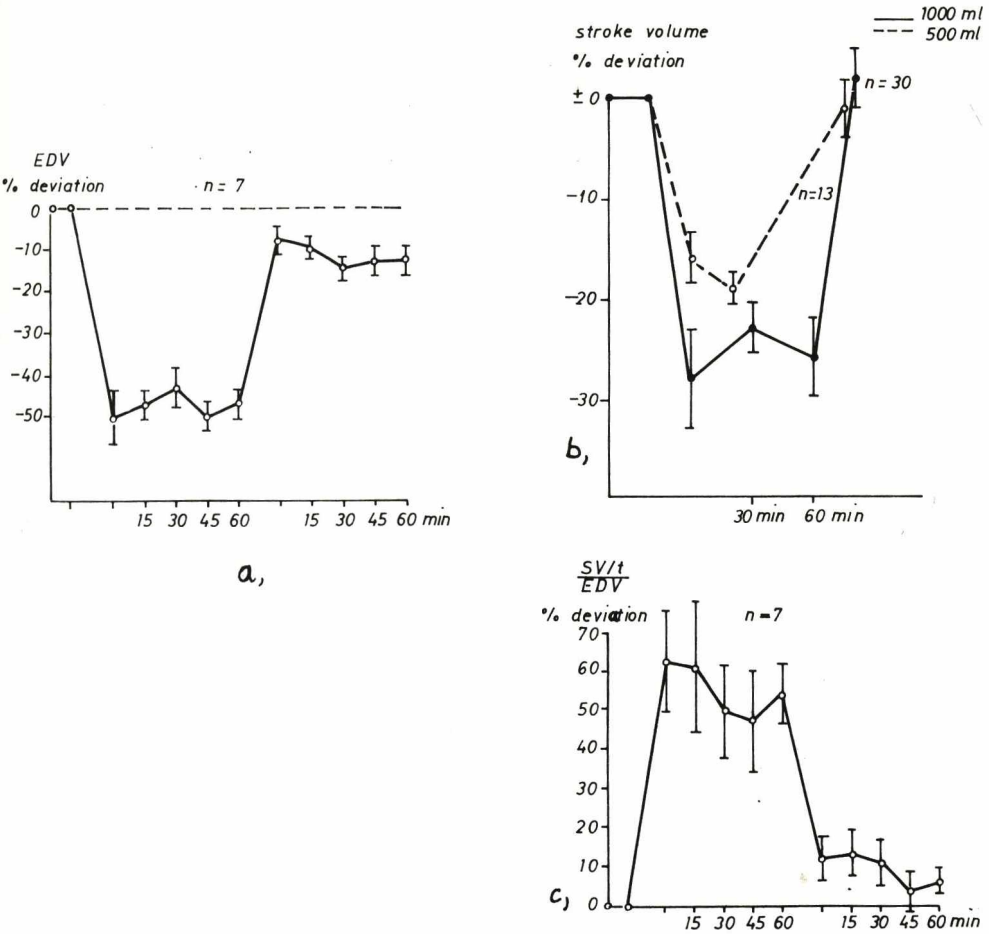
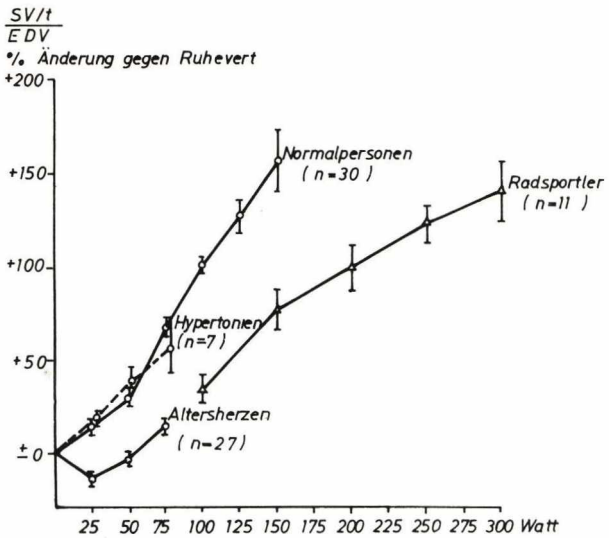
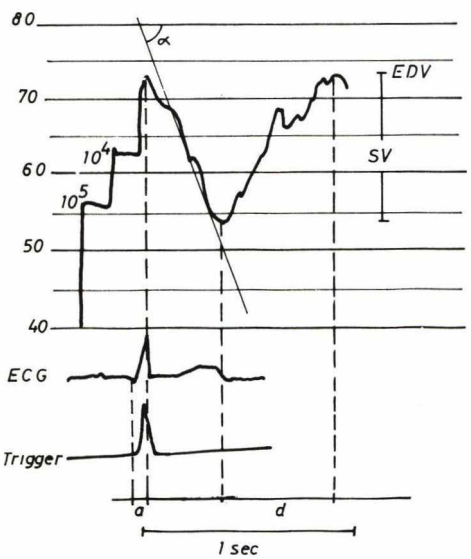
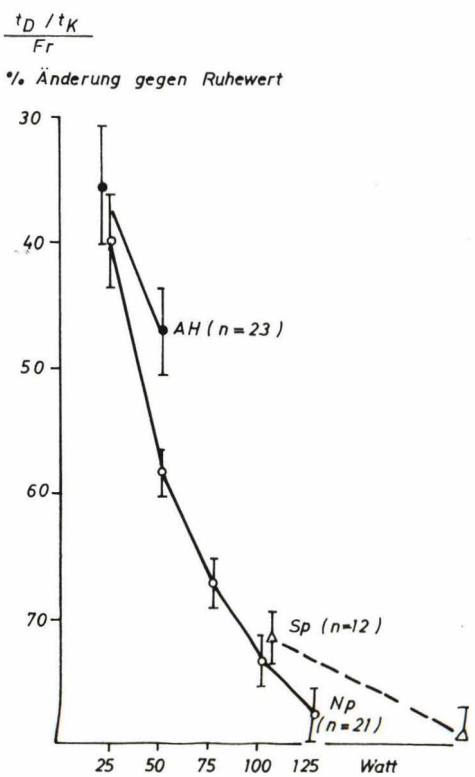


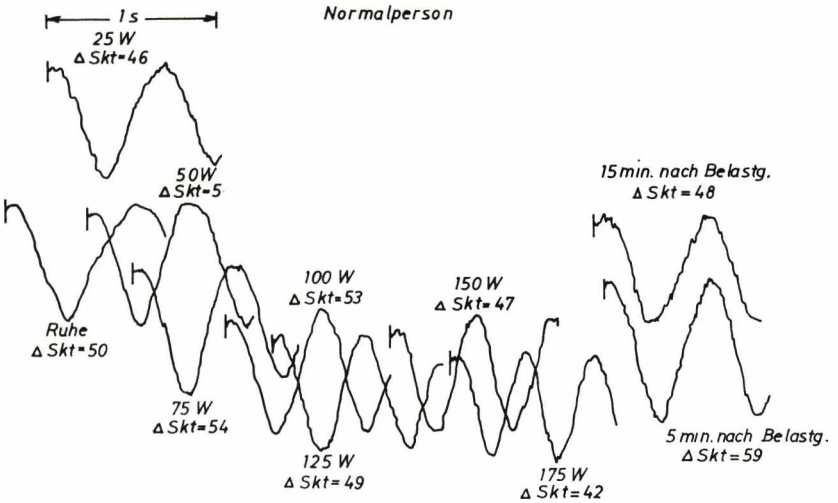
Fig. 3. a-c. Change of EDV, SV, SV/EDV x t after reduction of blood volume and after reinjection.



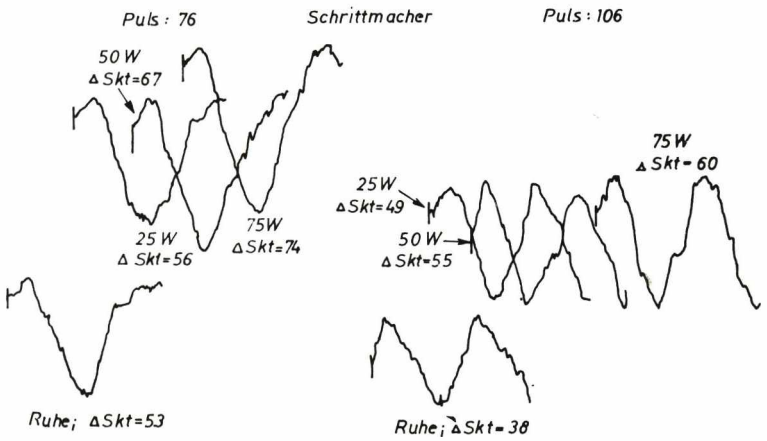


Der zeitliche Radioaktivitätsverlauf über dem Herzen während 180 Herzperioden

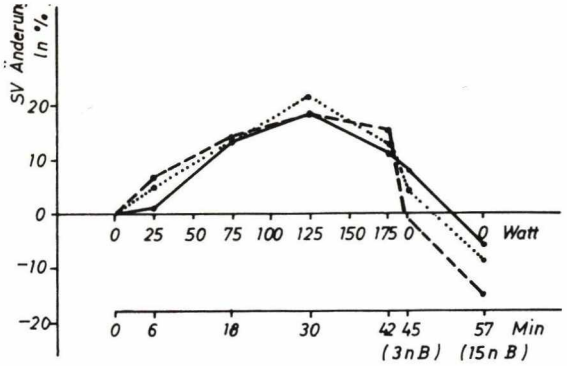




Verlauf der maximalen (EDV) und der minimalen Impulsraten (SKt ≙ SV) unter Belastung.

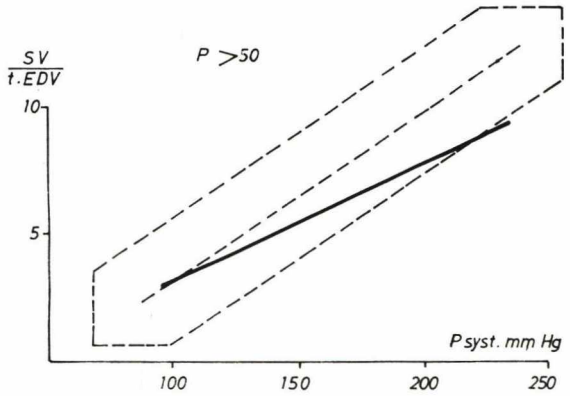


Der Informationsgehalt der radiokardiographischen Funktionsanalyse

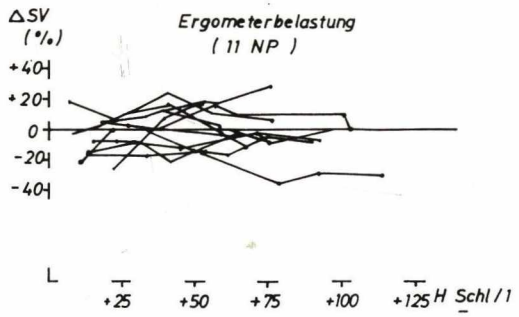


Durschnittliche Änderungen des Schlagvolumens in % bezogen auf den Ruhewert. Auf der Abszisse sind neben der Belastungsstufe die zeitlichen Verhältnisse wiedergegeben.

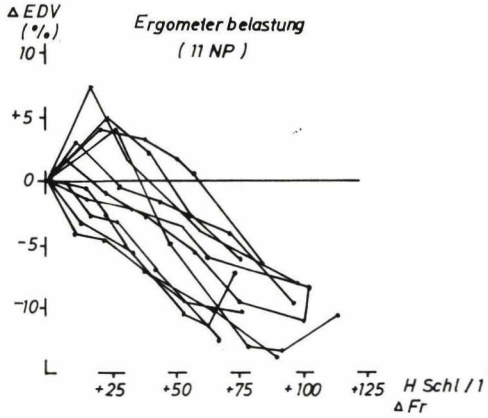
RCF-, Atlas Gerät-, Kipp Gerät.



Änderung der Kontraktions-geschwindigkeit unter ergometrischer Belastung, Normal ----, latente Herzinsuffizienz ——



Änderung der Schlagvolumens (ΔSV) in Abhängigkeit von der Zunahme der Herzfrequenz (ΔFr.)



Änderung des enddiastolischen Volumens

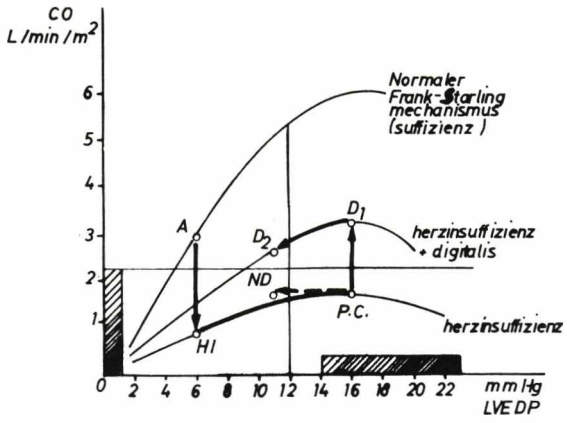


Abb. 1. Nach dem Frank-Starling-Mechanismus nimmt das Herzzeitvolumen (CO) mit zunehmendem Füllungsdruck (LVEDP) zu. Beim Auftreten einer Herzinsuffizienz (myokardialer Kontraktilitätsverlust) wird die Frank-Starling-Kurve abgesenkt (HI). Als Anpassungsreaktion wird der Füllungsdruck erhöht; dies bewirkt beim Patienten eine Lungenstauung (P.C). Durch Digitalis kommt es zunächst zu einer Verbesserung der Inotropie, die Starling-Kurve wird angehoben (Herzinsuffizienz + Digitalis); das Schlagvolumen steigt and, doch die Lungenstauung besteht zunächst weiter (D). Erst in weiterer Anpassung bilden sich auch die Stauungssymptome zurück, und eine endgültiges Gleichgewicht stellt sich ein (D_2). Die gestrichelte Linie zeigt an, da unter Nitraten wohl die pulmonale Kongestion (P.C) behoben werden kann, das Syndrom des kleinen Schlagvolumens aber bestehen bleibt (ND). Für Diuretika als Monotherapie gelten vergleichbare Wirkungsmuster (adaptiert nach Mason (10, 11)

OWN COMPUTED RADIOGARDIO-CYCLOGRAPHY /RKG-RCG/, MYOCARD CHECK-LIKE COMPLEX METHODOLOGY, WITH PRELIMINARY REPORT OF A MOBILE UNIT
/25yrs. experience in cardio-rehabilitation diagnostic utilization/

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Summary

It is indisputable that the new technical development of the nuclear stethoscope-like methods afford in some aspects, mostly in the better time resolution more than the gamma cameras, pointing out the beat-to-beat analysis and the combination with Holter-monitoring, not to speak about the mobile units, which put into practice the continous haemodynamical and electrophysological control during the stresses of the daily life.

It can not be neglected still in rich countries the cost/benefit ratio in relation of the answer to the putting of question and the desired accuracy for screening. The unfortunately great number of the cardiac patients, their categorization for surgical intervention and the control-duty of the cardio-rehabilitation training does such measuring detection compromise appropiate.

Introduction

In the second postwar period the cardiac diseases became also in Hungary the leading cause of death. Thereby our hospital considered as his duty to promote the cardio-rehabilitation since the fifties, namely the secondary form already after the heart damage and the primary form of the risked patients through preventive measures /8/. For the control of proper diagnostic procedures, among these the nuclear cardiological diagnostics, according to the actual state of the technical modalities.

At the beginning of the sixties our basic investigation was for the estimation of the general haemodynamical state the determination of the cardiac output /CO/, of the stroke volume /SV/, of the circulation times, including the pulmonary ones, too, by means of the Hungarian four-channel radiocirculograph, which has already at that time magnetic ta-

pe recording /16/. In the designing of the radiocirculograph J. Nagy had great merits. We adapted here in Balatonfüred the selective quantitative radiocardiography /10/, /which I was studying in the Pisa School, led by 1. Donato/. Figure I.

In the followings it became more and more obvious that the nuclear cardiology must be extended to the examination of the functional capacity, most suitable by means of different exercise tools, acutely in self-control mode. There were going two places in the mid-sixties on this decision independently: in Freiburg Br. G. Hoffmann and N. Kleine /12/ with the Radiocardiographical function analysis /1965/. in Balatonfüred M. Horváth and P. Horváth /15/ with the Radiocyclography /1966/. The name radiocyclography /RCG/ is from G. Somogyi, who contributed also to the statistical calculations of the RCG.

It was the principal novelty to approach the cyclic fluctuations of the heart-pool, /of the ventricles resp./in the equilibrium of the mixed radioactivity by means of coherent averaging, triggered by the R-wave of the ECG. The data have been synchronized in order by this operation, the measuring statistics has been improved in the order of the square root of the averaging numbers. This initiative found later general employment in the gamma camera measurements, in the echo, in the NMR, as well. /Moreover it was used also for the regional topographical analysis of the pulmonary function, distributed the breathing cycle into ex- and inpiratory phases./

The digital RCG as the functional amplification of the RKG

In contrast to the Freiburg solution, we registered the RCG in Balatonfüred as digital version in multiscaler function, by means of the home multichannel analyser of the Physical Research Institute of the Hung. Acad. of Sci., Budapest /16,17,18,19,20/ /KFKI/.

So we had at that time early the good possibility of compu - ting included also the Fourier-smoothing of the cyclic event, moreover the mentioned statistical analysis of the measuring accuracy, too /21,23/. The computer programs have been implemented by L. Németh and by myself. Some program elements we took over from J. T. Kuikka /44/, including the age and sex norm of the stress CO_i, SV_i and left ventricular ejection fraction /LV-EF/.

In the gamma camera era the attention directed more and more towards the imaging procedures, pointing out so the duty of the control of the detected area and it was critized "the relatively blind setting" of the RCG, the ambigously defined background, which objection is undoubtedly real. The background-marking is the more critical, because it refers fundamentally to the left ventricular global ejection fraction, of this undiscutable important fuctional index. By the

establishment of the cursors the measuring accuracy has been much improved.

We determined already at the end of the sixties the LV-EF during lood-tools, but we felt us reassured only thereafter for giving the percentual EF-values, not only the trend of the change during the load, when we did know the data of H. N. Wagner, Jr and His Group /55,56/ with the nuclear stethoscope of Bios. They published on the 2. Congress of the European Nuclear Medicine Society, London, 1978 similar results and H.N.Wagner, Jr. appreciated in his remark the experiences in Freiburg and in Balatonfüred /Figure II/.

Apart from this, we made effort on different ways to objectivate the LV-EF values by means of the adaptation of the parametric digital simulation of H.G.Parker, D.vanDyke and Coworkers /50/, on ODRA 1204 universal digital computer, producing so the possibility to compare "the pulsatile artefact" with his predefined LV-EF with the RKG-measured percentual value and formanalytical, as well. For modeling the cyclic event of the RCG, we began with centrifuge circulated radioactivity, the ratio of "the pooled-radioactivity" and of the amplitude of the so detected cyclic pattern has been so defined, included the time-resolution limits, too. Finally we verified in human experiments the equivalency of the RCG-amplitude and of the stroke volume of the heart by parallel dye dilution measurements still in the sixties /29/.
Our statement was supported gy G.Blümchen and G. Hoffmann in 1973. /5/.

The right and left /ventricular/ compartments of the RKG have been selected by gamma fit function and so we measured on the base of the left /ventricular/ emptying tendency on middle-aged males 55± 6% LV-EF value, with 5% reproduciblity. The correlation with the gamma camera examinations was also in our cases similar good as these ones of A. Tarkowska and W. Adam /54/. Our linear regression line was in broad ranges with r 0.82. LV-EF /g.c./ = 1.22 LV-EF /RKG/ - 3.7%.
A. Tarkowska and Coworkers found in the low EF-range r 0,82. moreover on the satellite A. Tarkowska rendered account of more better correlation between the EF measured by camera and by the beat-to-beat EF-analysis with r. 0,93.

Encouraged by the initiative of J.di Matteo /9/ from the Necker School of Paris, J. T. Kuikka /43/ drew in his computer program the estimation of the pulmonary capillary pressure /PCP/, which we found useful in the monitoring of the haemodynamics of the acute myocardial infarction patients in the ICU /30/.

We aimed from the beginnig, similar to G. Hoffmann and H. Kleine /13/ at the evolution of the contraction dynamical data of the RCG, as the maximal ejection and filling velocities, which latter we found in gamma camera comparisons very informative and relatively selective left ventricular function parameter. I should like still to draw the attention that in the case of the camera and of some nuclear stethoscope-like devices, the LV-EF is given in EDV %/sec dimension, while in our case in ml/10 millisec dimension, because we know the absolute SV_i value from the preceeding RKG. To express the RCG-pattern changes in millisec, the good time-resolution of our multichannel analyser afforded the possibility. On the satellite A. Tarkowska reported also good correlation between the ventricular wall motion indices measured by camera and by detector /Table 1/.

Measuring combinations

We combined the RKG-RCG recording to the claims of the daily routine with classical cardiological ones: being the ECG given also for the triggering, among them the cardio-mechanograms, moreover the flow-in micro-catheterization of the right heart, including the measurement of the mixed venous $p\text{-}O_2$,too /22/. G. Hoffmann and Coworkers studied the right ventricular compliance by means of RV pressure and volume parallelogram on similar way under the influence of beta-blockers /14/. We found good congruence of the contraction dynamical patterns, presented by RCG and apex-CG. /Figure III./

We began the RKG-RCG monitoring in the coronary care unit /ICU/ in the mid-seventies, completed with the special screening by 133-Xe injected in saline /30/. /In the ICU-s of the USA there are employed already mobile cameras, too./ So we could detect along the flow-pathway the RKG of the right heart, the radio-thorakogram of the rigt upper pulmonary area, and what is important, the 133-Xe radio-expirogram through bored scintillation crystal, thereby gaining a comprehensive information of the cardio-respiratory functional synchronization /Figure IV./

We registered by a special measuring combination on ischaemic coronary heart disease patients /IHD/ during atrial diagnostic pacing by means of Medtronic 5880-A, /but it can be due also through oesophageal way/, besides the serial RKG-s, also the right atrial one, the pressures in the right heart and in the pulmonary artery. We carried out beat-to-beat RCG, as well, We remark that we didn't know from that time anywhere nuclear cardiological analysis during atrial diagnostic pacing, but later very good and combined studies have been published /40/. By this way, which is a relatively selective route of the "pure" heart function examination, we could observe on the IHD-patients the breakdown of the SV

already at about 120/min pacing frequency. This observation agrees with the literature data published later, most detailed by A.S.Ishkandrian and cowokers /48/. /Figure V./

We verified also still in the mid-seventies, before the nuclear stethoscope-/NS/-era on IHD-patients with angina, that already a low level ergometric stress load /less than 100 W/ results to decrease of the SV and the LV-EF with more than 5% and this trend is suitable for screening of the severly damaged IDH-patients, by main branch or coronary multivessel stenoses /20,21,29/. Our statement has been supported later by gamma camera examinations with the conclusion, this pattern can be regularly expected by severly ill coronary patients /but not only by these patients, yet by severly damaged heart function of other origin, too./ So this test is from the side of negative outcome very useful and informative! About the distribution of the rest and stress LV-EF-s in the different variants of the coronary IHD R.H. Jones and Coworkers published important nomogram /42/. /Figure VII/.

Our efforts for new technical developments with semiconductor-detectors in the framework of an mobile NS-like unit

Being on the base of our fairly performed eight thousand RKG-RCG investigations, all the time concerned of the excellent clinical usefulness of our original methodology, we turned, nevertheless, our attention to the new technical modalities, included the microcomputers and semiconductor detectors, as well. The number of the cardiac patients is to much, related to the limited gamma camera capacities, therefore we wanted to extend the pre-screening solution before the definitive imaging examinations.

For this purpose in connection with ergometry is used still in the rich countries the nuclear stethoscope /NS/ with built in computer and nowadays also mobil units, which are less expensive than the cameras. They being equiped with cursors for finding the optimal detecting point, the scepticism because of the precise detection geometry could be mostly eliminated, so the NS-s have been for screening accepted, so much the more that beat-to-beat analysis became with the new types also possible /57/. Famous institutions took a stand on the usefulness and on the practicability of the NS /3/.

The elimination of the danger of the displacement of the detecting geometry became finally solved by the chest-surface fixed miniaturized-collimated semiconductor detectors, Qurselves gathered the first experiences with the miniaturized and lead collimated Si-semicenductor detectors of the Development Institute of the Hungarian Videoton Enterprise /33, 34,35/. First we measured out the collimation charasteristics of 113m-In and 99m-Tc point sources and we had according to the

literature data the limited yield and depth resolution related to the sceintillation crystal, as logical consequence of the less detecting volume of the semiconductor. The depth resolution was better for 113m-In, because of his more penetrating energy, of course. Fortunately we were doing our earlier investigations with 113m-In labeling. /Figure VIII./

Lahiri and Cowokers /7,45/ attached to NS the miniaturized /6,5 mm . 65 m/ HgI_2-detector without photomultiplier through impulse amplifier and they registered with 50 millisec RM-constant the RCG, with a yield of 55% related to the conventional detector. This system is suitable for beat-to-beat analysis, too./L. Fridrich, Sanatorium Hochegg, Austria commented upon this NS-like vanation./

The former Engypan of Siemens, invented by D. P. Pretschner was also packed in a hand bag, while the new developed variation with the congenial idea of the detection by miniaturized GM-tubes /in the proportional sector/ is delivered by "The Institute of the Nuclear Research, Karlsruhe",under the name of TOGAS II. In Hungary B. Andréka carried out cardio-rehabilitation investigations with Engypan /1/.

The poster of the Parametric Gammascope was demonstrated on the European Nuclear Medicine Congress, 1987, in Budapest and on the Balatonfüred satellite as well by K.B. Lauterbach, V. Becker, E. Vester, B. Schwartzkopff, B. Lösse and L.E. Feinendegen;Institute of Medicine,Nuclear Research Center, Jülich and Institute for Cardiology, University of Düsselforf/. The mobile device is working with NaI scintillation crystal and it is utilizable for RKG of the central circulation /included the lungs, too/ on the base of the minimal transit times, for RCG for both the averaged as well as the beat-to-beat variant.

The Gamma Works, Hungary developed the NK-262 type Nuclear Probe Radiokardiograph on the structural base of the Hungarian gamma camera, therefore the aquisition from the scintillation crystal is carried out in list mode, later processing the data in the built in microcomputer. After the preliminary reference of M. Istvánffy /41/ as basal functions, the CO and LV-EF results agreed with that gained on gamma camera.

In Hungary L. Nyitrai, L. Zsonda, G. Takács, M. Paczári, Zs. Nagy, M. Fodor constructed 10 Si-detector channel cage under the name Microgamma Z-87 with a very practicable drived reconstruction program on Spectrum microcomputer, but to be linked also to the Hungarian gamma camera computer MB 9101 as well /48/.

Amongst the semiconductor detectors there exist nowadays besides the Si, the Cd/Te detectors on the market, which are working lower basic noice and their bandgap energy range with

1,45 eV is also more suitable as of the Si-semiconductors.They were propagated mostly for the graphical radio-cardiography. The Biophaysical Institute of the Pasteur University of Strasbourg /J.Chambron, A.Gallmann, M.A.Molinari,Ch.Schreiber, C. Foeller/ constructed with the cooperation of Odam firm in Wissenbourg a device under the name of Gammagard, linked with dedicated computer Apple II. On the device left here we registered first of all the Cd/Te detector charasteristics for 113m-In and for 99m-Tc, after that we compared his measuring efficiency with our Si-semiconductor detector. The efficiency of the Cd/Te detector was for 99m-Tc point source 50% better than for our Si-one; for 113m-In the detector efficiency of the Cd/Te was left behind from that of the our Si-detector.

It is very promising the device of the Japan Tokai University by Y.Suzuki, I. Ide, N.Kanemoto, and Y.Goto /38,53/ linked with LSI 11/23 computer, which is suitable for beat-to-beat analysis too. This possibility is important to study the ar - rhythmic heart action, the post-extrasystolic potentiation, the decline of the delivered stroke during angina, the Valsava effect and the drug actions in minute time resolution /as we had done earlier also with our system/. It is specially exciting that they develop a telemetric variant, by which it is possible to come nearer to the analysis of the haemodynamics and of the electro-physiological effects of the stresses of the daily life in a realistic way.

The relation of RKG-RCG to other non-invasive /simple/ measurements

The other way of the clinicians for mass claims is to reckon with the echo possibilities. The 2-DE-/echo/, completed with Doppler flowmetry can be surely substitute in many relations the nuclear cardiology . There is problematical to carry out by this way measurements during exercise /what it is even the most important requirement for the decision/. It can be performed only after the stress, when the recuperation processes are quickly changing. /On my study courses in some developed ceuntries I have not seen convincing evidence of the adequate echo-cardiological quantitative measurements during ergometry./

The classical, well-established mechano-CG can be the rival for the sake of the simplicity, especially in the form of myocard-check,with the approach of the LV-EF after J.A. Antani and Coworkers /2/. In our practice the correlation of the PEP/LVET parameter /pre-ejection period/ LV ejection time/ was good with the RCG-derived ratio. The variation of DATI /the diastolic time amplitude index/ is also convenient. These simple mechano-CG-s are not concurrent, but complementary

of the RCG. I should like once again to point out those advantage of the digital RKG-RCG, that it produces flow and contraction dynamics data, especially the very informative peak filling velocity in absolute dimension, in very fine time resolution, attained by the multichannel analyser. This part of the RCG is distorted in hypertrophic cardiomyopathy /4/. /Fugure XI/.

Clinical results in the cardio-rehabilitation, decumented by RKG-RCG

We adopted the transfer function model of M. Saito /51/ on ODRA 1204 universal digital computer /25/, we calculated after Y. Ishii and W.J. McIntyre /39/ the blood content of the three compartment of the central circulation, i.e. of the right-and of the left heart and of the pulmonary vascular bed, given that in percent of the actual circulating blood volume-CBV /20,21,22/. We obtained on the same acute myocardial infarction patients, monitored in ICU, a strict inverse correlation of the patterns of the serum myoglobin RIA-values and of the LV-EF and SV, resp. in the first week. /28/. Thereby we verified at the same time not only the great diagnostical, but even the great prognostic valus of the LV-EF, followed by RKG-RCG. Further on, we used the stress LV-EF for staging of the LV-function damage, in combination of other nuclear cardiological and classical cardiological examinations, as well. This practice became especially important in the last years, because the considerably diminished LV-EF doesn't considered more as absolute contraindication of the coronary by pass or of the coronary ballon dilatation /34,35/.

We studied on young postinfarction males in the regular institutional training period the trend of the cardiological parameters, when we observed a small-grade, nonsignificant increase of the global LV-EF. The decrease of the peripheral resistance /as seen on the Figure XII./ contributed also besides the amelioration of the LV-EF to the doubtless clinical improvement as the consequence of the training /35/. /Figure XII/.

/In the self-programmed home-training period during the first yr., the quarterly follow up investigations by 99m-Tc radionuclid ventriculography, presented the stability of the institutional period obtained functional capacity, except the severe lesion of the extensive anterio-posterior scar group./ This study demonstrated at the same time the good reproducibility of our nuclear cardiological measuring technics /35/ .

We used the RKG-RCG in other cardiological disorders, as

rheumatic heart disease, essential hypertension, ischaemic coronary heart disaese, as well. We found it useful for the characterization of the improvement after arteficial valve implantation and after mitral commissurotomy /22/.

In the seventies we verifed with 133-Xe right heart RCG, with 133-Xe pulmonary clearance /wash out/, with gasometry and by micro-catheterization data of the right heart during ergometric stress exercise, that the loading capacity improvement attained by the surgical intervention of the valve failures remained stable and existed also after three and half yrs. /30/.

In the sixties we demonstrated synchronously with the famous Freiburg Clinicians, -by means of exercise stress CO and SV-examinations, moreover by the double product of the HR and syst.BP- the possibility of complete haemodynamical readaptation of the postmyocardial infarction patients through professional cardio-rehabilitation training /21/. The training strategy was published in details in the monography of E. Böszörményi, F. Endersz, A. Hoffmann /6/, which book is illustrated also by Figures.

RKG-RCG examinations of the acute cardio-pharmacological effects

We used the RKG-RCG also to control several pharmacological effects, in some cases in combination with the chemical determination of their actual blood lvels /27,31/: in the case of digitalis the inotropic effect /parallel with RIA-ELISA/; in the case of the nitrites the amelioration of the contraction dynamics /parallel with gas chromatography-mass spectometry/; in the case of dipyridamole the RCG bulge phenomenon as result of the steal effect of the coronary circulation on the damaged heart areas /parallel with fluorometric determination of DIP/ /37/; in the case of Nifedepine the enhacing inotropic effectiveness with relatively better energy utilization, similarly to the observation of Lahiri group /46/; diltiazem was potentiating on the aminophyllin effect, as regards the O_2-balance of the myocardium. In the cases of the nitrites and of the Nifedipine E. Ogris and Coworkers /49/ observed similar results by first pass 195m-Au radionuclid ventriculography./Figure XIII/.

Finally the acute effect of the carbon-dioxide bath has been found analogue to the peripheral venous pooling of the nitrites in the context of gasometric analysis and of 133-Xe cardio-respiratory investigations. /32/. That is in agreement with the theory of K.Gollwitzer-Meier about the autotransfusion in the body periphery. /Figure XIV./

Discussion

I should like to make clear that
I propose the RKG-RCG not against the modern imaging technics /26/, similarly meant it our fellow H.W. Stoll, too /52/. The time gain arising from the pre-screening RKG-RCG even does it help to carry out accurately and to extend them on the most informative variants /i.e. stress ergometry in more steps, etc./ /34,35/. In dubious cases we use also the whole spectrum of possibilities, of course, included the stress amplitude and phase scan, drug tests, etc. /36/. /Figure XV./

Conclusion

It is indisputable that the new technical development of the muclear stethoscope-like methods afford in some aspects, mostly in the better time resolution more than the gamma cameras, pointing out the beat-to-beat analysis and the combination with Holter-monitoring, not to speak about the mobile units, which put into practice the continous haemodynamical and electrophysiological control during the stresses of the daily life.

It can not be neglected even in rich countries the cost/benefit ratio in relation of the answer to the putting of question and the desired accuracy for screening. The unfortunately great number of the cardiac patients, their categorization for surgical intervention and the control-duty of the cardio-rehabilitation training does such measuring detection compromise appropiate.

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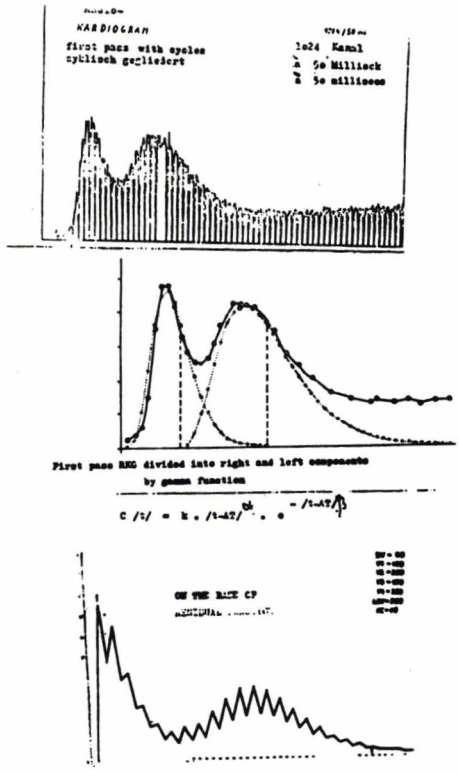
This article has been written according to the report of M. Horváth on the Balatonfüred-satellite of the Europ. Nucl. Med. Congr. 1987.



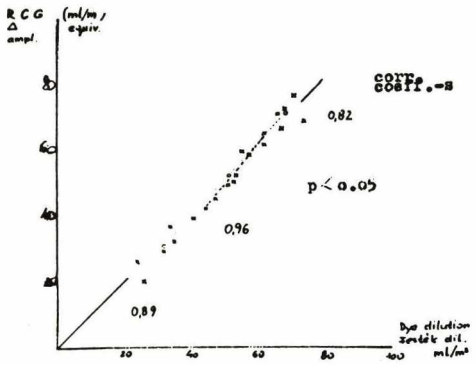
I./ top: Radio-cardiogram /RKG/ with cycles
middle: First pass RKG divided into right and left components by gamma function
bottom: own simulated digital RKG, on the base of residual function

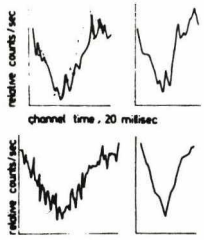
Radiocyclographically determined normal responses to ergometric loading according to the Freiburg criteria

Responses to ergometric loading in a normal middle-aged male group (40 to 60 yrs., n = 15) examined in recumbent position

	Basal	50 W	80 W	100 W
Heart rate	88	132	144	152
Systolic pressure, mm Hg	135/95	165/75	175/70	185/65
Systole, $t_{contr.}$	0.260	0.200	0.200	0.200
Diastole t_d sec	0.420	0.260	0.220	0.200
SV ml	81	91	92	100
EDV ml	212	209	193	200
SV/EDV	38%	42%	48%	50%
SV / EDV · t_c	1.45±0.55	2.15±0.62	2.4±0.85	2.65±0.8
$\Delta \frac{t_d/t_c}{\text{freq.}}$ per cent		−46±7	−58±8	−63±10

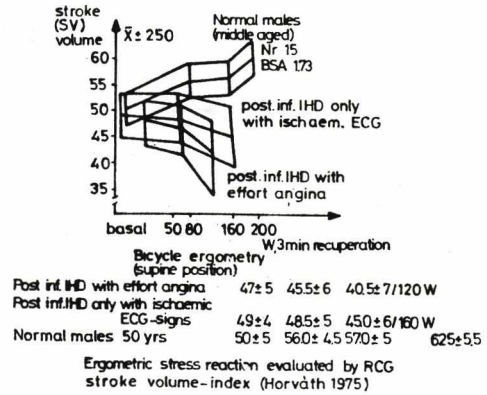
Acta Medica Academiae Scientiarum Hungaricae 33, 1976

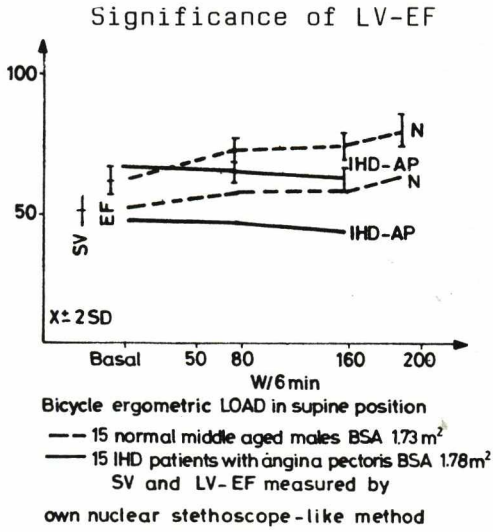




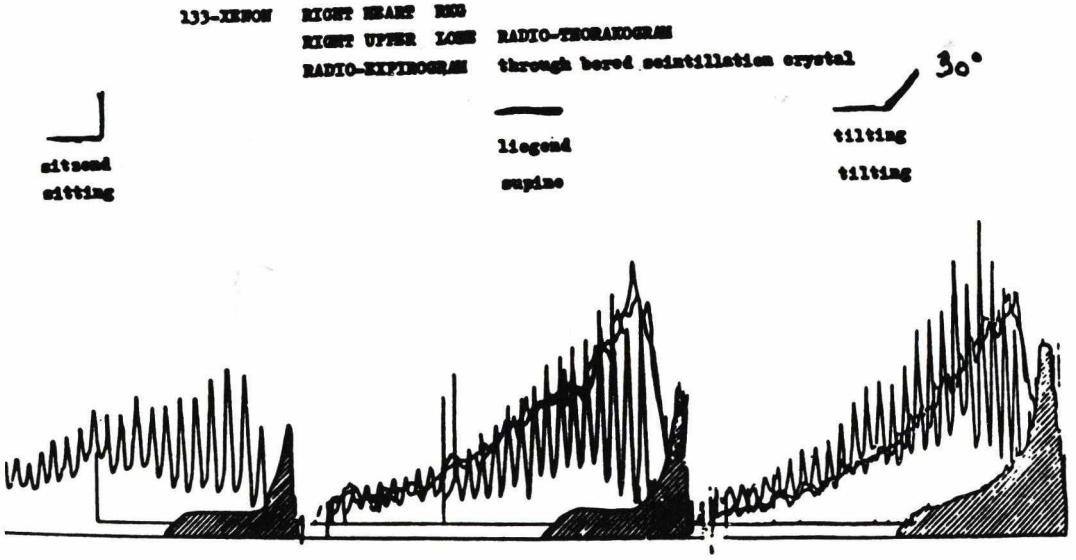
Top: RCG at rest. Bottom: under loading, evaluated by computer. Right: Fourier-analysis of RCG-s

II. left: verification of the radio-cyclogram /RCG/ amplitude-volume equivalence by simultaneous RCG and dye dilution
right: above: RCG determined normal responses to ergometric load according to the Freiburg criteria
below: own RCG at rest, under loading both evaluated by computer, as seen on the smoothed Fourier-curve

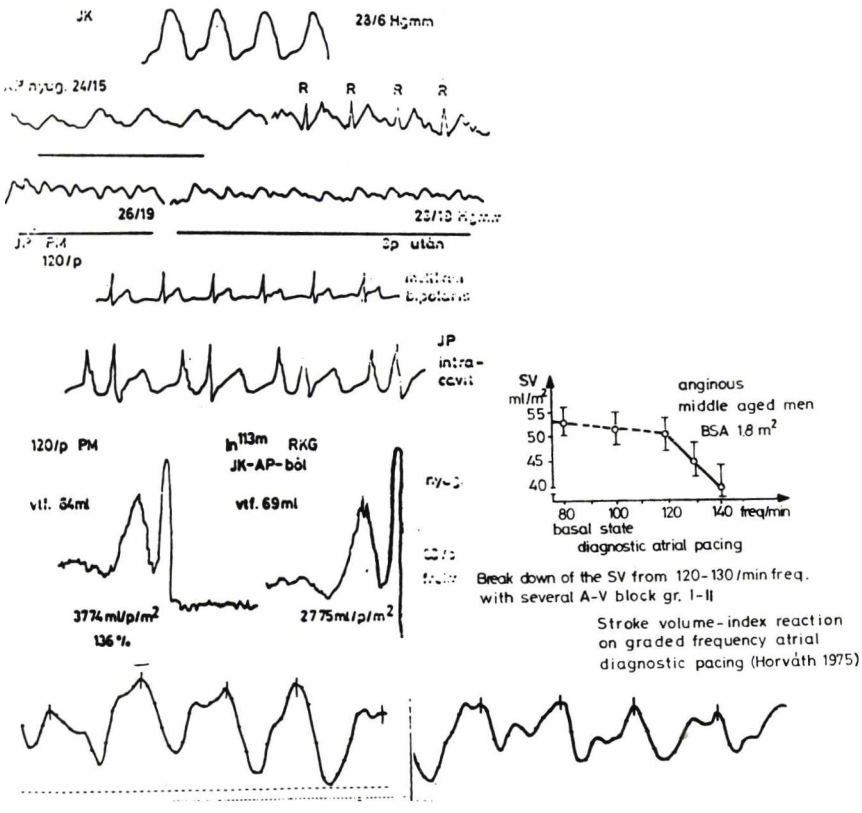




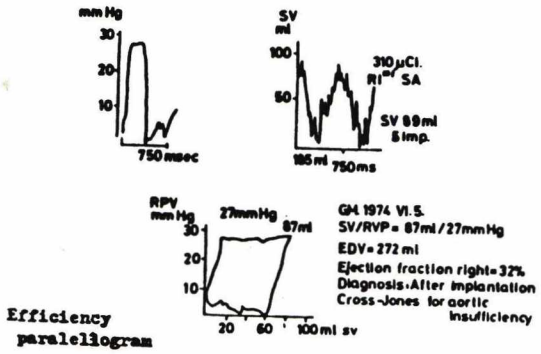
III./ The SV_i and left ventricular ejection fraction /EF/ stress reaction of silent ischaemicy, effort anginous and postinfraction patients, measured by our nuclear stethoscope-like method on gradual ergometric load /examinations in 1975/



IV. Comprehensive check of the peripheral venous, right heart, capillar-alveolar permeability and expiratory function by 133-Xe injection for screening purposes



V./ Atrialdiagnostic pacing RCG and RCG investigations, the latter being performed beat-to-beat /as seen below/. The pacing has been controlled by ECG, intracavitary, too and by pressure measurement in the right heart. The SV. of the anginous patients has been broken down abruptly on 120/min pacing frequency /examinations in 1975/.

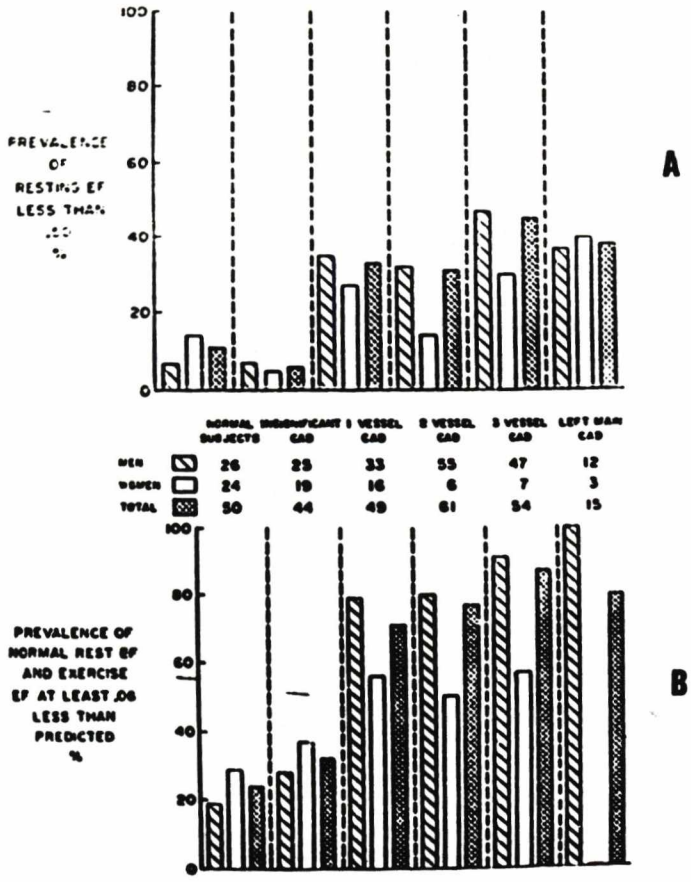


$$\text{EFFICIENCY PARALLELOGRAM} = \frac{k \cdot P / dV}{\text{cycle time /sec/}} = \frac{1{,}333 \cdot 10^{-4}\ \text{Joule}}{\text{cycle time /sec/}} = \frac{0{,}133 \cdot \text{kPa} \cdot \text{cm}^3}{\text{cycle time /sec/}}$$

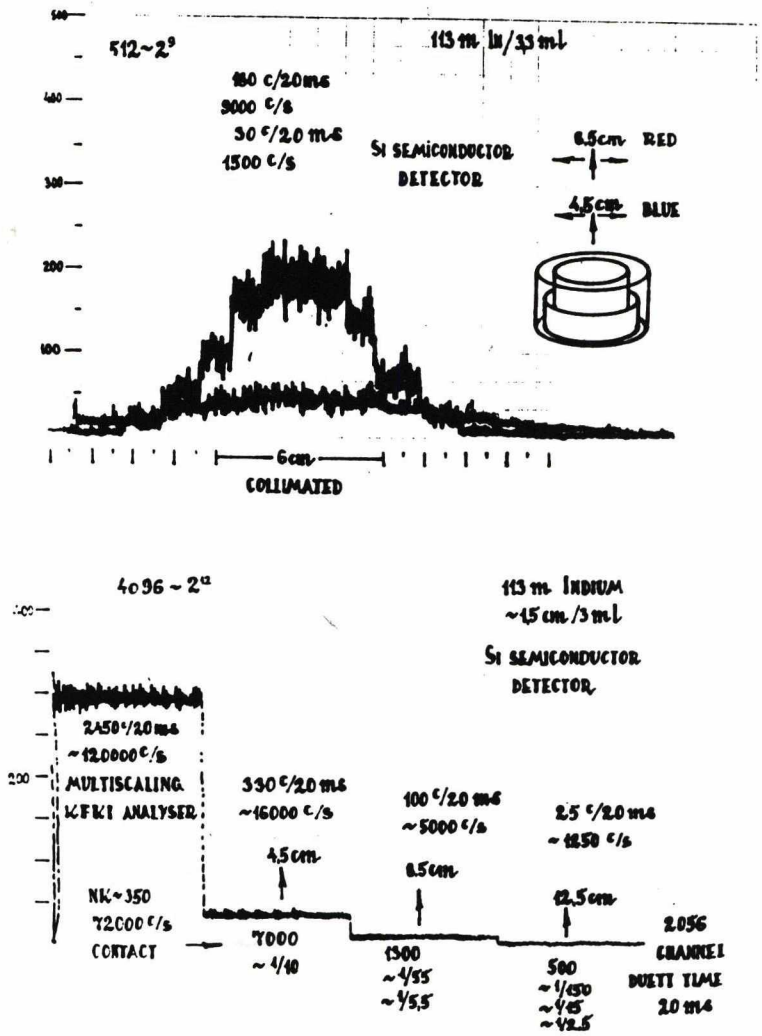
/Watt/

VI. Right heart pressure-volume compliance parallelogram top left: right ventricle pressure-curve, top right RCG

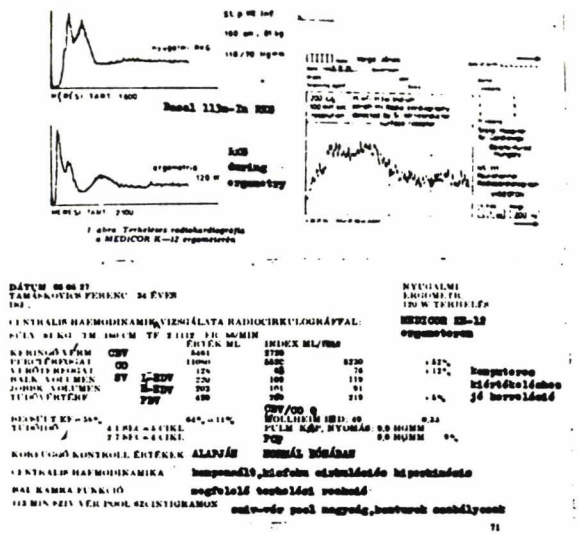
bottom: theparalellogram of arteficial vave implanted patients, with the dimension analysis of the paralellograms



VII. Nomogram of R. H. Jones and Coworkers about the prevalence of the rest and stress left ventricular ejection fraction /LV-EF/ of coronary heaft disease-patients /IHD/ with different severity. The data results from RNV.



VIII./ The collimator characteristics of our Si-semiconductor detector in side-direction and in depth



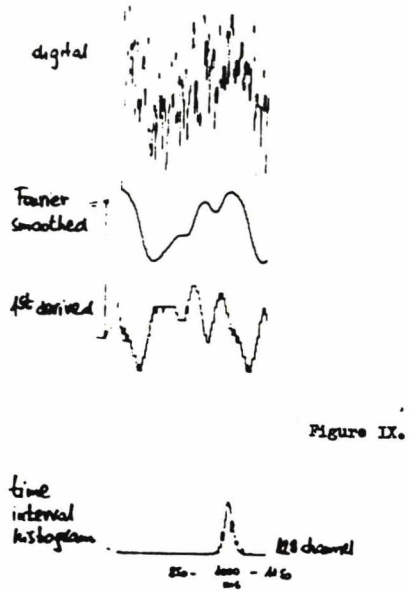
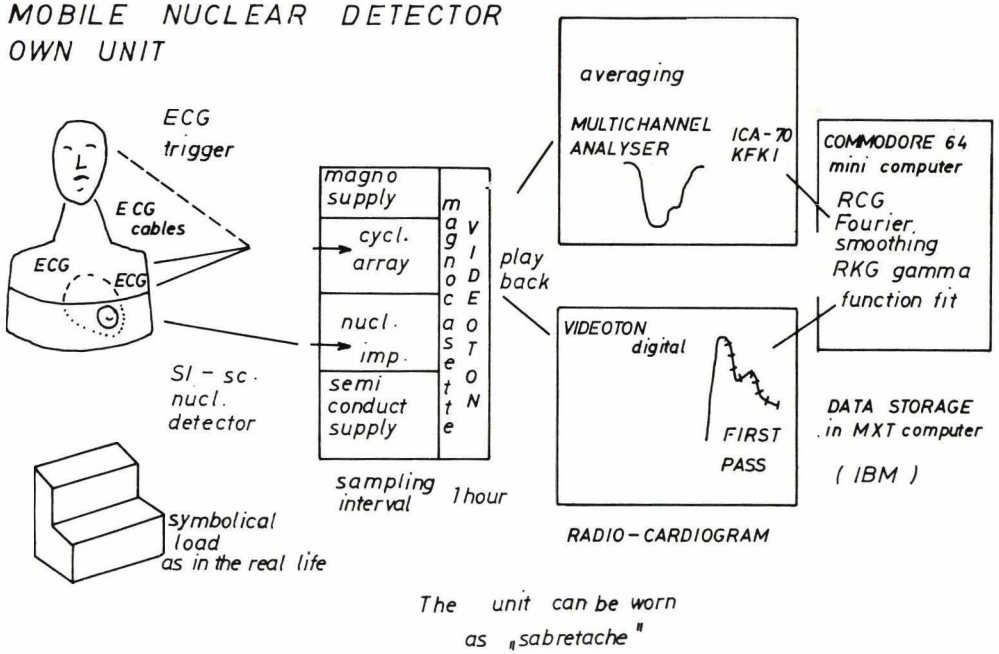


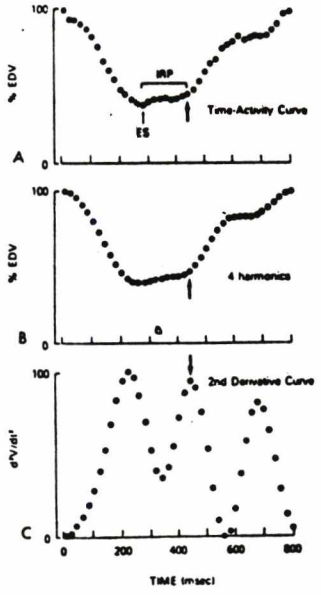
Figure IX.

IX. Left upper corner: RKG-s at rest and during stress
Left right corner: RKG carried out with Si-semiconductor
Left bottom: our computer program for the RKG-evalution
Right: RCG performed in avaraging mode by Si-semiconductor digital primary RCG, Fourier-smoothed RCG, 1st derivation of the smoothed RCG, each in lo millisec time resolution,
Bottom:time-interval histogram of the mean heart frequency



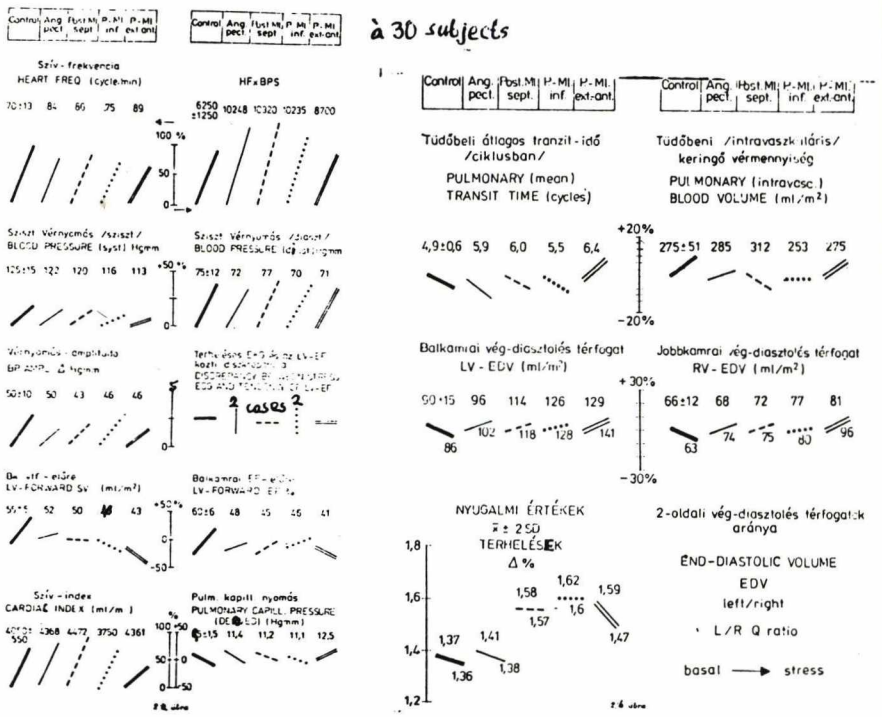
X./ Primitive scheme of our mobile nuclear detector with Si-semiconductor, using the equipments of Videoton and KFKI.

Figure 1. A. Raw time-activity curve of a patient with hypertrophic cardiomyopathy. The isovolumic relaxation period (IRP) is apparent. B. Time-activity curve of the same patient after Fourier filtering using four harmonics. C. Second derivative curve derived from the filtered curve in B. A maximum after end-systole (ES) is present on the derivative curve (arrow) and corresponds to the termination of the isovolumic period in A and B. Each point represents 20 ms. EDV = end-diastolic volume.

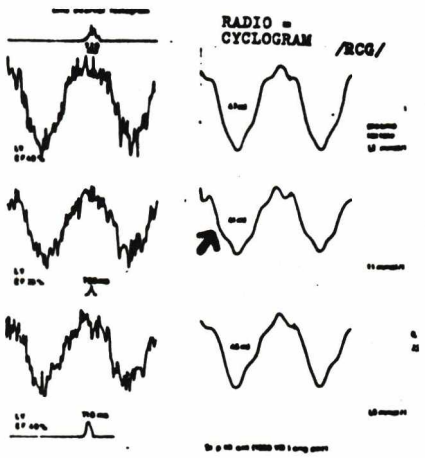


XI. Cyclogram of hypertrophic cardiomyopathic patient with clear presentation of the isovolumic relaxation period /IRP/

Betocchi and Cowokers (1986)



XII./ One-step ergometric stress reaction of young postinfarction patients at about 120-130/min stress heart frequency.The parameters include not only nuclear cardiological ones and it is especially worth mentioning the derived pulmonary capillary pressure.The numbers are the basal values dimensionally and the lines the grade of the changing tendencies on stress. The method serves for screening of the severly damaged leftventricular function of anginous and postinfarction patients.



Pathological dipyridamole drug test in IHD with provoked bulge phenomenon on the RCG /Horváth 1981/

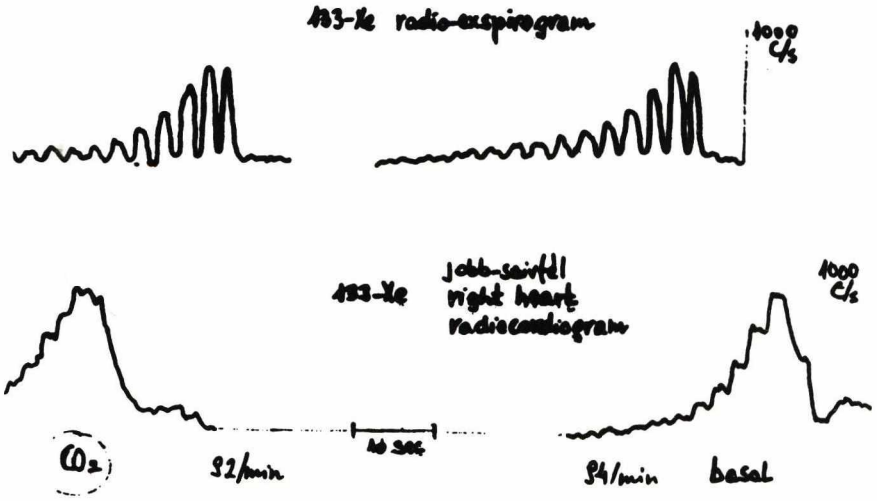
Cardiac index
4153ml/min/m^2
CBV/CO 0.64
PEP/LVET 0.28
A 20%
ET_C 420millisec
Mechano-CG
slight paradoxical motion

4ml/min iv. inf,
Dipiridamol/Persantin/
0,75ml/kg

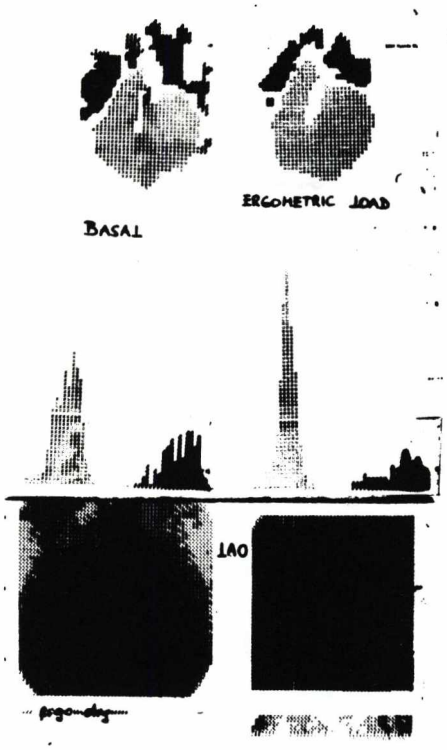
DIP blood level	plasma lactate
12,75ng/ml	1.2mmol/l
2.5min	
8.9"	1.8"

XIII./ Distorted RCG by bulge phenomenon during dipyridamole pharmacological test in consequence of steal effect; the tool was controlled by the determination of the DIP blood level by fluorometry and by the investigation of the haemodynamical parameters of the IHD-patient, of course.

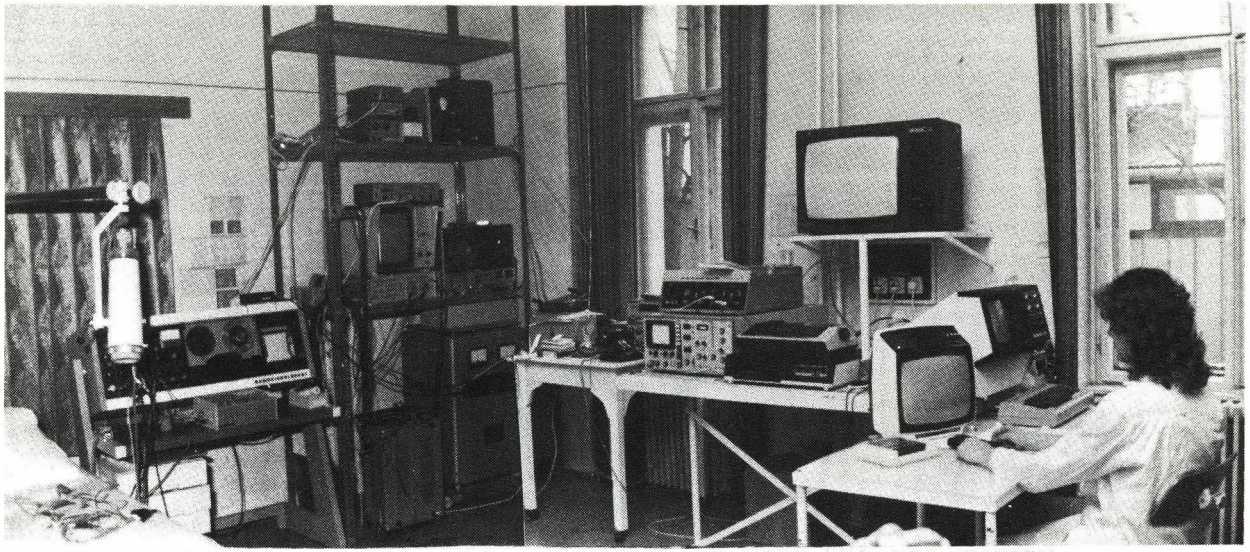
/M. Horváth 1981./



XIV./ 133-Xe right heart RKG and expirogram through bored scintillation crystal and detected with small scintillation detector before and during bath in carbondioxide springwater. This examination was a part of a study completed with gasometry and spirometry.



XV. An example of precise analysis of the ergometric stress by amplitude and phase scan. The program on the Hungarian gamma camera MB 9100-910T came from the Nuclear Medical Inst. of the Szentgyörgyi Univ. of Szeged



COMPUTED GRAPHICAL NUCL. STETHOSCOPE-LIKE RKG-RCG SYSTEM
OF THE STATE HOSPITAL FOR CARDIOLOGY
BALATONFÜRED HUNGARY

M i d d l e

Integr.circuit 4096 channel analysator ICA-70 OF THE RES. INST. OF THE HUNG. ACAD. OF SCI.
impulse and analog input, fast A/D converter connected with ECG-trigger device
hardware facilities: averaging, time interval histogr. interfaced with C-64

THERE EXISTS ALSO AN MODEST MOBILE UNIT fed from battery and detecting with Si-semiconductor isotope-impulse and ECG R-wave trigger-impulse collected on magnetic tape

XVI.

L e f t

OLD TYPE VIDEOTON RADIOCIRCULOGRAPH with magnetic tape record for isotope counts /impulses/ for electrocardiogram /ECG/

R i g h t

VIDEOTON NS-111 DIGITAL RADIOCIRCULOGRAPH interfaced with Commodore 64 - o-scintillation and miniaturized collimated Si-semiconductor detectors

GAMMAGARD EXAMINATION AT BALATONFÜRED

VIZSGALAT SZAMA11FICHIER CARDIO NUMERO 2

A BETEG NEVE : NADUDVARI ISTVAN

SZULETESI DATUM:05/01/1936 VIZSGALAT DATUMA:11/03/1988

1-ES DETEKTOR MAXIMALIS ERTEKE:5152

1-ES DETEKTOR MINIMALIS ERTEKE:4823

HATTER KOZEPERTEKE :4260

A HATTER KORREKCIO ERTEKE :1

EJEKCIOS FRAKCIO :39 %

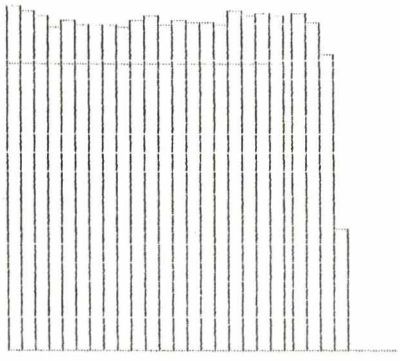
SZIVRITMUS :66 PULZ/MIN

A 40 MS-OS CSATORNAK SZAMA :22 +/-2

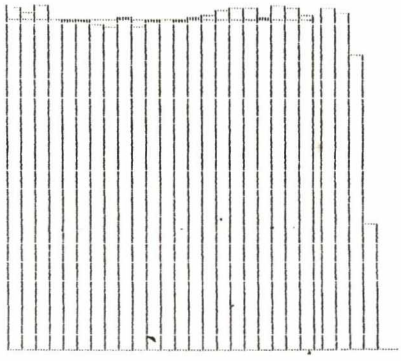
HASZNOS CSATORNASZAM :20

DET.1 A KAMRAVOLUMENHEZ RENDELVE

Apple-II program written from French to Hungarian /L. Németh, W. Pázmány/



basal RCG



oxygensaturation RCG

XVII.

Francia-nyelvűről magyarra általunk átírt Apple-II program

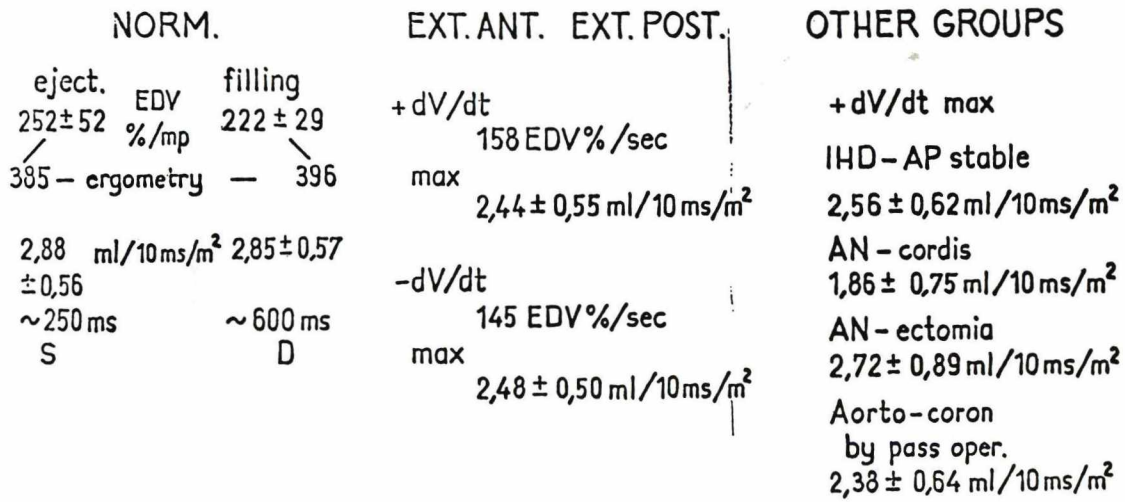
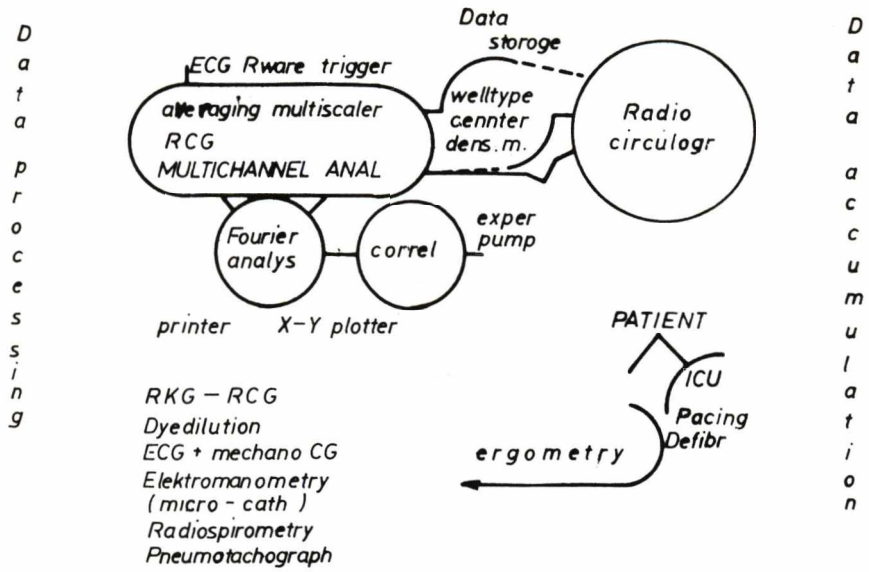


Table 1 Left ventricular maximal ejection and filling velocities measured by 113m-In RCG and by 99m-Tc radionuclid ventriculogram in different manifestations of the ischaemic coronary heart disease. The expression differ dimensionally, because of the different time-resolution, but they agree in their interpretation.



ORGANISATION OF THE COMPUTING SYSTEM
State Hospital for Cardiology
Balatonfüred HUNGARY

EMG 666/B /777/ desc calculator 8 K → COMMODORE 64 K

VIDEOTON
4-channel
digital
radio-circulography

Physical Res.Int
Hung.Acad.Sci.
KFKI
ICA-70
4096 channel
analyser

KFKI
TPA$_i$
16K-computer
built in the
MB 9101 scint.
gamma camera unit
of the GAMMA WORKS

GAMMA WORKS
MB 8100 - 8200
scintigraphy

RADIOCARDIOGRAPHICAL FUNCTION ANALYSIS
G. Hoffmann, N. Kleine (1965)

RADIOCARDIO-CYCLOGRAPHY
M. Horváth, P. Horváth (1966)
(Gy. Somogyi)
(W. Stoll as student-fellow in Bf.)

RKG-program elements
from J. T. Kuikka
(Bassingthwaite fellow)

identical principle
measuring in the radioactivity equilibrium state
with coherent averaging, synchronized by the ECG R-wave trigger

ratemeter — variation
with time constant 8oms
at the begin
adopted mainly for follow up
during several days
R I^{131} S A
later for different
drug-effect control
in combin. with
right heart compliance
nowadays Gamma Works
NK 362 Nucl. Probe
Radiokardiograph
with scint. probe
detector

digital — variation
beat-to-beat as well
with time resolution loms
and directly accessible
for computer analysis
used mainly for the follow up
of acute effect
in ICU and drugs,
of cardio-rehab. trainig effects
113m-In (transferrin) since 1970
RKG—RCG comp. progr. incl.
Fourier smoothing (1974)
+ myocard check-like system (1982)
in coop. with KFKI
and VIDEOTON, SzKI
completed — mobile system
with VIDEOTON Si-semiconductor
surface detector and magnetic
tape recording (1986)
demonstrated in function
during the visit in the
hospital laboratory

NUCLEAR STETHOSCOPE

H. N. Wagner, Jr and Coworkers 1976
BIOS, Inc.

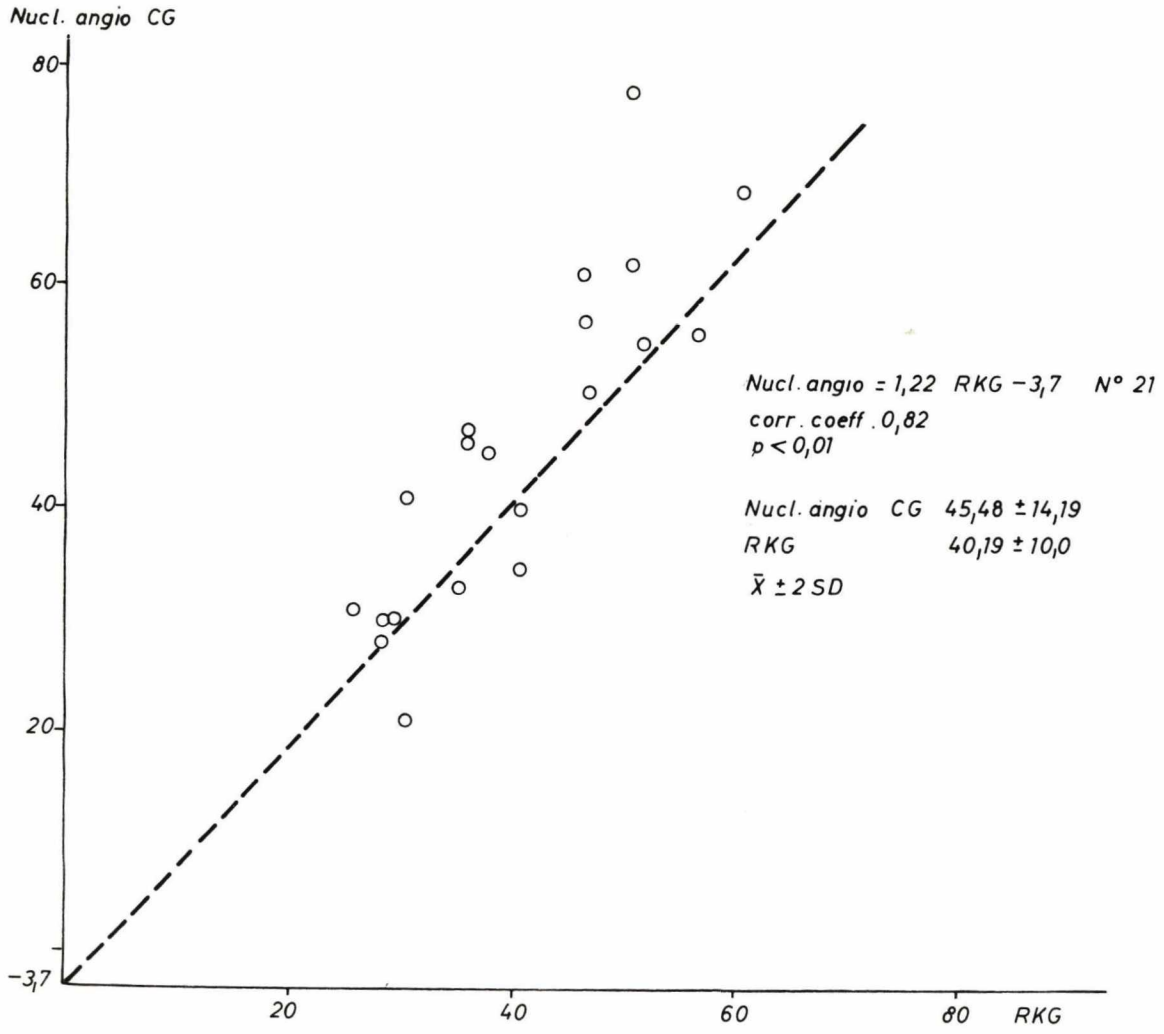
H. W. Strauss CHEST 1985
CAPINTEC, Inc.
ambulatory monitoring of LV function
in combination with Holter-monitor

ENGYMETRY
D. P. Pretschner 1982. J. Chambron
with Cd (Te) body surface detectors,
eventually for ambulatory purposes
semiconductor-devices
Siemens, later TOGAS
Karlsruhe portable system

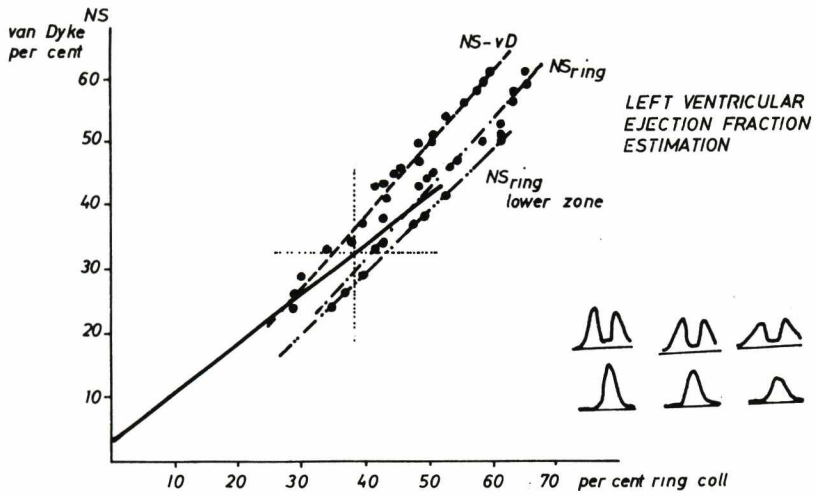
KANEMOTO, IDE
miniaturized Cd/Te detector

Parametr. gamma scan (Jülich)

THE RADIOCARDIOGRAPHY,
WHICH SERVES FOR THE
CALIBRATION OF THE RADIO-CYCLOGRAPHY HAS BEEN
CARRIED OUT
AFTER **DONATO AND COWORKERS**
THE MATHEMATICAL THEOREM
AFTER **ZIERLER AND BASSINGTHWAITE**



Confrontation of the LV-EF measured by nuclear angiocardiography on the Hung.scint.gamma camera /Gamma Works/ and with radio-cyclography.
In the right lower corner for comparison the data of Adam and Tarkowska



CORRELATION OF THE LEFT VENTRICULAR EJECTION FRACTION MEASUREMENTS
between nuclear stehoscope (HS) von Dyke (vD.)
and eclipse ring methods

In the right upper corner: the characteristics of special own-constructed/ring and disc/ Collimators after Steele and Cow. for the RKG-RKG LV-EF determination.

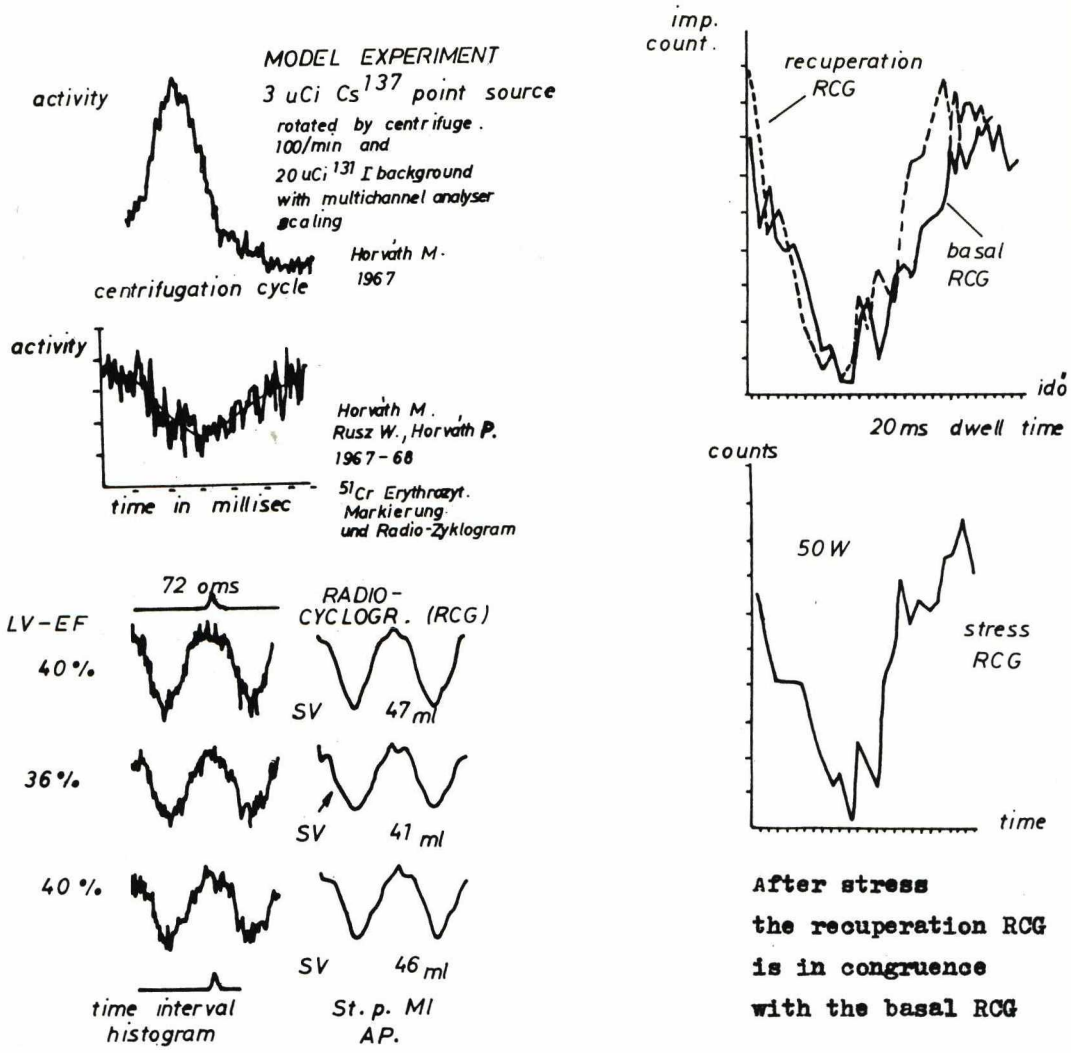
On the diagram comparison of the three EF-techniques: eclipse with collimator change /Steele/, vanDyke technique, modified in our practice, nuclearstethoscope-like cyclographic

corr. coeff.-s > 0,90

carried out on the same patients and in basal state, supine position

Beside the inter-correlations was the reproducibilty also cheked

variation coeff. < 5.0%



COMPREHENSIVE FIGURE OF THE RADIO-CYCLOGRAPHY

Upper corner left: preparatory pendulum experiment

left middle: first digital RCG with 51-Cr marked own red blood cells /RBC/

left bottom: RCG with 113m-In labeled primary and Fourier smoothed RCG with stroke volume and ejection fraction change under load; demarcation of the cycle time with time interval histogram of the trigger ECG /i.e. heart frequency reference/; pathological bulge appeared on the ejection during load

upper right: the program for the evaluation of the RCG parameters on desk computer

lower right: the measuring statistics of the RCG in basal state and under load

STATISTICS OF THE RADIO-CYCLOGRAM

/Horváth M., Horváth P., Somogyi Gy./

$$n_o = \bar{n}_v \cdot EDV \cdot \frac{Q_o}{CBV} \cdot t \cdot r_{\substack{aver \\ Nr.}} \quad \text{where}$$

n_o impulse count of the heart in end-diastole /ED/during t time

$\bar{n}_v$ average measuring efficiency in heart-detector distance /Imp/sec/uCi/

EDV end-diastolic volume

Q_o injected activity /uCi/

CBV circulatory blood volume /ml/

t dwell time of the analysis /msec/

aver. averaging number

Nr.

r

$$\frac{\Delta n}{0{,}85\ n_o} \qquad \frac{SV}{EDV} \qquad \text{where}$$

Δn diastolic-systolic impulse difference in the heart

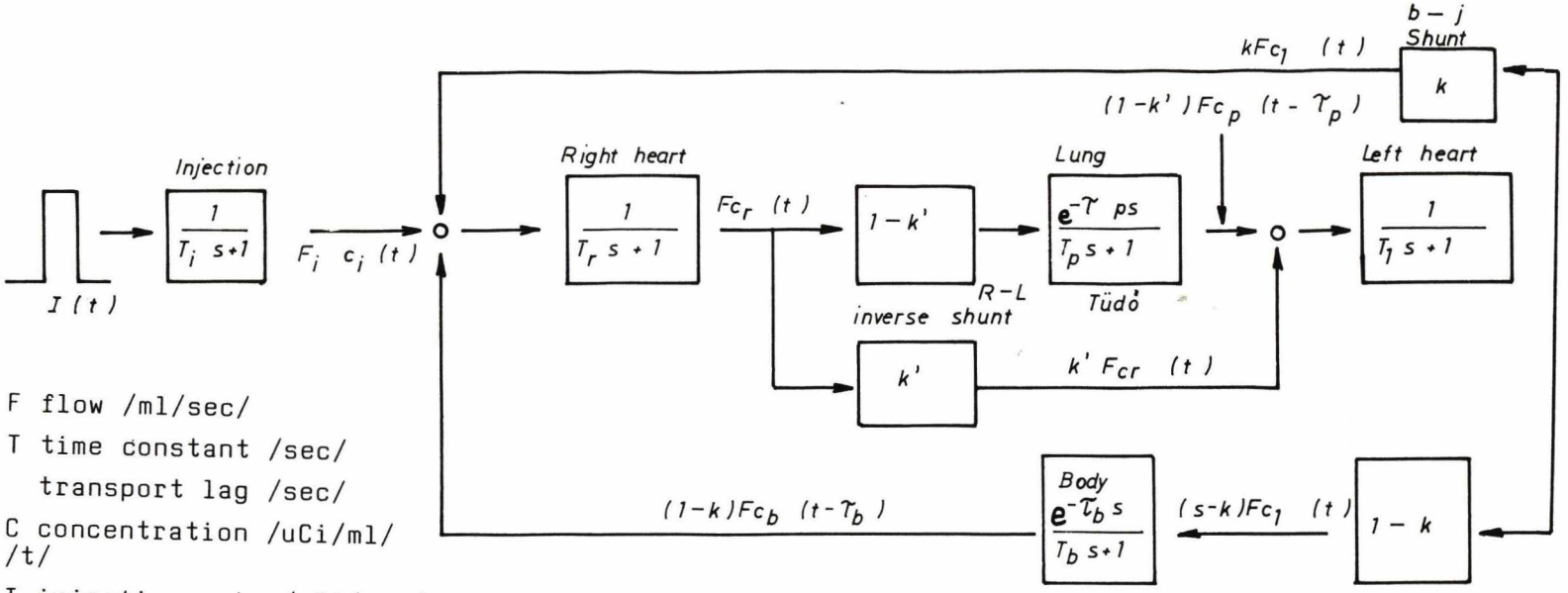
SV stroke volume /ml/

0,85 correction factor of the extracardial activity

$$n = \bar{n}_v \cdot SV \cdot \frac{Q_o}{CBV} \cdot \Delta t \cdot r_{aver.Nr.}$$

$$\left(\delta_{rel} = \frac{1}{\sqrt{n}} \right. \qquad \text{where}$$

n collected impulse-summary
summarized impulses



F flow /ml/sec/

T time constant /sec/

transport lag /sec/

C concentration /uCi/ml/ /t/

I injection rate /uCi/sec/ /t/

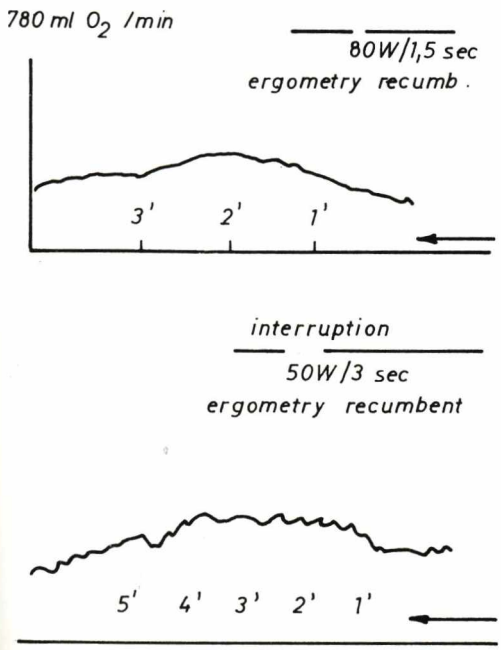
Transport process during radiocardiography, transfer function of the whole system of Saito

TRANSPORT FUNCTION MODEL FOR THE WHOLE CIRCULATION DIVIDED IN VIRTUAL COMPARTMENTS IN HEALTHY, PATHOLOGICAL AND SHUNT-SITUATION
AFTER LAPLACE TRANSFORMATION

Our system similar in the heart and lung compartments to this model

CARDIO-REHABILITATION ERGOMETRIC TEST OF A POSTINFARCTION PATIENT

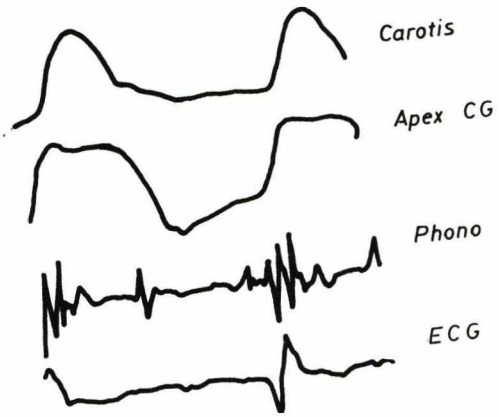
ECG, O-2 CONSUMPTION, O-2 PULSE, GASOMETRY, pH, HEART FREQUENCY



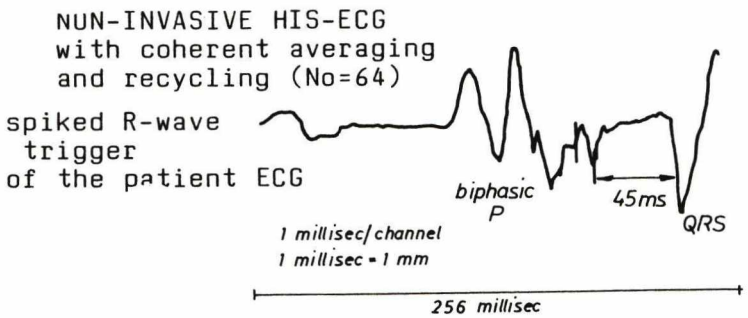
VL 44 yrs 1988. VIII. 26.
86 kg 176 cm
BSA 2,03 m^2
St.p. infarct.myocardii /1977.IV/
Basal O_2 consumption /ml/min/

norm 204
measured 280

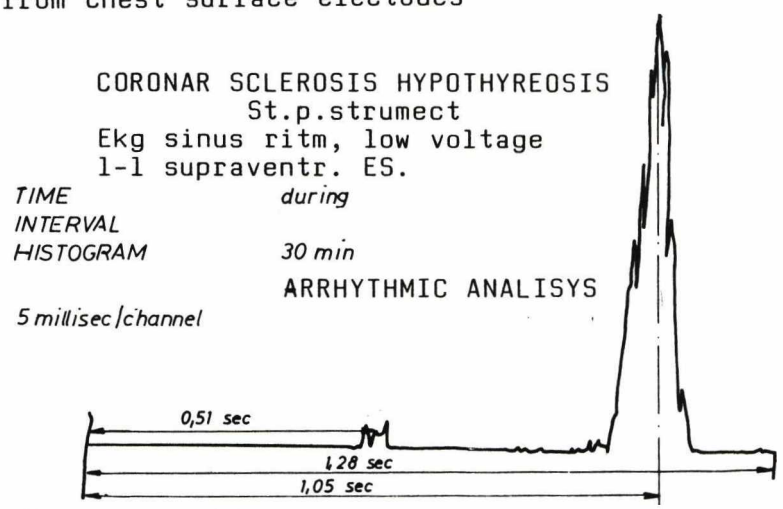
heart freq.	B.	50W.	80W
syst.blood pressure	83 130/80	125 165/90	130/min. 180/93
O_2 consumption			
$ml O_2$/min	280	600	625
O_2 cons.%		+214	+223
O_2 pulse			
$ml O_2$/frequ.	3,4	4,8	4,8
EKG	norm. curve	normal	1-1 supra
pH	7,39	7,33	ventr.
pCO_2 Hgmm.	36	37	ES
pO_2	86	110	ST-depression
O_2. satur %	96	97,3	
m.eq/l stand bicarb	22	10.5	
BE	-3	-6	



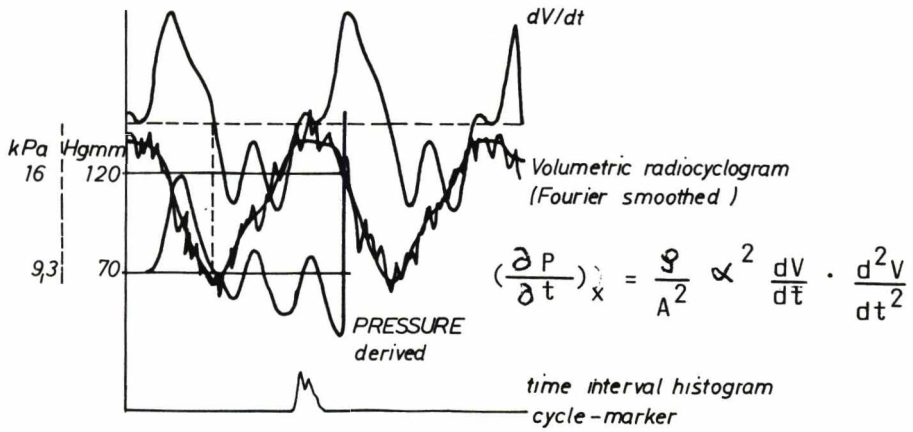
Myocard check-like mechano-cardiograms (M-CG-s)



Non-invasive His-bundle ECG (Balatonfüred, 1977).
from chest surface electodes

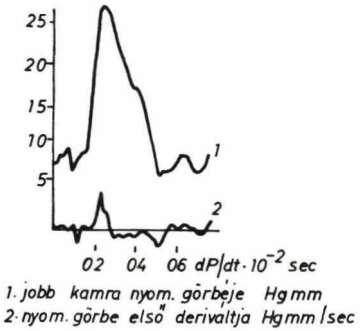


Top: the ECG R-wave trigger synchronized sampling of the carotis curve, apex-cardiogram and the leading ECG.
Middle: non-invasive His-ECG.
Bottom: arrhythmic analysis

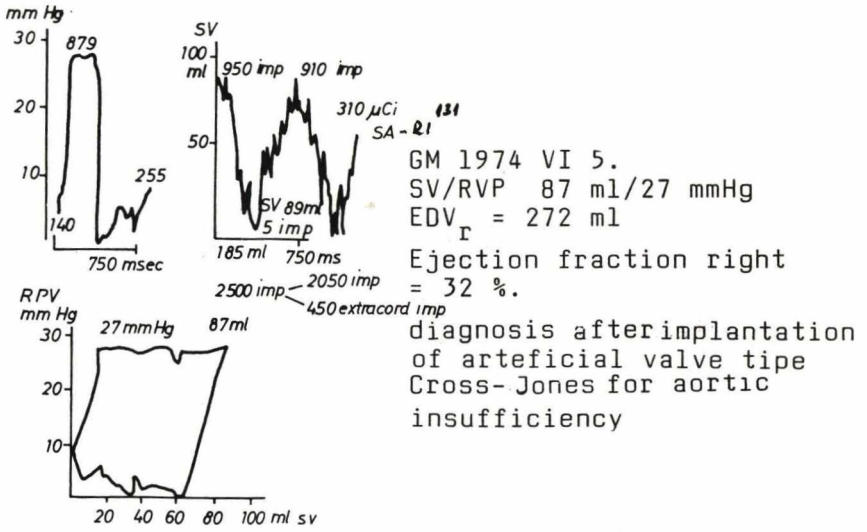


Derivation of the left ventricular pressure pattern from RCG-volumetric curve

attempt to the derivation of the LV systolic pressure pattern from the RCG volumetric curve after Bourguignon and Cow.



1. jobb kamra nyom. görbéje Hgmm
2. nyom. görbe első derivaltja Hgmm/sec



GM 1974 VI 5.
SV/RVP 87 ml/27 mmHg
EDV_r = 272 ml
Ejection fraction right = 32 %.
diagnosis after implantation of arteficial valve tipe Cross-Jones for aortic insufficiency

	t(s)	IM	106000 E-01
P(t)	Hgmm	P(IM)	240000 E+02
max dP/dt	Hgmm/s	D MAX	450000 E+03
max dP/dt/p	1/s	H MAX	187000 E+02
max P	Hgmm	D MAX/P MAX	166667 E+02
P(t)max P		P(IM)/P MAX	811839 E+00
	T(s)	IPM	108000 E+01
	t/T	IM/IPM	281431 E+00

Programhoz PMAX és ciklusidő 3 ciklus alapján megadva.

$$\frac{1.333.10^{-4}\,\text{Joule}}{\text{cycle time /sec/}}$$

$$\frac{0.133.\text{kPa.cm}^3}{\text{cycle time /sec/}}$$

$$\frac{k\ .\ P/dV}{\text{cycle time}}$$

/sec/
insofar
P = 1 Hgmm
k = 133.3 Pa

HAEMODYNAMIC DATA OF ISCHAEMIC HEART PATIENTS

	Nr. of Pat total/decomp./	stroke volume-index sv_i comp. ml/m^2	decomp.	estim left ventr. EF. comp.	decomp.
Cardiovasc. normals	5	57.1±2.9		63.6±10.0	
Unstable angina pectoris	17	48.0 5.0		46.2 5.1	
Subendocardial postifarction	5	44.0 5.6		45.1 9.1	
Septal postinfarction	25 /5/	43.2 8.1	30.0±10.1	43.1 7.3	34.0±8.7
Anterior postinfarction	50 /11/	40.7 9.4	33.2 12.2	38.6 8.4	33.3 11.1
Extensive ant. postinfarction	73 /26/	36.1 9.7	32.9 8.5	33.3 7.8	30.0 7.9
Posterior postinfarction	22 /1/	50.0 11.0	40.0	44.0 6.5	44.0
Extensive post. postinfarction	8 /1/	48.7 4.2	39.0	47.1 5.8	36.0
Ant.-post. double postinfarction	13 /4/	32.4 14.0	25.4 8.4	32.6 5.6	27.6 11.4
St. p reinfarction	8 /4/	33.5 12.4	25.0 10.4	32.0 9.8	26.2 9.2
IHD cardmyopath.diff.-insuff.haemodyn	8 /8/			26.8 11.9	29.0 8.5
IHD + Hypertension	10	49.2 6.6		65.0 11.2	
Coronary by pass mostly RAD	9	49.6 16.0		44.4 10.8	
Aneurysm ventr. sin.	37 /11/	46.4 11.8	39.1 10.6	41.2 15.8	35.8 12.4
St. p. aneurysmect.	16	42.0 6.0		45.0 11.2	
Coron. by pass + aneurysmect.	2	43.3 5.3		46.4 8.1	
Primer congestive cardiomyopathy	7		32.0 8.2		26.7 7.0

THE DIMENSION ANALYSIS OF THE LEFT VENTRICULAR SYSTOLIC PRESSURE CURVE DERIVED FROM THE LV VOLUME CHANGES

$$/\frac{\partial p}{\partial t}/_x = \frac{\rho}{A^2} \cdot \mathcal{L}^2 \cdot \frac{da}{dt} \cdot \frac{d^2a}{dt^2}$$, ahol

a /sec^{-1}/ $\frac{da}{dt}$ /sec^{-2}/ $\frac{d^2a}{dt^2}$ /sec^{-3}/ $\mathcal{L}$/cm^3 sec/

ρ/$g.cm^3$/ $V = \mathcal{L} . a$ A /cm^2/ .

Hgmm /cm/ . /$g.cm^{-2}\ sec^{-2}$/ = g . cm . sec^{-2} /cm^2= g . cm^{-1}. sec^{-2}

cm is pointing out because of change of distance, so cm
/g . $cm^{-2}\ sec^{-2}$/

$$/\frac{\partial P}{\partial t}/_x = \frac{1.054}{1335} \cdot \frac{\mathcal{L}^2}{A^2} \cdot \frac{da}{dt} \cdot \frac{d^2a}{dt^2}$$

$$/cm . sec^{-1} = \frac{g . cm^{-3}}{g.cm^{-2}sec^{-2}} \cdot \frac{cm^6\ sec^2}{cm^4} \cdot /sec^{-2}/ \cdot /sec^{-3}/$$

$$cm . sec^{-1} = cm . sec^{-1}$$

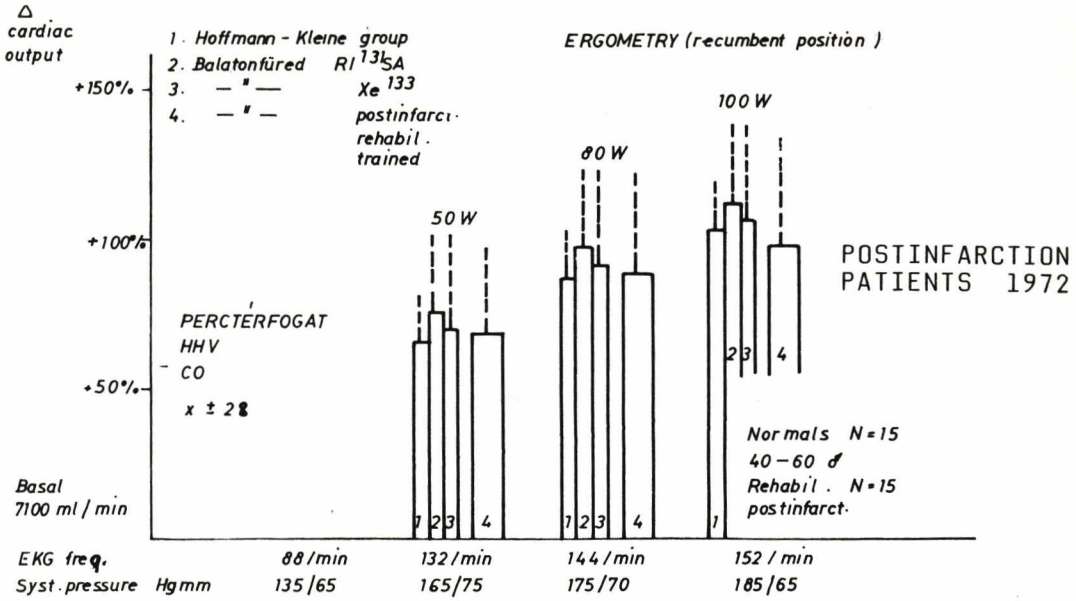
$$/\frac{\partial P}{\partial t}/_x = \frac{\rho}{k . A^2} \cdot \frac{dv}{dt} \cdot \frac{d^2v}{dt^2}$$

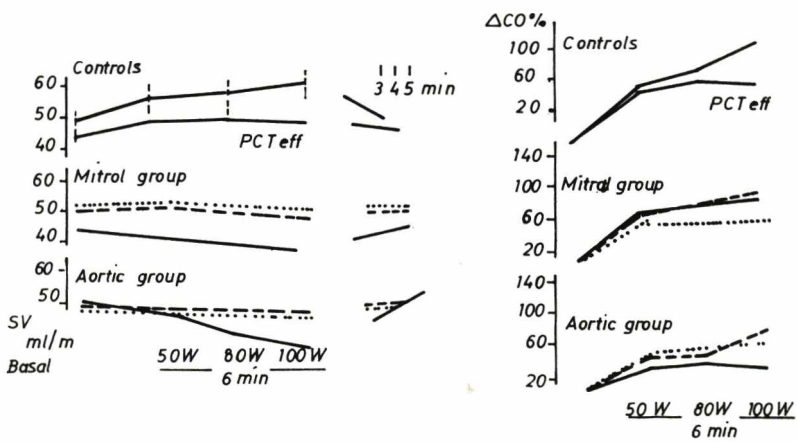
constant

$$/cm . sec^{-1}/ = \frac{g . cm^{-3}}{cm^{-4}} \cdot \frac{1}{g\ cm^{-2}sec^{-2}} \cdot cm^3\ sec^{-1} . cm^3\ sec^{-2}$$

constans

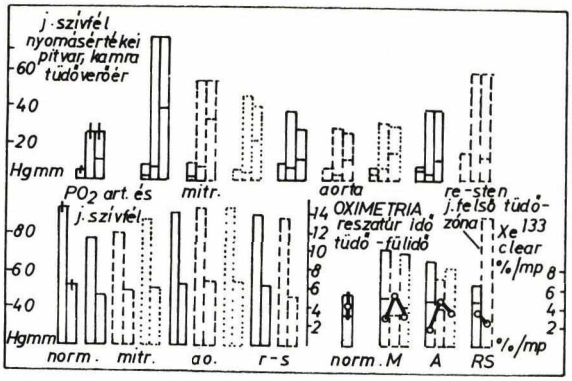
$$/cm . sec^{-1}/ = cm . sec^{-1}$$





Top: Verification of the 2 yrs. cardio-rahabilitation training effect with RKG-RCG on non-aneurysmatic postinfarction patients with similar good results in Freiburg and in Balatonfüred

Bottom: long-term results of arteficial valve implantation and commissurotomy on heart failure patients, documented by the improved ergometric stress reaction



Follow up series of the characteristic parameters /through micro-catheter measured right atrial, ventricular and pulmonary pressures, p-O_2 pressures; oxymetric circulation and ventilation time values/ of aquired mitral vale failure, aortic failure and mitral restenotics patients preoperatively, after 1-2 months postoperatively and 3 1/2 years in rehabilitation traning

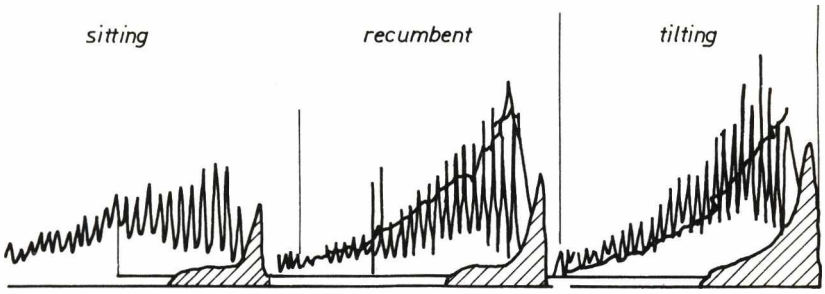
upper line the pressure values

bottom left the p-O_2 pressures

bottom right corner the oxymetric values

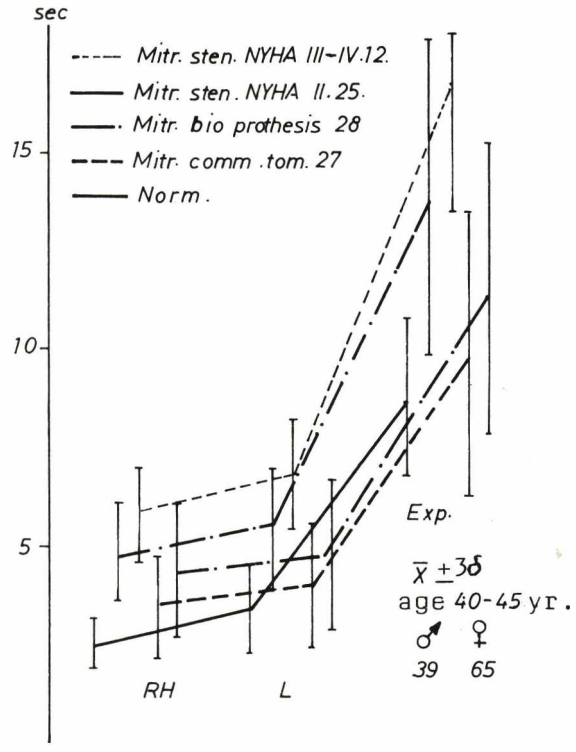
on the left of each block the norms are presented

Conclusively: effective surgical intervention and the favourable effect could be maintened with rehabilitation training

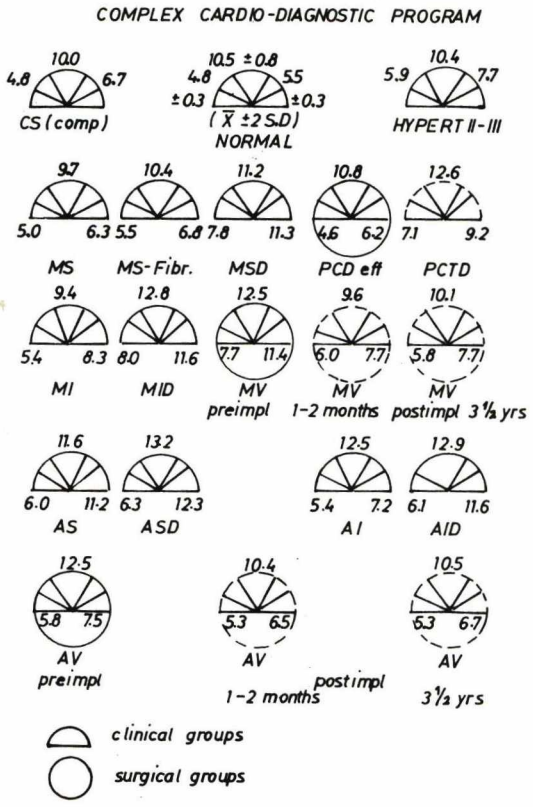


Comprehensive orientation of the cardio-pulmonary funct.study of the influence of body positions
The technique can be practically employed in the coronary care unit /ICU/

Shaded area right heart partial radio-cardiogram continous line right upper lung zone thorakogram, cyclic 133-Xenon expiration



133 - Xenon in phys.saline iv.injected appearance-times in the right heart /RH/, right upper lung-region and in the expired ventilation volume /Exp./L/



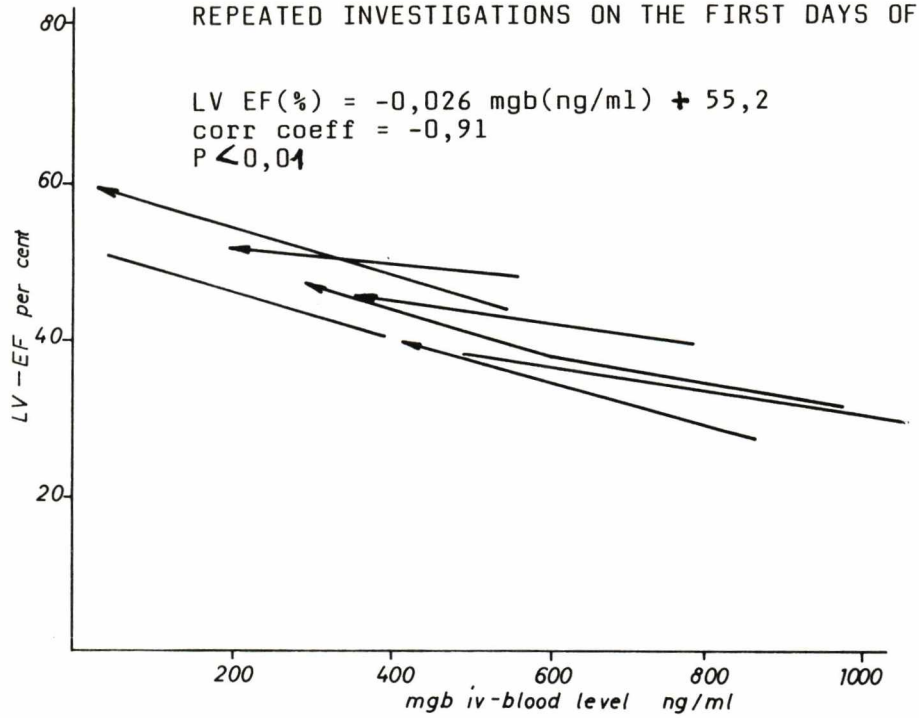
Schematic diagram of blood distribution in the successive clinical stages of heart diseases

Group of patients	Normal controls	4,9-0,29	10,5+0,63	5,5+0,33
Cardiac sclerosis	CS	4,8±0,38	10,7±0,86	6,7±0,54
Hypertension	HT	5,9±0,47	10,4±0.83	7,7±0,62
Mitral stenosis	MS	5.0±0.50	9.7±1.00	6.3±0.60
Mitral stenosis fibrill	MSF	5.5±0.77	10.4±1.46	6.8±0.95
Mitral stenosis decomp	MSD	7.8±1.56	11.2±2.50	11.3±1.26
St.p.commiss.tom.mitr.	PCT	4.6±0.64	10.8±1.74	6.2±0.87
St.p.comiss.tom.decomp.	PCTD	7.1±1.42	12.6±2.77	9.2±1.84
Mitral insufficiency	MI	5.4± 0.76	9.4±1.31	8.3±1.16
Aortic stenosis	AS	6.0±0.72	11.6±1.40	11.2±1.34
Aortic stenosis decomp.	ASD	6.3±1.13	13.2±2.40	12.3±2.21
Aortic insufficiency	AI	5.4±0.65	12.5±1.50	7.2±0.86
Aortic insufficieny decomp	AID	6.1±1.10	12.9±2.22	11.6±2.52

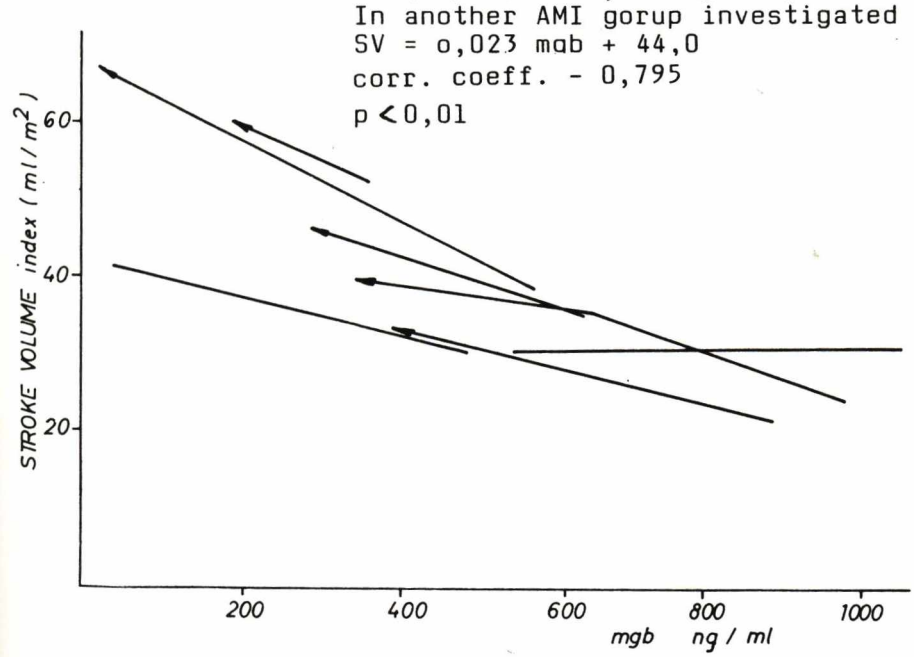
Acta Medica Acad. Sci. Hung. 33, 1976
dr. Horváth M.

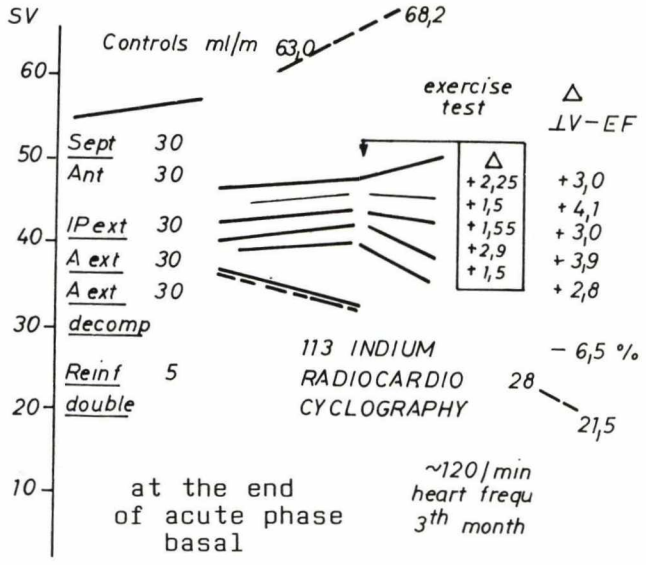
REPEATED INVESTIGATIONS ON THE FIRST DAYS OF AMI

LV EF(%) = -0,026 mgb(ng/ml) + 55,2
corr coeff = -0,91
P < 0,01



SV (ml/m^2) = -0,032 mgb (ng/ml) +54,5
In another AMI gorup investigated earlier
SV = o,023 mab + 44,0
corr. coeff. - 0,795
p < 0,01





113 m In(transf.) radiocardiography (RKG)
assessed by own computer - program
on Commodore - 64

ISCHAEMIC HEART DISEASE PAT-S
haemodynamically compensated

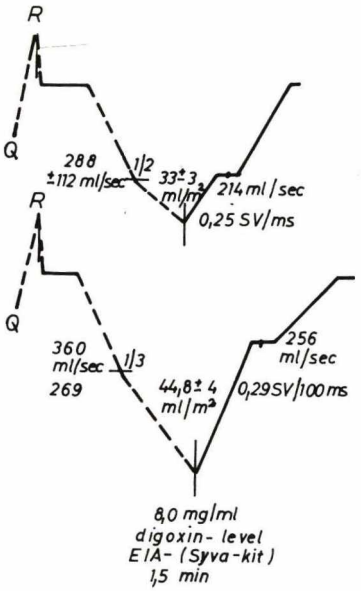
Angina pectoris		MI within lyr
	dg criteria	
ECG S1 and T signs		pathol ECG Q wave and/or ST-T sings
	age 40 yr	
	BSA 20 mm^2	150 patients
	BP normal	in 5 groups
	capillary (art.) O_2 tension > 70 Hgmm	
	ERGOMETRY (sitting)	
110 W	heart frequ.	90 W
130/min		135/min

routine medical th. (nitr. and/or betabl., Ca-antog.)

THE MEASURED EFFECTS WERE

1./ DIGOXIN	hyperdynam, ergotrop increase of the stroke volume, improvement of the contract.dynam. velocity parameters
2./AMYLNITRITE INHALATION	non significant change of the cardiac output /CO/ in conseq. of the increase of the freq. and decrease of SV
NITROLINGUAL NG-tbl. INFUSION subling	more considerable improvement of the contraction dynamics parameters
3./ DIPYRIDAMOLE INFUSION	non sign. changes of the left ventricular ejection fract. of the stroke volume /SV/
	on ischaemic heart disease pat.-s /remote MI/ in conseq. of pathol. steal effect impairment of the contract.dynamics decrease of the peak ejection and filling velocities increase of the ejection and filling times
4./ CO_2-bath	transitorial improvement of the card.-pulm. function on ischaemic heart pat.-s in conseq. of venous pooling and of increased alveolo-capillary permeability

As the haemodynamic insufficiency is put into order the SV increases, the heart cycle lenghts /particulary the diastole/, the ejection becomes dynamical /the 1/2-1/2 proportion of the fast and slow ejection being restored to the normal 1/3-2/3 relation/,
the pre-ejection is shortened, so the PEP/systolic time ratio /PEP/ $LVET_{volum.base}$ will be diminished



ACUTE DIGOXIN EFFECTS
after the inj.of. 0,5 mg Digoxin
in the 1,5 minute
10 IHD - patients
with haemodynamic insufficieency
/50-55 years, males/
BSA 1,85 m
Digoxin in the serum 8.0 mg/ml

with enzyme immuno assay

heart frequency
112±5 88±5 $mint^{-1}$

stroke volumes index
33.0±2.7 ⟶ 44.9±2.7 ml/m^2

pre-ejection
100±40 ⟶ 80±20millisec-s

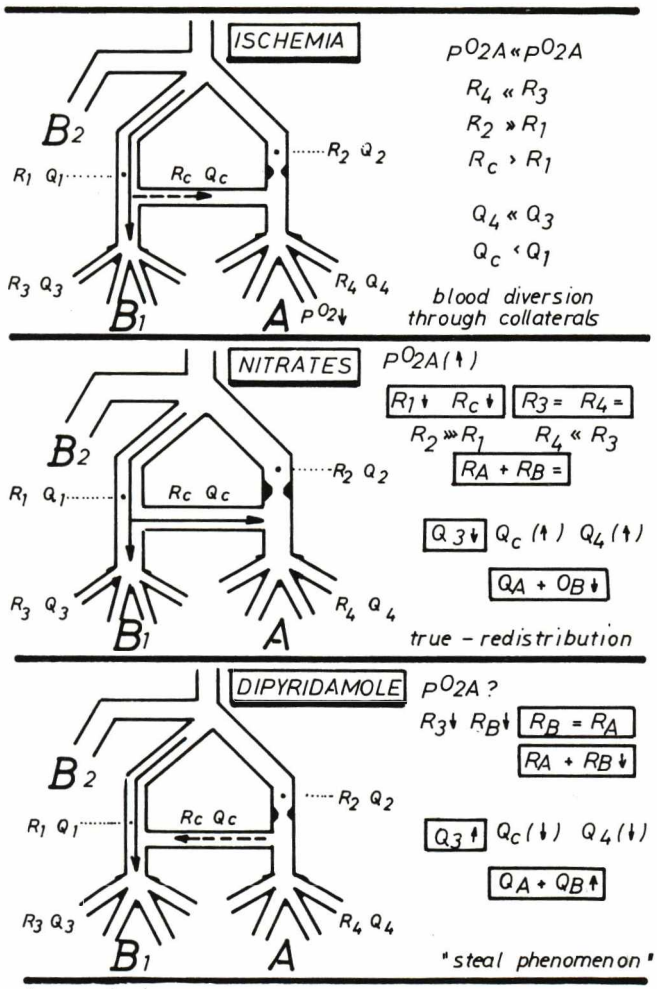
ejection
220±60 ⟶ 240±60millisec-s

PEP/LVET radcycl.gr.volum.base
0.46±0.06 ⟶ 0.33±0.05

$-dV/dt_{max}$ in per cent of systole
48±6 ⟶ 33±4%

dV/dt/100 millisec-s
18.5±7.5 28.5±6.6 mol

in the per cent of the SV
25% ⟶ 29%



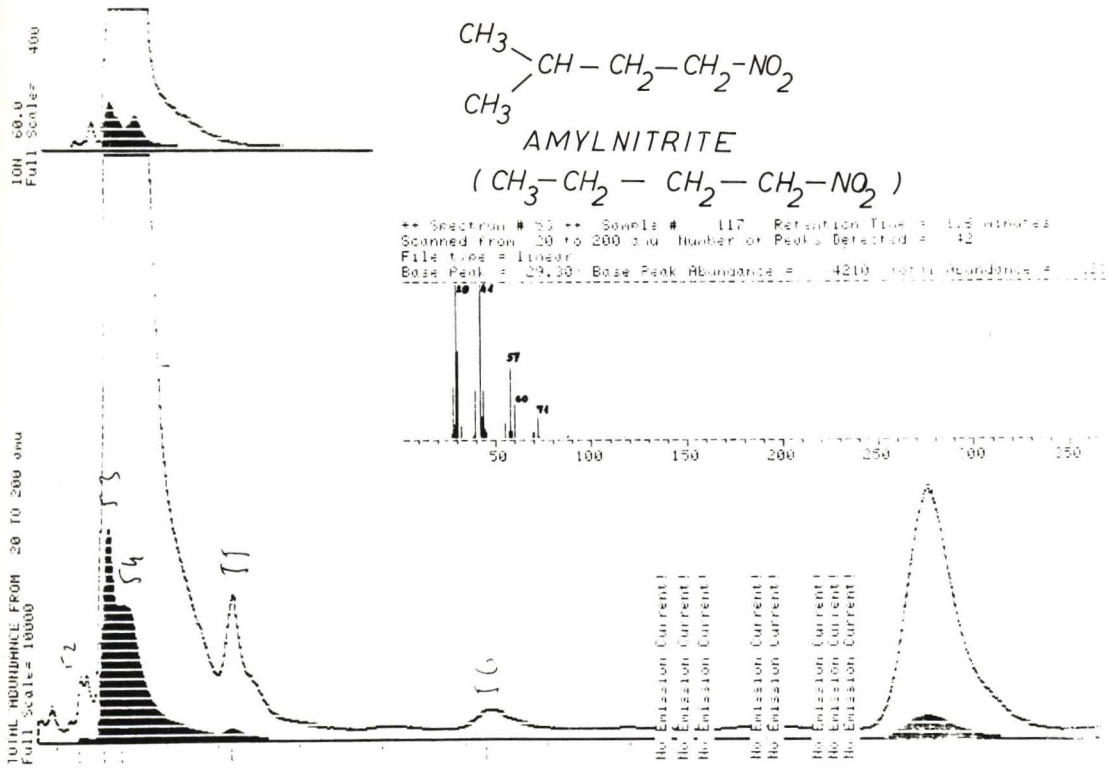
R_4 lowest resistance
R_2 highest resistance fixed $Q_4 = Q_c + Q_2$ $Q_c > Q_2$ Area B..Bn..A

Behavior of local coronary flow (Q) and resistance (R) in the normal (B_1.B_2) and the poststenotic areas (A). The situation is demostrated for ischemia medication with nitrates and dipyridamole.
Rc. collateral resistance Q_2 collateral flow. Q_3 and R_3 arteriolar flow and resistance in the normal area. Q_4 and R_4 in the poststenotic, potentially ischemic area. (From LICHTLEN /6/).

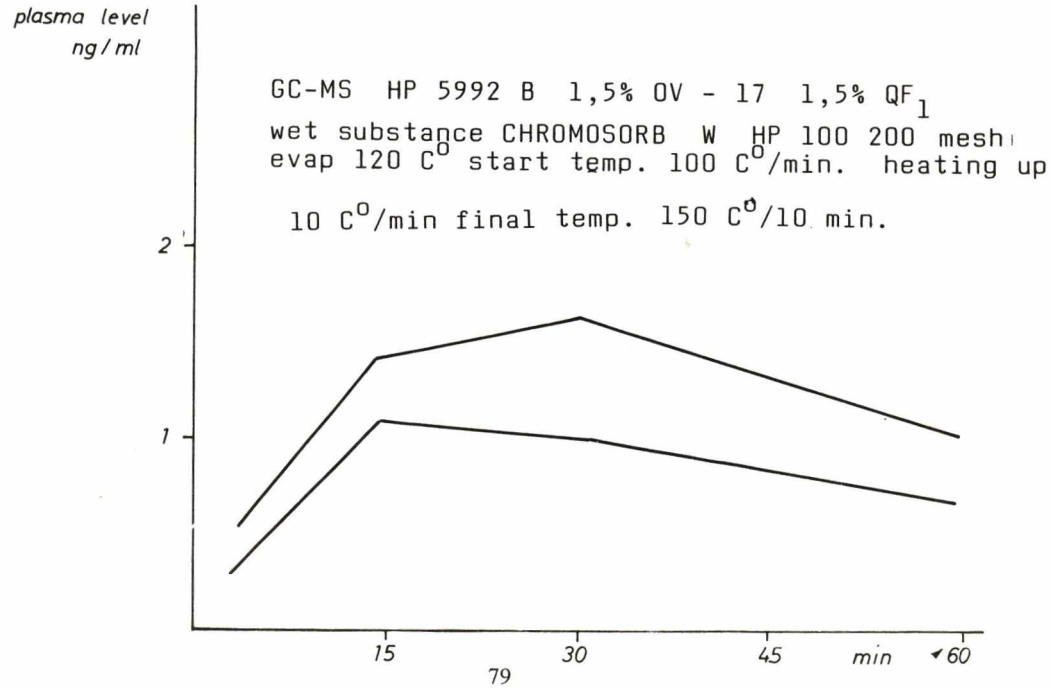
RELATIVE CHANGES OF SOME HEEMODYNAMIC AND CARDIAC CONTRACTION DYNAMIC PARAMETERS IN THE TIME OF THE MAXIMAL EFFECT ON IHD PATIENTS /15 middle aged normal males/

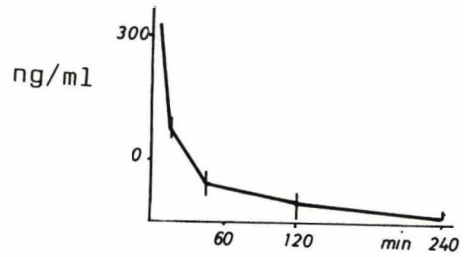
		AMYLNITRITE IHALATION	NITROLINGUAL/NG/ INFUSION	ABS.VALUES OF NORMALS
Heart frequency	1/min	+9.6%	+10.5%	73±13
Blood pressure	Hgmm. kPa	-4.2/12.4	-4.9/14.5	135/85 ±11/6
Circ.blood volume/CO CBV/CO		-4.7	-5.25	0.81±0.17
Cardiac output cardiac index	$l/min/m^2$	+1.8	+2.45	3919±535
Stroke volume-index	ml/m^2	-7.5	-8.4	53±13
Left ventr.eject.fr.	/%/	-0,3	-3.0	64±16
Prae-eject./PEP/ RCG-corr.	millisec	-5.5	-6.25	80±12
Left ventr.eject.time LVET	millisec	-0.3	-3.0	250±23
-dV/dt eject.velocity	ml/loms	+0.9	+5.1	4.12±0.96
peak ejection time	millisec	+0.8	-3.6	97
EF/LVET		+12.0	+15.5	2.46±0.30
PEP/LVET /RCG-corr./		-11.4	-12.6	0.32±0.04
Diastole	millisec	-17.0	-20.0	500±112
+dV/dt filling velocity	ml/10	-0.5	+10.6	2.94±0.36
peak filling time	millisec	+5.7	-2.5	128
Filling/looms	ml	+1.8	+13.2	34.5±6.8
Filling/stroke vol.%/100ms		+1.0	+4.7	36.6±7.5

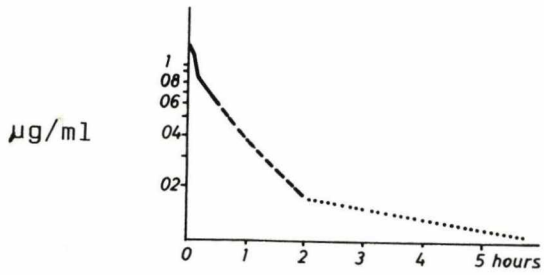
ONLY THE DIASTOLE, THE PEP/LVET, +dV/dt, THE PEAK FILLING TIME AND THE FILL./SV % ARE ON THE BORDERLINE OF THE SIGNIFICENCE ON NITROLINGUAL INFUSION IN THIS GROUP OF IHD-PATIENTS MOSTLY WITH REMOTE TRANSMURAL EXTENSIVE MYOCARDIAL INFARCTION



NITROLINGUAL in ethanol solution intravenous infusion-60min.
80 /µg/min
Glicerol-trinitrat NO_2. 46 mass number GC-MS retention time
7,4 min.







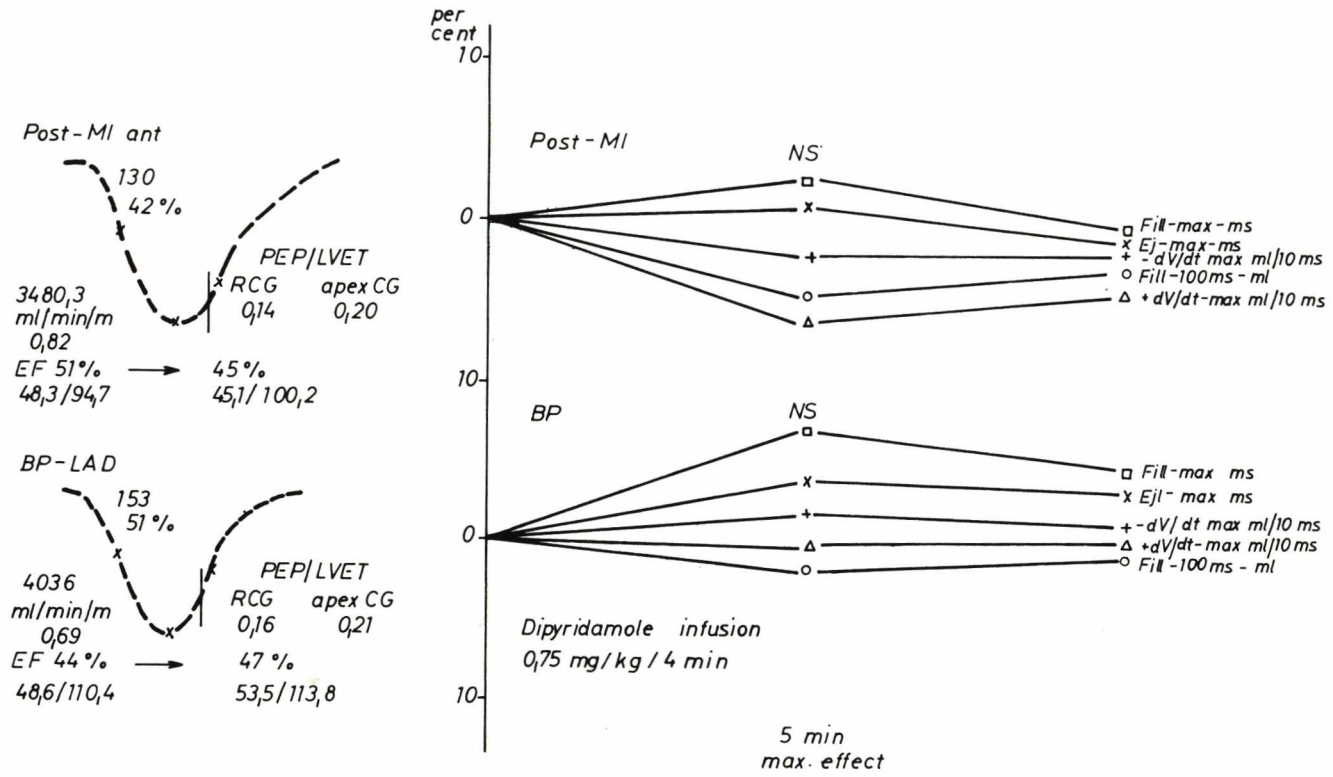
gel separation
fluorometry

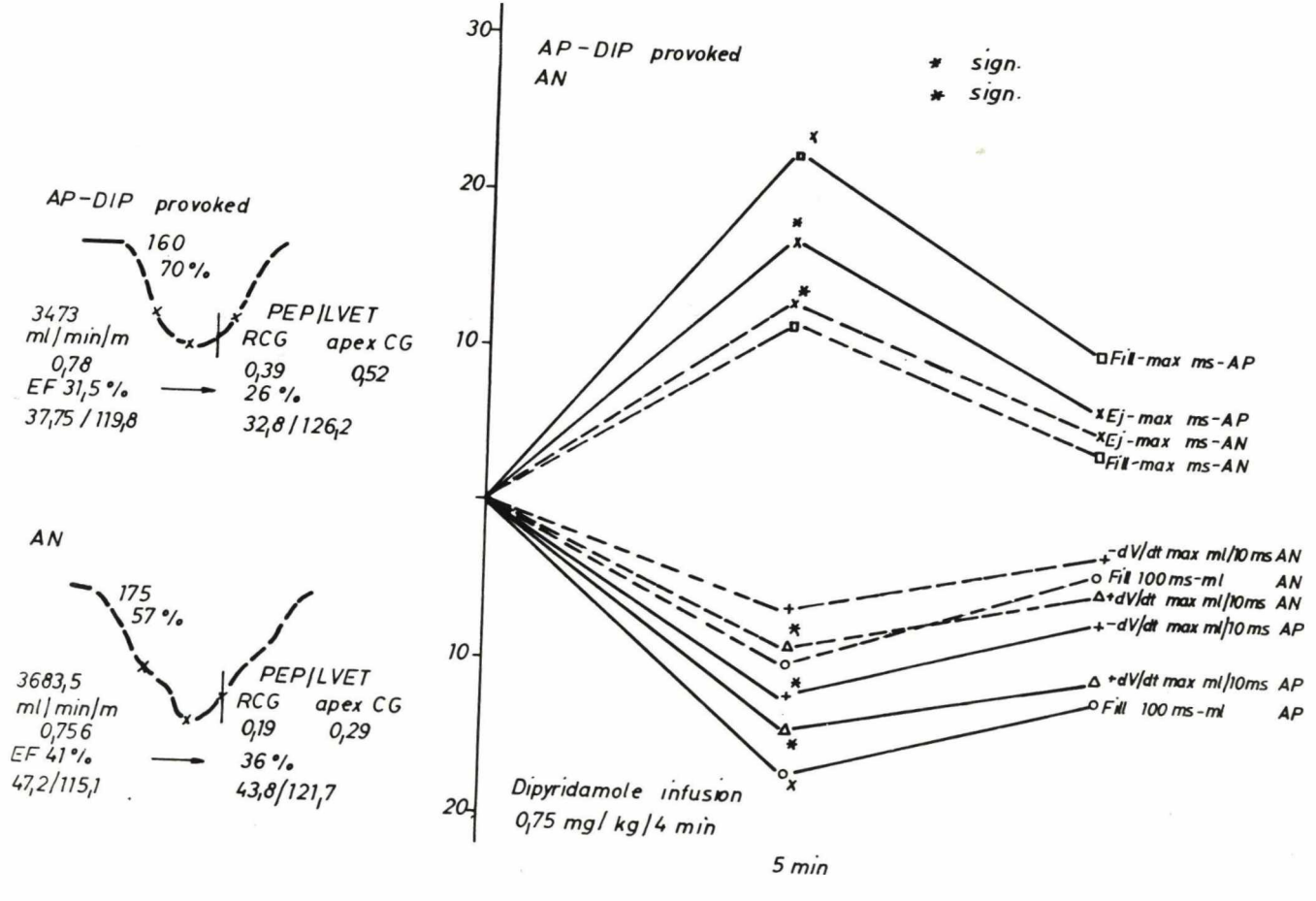
DIPYRIDAMOLE INFUSION-EFFECTS
/0.75 mg/kg/4 min/

		stroke-volumen ind. SV_i	left ventr. eject. fraction LV-EF
Normal	/1/	54.0-59.0 ml/m^2	63 % -- 68 %
Sept. post-MI	/4/	49.5-49.5	50.75%-- 53 %
Ant.	/7/	46.0-45.3	40.3 -- 41.6%
Ant.decomp.	/3/	35.3-29.0	30.0 -- 27.6%
Ext-ant."	/2/	41.5-50.0	34.5 -- 46.5%
Ext.ant.decomp.	/9/	32.9-33.2	33.3 -- 33.7%
Post."	/1/	55.0-66.0	57.0 -- 60.0%
Ext.post.	/1/	44.0-55.0	45.5 -- 52.0%
Ant.post/dc./	/2/	36.0-38.0	35.0 -- 40.0%

——— improvement
javulás
41.0-41.9

--- impairment
romlás
39.3 -- 41.4%


LV kinetic - reaction of DIPYRIDAMOLE
per cent
10
0
10
Post - MI ant
130
42 %
PEP/LVET
RCG
apex CG
0,14
0,20
3480,3
ml/min/m
0,82
EF 51 %
48,3/94,7
45 %
45,1/100,2
BP - LAD
153
51 %
4036
ml/min/m
0,69
EF 44 %
48,6/110,4
47 %
53,5/113,8
Post - MI
NS
Fill-max-ms
Ej-max-ms
- dV/dt max ml/10 ms
Fill-100ms-ml
+ dV/dt-max ml/10 ms
BP
NS
Fill-max ms
Ejl- max ms
- dV/dt max ml/10 ms
+dV/dt-max ml/10 ms
Fill-100 ms - ml
Dipyridamole infusion
0,75 mg/kg/4 min
5 min
max. effect


AP-DIP provoked
160
70 %
3473
ml/min/m
0,78
EF 31,5 %
37,75 / 119,8
PEP/LVET
RCG
apex CG
0,39
0,52
26 %
32,8 / 126,2
AN
175
57 %
3683,5
ml/min/m
0,756
EF 41 %
47,2/115,1
PEP/LVET
RCG
apex CG
0,19
0,29
36 %
43,8/121,7
AP-DIP provoked
AN
* sign.
* sign.
30
20
10
10
20
Fill-max ms-AP
Ej-max ms-AP
Ej-max ms-AN
Fill-max ms-AN
-dV/dt max ml/10 ms AN
Fill 100 ms-ml AN
+dV/dt max ml/10ms AN
-dV/dt max ml/10 ms AP
+dV/dt max ml/10ms AP
Fill 100 ms-ml AP
Dipyridamole infusion
0,75 mg/kg/4 min
5 min

COMPARISON OF NUCLEAR STETHOSCOPE-LIKE RADIOCYCLOGRAPHIC AND COMPUTED GAMMA CAMERA INVESTIGATIONS WITH DIPYRIDAMOLE LOADING /DIP/

	nr.of pat.-s	RCG Videoton digit.RKG bulge phenomenon paradox pulsation		regional wall motion-dyskinesis 99m - Tc nucl.angio		GAMMA CAMERA Gamma Works,Hungary regional myocardial perfusion 201 - Tl defect	
		basal	DIP	basal	DIP	basal	DIP
Post-myocardial infarction ant.later	10	1/10	2/10	5/10	5/10	6/10	8/10
LV - aneurysm	12	8/12	10/12	12/12	11/12	12/12	11/12
LAD coron. sin. by pass operation	4	0/4	0/4	0/4	0/4	2/4	2/4
Angina pectoris syndrome with DIP-provoked attack and unfavourable steal ph.	10	2/10	5/10	1/10	3/10	5/10	8/10

TIME RESOLUTION OF CYCLOGRAM IN GATED EQUILIBRIUM — 10 millisec — 40-50 millisec

p r o v o k e d

THE DYSKINETIC REHABILITY — I S S I M I L A R — WITH RCG AND GAMMA CAMERA INVESTIGATIONS (RNV)

R c g m o r e a n d v a n t a g e c u s l y by better time resolution

C a m e r a topographical

CONTINOUS MONITORING OF LEFT VENTRICULAR FUNCTIONS AND PULMONARY BLOOD VOLUME, USING A DUAL CADMIUM-TELLURIDE PROBE SYSTEM

Michiru Ide, Yutaka Suzuki, Nariaki Kanemoto and Yuichiro Goto
Tokai University School of Medicine, Isehara, Japan

Currently, scintillation camera-computer systems are mainly used in the field of nuclear cardiology. The camera-computer system offers a high degree of spatial resolution, but its counting efficiency and temporal resolution are not high enough to assess continously rapid responsiveness of ventricle to various stimulations. On the other hand, single cardiac probe system made by sodium iodide (so-called nuclear stethoscope) has high temporal resolution, but this system is still too large for continuous monitoring of left ventricular functions. Therefore, it would be desirable more light and small equipment. So, we had developed a new single cardiac probe system made by cadmium telluride (that is Cd/Te).

When we estimate the left ventricular functions by a single cardiac probe system, we should take background counts every time. Therefore, we have developed a computerized dual CdTe probe system which make it possbile to estimate left ventricular and background counts, simultaneously. Furthermore, in our new system, counts from patients are sent wirelessly to microprocessor, so we can do telemonitoring of the left ventricular pump functions with radio nuclide.

The aims of this study are 1) to evaluate the feasibility for the evaluation of left ventricular functions obtained by the CdTe probe system comparing those obtained by standard gamma camera (that is G), 2) to discuss the preliminary study of potential value in continuous monitoring of the cardiac functions and pulmonary blood volume (that is PBV) using a dual CdTe probe system and 3) to our prototype of wireless telemonitoring system.

Figure 1 shows the CdTe detector. This detector is very small and light weight, high count efficiency to gamma-ray and high reliability.

A detector module is consisted bystraight bore lead collimator, CdTe detector, housing and pre-amplifier (figure 2). Total weight of this module is about 250 grams.

Figure 3 shows a block diagram of the system which is consisted by dual detector modules, portable data acquisition unit and microprocessor. We place one probe over the left

ventricle under the image of gamma camera and another one over the right upper lung field for counting background or pulmonary counts, simultaneously.

Figure 4 shows correlation between the left ventricular ejection fraction obtained by gamma camera and those obtained by our system. There is good correlation between these values.

Left ventricular and pulmonary or background counts can be monitored simultaneously in real time fashion. Sampling interval of the data is 50 msec data acquisition time can be up to 6 hours.

Our system has following data analysis and display programs; first, display left ventricular and pulmonary or back ground time activity curves. Second, left ventricular ejection fraction is estimated by root mean square method and presented as a trend gram. Third, left ventricular end diastolic and systolic counts are calculated by root mean square method and displayed as trend grams. Fourth, beat-by-beat left ventricular ejection fraction is estimated from one block, for six seconds of data. Fifth, the left ventricular functional parameters (first-third ejection fraction, peak ejection rate, peak filling rate, time to peak ejection rate, time to peak filling rate and heart rate) are estimated from the data of every six seconds,and presented as trend grams.

Figure 5 shows an actual diplay of the continuous monitoring of the left ventricular functions using our dual CdTe probe system. In the upper left hand corner of the figure, time activity curve of the left ventricle and background are shown. In right upper hand corner, beat-to-beat analysis of six consecutive beats are shown. In lower right, the multi-gated analysis of the same periods are shown. The lower left, there are trend grams of ejection fraction, end diastolic volume, end systolic volume and background counts.

Figure 6 shows an example of continuous monitoring before and after sublingual administration of isosorbide dinitrate(that is ISDN) for the patient with angina pectoris. Both end diastolic and systolic counts of left ventricle clearly decreased, but the back ground counts remained the same range. Although, the heart rate increased significantly, after administration of ISDN, ejection fraction stayed the same range.

Table 1 shows the summary of the sublingual administration of ISDN on cardiac functions for eight patients with ischemic heart disease. Heart rate and ejection fraction were increased significantly. And pulmonary blood volume or back

ground counts, end diastolic and systolic counts were decreased.

Figure 7 shows the effect of ergometer exercise for the patients with old myocardial infarction. Note that the counts of left ventricle as well as background counts, increased during exercise. The heart rate also increased, but the ejection fraction decreased.

Samely, figure 8 shows the continuous monitoring of two cases , during ergometer exercise. Case two is a same one of the former figure. In case one, the background counts increased significantly, but in case two decreased. So, the background counts were differ from patients to patients, Therefore simultaneous monitoring of the counts of left ventricle and background counts would be indispensable for continuous monitoring of cardiac functions.

At the present time, we are developing a wireless telemonitoring system with dual CdTe probes. In the upper part of the figure 9, one of our technical staff wearing our dual CdTe probe system, is walking on the treadmill and climbing up stairs. The lower part of the figure shows a real time display of the time activity curves of the left ventricle and pulmonary or background .

Figure 10 shows an example of the area covered by telemonitoring in our department of nuclear medicine. In straight direction, data can be transmitted as far as one hundred meters.

In summary, wireless telemonitoring of the left ventricular pump funtcions and pulmonary blood volume with radio nuclide has been attained by our new system. With this system, the rapid responses of the left ventricle to the various interventions can be monitored continuously. Therefore, capability of this system may open a new field in nuclear cardiology.

Table 1

Effect of ISDN sublingual administration

	pre	post
HR	66.0 ± 4.8	72.3 ± 9.2*
EF	49.6 ± 7.5	53.6 ± 9.4*
PBV	48.1 ± 8.8	46.5 ± 9.1*
EDV	31.5 ± 8.0	27.7 ± 6.9*
ESV	17.3 ± 6.1	14.7 ± 5.5*

(n=8, OMI:6, AP:2)

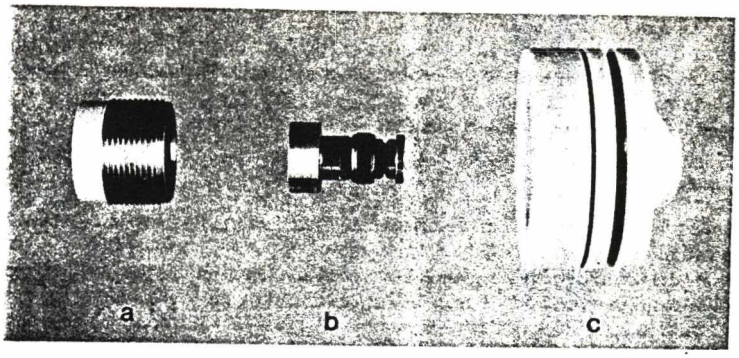


Fig. 1., Fig. 2. Detector module. (a) collimator, (b) CdTe detector, (c) plastic housing.

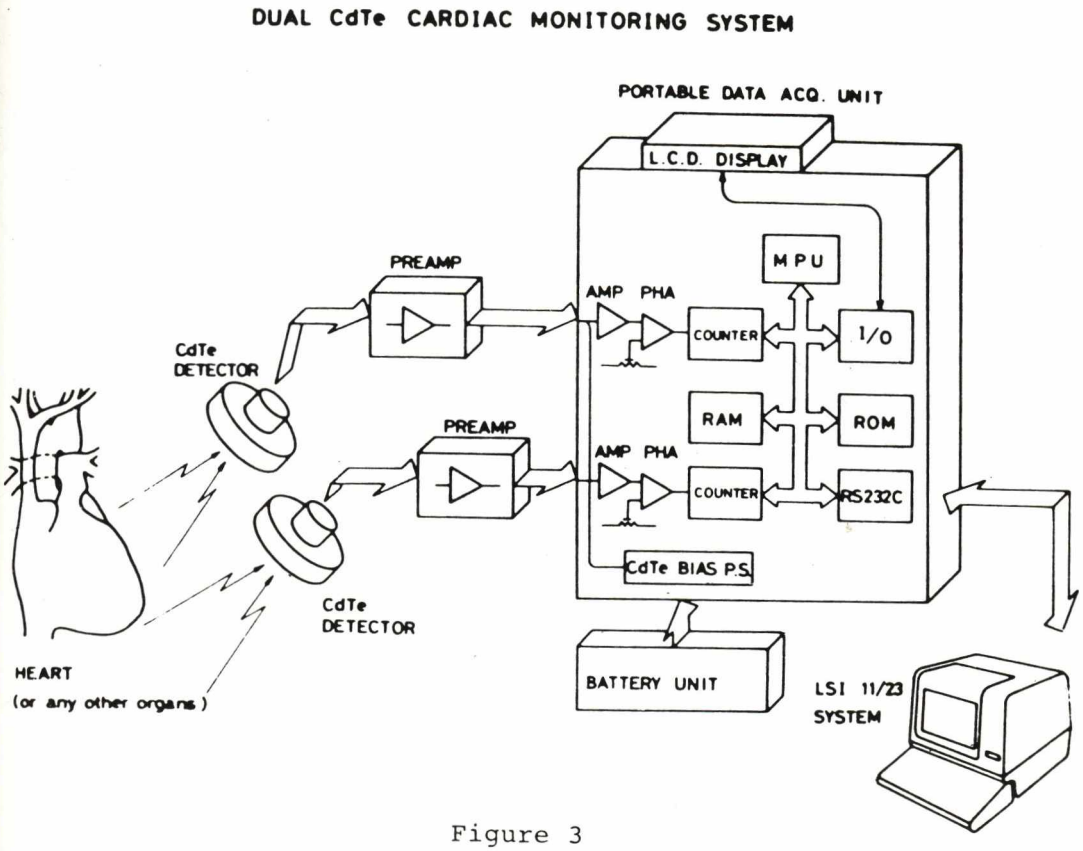


Figure 3

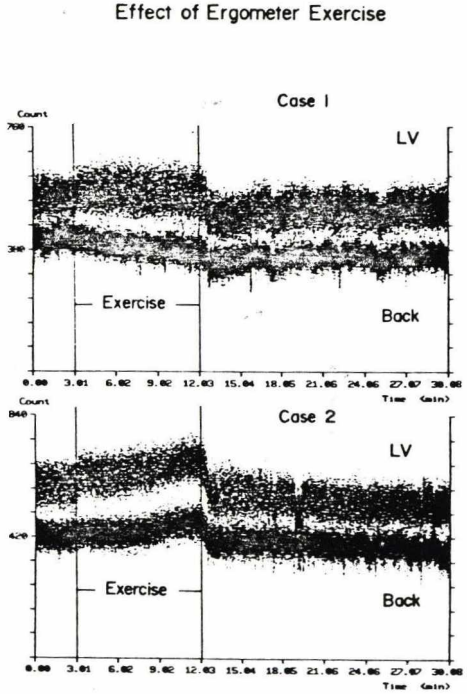


Figure 8

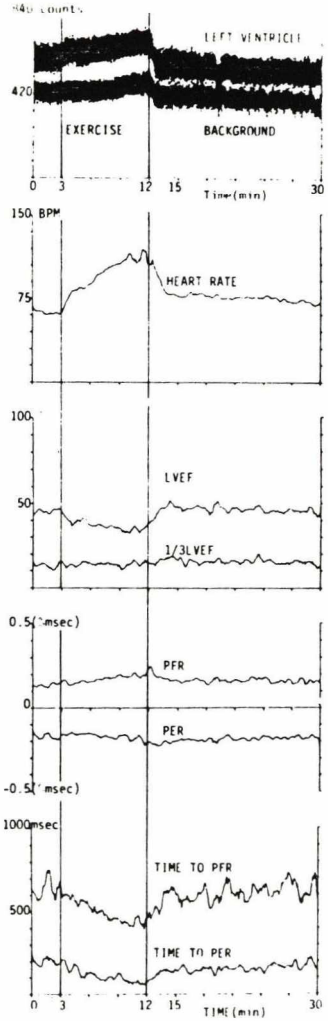


Figure 7

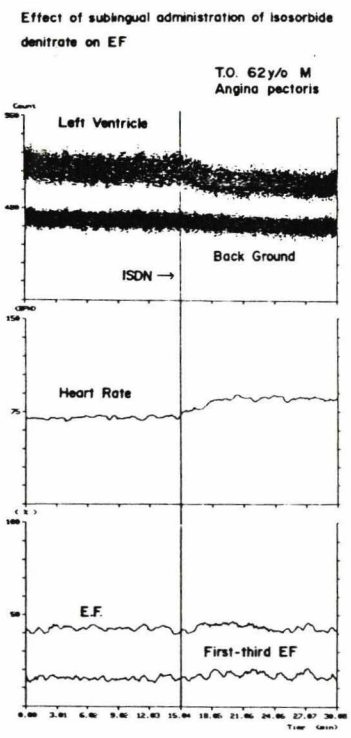


Figure 6

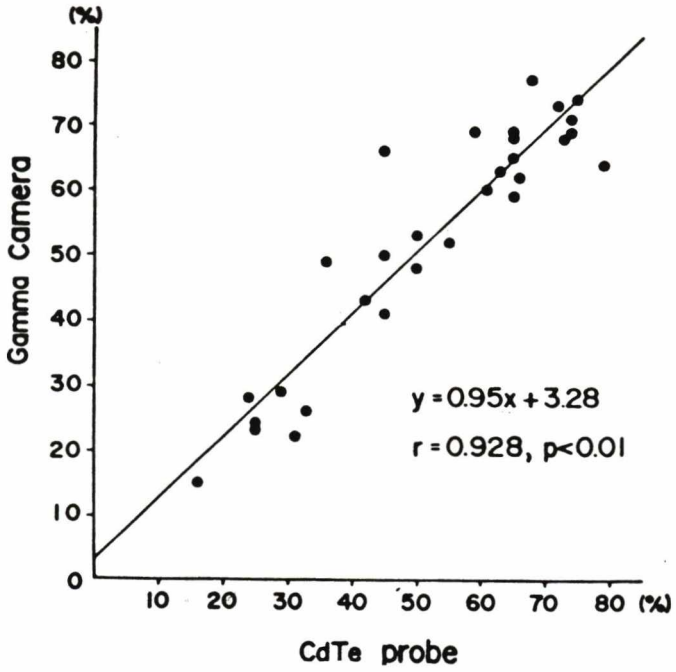


Figure 4

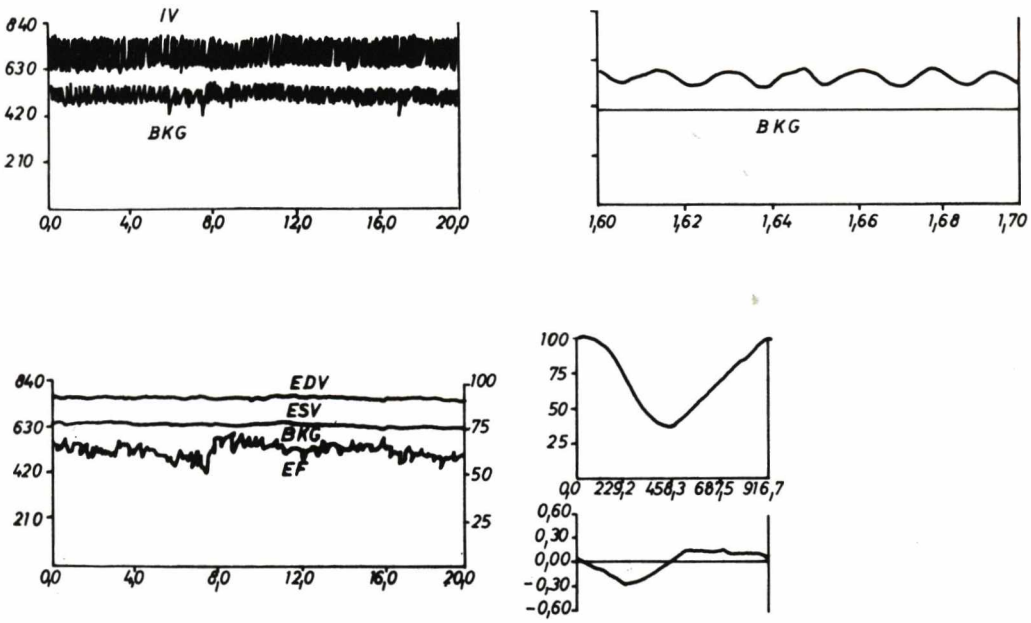


Figure 5.

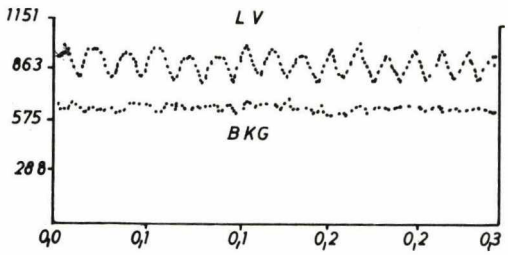


Figure 9.

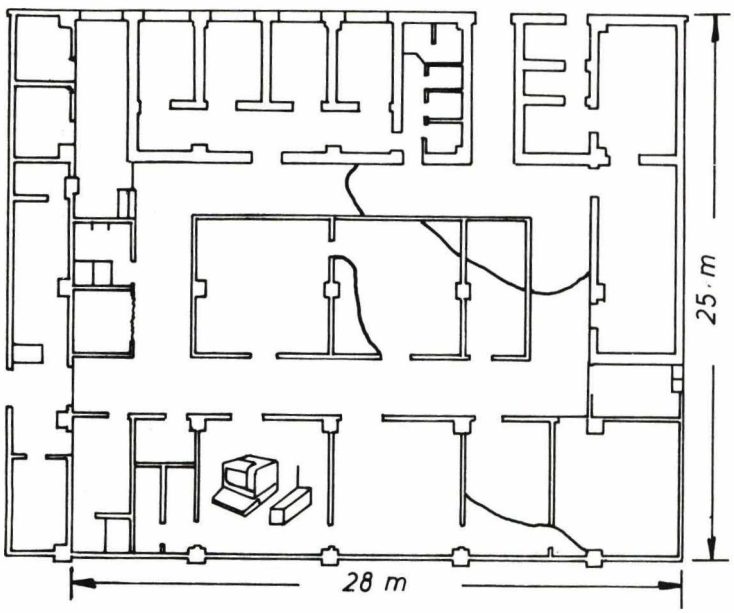


Figure 10.

RADIOCARDIOGRAPHY: ITS THEORY AND LIMITATIONS

J.T. Kuikka, T. Hirvonen, J. Mustonen, M. Pirnes, J. Remes, M. Helin, E. Länsimies

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Radionuclide blood pool techniques have been extensively used in the last two decades and these procedures have become essential dignostic tools. Single detector radiocardiography can be divided into two techniques: 1) low frequency (tracer dilution technique) counting or 2) high frequency (count based volumetric technique) counting. We shortly summarize these two techniques.

1) Low (100 msec) frequency counting radiocardiography

After an intravenous injection of tracer (Tc-99m RBC, in 113m, etc) the widening bolus-flow through the heart and lungs is monitored by a single detector. More or less complicated mathematical models are used to estimate right and left ventricular ejection fraction, stroke volume and cardiac output (i.e. strictly speaking systemic flow). This technique was generally used 10 to 25 years ago (Donato et al., 1962, Hoffmann et al., 1965, Horvath et al., 1966, Vernejoul et al., 1965, Heiskanen, 1971, Kuikka et al., 1974). There are theree fundamental problems in the actual measurement.

First, the input of tracer into the ventricle or even the injection of tracer is not instantaneous and the dispersion of tracer across a vascular bed, which is the result of tracer particles traversing vascular pathways with different mean transit times, cause the tracer time activity curve has a finite mean and time dependent variance.

Second, the vascular bed is a closed recirculating system and the effects of recirculation must be removed by making a mathematical approximation of the first passage of tracer through the system.

Finally, the radioactivity is not usually measured at both input and output ends of the circulating segments but rather externally to the system (residue detection).

These conditions result in distortion of the measured time activity curve. It may be assumed in a linear system that the function representing the recorded time activity curve at the measurement point is the result of convolutions of the detector, overlapping compartments etc) functions with the actual transfer function of the system studied. Unless

corrections were applied, these errors would result in a large overestimation of the transit time and cardiac output and underestimation of ejection fraction.
However, the results obtained by this technique are well comparable with those ones obtained by more elaborate techniques. Finally, I here summarize the results from 52 controls:

		at rest	during exercise (mean HR of 135)
LVEF		0,65 +/- 0.08	0,76 +/- 0.07
LVEDVI	(ml/m 2)	75 +/- 10	76 +/- 12
PBVI	(ml/m 2)	260 +/- 30	310 +/- 60
CI	(l/min/m 2)	3.3 +/- 0.5	7.7 +/- 1.4

Low frequency counting is sufficiently accurate to calculate ejection fractions and volumes directly derived from a simple mathematical relation. However, it should be emphasize that the ejection fraction and volume values calculated are not exactly anatomical volumes, but rather functional volumes. This is well understandable considering the assumptions on which the equations are based. They include linearity, steady flow, instantaneous mixing and time invariance; moreover the recirculation and input distribution approximation employed are empirical.

2) High (100 msec) frequency counting radiocardiography

Last ten years the count based volumetric technique has been generally used (Wagner et al., 1975, Horvath et al., 1976, Schneider et al., 1983, Lahiri et al., 1984). This method involves ECG-triggered, computer-processed recording of counts over the left ventricular area after tracer has achieved the equilibrium. The background-corrected activity (counts) changes are assumed to reflect the volumetric changes of the left ventricle. The excellent temporal resolution (up to 100 frames/sec) allows to visualize time and volumetric changes. The equipment is relatively easy to use, and the cost of the system is typically $50.000, only 1/4 of the gamma camera - computer. The measured parameters usually are:

- relative cardiac output
- relative stroke volume
- left ventricular ejection fraction
- relative left ventricular end-diastolic volume
- peak ejection rate
- peak filling rate

It also allows to look at ventricular performance even during single ventricular beats and these relative volume parameters can later be normalized to real volume units using a known (measured) cardiac output. These results usually based on three measurements:

- first-pass detection (low-frequency radiocardiography) to estimate cardiac output (systemic flow) and pulmonary transit time and volume
- monitoring (i.e. detector positioning over precordium; in the MLAO-40). How can we be sure we are viewing the left ventricle properly? There are theree characteristics: 1) the real-time display of the ventricular volume curve permits the physician to look at the curve where the stroke volume is its maximum (the horizontal display bar has its maximum) when he moves the detector from one position to another; 2) end-diastolic activity (counts) must be approximately twice the background; and 3) at the background position of the detector, inferolateral to the ventricle, the horizontal to the ventricle, the horizontal display bar has to be at its minimum. The background curve is recorded.
- beat-to-beat detection or summarized (30-120 sec) ventricular volume curve detection. The detector is repositioned at the left ventricle and a real time beat-to-beat volume curve is recorded and also a summarized volume curve (similar to that obtained with multiple gated blood pool gamma camera imaging).

Figure 1 shows typical curves and their results obtained from a patient with acute myocardial infarction.

The results are well comparable with the results obtained from the gamma camera measurements. Some questions still arise with respect to whether this method enough accurate and reproducible. Are the positioning problems insurmountable? Is the background correction correctly performed? The methods used in hospitals are always specific to a given hospital, because methods of analyses are not standardized. For example the mean values for normal resting LVEF vary from 0,50 to 0,70 depending on the methods and equip-

ment used. However, the single probe methods give extremely valuable information in patients management and care. The techniques are relatively simple and can be performed repeatedly both at rest and during exercise.

Clinical application

Finally we summarized some results from one clinical study. The influence of left ventricular systolic and diastolic function on cardiac events following acute myorcardial infarction was evaluated in 22 male patients, aged under 65 years. A nonimaging nuclear stethoscope (Bios Inc., Valhalla, New York) was used to determine left ventricular ejection fraction (LVEF) and peak ejection rate (PER). The first study was repeated 8-12 days later. Immediately after the second study a radionuclide ventriculography (RNV) was performed using a Siemens LFOV (ZLC) gamma camera. The gamma camera results served as a control for the nuclear stehoscope.

There was a significant (p 0.001) correlation (r = 0.86) in LVEF between these two last determinations. The mean LVEF was 0.45 +/- 0.11 (range: 0.35 - 0.73) immediately after the onset and 0.47 +/- 0.12 prior to hospital discharge. The difference was not statistically significant. Peak ejection rate varied from 2.1 to 4.1 l/sec. One patient who died on the third day after infarction LVEF was only 0.25 and PER 1.6 l/sec.

A nuclear stethoscope provides a cheap and noninvasive tool to assess ventricular function in acute myocardial infarction and to depict patients with high mortality risks (resting LVEF 0.30 and PER 2.0 l/sec). It is easy to use and is a well-suited method in cardiac care unit.

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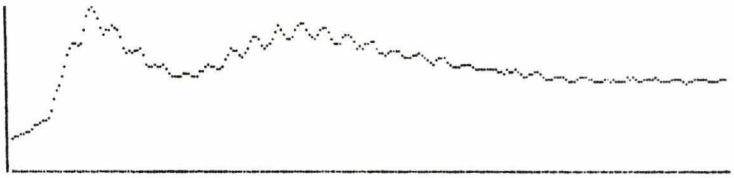
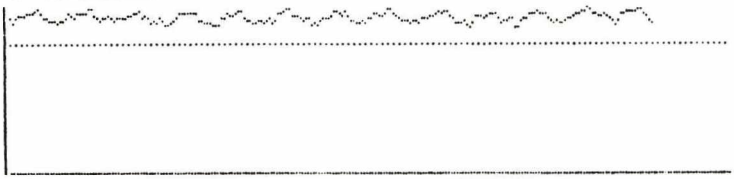
FIRST TRANSIT MODE



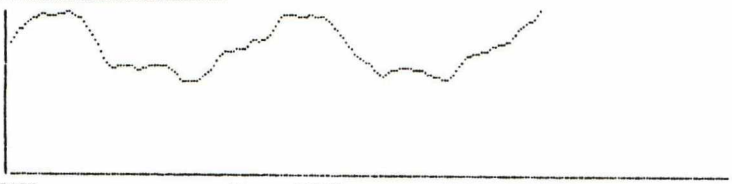
CARDIAC OUTPUT RATIO	1.84	V/M
PULMONARY TRANSIT TIME	7.4	S
CARDIAC OUTPUT	7.8	L/M
PULMONARY BLOOD VOLUME	965	ML
CARDIAC INDEX	4.1	L/M/M2

POSITION MONITOR MODE



HEART RATE	67	BTS/M	STROKE VOLUME	0.44	EDV
EJECTION FRACTION	44	%	END DIASTOLIC VOLUME	1.00	EDV
EJECTION RATE	0.99	EDV/S	FILLING RATE	0.99	EDV/S
EJECTION TIME	446	MS	FILLING TIME	445	MS
CO	29.6	EDV/M			

VENTRICULAR FUNCTION MODE



HEART RATE	68	BTS/M	STROKE VOLUME	0.52	EDV
EJECTION FRACTION	52	%	FILLING RATE	1.45	EDV/S
EJECTION RATE	1.16	EDV/S	FILLING TIME	340	MS
EJECTION TIME	450	MS	PEAK FILLING RATE	2.47	EDV/S
PEAK EJECTION RATE	3.97	EDV/S	TIME TO PEAK FILLING RATE	80	MS
CARDIAC OUTPUT	35.6	EDV/M	CARDIAC INDEX	3.0	L/M
END DIASTOLIC VOLUME	1.00	EDV			

Fig. 1. Typical computer printouts of the first-pass study (upper), position monitoring (middle) and ventricular function study (bottom). Note the paradoxal "hump" in the ventricular volume curve (apical aneurysm).

ASSESSMENT OF LEFT VENTRICULAR PERFORMANCE AND ITS FOLLOW-UP AFTER AN ACUTE MYOCARDIAL INFARCTION BY A NUCLEAR STETHOSCOPE

J. T. Kuikka, E. Länsimies and Coworkers

The influence of left ventricular systolic and diastolic function on cardiac events following acute myocardal infarction was evaluated in male patients, aged under 65 year. A nonimaging nuclear stethoscope (Bios Inc, Vahalla, New York) was used to determine left ventricular ejection fraction (LVEF), end-diastolic volume index (LVEDVI), stroke volume index (SVI) peak ejection rate (PER), and peak filling rate (PFR). The firts study was taken 24-48 horus after the onset of the symptoms, and the study was repeated 10-14 days later. Immediately after the second study a radionuclide ventriculogrpahy (RVG) was performed using a Siemens LFOV gamma camera. The gamma camera results served as a standard for the nuclear stethoscope. There was a singificant (p 0,001) correlation in LVEF (r=0,84, n = 42) and in LVEDVI (r = 0,77) between these two determinations, but the correlation of SVI remained lower (r = 0,35). According to our preliminary results LVEF varied between 35-73 % , PER 2.1-3.8 l/s, and PFR 1.9-3.9 l/s expect of one patient who died on the third day after infarction (25 %, 1.8 l/s and 1,6 l/s, respectively).

A nuclear stehoscope provides a cheap and noninvasive tool to assess ventridular function in acute myocardial infarction and to depict patients with high mortality risks. It is easy to use and is a well-suited method in cardiac care unit.

The patient is 64 years old male with CAD.

The equipment is a Siemens LFOV (ZLC) gamma camera with a LEAP collimator.

The tracer is in vivo Tc-99m labeled red blood cells.

The patient is lying is supine position on the measuring table and two radionuclide studies are done:

1) the list-mode first-pass in RAO-15 projection, and
2) the MUGA in MLAO-40 projection.

The list-mode first-pass study shows that the global LVEF is 38 % with apical hypokinesia. The MUGA study matches with the first-pass study. From this simple example you can easily seen that the gamma camera first-pass studies are available even with the conventional gamma cameras. Of course the counting statistics is poor (in this case 1836 counts at end-diastole and 1067 counts at end-systole) but in the accessable limits. The functional images (phase and amplitude) even more reveal the superiority of the imaging study. However we are also using the single probe in CCU, because it is always available, and it gives the global ejectionfraction which may be enough from the clinical point of you.

COMPARISON OF THE COMPUTERIZED PROBE AND GAMMA CAMERA FOR THE MEASUREMENT OF THE GLOBAL LEFT VENTRICULAR EJECTION FRACTION AND CONTRACTION DYNAMICS

A. Tarkowska.

Department of Nuclear Medicine, Medical Academy, Lublin, Poland.

Introduction

Cardiac porbe, introduced by Hoffmann and Kleine in 1965 /6/ and developed further by Wagner et al /13/, draws attention of nuclear medicine physicians and scientists mainly because of such qualities, as: relativley low price; small weight and dimensions enabling easy transportation to the bed of the patient; ease of operation; high sensitivity of the detector; different modes of determination of left ventricular /LV/ function, including both ECG-gated study and beat-to-beat study; calculation and presentation of heart fuction parameters in real time, enabling, among others, continous monitoring of severely ill patients, monitoring drug effects or monitoring arrhythmias /1-3, 5, 7-13/.

However, it should be taken into account that chances of false results are greater in measurements of LV function with a nonimaging computerized probe than in those with a scintillation camera /1-3, 7, 9-11/.

First, measurements by probe are connected with a risk of errors due to the positioning of the background /B/ area. The best approximation to the real background is in immediate vicinity of LV border and this area should be localized by the probe.
Shifting the detector more to the right results in including heart activity into measurements, which means B-overestimation and, in consequence, overestimation of EF. On the other hand, shifting the detector to the left usually means B-underestimation leading to underestimation of EF /Fig. 1./.

Further, there is a risk of errors due to positioning of LV area. The field of view of the probe should cover the region between medial and lateral border of LV, avoiding both the atrium and apex. Shifting the probe to the right or to the left results in underestimation of enddiastolic-endsystolic /ED-ES/ count differences due to the effect of less contracting parts of LV and to contribution of the right ventricular or B area. That means underestimation of LV function. Shifting the probe upwards means contribution

of atrial activity and also results in underestimation of LV function . Shifting the probe downwards and projecting it over the apex reigon leads to overestimation of ED-ES count differences because the strongly contracting apex escapes from the detector field of view in end-systole /Fig. 2./

Next, in measurements with probe there is a risk of errors due to collimator characteristics. Depending on collimator properties, counting efficiency and field of view of the detector change with the distance from the collimator face, resulting in distortion of countrate- volume relationship.

Moreover, there is a poor fit between the elipsoidal shape of LV and the smaller, circular field of view of the probe /Fig. 2./ For this reason ES-ES count differences measured by probe are not representative for the whole left ventricle. Hence, in patients with regional wall motion abnormalities /RWMA/ the results of measurements differ, depending on whether the probe in positioned over a normally contracting area or over a pathologic one. Taking into account the strategy of probe positioning, rather an overestimation of LV fuction should be expected in these patients.

In view of all those error possibilites, the study was undertaken to compare evaluation of LV function by computerized probe with that by camera.

Materials and methods

The test group comprised 30 subjects, aged 24-77 years, including 6 normals and 24 patients with heart diseases. Four patients had RWMA, but in none of them LV aneurysm was diagnosed. All subjects were in normal sinus rhythm.

Measurements were performed at rest, with subject supine, after homogeneous distribution in blood pool of 99mTc-erythrocytes labeled in vivo had been reached.

The ECG-gated camera ventriculography was performed first, and examination by computerized probe began immediately afterwards. For the purpose of the study, a commercially available scintillation detector with Ø 40 mm x 25 mm NaI /Tl/ crystal was equipped with a single-hole converging collimator and interfaced to a microcomputer based on Intel 8080 microporcessor with 5 k EPROM and 2 k RAM. The probe was placed over the heart area at an angle of 30^{0} left anterior-obliquely. The regions of interest were defined according to accepted principles /1,2,10-13/, basing on the beat-to-beat time activity curve and on the analogous-index in form of a bar, both displayed in real time on on the screen.

In the beat-to-beat study, LV activity was measured using time resolution of 20 msec. Time activity curve and ECG signal were presented continuously, in real time. Beat-to-beat ejection fraction /S btb EF/ was calculated automatically and displayed inreal time. S btb EF from 10 consecutive cardiac cycles was used in each subject to compute the mean value.

In ECG-gated study, LV activity was measured and integrated during 128 cycles, using time resolution of 10 msec. Ejection fraction /S EFg/, mean ejection rate /S ER/ and mean filling rate /S FR/ were calculated and displayed automatically after manual selection of points of interest in the time activity curve obtained.

In order to check the reproduciblity of LV parameters measured by computerized probe, the study was repeated twice by the same observer in 20 subjects and in 22 subjects the study was repeated by two independent observers. The results of the repeat observations were compared using t-test for paired data.

The mean values of S EFg, S ER and S FR obtained from the repeat studies as well as the mean values of S btb EF were compared with corresponding parameters determined by camera using correlation and regression analyses. The following parameters measured by camera were taken for these comparison; ejection fraction /C EF/, mean ejection rate /C mER/ peak ejection rate /C pER/, mean filling rate /C mFR/, and peak filling rate /C pFR/.

Results

No significant differences were found between repeat values of S EFg, S ER and S FR obtained by one observer and by two observers. The variability of measurements, expressed in parameter units, was respectively: 3.22 and 2.44 by S EFg, 0.14 and 0.16 by S ER, and 0.19 and 0.14 by S FR /Table 2./

The results of comparisons between the parameters under study are presented in Table 3. An excellent agreement was found between C EF on one hand and both S EFg and S btb EF on the other /Fig. 3 and Fig. 4/. These relationships were linear over the whole range of values observed. The regression analyses revealed a slight tendency to overestimate the results by probe as compared with those by camera, especially at lower EF values. This tendency was more expressed by beat-to-beat measurements, than by gated study.

A very close relationship existed between S EFg and S btb EF r=0.937; S btb EF=12.00 + 0.89 S EFg/ /Fig.5/.Weakerthan byEF,but still good agreements were found in both comparisons of ER /Fig. 6/. The relationship between C pFR and S FR was distinctly poorer, but not bad. On the other hand, weak correlation only was observed in comparison of S FR with C mFr.

Discussion

The data presented above agree both with our earlier results /11/ and with observations by other authors /1-5, 7-10, 12, 13/. They indicate that, in spite of the previously mentioned error possiblities in measurements by probe, the operator routines based on beat-to-beat time activity changes allow appropiate regions of interest to be satisfactorily defined and true results of evaluation of LV function to be obtained.

The values of mean ER and mean FR obtained by probe considerably higher than those determined by camera result from different modes of calculating these indices in both methods compared. By camera they are expressed as count difference during ejection or fast filling period per time unit, normalized per Ed counts; by probe - as count difference per time unit, normalized per mean counts measured over LV area.

Conclusions

1. Computerized probe provided a reliable evaluation of LV function;

2. EF is determined by probe with great accuracy both on ECG-gated and on beat-to-beat basis.

Summary

Left ventricular EF, mean ER and mean FR were determined by computerized probe /S/ in 3o subjects and compared with corresponding parameters obtained by camera /C/. All comparisons of EF and ER revealed very good agreements, with correlation coefficients r = 0.774 - 0.839. Distinctly poorer but still significant relationships were observed between C pFR and S FR /r = 0.711/ as well as between C mFR and S FR /r = 0.460/. Intra-and inter-observer variability of parameters measured by probe was low.

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Table 1. Intraobserver veriability of LV parameters measured by probe.

Parameter	No of repeat studies	1st study mean	± SD	2nd study mean	± SD	paired t-test	Standard Error
S EFg	20	66,0	14,5	61,7	13,1	NS	3,22
S ER	20	2,69	0,53	2,53	0,56	NS	0,14
S FR	20	2,60	1,04	2,38	0,93	NS	0,19

Table 2. Interobserver variability of LV parameters measured by probe.

Parameter	No of reperat studies	1st observer mean	± SD	2nd observer mean	± SD	paired t-test	standard error
S EFg	22	59,2	12,5	62,1	12,4	NS	2,44
S ER	22	2,49	0,70	2,63	0,79	NS	0,16
S FR	22	2,13	0,61	2,23	0,73	NS	0,14

Table 3. Correlation between LV parameters measured by camera /C/ and by probe /S/

Parameters compared X	Y	n	X mean	± Sd	Y mean	± SD	r	Regression equation
C EG	S EFg	30	55,9	10,2	59,2	11,3	0,839	Y=7,60 + 0,93 X
C mER	S ER	30	1,61	0,34	2,37	0,51	0,776	Y=0,49 + 1,20 X
C pER	S ER	30	2,61	0,56	2,37	0,51	0,774	Y=0,53 + 0,71 X
C mFR	S FR	29	1,05	0,31	2,01	0,62	0,460	Y=1,00 + 0,92 X
C pFR	S FR	29	1,90	0,51	2,01	0,62	0,711	Y=0,38 + 0,86 X
C EF	S btb EF	29	56,5	10,0	64,9	10,8	0,809	Y=16,0 + 0,87 X

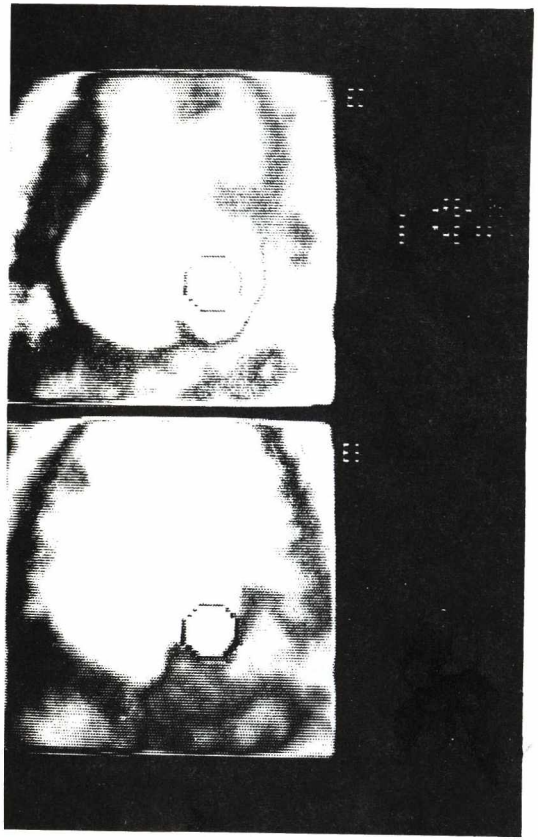


Fig. 2.
LV area "seen" by the probe in end-diastole /upper square/ and in end-systole /lower square/.

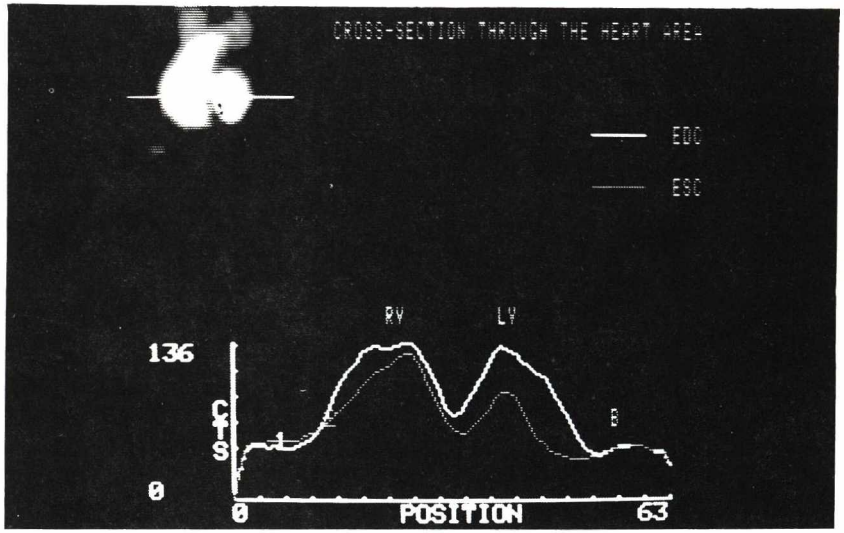


Fig. 1.
Cross-section through the activity of both ventricles and surrounding tissues in end-diastole /EDC/ and in end-systole /ESC/. RV-right ventricle; LV-left ventricle; B - background area.

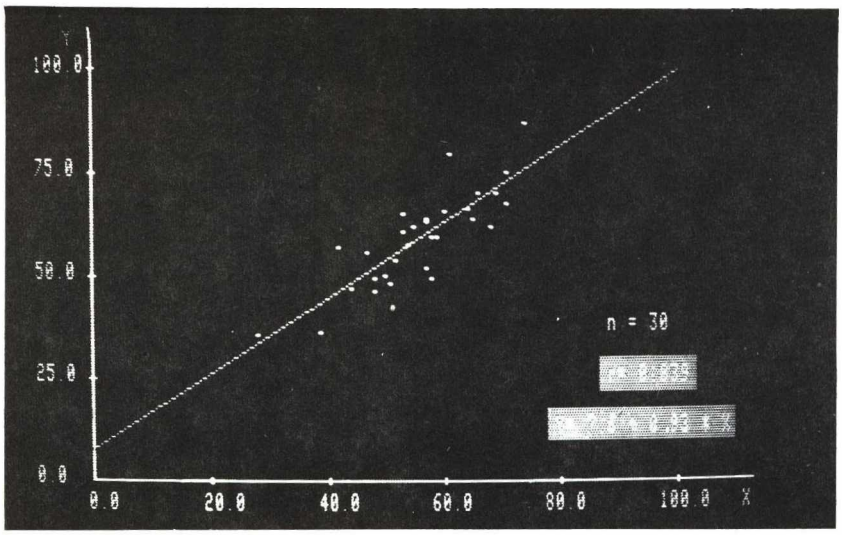


Fig. 3.
Correlation between C EF /X/ and S EFg /Y/. Correlation coefficient r = 0.893. Regression equation: Y = 7.60 + 0.93 X.

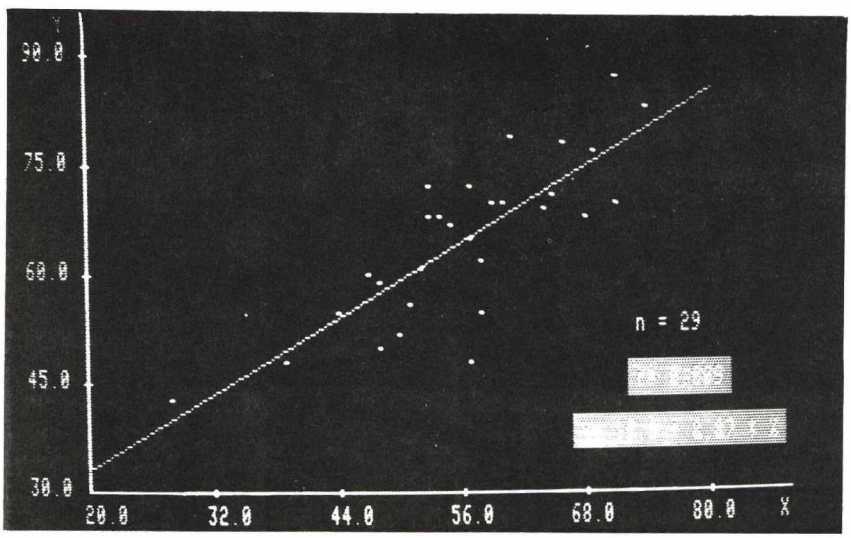


Fig. 4.
Correlation between C EF /X/ and S btb EF /Y/. Correlation coefficient r = 0.809. Regression equation: Y = 16.0 + 0.87 X.

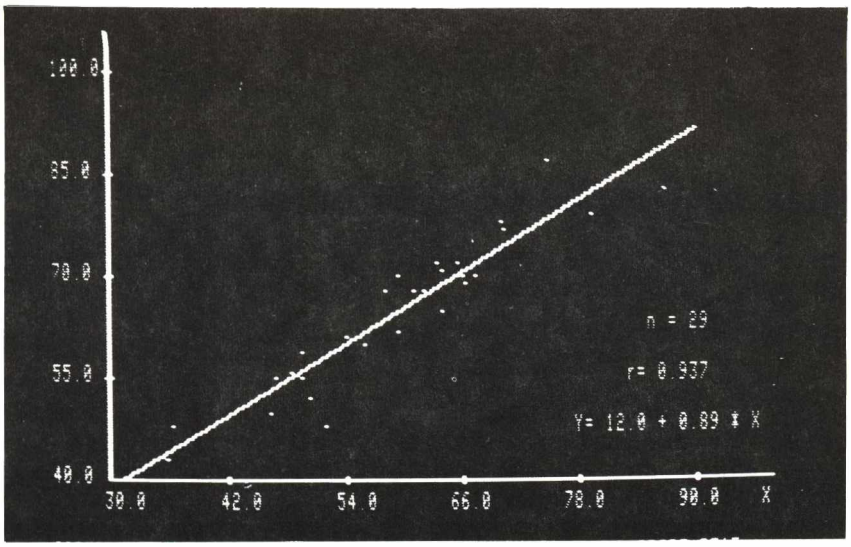


Fig. 5.
Correlation between S EFg /X/ and S btb EF /Y/. Correlation coefficient r = 0.937. Regression equation: Y = 12.0 + 0.89 X.

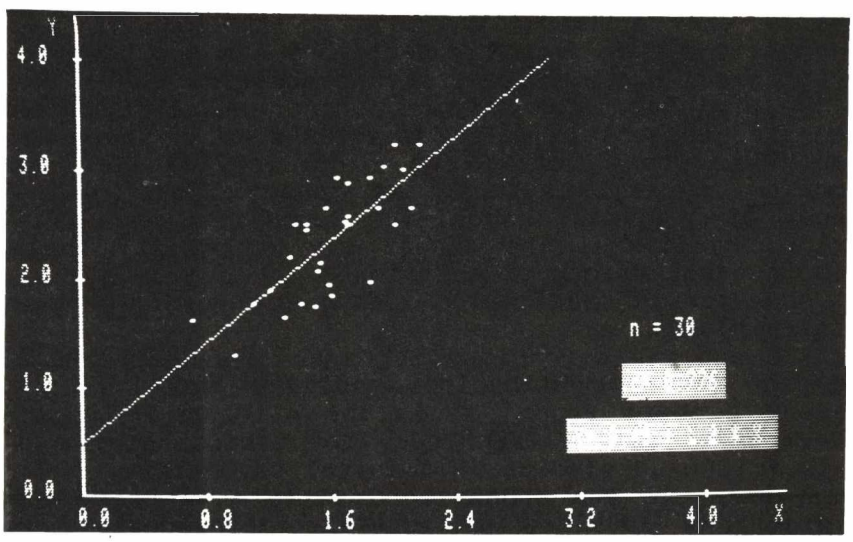


Fig. 6.
Correlation between C mER /X/ and S ER /Y/. Correlation coefficient r = 0,776. Regression equation: Y = 0.49 + 1.20 X.

CLINICAL VALUATION of RADIOCARDIOGRAPHY

M. Istvánffy M.D, Zs. Tarján, M. R. Halmágyi, D. Pártos, M. Lengyel, L. Cserhalmi

Hungarian Institute of Cardiology, Budapest

Progress in medical science and in cardiology as well, has been so rapid and so real, that every day now we expect to learn new methods,- new miracles.
All this week you could hear excellent rewiews and papers of the newest discoveries and technological advences in the field of nuclear medicine, with promises of more to come. But after all, we must recognize that not all analytical data are especially valuable. There is a powerful but evil temptation for us to become intellectually arrogant, duzzled by the computer printout and shadowy depictions of isotopes.
Professor Thomas James, President of the Tenth World Congress of Cardiology told in his presidental address: "I am fearful that we are depending too much on new technology in making diagnostic and therapeutic decisions and not adequately using our clinical judgement and common sense.
In the mix of art and science, which have always been equally essential components of a physician's work, there was a time, when there was a lot of art and a very little science. But pendulum naturally swings, and today we are in a very real danger of becoming insensitive technician-scientist and not caring physicians. The danger may be greater in cardiology than in other branch of medicine"
But now,- could one imagine today's cardiology without nuclear cardiology?
Today's nuclear cardiology is based upon yesterday's cardiology and yesterday's nuclear medicine, and I would like to present a short report about the clinical value of an old, every day's routine technique, the radiocardiography, applied in follow-up studies in clinical cardiology.
Since 1972, in the Hungarian Institute of Cardiology radiocardiography provides an accurate, reproducible method to determine cardiac output, calculate stroke index with the syncronized ECG and meanwhile in well-counter measured actually circulating blood volume, based on a used, suitable,

in the blood complete mixing radioactive indicator. /Figure 1/

RADIOCARDIOGRAPHY

99mTc-HSA i.v. bolus.

"In house" normal values:

Cardiac index:	3,67	± 0,31	liter/min/m2
Stroke index:	45	± 5	ml/m2
MPTT:	6,7	± 0,8	heart cycle

The prognosis of ischemic heart disease in determined essentially by the severity and extension of coronary stenotic lesions and by left ventricular function.
The purpose of our study was to investigate prospectively the prognostic value of data of applied non-invasive methods, including radiocardiography, in ischemic heart disease.
In the Hungarian Institute of Cardiology, in 1981-1983, five-hundred patients underwent coronarography.
Follow-up investigations with clinical and non-invasive methods were performed during a three-years follow-up period. /Figure 2/.

IHD
Follow-up period: 3 years
Number of patients: 500 365 male 115 female
mean age: 49,2 years
NYHA II-III.

Coronarography	patients %
normal coronarogram:	25,2 %
single-vessel disease:	18,8 %
double-vessel disease:	12,0 %
triple-vessel disease:	44,0 %

Left ventriculography

LVEF > 0,54 LVEDP < 12 mmHg	51 %
0,50 > 14 mmHg	26 %
< 0,30 > 20 mmHg	23 %

The clinical, coronarographic and left ventricular functional characteristics of patients are listed in the next table. The coronarograms were normals in 25% of the cathererized patients.
We have found in 18% single-vessel, and in 56% multivessel co-

ronary artery disease, respectively, with greater than 50% luminal stenosis of arteries.
At rest there were no significant differences in heart rate, mean aortic pressure and pressure-rate product between these groups.
Left ventricular function, based on LVEDP an LVEF values, were normals in 51% of patients. /Figure 3./.

IHD
Number of patients: 500

		n	male	female	%
Group I.	normal coronarograms	116	65	51	23,2
	single-,or multivessels coronary artery disease				
Group II.	-suitable for revascularization	245	196	49	49
Group III.	-non suitable for revascularization	121	108	13	24,2
Group IV.	impaired left ventricular function	18	16	2	3,6

According to the coronarogram and left ventricular function, patients were divided into four groups, for further analysis.
Group **I.** was composed of 116 patient, without significant coronary artery disease.
Group **II.** was composed of 245 patients, with single-, or multivessel disease. All of them were suitable for revascularization.
121 patients were in the Group **III.** and all of them were not recommended to surgical revascularization, and medically treated.
In the Group **IV.** were 14 patients with impaired left ventricular function, with normal or mild stenotic coronarograms. /Figure 4./

IHD
n: 500

	LVEF	LVEDF
Group I.	0,61 ± 0,13	11,57 ± 3,2 mmHg
Group II.	0,51 ± 0,13 p%<5	11,56 ± 3,0 N.S.
Group III.	0,37 ± 0,16 p%<0,1	15,62 ± 6,8 p%<5
Group IV.	0,22 ± 0,11 p% < 0,1	23,7 ± 7,9 p% < 0,1

You can see here the values of left ventricular ejection fraction and left ventricular end-diastolic pressure in the four composed groups, with significant difference between the normals and those ischemic disease, and between the suitable and non-suitable groups for revascularization. /Figure 5./.

IHD
n:100

	Cardiac index liter/min/m2	Stroke index ml/m2
Group I.	3,79 ± 0,81	53,02 ± 12,0
Group II.	3,09 ± 0,50 p% < 1	46,09 ± 11,03 N.S.
Group III.	3,05 ± 0,82 p% < 1	43,13 ± 13,6 p% < 5
Group IV.	2,38 ± 0,53 p% < 0,1	28,5 ± 7,59 p% < 0,1

Mean cardiac index and stroke index values of 100 patients are demonstrated in the next slide, with similar, significant differences between the normal group, and groups with coronary artery disease, and with decreasing tendency in the direction of impaired left ventricular function.
There is no close correlation between left ventricular ejection fraction and stroke index. Regression coefficient was 0,683. /Figure 6./.

IHD
n:100

M-mode echocardiogram

	left atrial diamter mm	e-ivs distance mm
Group I.	34,17 ± 4,7	3,6 ± 2,7
Group II.	34,31 ± 5,9 N.S.	7,2 ± 4,6 p % 5
Group III.	36,12 ± 7,7 N.S.	12,2 + 9,2 p % < 0,5
Group IV.	41,14 ± 3,9 p % 5	25,43 + 9,7 p % < 0,1

We have also found similar characteristics and correlations with echocardographic findings, and /Figure 7./.

IHD

n: 100

	PEP/LVET
Group I.	0,380 ± 0,106
Group II.	0,377 ± 0,082 N.S.
Group III.	0,462 ± 0,094 p% < 5
Group IV.	0,515 ± 0,130 p% < 0,5

in the mechanographic PEP/LVET values as well.

IHD

n: 100

	Exercise capacity watt
Group I.	101,67 ± 42,1
Group II.	79,10 ± 38,1 p% <0,5
Group III.	70,74 ± 29,63 p% <0,1

The sympton-limited maximal exercise capacity was significantly higher in the group with normal coronarogram.

Follow-up

The subjects were seen as outpatients in every year-, the patients, who had undergone ACBG or PTCA revascularization, 3,- 6,- 12 months after the operation, and subsequently in every year. When clinically indicated, patients were seen more frequently, until their clinical status was stable.
We have obtained and analyzed the follow-up data of 472 patients.
The three years survival rate is 77%.
There was no death in the normal coronary artery groups.
The highest mortality was in multivessel diseased patients, with severely impaired left ventricular function, 36 %.
Cause of deaths:
91% of deaths were of cardiac origin, 56,5% of cases because of myocardial infarct. /Figure 11./.

IHD

Data of 100 patients after 3 years follow-up period

	n	LVEF /RNA/	Cardiac index /liter/min/m2	Stroke index ml/ m2
Group I.	23	0,59	3,54	47,7
Group II.	50	0,54	3,49	46,5
Group III.	22	0,32	2,18	24,6
Group IV.	5	0,20	1,90	19,2

At the end of three year follow-up period, we obtained the next nuclear parameter , and demonstrate the data of 100 consecutive patient.
LVEF were determined by an equilibrium radionuclid angiocardiography. In the group II. 38 patients underwent coronary artery bypass graft operation, with 1-3 grafts. The progressive decrease in LVEF and cardiac index, and stroke index as well, can be seen in the group III. and IV.
These "first pass" data were in paralel, with those registered and determined in the same time by the new "nuclear probe system" of Hungarian Gamma Corporation. /Figure 12./
The comparative study showed very good correlations, between the two techniques.
Although, according to our earlier investigation, normal cardiac index may be measured at rest in left ventricular insufficiency, the decreased values clearly show the hemondynamic differences between the groups, and may be evaluated as a charecteristic sign of the progression.

DÁTUM : 1987 JÚLIUS 15

AZONOSÍTÓ SZÁM :

NEM(F,N) : F

TESTSÚLY(KG) : 86

TESTMAGASSÁG(CM) : 187

TESTFELSZÍN(M2) : 2.1

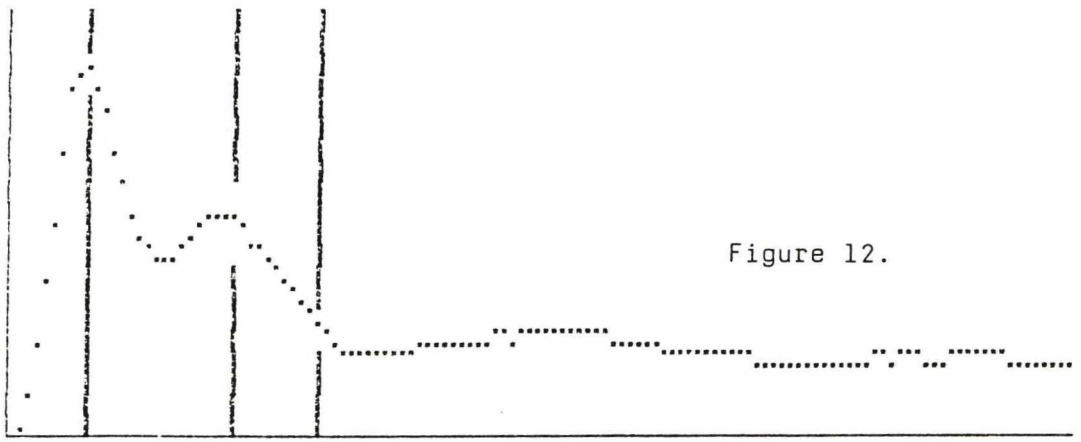
PULZUSSZÁM(/MIN) : 62

MEGJEGYZÉS : 126/70

NUCLEAR CADIAC PROBE
RADIOKARDIOGRAPH
NK-362

Gamma Works
Hungary

1058 C/0.4SEC



0 T1= 4.0SEC T3= 14.8SEC 50SEC

T2= 10.8SEC C3=284

PV= 6.07L/MIN PVI= 2.89L/MIN/M2 MPT= 7.03CIKL

SV= 97.94ML SVI= 46.64ML/M2 VV = 5.90L

Figure 12.

Electrocardiography – Cardiac Monitoring NK-362

Operation modes:

1. Sprectrum mode
   energy range from 15 keV – 1265 keV
2. First pass mode
   cardiac output, pulmonary transit time measurement
   time resolution: 100 msec, 200 msec, 400 msec, 900 msec
3. Monitor:
   left vetricle activity curve and ECG signal simultaneously displayed with 20 ms sampling time
4. R – R mode
   R – R wave interval histogram
5. Ventricular function mode
   calculation of ejection fraction, filling and emptying parameters

Applications:

ejection fraction measurement

intensive care unit monitoring of acute myocardial infarction

post-surgery monitoring

pre-angiography/camera screen examinations

disengaging of gamma cameras

Betriebsarten

1. Spektrum
   Energiebereich 15 keV – 1265 keV
2. Erste kardiale Indikatorpassage
   Herzminutenvolumenmessung, Messung der durchschnittlichen pulmonalen Durchflußzeit
   Zeitschritt: 100 msec, 200 msec, 400 msec, 900 msec
3. Darstellung auf dem Bildschirm:
   Die gleichzeitige, ständige Darstellung des Herzblutvolumens und des EKG-Signals mit 20 msec Auflösung
4. R – R Modus
   R – R-Zackenhistogramm mit 20 msec Auflösung
5. Ventrikelfunktion
   Ejektionsfraktion, Messung des Füllungsvolumens und des Restvolumens

Anwendungsgebiete:

Messung der Ejektionsfraktion

Beobachtung von Patienten mit akutem Myocardinfarkt auf Intensivstationen

Beobachtung nach Operationen

Prüfung vor Untersuchungen mit Angiographie und Gammadetektor

Entlastung von Gammakameras

GAMMA WORKS-Budapest

NUCLEAR CARDIAC PROBE

Radiokardiograph

CADMIUM-TELLURIDE (CdTe) MINIATURE PROBES FOR CARDIAC MONITORING BASED ON MUGA STUDY-PRESENT LIMITATIONS

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PURPOSE OF THE WORK

To study the feasibility of nuclear medicine cardiac studies with an home-built miniature probe system based on Cadmium-Telluride semiconductors detectors.

INTRODUCTION

Ambulatory monitoring of ventricular function parameters together with ECG data could be of some help in the management of patients wiht cardiac pathologies. For example for choosing a more personal therapeutic schema. Various detectors can be use if they are sufficiently small, light and their power consumption low. Conventionnal INa porbe are not suitable for this purpose but a new small collimated probe is now commercially available (VEST from CAPINTEC). Semi-conductors detectors represent an alternative choice which could be discussed.

The Nuclear medicine service of the Institut de Physique Biologique (IPB) (Strasbourg) has built with the detector group of Pr. GALLMANN at the Nuclear Research Center (CRN-Strasbourg Cronenbourg) a two probe portable autonomous gamma detector system (1). This apparatus was used to monitor the renal function (1). Some cardiac studies were processed with an home-built micro-processor unit (2). As describe by others authors (3, 4) severe limitations of these small probes were found in dynamic studies where high sampling rate are required. The potential clinical interest of such techniques and the arrival of new technologies in the domain of electronics miniaturization decide us to perform new investigations before starting a new research project based on a multidetector matrix system.

Material and methods

Since 1969 the detector group of CRN made basic and apply research work on semi-conductor detectors. Among various detectors available we choose a Cadmium-Telluride P-type chlorine doped detector (5,6).

The traveling heating method (THM) was used for crystal growth

CdTe detector specifications:
resistivity. 10e-6 to 10e-9 Ohm.cm
current-leakage: 10e-7 to 10e-10 A for 100-1000V bias voltage.
e+e- energy: 4,46 eV (300 K) compare to 2,98 eV for Germanium at 77K; crystal thickness 4-6 mm.; 88 % attenuation for 144 KeV (99mTc photopeak). Both the detector and the electronics were built at the CRN.
Electronics: A charge preamplifieris followed by operationnal amplifiers and a single channel pulse-height discriminator.The circuits have a low power consumption, allowing battery supply (Cadmium-Nickel).

Specifications: linear count rate up to 10000 imp/sec. Energy between 50 keV (electronic noise) and 390 keV. (detector efficacy and electronics).

Acquisition and data processing:
1. A system based on a Apple 2 (48k memory) microcomputer with a dedicated timer-counter interface card. Acquisition and application software was developed by IPB nuclear medcine service and ODAM (Wissembourg France). Acquisition software available include standard MUGA acquisition with Ventricular extrasystolic beat cycle rejection. The application software include renal (clearance) and cardiac processing (cardiac output MUGA analysis). A so-called quality control package is also available for spectrometric analysis. This low-cost system isn't powerful enough to support additionnal probes and multitasking.

2. In order to assess the feasibility of cardiac study with a multidetector device we have programmed am IBM AT R* equipped with a Lab-Master acquisition card with the ASYST software (MacMillan corp.). First application was standard MUGA study with two detectors and an external ECG trigger. All cardiac cycles are recorded, the postprocessing analysis allows the user to select which cycles he wants to select for the mean representative curve. This acquisition software works in backgroup and can manage a ten-detector system. This system was tested in the NM service of Anderlecht (Brussel - Belgium).

Patients:
30 patients with various cardiologic pathologies were studied. All of them have dilated or dyskinetic left ventricule and/or dysrythmia.

Methods:

After standard MUGA acquisition with the gamma-camera (20mCi-TC99m serum-albumin) the CdTe probe was placed according to the left ventricular activity on the persistence display of the gamma-camera. A 30 degree LAO tilt was chosen. The background probe was placed in the liver projection area. 600 cardiac cycles were averaged and the left ventricular ejection fraction (LVEF) was derived from the mean time-activity curves.

Comparison between CdTe and gamma-camera measurements was made both with background probe counts for background correction and with a constant factor.

Results

No significant correlation was found when the backgroup probe was used. We choose a constant subtraction factor in order to obtain the best correlation between the two methods. When a factor of 80 % of the diastolic counts was used the correlation coefficient was r = 0,56 y = 0,78 + 15) n= 30. The low sensivity of the CdTe collimated probe result in a 100 counts/40 msec channel.

Discussion

The poor correlation observed with gamma-camera study is explained by various factors: the population of patients studied, the single hole collimated probe specific problems of this miniaturized CdTe probes. Theoretical limitations of the single detector collimated probe are well documented in the literature. Nevertheless satisfactory correlation with gamma-camera studies were found for a large range of LVEF (r=0,85 to 0,90). In most of the cases a constant substraction factor was used.

Our small miniaturized probe is more sensitive to these problems as can be shown by the isosentivity curves in water.

The problems became dramatic in cardiac patients with dilated or dyskinetic hearts especially those with low LVEF.

Monitoring for several hours of beat to beat ventricular function parameters together with ECG will improve the therapeutic management of coronary disease patients. Recently small detectors suitable for ambulatory purpose were built. Among the various detectors available our CdTe miniature probes have several advantages: high resistivity and thus good energy resolution, sensitivity curve show no variation between 25 and 40 degree Celcius.

Specific limitations of present detectors for these applications are: a small sensitive area of 0,2 to 0,4 cm2 to monocrystal size and long term stability of the detectors characteristics mainly due to surface pollution and/or contacts problems. The low sensitivity when selecting the photo-electric peak, does not allow beat to beat LVEF measurements with conventionnal 20mCi patient dose. The collimated probe MUGA studies are poorly correlated with the gamma-camera measurement when dilated ond/or dyskinetic hearts are investigated and constant backgroup substraction is use. However it should be noted that in an additionnal experimental study where the CdTe probe was fixed on the gamma-camera collimator for positioning and acquisition the coefficient rose to 0,85 (y : 0,85 + 12) n = 40 (correlated with the gamma-camera MUGA study acquired with the same patient/detector geometry). Positionning seems to be the main limitant factor . Altough two probe system allows conti-

nous monitoring of the backgroup but probe positioning and calibration are not fully controlled for the moment.

These problems may be solved by the use of a multi-detector matrix of 9 CdTe and miniaturized electronics linked with an autonomous recording system. The data will be process later through a personal computer system. With such a miniature multiprobe system we should improve probe positioning by the use of more sophisticated algorithms, the sensitive area is controlled by the number and the spatial distribution of the CdTe elements. Unfortunately the cost of CdTe crystal detectors should be a severe limitation.

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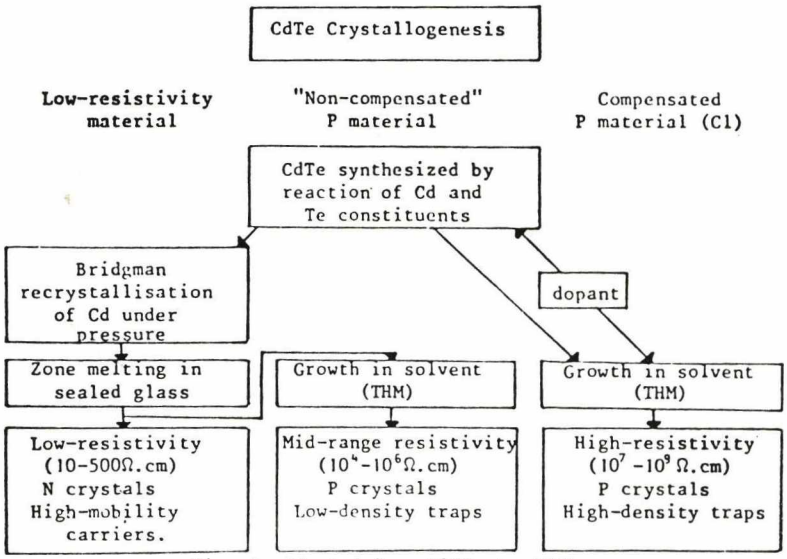


Fig. 1. Adapted from Siffert, 1978.

GAMMAGARD EXAMINATION AT BALATONFÜRED

VIZSGALAT SZAMA11FICHIER CARDIO NUMERO 2

A BETEG NEVE : NADUDVARI ISTVAN

SZULETESI DATUM:05/01/1936 VIZSGALAT DATUMA:11/03/1988

1-ES DETEKTOR MAXIMALIS ERTEKE:5152

1-ES DETEKTOR MINIMALIS ERTEKE:4823

HATTER KOZEPERTEKE :4260

A HATTER KORREKCIO ERTEKE :1

EJEKCIOS FRAKCIO :39 %

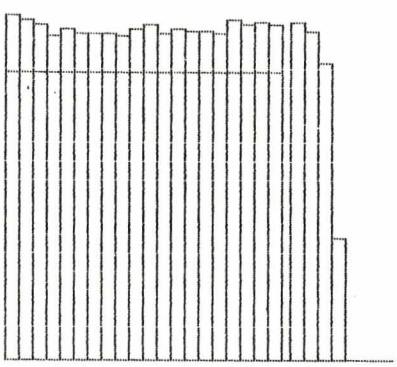
SZIVRITMUS :66 PULZ/MIN

A 40 MS-OS CSATORNAK SZAMA :22 +/-2

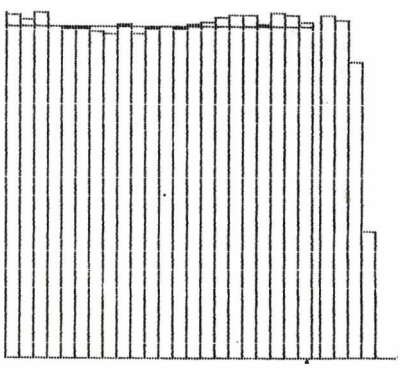
HASZNOS CSATORNASZAM :20

DET.1 A KAMRAVOLUMENHEZ RENDELVE

Apple-II program written from French to Hungarian /L. Németh, W. Pázmány/



basal RCG



oxygensaturation RCG

A MOBILE, VARIABLE, MULTICHANNEL MICROCOMPUTER CONTROLLED SYSTEM /MVSU/ WITH SEMICONDUCTOR DETECTORS LINKED TO A GAMMAKAMERA COMPUTER SYSTEM /GCCS/.

L. Nyitrai, L. Zsonda, Zs. Nagy, M. Fodor

The MVSU was built and used:

1.- for enlargement of the field of view of the GCCS
2.- for bedside /in an intensive care unit /and exercise radioisotope measurements.

Our MVSU is capable to transmit data of 15 channels into the GCCS at the same time. The transfered data can be analysed both by SUPER SEGAMS/SZOTE KIL AND BY UNIDEK Program Package. Data acquisition of the GCCS and MVSU can be performed together, and curve analysis is allowed at the same time too. The MVSU can be linked to all the systems in a nuclear medicine laboratory /ratemeters, X-Y plotters ../ but it can also work using its own analysator unit and dedicated microcomputer as a perfect system for nuclearmedicine investigations. The MVSU was tested in heart lung first-pass radioisotope studies applied 99mTcO4-as tracer. The curves detected by the micro gamma detectors /μ ϒ D/ were compared with the curves generated on the basis of the GCCS ROIs.

There was a good agreement between the curves. In some cases/eg. in left-to-right cardiac shunt-quantitaion/ the curves of the μ ϒDs were more impressive to detect the shunt recirculation peak on the lung TAC. USING 99mTc-DTPA the clearance curves can be measured also with u ϒDs. The advantages and disadvantages of our system will be discussed.

Mikro Gamma Z87 system

Hordozható mikroszámítógépes mérőberendezés radioizotópos vizsgálatokhoz. Haemodynamika, vesefunkciós-, szervperfúziós vizsgálatok, állapotmonitorozás, fiziológiásan jelentős paraméterek becslése a betegágy mellett

ASSESMENT OF LEFT VENTRICULAR EJECTION FRACTION USING MOBILE ECG-GATED SCINTILLATION PROBE DEVICE. COMPARISON TO CINEVENTICULOGRPAHY, ECHOCARDIOGRAPHY AND RADIONUCLIDE VENTRICULOGRPAHY

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Summary: in 29 unselected patients, the left ventricular ejection fraction was evaluated usinga mobile ECG-gated scintillation probe. (Nuclear Stethoscope) after in vivo labeling of the erythrocytes with 15 mCi technetium-99m. To validate the method, the Nuclear Stethoscope measurements were correlated to the results of.

1. Single-plane contrast cineventriculography in the right and left anterior oblique projections (RAO, LAO),
2. Radionuclide ventriculography with a gamma-camera computer system.
3. Two-dimensional echocardiography from the apical two-end four-chamber views.

The ejection fraction measured by the Nuclear Stehoscope showed a close correlation to the values obtained by cineventriculographic in the RAO projection (r=0,748) and radionuclide ventriculography (r = 0,785). In this group of unselected patients, the correlations with the results of unselected patients, the correlations with the results of two-dimensional echocardiography were poor (r = 0.451 and 0,557). Cineventricolgorpahci findings and radionuclide ventriculography correlated well (RAO r = 0,786; LAO: r = 0,758).

The Nuclear Stethoscope provides a simple, reliable and noninvasive method for measuring ventricular ejection fraction. Ongoing studies indicate that the Nuclear Stehoscope is a valid method even at a lower dose of 5 mCi technetium-99m.

SZINTIGRAPHISCHE VENTRIKELFUNKTIONS-BESTIMMUNG: TRAGBARE DETEKTOREN VERSUS GAMMAKAMERA - EINE KRITISCHE GEGENÜBERSTELLUNG AM BEISPIEL DER CARDIOPULMONALEN REHABILITATION.

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Zusammenfassung

Bei Patienten mit cardiopulmonalen Erkrankungen können als aussagekräftige Funktionsvariablen zur Beurteilung der Diagnose, Prognose oder eines Therapieeffektes szintigraphisch bestimmte links- und rechtsventrikuläre Funktionsvariablen in Ruhe und unter Belastung herangezogen werden. Auf Grund ihrer technischen Gegebenheiten sind tragbare Detektoren und Gammakameras unterschiedlich in der Güte zur Beurteilung der einzelnen Variablen geeignet. Anhand der Gegebenheiten in einem grossen Rehabilitationszentrum wird beschrieben, wie die verschiedenen Methoden einander ergänzen können. Dabei wird festgestellt, dass die Verwendung einer Gammakamera vorteilhafter für diagnostische und prognostische Zwecke, und die tragbaren Detektoren zur Beurteilung von pharmakologischen Interventionen eingesetzt werden sollen. Verschiedene tragbare Detektorsysteme werden miteinander verglichen. Bei sehr unterschiedlichem Preisniveau finden sich auch Unterschiede was die Leistungsfähigkeit oder den Anwendungsbereich betrifft. Anhand von zwei Detektor-Computer-Systemen werden wesentliche Unterschiede hervorgehoben. Vor Anschaffung eines tragbaren Detektor-Systems sollten deshalb für jede Institution genau der Bedarf (die Untersuchungsart und zahl betreffend) analysiert werden, damit das den Gegebenheiten entsprechende optimale Detektorsystem installiert werden kann.

1. Einleitung

In der Beurteiling von Patienten mit cardo-pulmonalen Erkrankungen, insbesonders von Patienten nach Myocardinfarkt, haben szintigraphische Methoden zur nichtinvasiven Bestimmung der Ventrikelfunktion zunehmend Bedutung erlangt. Da neben der globalen Bewertung der links-und rechtsventrikulären Auswurffraktion in Ruhe und unter Belastung zur Beurteilung der Prognose dieser Patienten für die weitere Diagnostik auch die Bewertung der regionalen Wandbeweglichkeit notwendig erschien, stand die Aquisition mit der Gammakame-

ra als primär bildgebendes Verfahren auch bei cardio-pulmonalen Patienten im Vordergrund. Obwohl der Einsatz einer Gammakamera auch bestens zur Beurteilung eines pharmakologischen Effektes auf die Ventrikelfunktion geeignet ist (1), sind aus Gründen der Aufnahme-Dauer und Technik solche pharmakologischen Interventionen in ihrer Wiederholbarkeit Grenzen gesetzt; ausserdem kann der Patient nicht unter seinen Alltagsbedingungen untersucht werden.
Die letztgenannten Umstände haben dazu geführt,dass am Patienten direkt fixierbare Detektor-Aufnahmesysteme entwickelt wurden, die eine kontinuierliche Aufzeichnung der Ventrikelfunktion über einen längeren Zeitraum ermöglichen.
Das Ziel der folgenden Darstellung sollte es sein, anhand der Gegebeneheiten eines grossen cardio-pulmonalen Rehabilitationszentrums darzustellen, wie die Schwerpunkte der szintigraphischen Funktionsprüfung gelagert sind, und welcher Stellenwert der Verwendung einer Gammakamera oder einem direkt am Patienten fixierbaren Detektorsystem zukommt. Darüber hinaus soll anhand verschiedener Detektor-Computer-Systeme auch der ökonimische Aspekt nicht ausser Acht gelassen werden.

2. Ziele der Ventrikelfuntionsuntersuchung beim cardio-pulmonalen Patienten

Ermittlung der Prognose.
Bei Patienten mit Herzerkrankungen steht an vorderster Stelle der szintigraphischen Funtionsvariablen des Herzeus traditionsgemäss die linksventrikuläre Auswurffraktion (LV-EF). Ihre unabhängige prognostische Bedeutung beim Patienten nach Myocardinfarkt wurde zwar unter Ruhebedingungen anhand einer grossen Anzahl von Patienten nachgewiesen (2), jedoch hat sich die linksventrikuläre Belastungs-Auswurffraktion (B-LVEF) als überlegene prognostische Variante erwiesen (3); darüber hinaus kommt auch der rechtsventrikulären Belastungsfunktion (B-RVEF) unabhängige prognostische Bedutung zu (eigene noch nicht publizierte Ergebnisse).
Alle diese Ergebnisse wurden unter Anwendung einer Gammakamera erhoben. Es finden sich jedoch übereinstimmende Ergebnisse, welche für eine gute Korrelation zwischen Gammakamera - LVEF und der LVEF gemessen mit am Körper tragbaren Detektoren oder mit dem Nuklearstethoskop, sprechen (4,5).Für die RVEF sind Korrelationsuntersuchungen bis jetzt nur mittels Nuklearstethoskop durchgefürt worden (6). Auch für Belastungsuntersuchungen existieren nur wenig direkt vergleichende Untersuchungen (7).

Diagnostische Aufgaben.
Auf Grund globaler Funktionsstörungen in Ruhe oder unter Belastung kann das Vorhandensein einer Herzerkrankung prinzi-

piell festgestellt werden, eine Differenzierung mittels Beurteilung der regionalen Wandbeweglichkeit, insbesondere die Erkennung aneurysmatischer Herzabschnitte, ist nur mittels Gammakamera möglich (8). So scheint auch die weitere szintigraphische Differenzierung von Patienten nach Myocardinfarkt in solche mit 1,2 und 3-Gefässerkrankungen nur mit bildgebenden Verfahren erfolgversprechend (9, 10). Auch für die nicht-invasive Diagnostik bei Patienten mit chronischen Lungenerkrankungen konnte die Bedeutung der mittels Gammakamera gemessenen B-RVEF für die Erkennung einer pulmonalen Hypertension unter Beweis gestellt werden (11). Soll jedoch bei herzkranken Patienten eine linksventrikuläre diastolische Funktionsströrung erkannt werden, scheinen Volumenkurven die von Detektor-Systemen mit hoher zeitlicher Auflösung hergeleitet sind, besser für die Ermittlung von maximalen Füllungsraten geeignet als Gammakameras. So konnten Sales et al. erst kürzlich zeigen, dass im Vergleich mit invasiv ventrikulographisch gemessenen maximalen diastolichen Füllungsraten, ein Nuklearstethoskop einer Gammakamera überlegen scheint (12). Allerdings gibt es kaum Vergleichsuntersuchungen, ob diese Übereinstimmung auch für andere tragbare Detektorsysteme zutrifft (4), jedoch scheint hier ein Vorteil von Detektorsystemen mit hoher zeitlicher Auflösung gegeben (12).

Erfassung eines Therapie-Effektes.
Zum Nachweis eines Therapieeffektes wie z.B. einer Langzeitmedikation mit Herzglycosiden konnte die hohe Reproduzierbarkeit der MUGA-Radionuklidventrikulographie in einer placebokontrollierten Studie gerade bei Patienten mit herabgesetzter Ventrikelfunktion nachgewiesen werden (1). Da hier bei länger dauernder ausreichender Dosierung ein dauerhafter Therapieerfolg nachgewiesen werden musste, war eine Wiederholung der Untersuchung in grösseren Zeitabständen von mehreren Wochen notwendig. Das hat auch Gültigkeit zur Überprüfung des Effekts einer Bypassoperation oder Koronardilation auf die globale und regionale Ventrikelfuntion. Soll jedoch ein Medikamenteneffekt, welcher einer raschlebigen Pharmakokinetik oder gar einem Toleranzphänomen unterliegt, wie dies für Nitrate, Ca-Antagonisten oder andere herzwirksame Pharmaka der Fall sein kann, erfasst werden, müsste der Patient mehrmals am Tag unter ergometrischer Belastung untersucht bzw. zur Erreichung einer hohen Reproduzierbarkeit, eine unzumutbar lange Zeit unter der Gammakamera positioniert bleiben, um das zeitliche Wirkungsspektrum eines medikamentes individuell zu erfassen. Die sinnvolle Durchführung solcher Aufgabenstellungen wurden auf Grund placebokontrollierter Reproduzierbarkeits- oder Interventions-

untersuchungen mit dem Nuklearstethoskop plausibel gemacht (7,13,14). Derartige ausgereifte Studien sind für tatsächlich vom Patienten tragbare Detektoren noch nicht in extenso publiziert.

3. Möglichkeiten des Einsatzes verschiedener Systeme zur szintigraphischen Ventrikelfunktionsprüfung.

Wie sich derzeit die Bedeutung von Gamma-Kamera's oder tragbarer Detektor-Systeme zur Beurteilung von Patienten mit Herz- oder Lungenerkrankungen darstellt, ist anhand der Abb 1 zu erkennen. Trotzdem mit verschiedenen Systemen zur szintigraphischen Funktionsprüfung die gleichen Fragestellungen (jedoch in unterschiedlicher Qualität) bearbeitet werden können, ist in den meisten Institutionen. die über nuklearmedizinische Einrichtungen verfügen.traditionsgemäss ein Gamma-Kamera-Computer-System vorhanden;dass ein solches System aus diagnostischem Bedarf ausgelastet ist, lässt die Abbildung 2 erkennen. Es ergibt sich deshalb die Frage, ob zur szintigraphischen Überprüfung der medikamentösen Therapie eine zweite Gamma-Kammera oder ein tragbares Detektorsystem eingesetzt werden soll; dabei sollten neben den eingangs erwähnten methodischen Erwägungen auch ökonomische Faktoren wie der Anschaffungpreis berücksichtigt werden.

4. Tragbare Systeme zur szintigraphischen Ventrikel-Funktionsprüfung

Einen Überblick über derzeit erhältliche oder in Erprobung befindliche, am Körper tragbare Systeme im Verbleich zur Gamma-Kamera gibt Tabelle 1. Von den dort angeführten Systemen werden die Systeme 3. u. 5 in diesem Heft an anderer Stelle beschrieben,so dass hier nicht im Detail auf sie eingegangen würde. Die beiden verbliebenen Systeme, welche sich wesentlich in ihrem Preis und in ihrer Konfiguration unterschieden, sollen jedoch näher miteinander verglichen werden.

Das Vest-System der Firma Capintec , Inc. besteht aus einer nach einer konventionellen Gamma-Kamera-Untersuchung über dem herzen mittels einer flexiblen kunstoffweste anzubringender NaJ-Kristall-Photomultiplier-Einheit für die Messung der zyklisch schwankenden Herzaktivität und einem Cd/Te Detektor zur Messung der Hintergrund-Aktivität. Es ermöglicht die kontinuierliche Aufzeichnung der Ventrikelfuntion während der täglichen Aktivitäten (12 oder 24 h), bei gleichzeitiger Registrierung des EKG s, jedoch ist das vom Patienten zu tragende Aufzeichnungsgerät noch schwer (1,5 kg); die Auswertung erfolgt nachträglich. Dieses Gerät fällt durch den hohen Preis auf, der mit dem einer Gamma-Kamera vergleichbar ist. Es muss jedoch berücksichtigt werden, da

dieser Preis auch ein vollständiges hochwertiges Micro-Computer-System (PDP 11/73) beinhaltet, welches jedoch in manchen Institutionen bereits vorhanden ist und wenn zusätzlich ausgenützt, eine 40%ige Kostenreduktion ermöglicht. Der nach wie vor hohe Restpreis (ohne Computersystem) ist einerseits durch die hohe Software-Linzenzgebühr bedingt, andererseits durch das teure Detektor-Aufnahmesystem. Dabei erscheint die verfügbare Software komfortable und ausgereift, sowohl was die Schlag zu Schlag-Analyse betrifft, als auch die Trendanalyse über längere Zeiträume (siehe Abb.3 u. b). Demgegenüber hebt sich das CsJ 2-Detektoren-System (Firma John Caunt Scientific Ltd.) durch seinen wasentlich niedrigeren Preis ab.
Das System besteht aus zwei CsJ(Tl) Detektoren, welche mit Vorverstärker, Abschirmung und Kollimation 45 mm hoch sind und 35 mm im Durchmesser nicht überschreiten. Sie können leicht mittels eines Gürtels oder Klebebandes stabil am Körper befestigt werden. Die vorverstärkten Signale werden mit einem Kabel zu einer Zählbox übertragen, welche auch die Arbeitsspannung von +/- 15 Volt liefert. Diese Aufnahmeeinheit verstärkt die Signale weiter und beinhaltet einen Analyser, Scaler und Timer. Über ein zusätzliches Interface können die resultierenden Signale an einen Drucker oder Personal-Computer übertragen werden. Die kardiologische Software ermöglicht eine Schlag zu Schlag Analyse der Auswurffraktion sowie der schnellen Auswurfs-und Füllungsraten auch während der Aufnahme. Ausserdem ist Software für andere Organsysteme (Hirn, Lunge, Niere, Blutlfuss) in Erporbung. Auf Grund des notwendigen Kabels (Länge bis zu lo m möglich) zur Datenübertragung und Aufzeichnung ist der Einsatzradius derzeit auf einen Raum beschränkt in dem sich der Patient jedoch bewegen kann (eine tragbare Einheit ist vorgesehen); damit bietet sich dieses System neben der bettseitiben Überwachung, für die Durchführung mehrmaliger ergometrischer Belastungstest nach pharmakologsichen Interventionen, geistige Belastungstest (15) im Sitzen, sowie zur Beurtellung längerer Übungsporgramme im gleichen Raum an. Wesentliche Eigenschaften der Detektor-Einheit der letztgennanten Systeme sind in Tabelle 2 gegenübergestellt. Die Empfindlichkeit und die Linearität der zahlraten im klinischen Raum an.
Wesentliche Eigenschaften der Detektor-Einheit der letztgennanten Systeme sind in Tabelle 2 gegenübergestellt. Die Empfindlichkeit und die Linearität der Zahlraten im klinisch relevanten Bereich (Abb. 4 a,b) lassen von der neuen CsJ-Detektor-Generation klinische relevante Ergebnisse erwarten.

	System 2*	System 4*
Szintillationsmaterial	NaJ(Tl)	CsJ(Tl)
Kristallgröße	Dicke 6,4 mm Durchm. 57 mm	8 mm 14 x 14 mm
Arbeitsspannung	1000 Volt (PMT)	15 Volt (Vorverst.)

Tabelle 2: Technische Charakteristika unterschiedlicher Detektorsysteme

* siehe Tabelle 1

5. Abschliessende Feststellungen

Insgesamt erscheinen die Möglichkeiten, welche Detektorsysteme wie das Nuklearstethoskop oder andere tragbare Detektoren bieten, in der etablierten Nuklear-Kardiologie noch keinen Eingang gefunden zu haben, da sie in einer kürzlich erschienenen umfassenden Darstellung weder bei der Thematik der Diagnose, Prognose oder Therapieüberwachung auch nur erwähnt wurden (169. Es wird ihnen jedoch in Hinkunft besonders bei der Überwachung der Pharmakotherapie eine grosse Bedeutung zukommen. Insbesondere die Beschäftigung mit der Thematik der stummen Ischämie (17) hat gezeigt, da relevante Ventrikelfuntionsstörungen auch ohne Schmerzsensationen oder EKG-Veränderungen auftreten können (18,19), so dass eine Behandlungsstrategie, welche allein auf letzteren Symptomen oder Zeichen basiert, wenn auch bis jetzt praktiziert, insuffizient bleiben muss. Hier eröffnet sich eine Anwendung für die szintigraphische Funktionsprügung welche, wie gezeight werden konnte, nicht durch Anschaffung zusätzlicher Gamma-Kameras sinnvoll abgedeckt werden kann, da dieses Vorgehen mit wesentlichen zeitlichen sowie Mobilitätslimitierungen behaftet wäre, welche die Dynamik des Patienten im täglichen Leben nur unzulänglich berücksichtigt. Das ist aber besonders für die Rehabilitation dieser Patienten von Bedeutung. Die derzeit erhältlichen tragbaren Detektor-Systeme sind zwar alle noch nicht klinisch validiert, erscheinen jedoch auf Grund vorläufiger Erfahrungen zufriedenstellend geeignet die angefügten Aufgaben zu bewältigen . Obwohl das vorgestellte teure System hauptsächlich durch eine besonders komfortable Software (unter Verwendung eines Mikrocomputer) und eine hohe Mobilität der Funktionsprüfung gekennzeichnet ist, sind bei ähnlich guter Software andere Systeme durch ihren wesentlich niedrigeren Preis vorteilhaft. Bei diesen Detektor Auswerte-Systemen kann durch entsprechende Aufgabenstellung ebenfalls ein wesentlicher Teil der Therapieüberwachung abgedeckt werden. Bevor die Entscheidung für das eine oder andere System fällt, sollte es wesentlich sein, da jede Institution eine genaue Bedarfsprüfung nach Patientenart und- zahl vornimmt und sich dann erst die Wahl eines für die gegebenen Verhältnisse optimalen Systems trifft.

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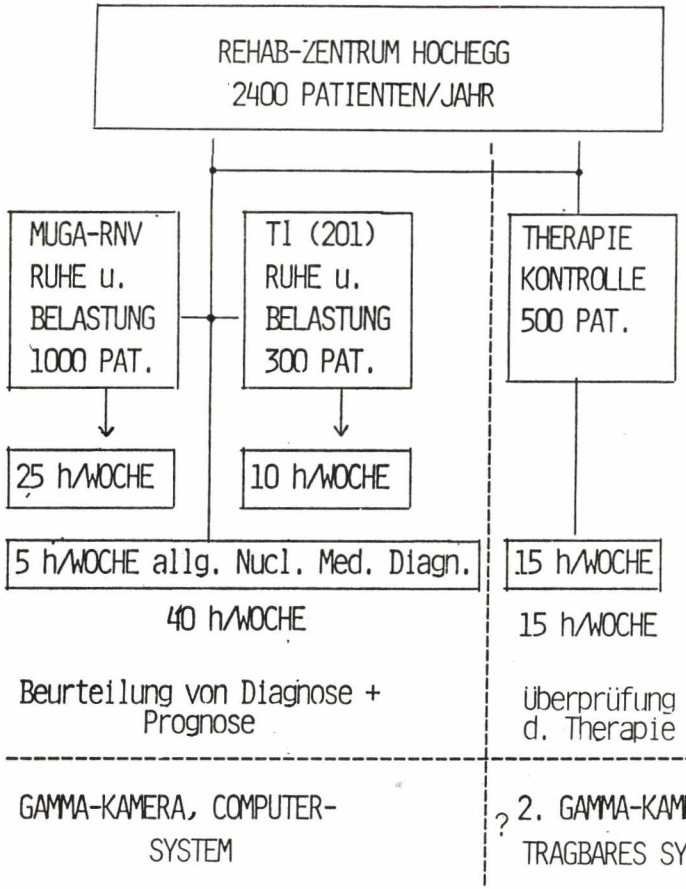
	Szintigraphisches System	Detektor	Computer	zumutbare Aufnahmedauer	Preis *
1	Gamma-Kamera	NaJ-PMT	wahlweise (exkl.)	2 h	75 000 $
2	Vest-System (Capintec. Inc. N.J.)	NaJ-PMT, Cd/Te	Aufnahmeeinheit+Soft-ware, Micro PDP 11/73		82 000 $
			Aufnahmeeinheit+Soft-ware (exkl. PDP)	12 (24 h)	50 000 $
			zusätzliche Aufnahmeeinheit (exkl. PDP-Software)		18 000 $
3	Engypan (Kernforschungszentrum - Karlsruhe)	Geiger Müller Röhren	Epson PX-4 mit Aufnahme + Ausw. Software	8 h - unbegr.	20 000 $
4	2 Detektor-System (John Caunt Scientific, Ltd. Oxford)	CsJ Photo-dioden mit Vorverst.	AT-Personal-Computer + Aufnahme + Ausw. Softw.	unbegrenzt	25 000 $
			zusätzl. Aufnahmeeinheit		8 500 $
5	2 Detektor-System (nicht komerziell erh.)	Cd/Te	Tragbare Aufnahmeeinheit + LSI 11/23 (CPU)	unbegrenzt	——

Tabelle 1: Approximativer (*) Preisvergleich von tragbaren Detektor-Systemen, unterschiedlicher Bauart, zur kontinuierlichen Ventrikelfunktionsprüfung (im Vergleich zu einer Gammakamera).

* Die hier angegebenen Preise sind Richtpreise, welche nur für ungefähre Vergleiche herangezogen werden sollen; sie beruhen auf unverbindlichen Angaben der Hersteller und unterliegen Kurs-schwankungen sowie Änderungen in der Konfiguration.



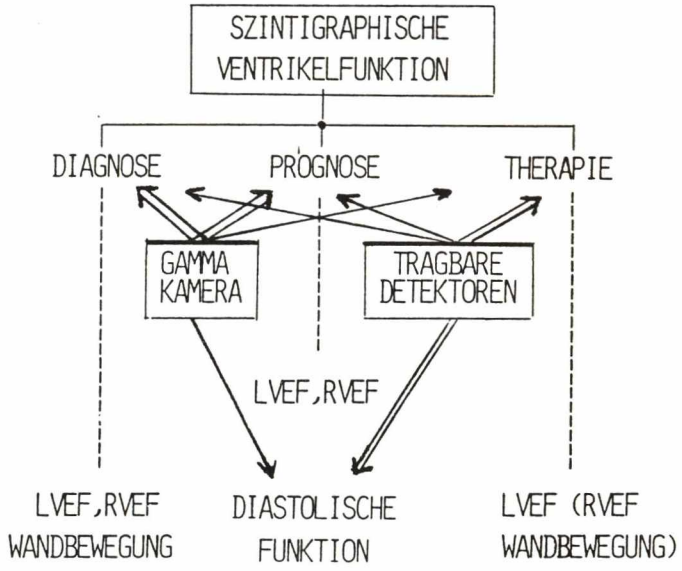


Abb. 1

Bedeutung unterschiedlicher szintigraphischer Funktionsprüfung für die Beurteilung der Diagnose, Prognose und Therapie beim Patienten mit Herz- oder Lungenerkrankungen.

Abb. 2

Auslastung und Bedarf szintigraphischer Diagnostik in einem Herz-Kreislauf-Rehaiblitationszentrum.

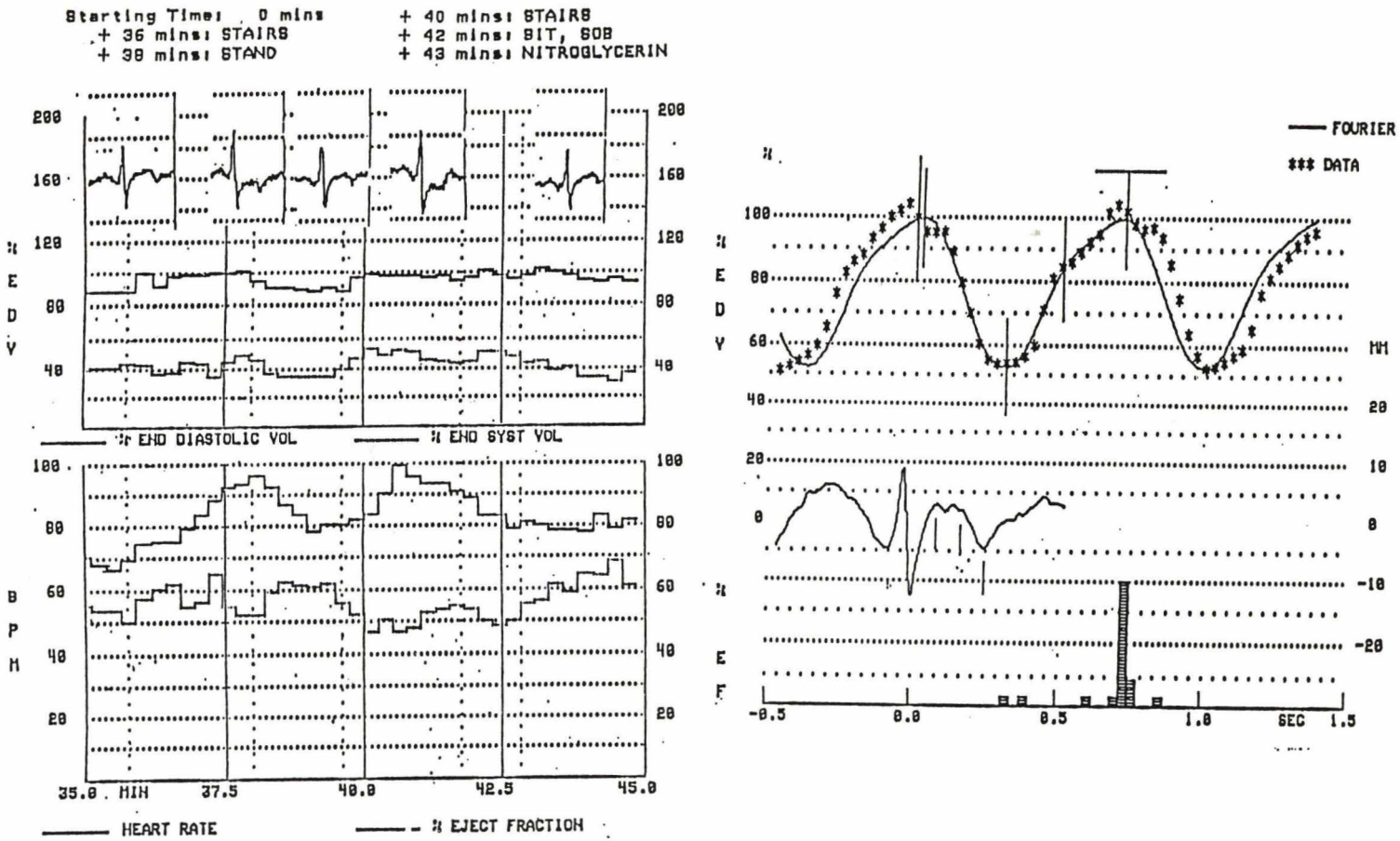


Abb. 3

Daten-Ausgabe für einen tragbaren Ventrikelfunktions-Detektor

a: EKG-Veränderungen und Änderung der Ventrikelfunktion während verschiedener Übungen sowie unter Therapie.

b: Schlag zu Schlag-Analyse der Ventrikelfunktion.

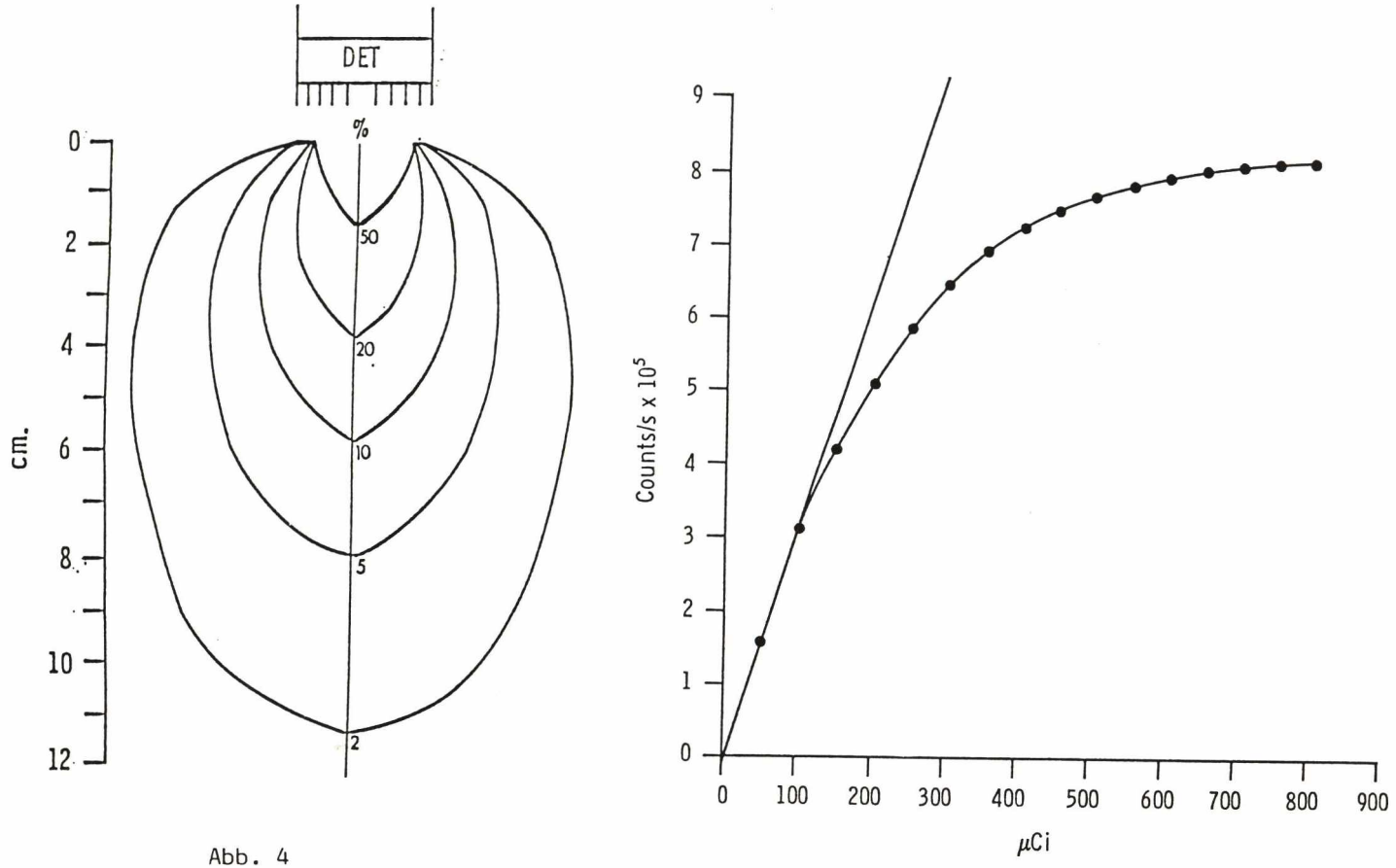


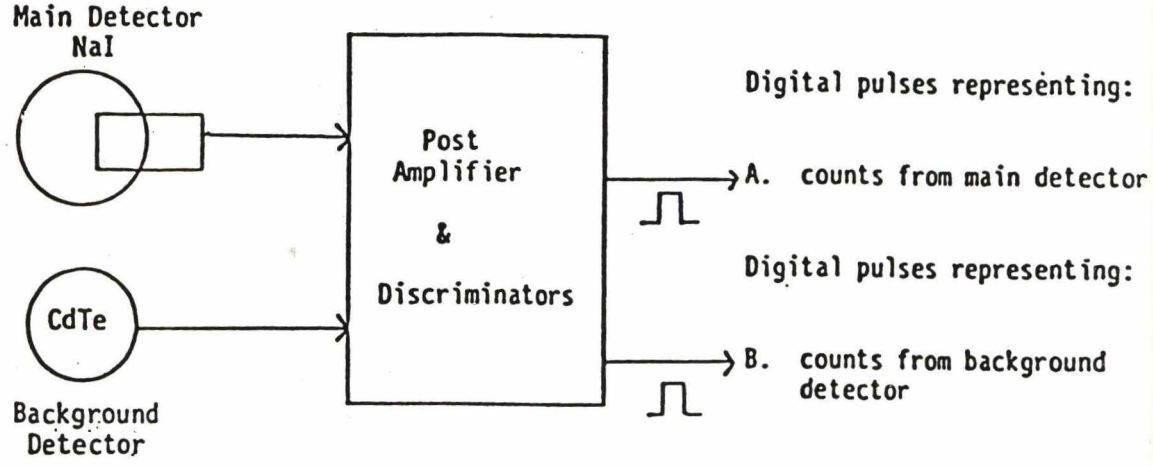
Abb. 4

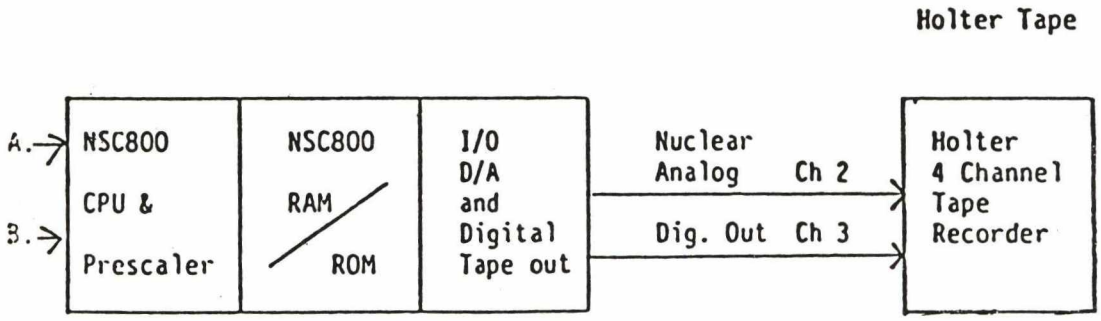
Technische Charakteristika des CsJ (Tl) Detektors:

a: Polare Empfindlichkeit des Photopeaks gemessen für 99m-Tc (140 KeV) am Wasser-Phantom.

b: Linearität der Zählraten bei steigender Aktivität.

DATA LOGGER





NSC800 Module

In-House Design

CAPINTEC

System MGH

Prof.

H. W. Strauss

ENGYMETRIE - A NEW METHOD GENERATION

B. P. Pretschner and Coworkers

Low-priced hand-held computers made it possible to develop a new generation of portable instruments for continuous nuclear medicine measurement, without restriciton of patient modality.

Nuclear radiation is recorded by 4 detectors, which are fixed on the body. Results will be displayed contrinuosly as online-time-activity-curves on the LCD-Display of a portable EPSON PX-4 computer. Evaluation is possible at the same computer at once. Collected data can be stored on a disk drive, which is also portable.

Applications:

1.) Double-nuclide-measurement with Tc-99m-DTPA and J-131-OIH for analysis of the acute nephrotoxic effect of Cyclosporin A.
2.) Analysis of therapeutic effects of compression on the intravasal and extravasal volume at patients with post-trombotic syndrom using Br-82 and Tc-99m.

Conclusion: A fen clinical examples will show the advantages of engymetrie as a low-priced completion of, conventional examinations using gamma-cameras.

DETERMINATION OF CHANGES IN INTRAVASCULAR AND EXTRACELLULAR VOLUME BY ENGYMETRIC DOUBLE RADIONUCLIDE MEASUREMENT. Special detectors with miniaturized GM-counter tubes and a portable storage unit are offering continous and syncron measurement of both compartments in every position wanted (sitting, lying, going, standing). Br-82 was used as radio-indicator for the extracellular, Tc99m in vivo labelled e-rythrocytes) for the intravascular compartment.

Results: changes of blood volume and edema volume in post-trombotic legs in various positions
(standard: lying $\triangleq$ 100 % ; n = 15)

blood volume	increase of edema volume	position
270% $\pm$ 41% sign.	107% $\pm$ 4% n.s.	standing
245% $\pm$ 43% sign.	105% $\pm$ 3% n.s.	walking
340% $\pm$ 50% sign.	118% $\pm$ 6% sign.	lying

(sign. $p < 0,05$)

Results: effects of compression therapy on legs with varicous veins
(standard: lying = 100% ; n = 30)

increase of blood volume without compression		increase of blood volume with compression	position
258% ± 63%	sign.	194% ± 58%	sign. sitting
118% ± 9%	sign.	110% ± 7%	sign. sitting

sign. $p < 0,05$

The method offers a new possibility of measurment of pathophysiological dysregulation and the judgement of therapeutical effects on both of the compartments.

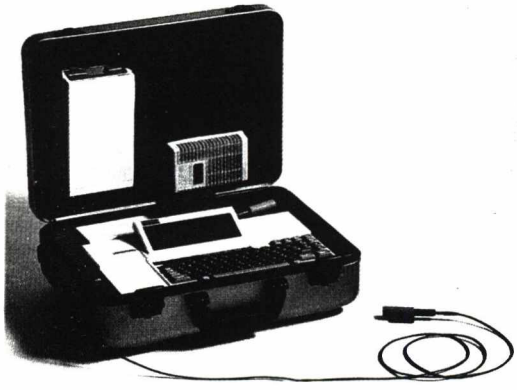
ENGYPAN-TOGAS

a portable system for acquisition and analysis of nuclear gamma radiation.

"ENGYPAN" extends time dependent measurement and monitoring of nuclear gamma radiation to new dimensions. Although originally designed as an instrument for engymetric radiomedical diagnostics of local biological function, it can also successfully be used in nonmedical applications, such as environmental radiation detection and monitoring or tracer measurements.

Hardware Description

The system is based on a hand-held CP/M micro computer (EPSON PX4). A 3 ½" floppy drive is included to load programs and for permanent storage of the collected data. The operating system, important system programs and, optionally, the ENGYPAN data aquisition- and analyzing-software are independently accessible in the computer's EPROM memory. Acquisition



data can also be stored in a RAM-disk that is battery backed-up. Up to four gamma detectors can be connected to the system by a specially constructed interface. Besides the power supply and the necessary pulse shaping for the GM-detectors, it also handles the data transfer to the computer. Additionally it is possible to connect special, user supplied detection systems, confirming to TTL or NIM signal standards at counting — rates up to about 10 kHz per channel. Also a mixed configuration is allowed. The complete system can be battery operated for up to eight hours.

Software Description

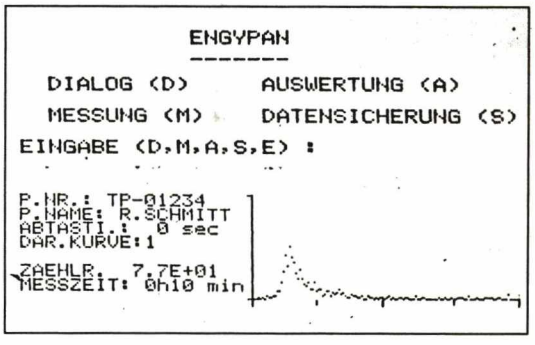
ENGYPAN's application software is specially designed for easy 'off-road' use. So it is divided into several different parts. First, the data acquisition program. This operates the counting interface, performes the data acquisition, ensures data storage and security, and also allows on-line data display and some simple analysis. Data can be stored either in the microcomputer's permanent RAM-disk or on the 3 ½" floppy-disk drive. The acquisition-parameters may vary in wide range. A maximum of 128 data points can be collected within a time-range of 1 s up to several hours per point. Studies may be predefined and stored in advance. They can be easily recalled and executed for the actual study. Also some analysis capabilities are incorporated in the system. This program offers the possibility of different mathematical manipulations, of curve fit procedures, and, of course, of data-display, -plot, and -storage. Simultanious work is possible with up to ten curves.

Data-transfer to more powerfull computers, such as IBM-PC or even DEC PDP or VAX mini-mainframe computers, is supported via the serial RS232 line.

Applications

In nuclear medical diagnosis, some typical applications of the ENGYPAN system are:

- — Diagnostics of heavily injured patients without the need and the risc of transportation.
- — Measurements of biological function in extreme situations such as external stress or sports.
- — Easy and cheap possibility of multiple diagnosis of transplantation patients pre- and post-operative.



System Prof. D. P. PRETSCHNER

For further information contact:

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DETERMINATION OF THE EJECTION FRACTION OF THE LEFT VENTRICLE AND THE MINIMAL TRANSIT TIME WITH THE PARAMETRIC GAMMASCOPE, DATA COMPARISON WITH THE LAEVOCARDIOGRAM AND CONVENTIONAL GAMMA CAMERA IMAGING.

K. Lauterbach, V. Becker, E. Vester, V. Schwartzkopff, B. Lösse, L. E. Feinendegen

The Parametric Gammascope (P.G.) is a multipurpose and multiprobe fast activity counting instrument for functional analysis without imaging. It is especially suitable for studying circulatory function.
Heart and circulatory function was determined on three levels: 1. of the left ventricle of the heart on the basis of the left ventricular ejection fraction (LVEF), 2. of the central circulation by measuring the minimal transit time (MTT) from right atrium to aortic root and 3.of the entire circulatory system by continuous monitoring of exercise induced changes of blood volumes in the total heart, for lung areas and the liver. Conventional gamma camera measurements (G.C) and laevocardiogram (L.C.) were used for testing the precision of P.G. performance on level 1 and 2 in four groups of a total of 155 patients.
In group I. (GI, n=57) LVEF was determinded by the gated blood-pod technique (GBP) with P.G. and G.C. In GII (n=32) P.G. was used alone for comparing LVEF from GBP-and beat-to-beat-mode. In GII I. (n=15) LVEF from G.C. and L.C. was compared. In GIV (n=51) MIT was measured with P.G. and G.C. In all four groups of patients the results showed a good correlation ($0,85 < r < 0,95$). Hence, P.G. proved to be precise and in view of versatility of the robust instrument and simplicity of measurement, promises to be useful for clinical routine.

Parametric Gammascope eine kompakte mobile Untersuchungseinheit für nuklearmedizinische Organfunktionsdiagnostik

Die Kernforschungsanlage Jülich GmbH, Institut für Medizin, hat einen Kompaktradiokardiographen konstruiert, den a & p zu einem programmierbaren, vielseitig einsetzbaren, parametrischen Meßplatz weiterentwickelt hat.

Als kompakte mobile Einheit gewährleistet das Gerät den direkten Einsatz am Krankenbett sowie die Bearbeitung verschiedener Laboranalysen.

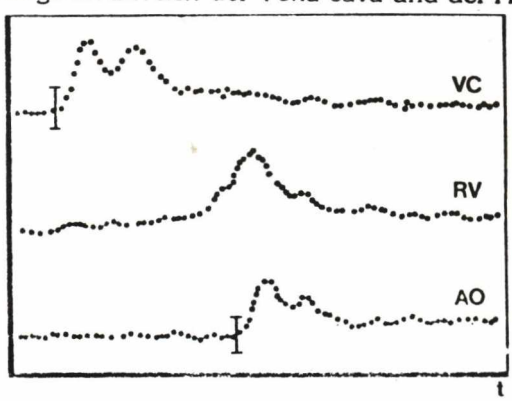
Methodische Grundlagen der Herzfunktionsdiagnostik

Die Anwendung intravasal verbleibender Radiopharmaka ermöglicht die externe Messung der Kreislaufzeiten in der kardiopulmonalen Zirkulation. Mit der Methode der minimalen Transitzeiten (MTTs) werden die schnellsten Passagezeiten als Differenzen der Indikatorerscheinungszeiten in nachfolgenden Kompartimenten bestimmt, und es konnte nachgewiesen werden, daß die MTTs[1] als sensitive Parameter für das Verhältnis Segmentvolumen/Fluß gelten können.

Die Ejektionsfraktion (EF) des linken Ventrikels als der Anteil des ventrikulären Füllungsvolumens, der bei einer Kontraktion ausgeworfen wird, ist ein sehr empfindlicher Parameter für die Pumpfunktion des Herzens[2,3]. Mit Hilfe intravasal verbleibender Radiopharmaka lassen sich Zählratenänderungen erfassen, die den Volumenänderungen des linken Ventrikels zugeordnet werden können und in vielfältiger Weise wichtige Prüfgrößen zur Beurteilung der Ventrikelfunktion zu berechnen erlauben. Für die Messung der globalen Herzfunktion werden zwei unterschiedliche Techniken angewendet:

Beurteilung der ersten Indikatorpassage durch das Herz

Bei der Durchführung der Messung befindet sich der Patient in sitzender oder in liegender Position -- auch unter Belastungsbedingungen, und der intravasal verbleibende radioaktive Indikator (z.B. 1–1,5 mCi ^{99m}Tc-Albumin oder mit ^{99m}Tc markierte Eigenerythrozyten) wird bolusartig in die Kubitalvene injiziert. Zeitgleich beginnt die Datenerfassung und die Datenauswertung durch das System. Nach wenigen Sekunden erreicht der Bolus den rechten Vorhof und verläßt den linken Ventrikel ca. 6,5 Sekunden später. Mit dem Start der Datenerfassung erfassen Gammasonden über dem 2. Interkostalraum, jeweils ca. 3 cm links und rechts vom Sternum, über 10 Sekunden die durchfließende Bolusaktivität. Auf dem Bildschirm kommen dann die unbearbeiteten Daten zur Darstellung, die interaktiv derart durch Glättung und Ausschnittsvergrößerung bearbeitet werden können, daß die Aktivitätsanstiege im Bereich der Vena cava und der Aorta



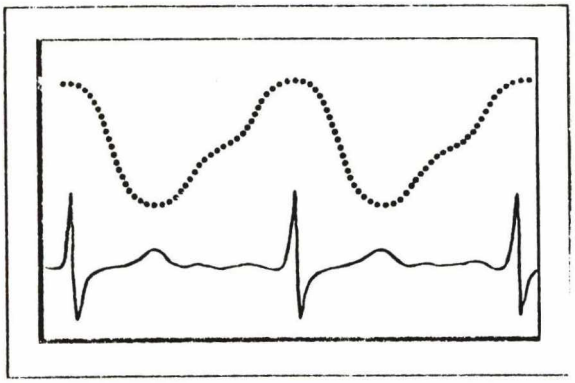
VC = Vena Cava RV = Rechter Ventrikel AO = Aorta

MTT frequenzkorrigiert auf 80 Herzschläge/Minute

Der Rechner ermittelt zeitgleich zu jeder Ventrikelaktion die zugehörige EF sowie den Mittelwert aus allen vorherigen EFs.

Dieses Verfahren ist vor allem bei Arrhythmien von hoher Wertigkeit, da jede Herzaktion individuell ausgewertet wird und die Ausgangsdaten zur detaillierten Analyse dokumentiert werden. Schwierigkeiten können sich aus der Einstellung des linken Ventrikels ergeben, auch die Subtraktion der extrakardialen Aktivität ist gelegentlich problematisch. Ein von a&p entwickeltes Verfahren gestattet es, diese Schwierigkeiten weitgehend zu eliminieren und zu reproduzierbaren Ergebnissen zu kommen.

Die BTB Methode erfordert ca. 15–25 mCi ^{99m}Tc-Aktivität, z.B. ^{99m}Tc-Albumin oder ^{99m}Tc-markierte Eigenerythrozyten.



Beat-to-Beat in Verbindung mit dem EKG

Gated Blood Pool-Methode (GBP)

Bei gleicher Positionierung der Sonde ist der Aktivitätsbedarf – im Unterschied zur BTB Methode – deutlich niedriger (5–15 mCi ^{99m}Tc-Aktivität), denn mit Hilfe des EKG und des Rechners werden zeitgleiche Herzaktionen aufaddiert, bis sich eine statistisch ausreichend sichere Ventrikelkurve ergibt. Herzfrequenztoleranzen sind frei einzugeben und stellen sicher, daß nur vergleichbare Herzzyklen zur Auswertung kommen.

Dieses Verfahren setzt einen Sinusrhythmus voraus, und je nach verwendeter Aktivitätsmenge werden 10–50 Herzzyklen aufaddiert, aus denen der Rechner eine mittlere Volumenkurve bestimmt, aus der sich folgende Meßgrößen ermitteln lassen:

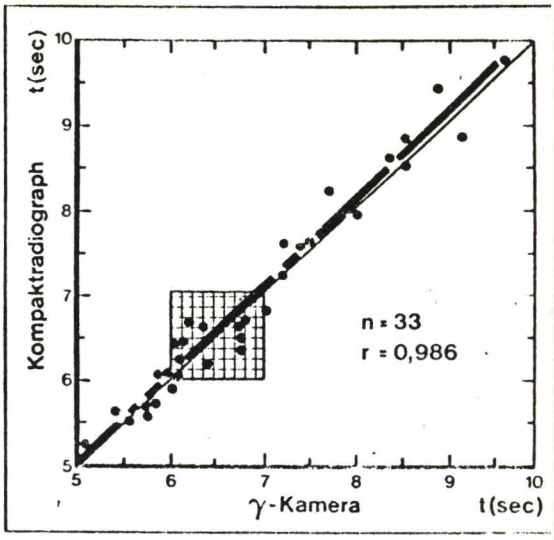
- Entleerungs- und Füllungszeiten
- Ejektionsfraktion des linken Ventrikels
- max. Entleerungs- und Füllungsgeschwindigkeiten
- relatives Schlagvolumen
- relatives enddiastolisches Volumen

Die aufgeführten Methoden eignen sich hervorragend zur schnellen Beurteilung der globalen Herz- und Ventrikelfunktion, auch vor und nach kardiologischen Interventionen (z.B. Kardioversion, Ermittlung der optimalen Ejektionsfraktion bei Verwendung programmierbarer Schrittmacher etc.), da die Untersuchung im Prinzip beliebig oft wiederholbar und nur durch die Zählratenstatistik von der Untersuchungsdauer letztlich limitiert ist.

Speziell für Belastungsuntersuchungen ist es notwendig, eine ständige Kontrolle über das EKG zu haben. Das EKG erscheint auf einem zweiten integrierten Bildschirm bei gleichzeitiger Angabe der mittleren Herzfrequenz und der oberen und unteren Herzfrequenzgrenzwerte, deren Überschreiten durch ein akustisches Signal angezeigt wird.

klar markierbar werden. Nach Eingabe der Pulsfrequenz des Patienten erfolgt die automatische Berechnung der Transitzeit mit Normierung auf die Pulsfrequenz von 80/min.. Das Ergebnis erscheint auf dem Bildschirm, es wird parallel vom Plotter ausgedruckt neben den bearbeiteten Kurven. Die Bearbeitung der Kurven zur Darstellung der Anstiegspunkte kann aus den gespeicherten Ausgangsdaten beliebig oft wiederholt werden. Dies ist bei schwierigen Injektionsbedingungen häufig nützlich.

Vergleichende Untersuchungen mit der biplanen Ventrikulographie ergaben eine enge reziproke Korrelation zwischen MTT und EF des linken Ventrikels.



Korrelation der Meßergebnisse mittels Kompakt-Meßplatz und γ-Kamera. Das schraffierte Feld gibt den Normalbereich der Gesamt-MTT an [5].

		TI^{201}		GBP		MTT	
		Rest	Exercise	Rest	Exercise	Rest	Exercise
CAD 33	without MI 24	5	19	7	15	8	17
	with MI 9	8	9	6	7	4	7
MI without detectable CAD **5**		4	4	3	4	4	3
ANEURISMS 6		6	6	6	6	2	4
CM 5		1	3	1	2	3	3
NORMALS 10		2	2	0	0	3	1

Kombinierte Messung MTT und GBP [4].

Beurteilung der Blutpool-Verteilung des Indikators im Äquilibrium

Die Volumenschwankungen der sich kontrahierenden Herzkammern bewirken zeitgleiche Schwankungen der präkordial gemessenen Impulsraten. Die Auswertung dieser Schwankungen erlaubt die Messung der Ejektionsfraktion des linken Ventrikels nach zwei Verfahrer

Beat-to-Beat-Methode (BTB)

Unter Verwendung eines speziell kollimierten Szintillationszählers, der über ein eigens entwickeltes Stativ sehr leicht und frei beweglich am Thorax des Patienten positioniert werden kann, werden die präkordial gemessenen Zählraten 2–3 Minuten lang fortlaufend zusammen mit einer EKG-Ableitung auf dem Bildschirm aufgezeigt und mit dem Plotter aufgezeichnet.

BEAT-TO-BEAT ANALYSIS OF THE EJECTION FRACTION, A NEW WAY OF MONITORING.

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The ejection fraction (EF) presents an important information about the heart function in acute circulatory stress situations such as myocardial infarction, during or after surgical intervention. Therefore it is of special interest to look for methodes allowing the estimation of the EF in intensive care units. The invasive methods such as thermodilution need a left heart catheterization and therefore its use is restricted. Ultrasound and scintillation cameras are in use. The expensive equipment has limited the use in intensive care units. Therefore the investigations with single scintillation probes, known as nuclear stetnoscope becomes more and more interesting. The advantage of these methodes are the low costs, its high mobility, its easy use and the on line results. Additionally the use of the single probe methode is excellent in follow up studies. On the other hand the relative loose correlation of the EF in comparison with other methodes have restriced the use in the past.
We used the single probe investigation of the EF as well by bolus injection as in gated blood pool studies since more than 20 years. A critical review of our results, show that a single value of the EF is not so informative than the EF value estimated by the scintillation camera. The single probe methode is much better in follow up studies. Due to the difficulties in a correct background substraction and the moving of the heart during respiration the value of the EF and the reproducibility are significant lower in comparison to scintillation camera.

Therefore we looked for a variation of the used methodes to solve these problems and to simplify the method of the estimation of the EF by a single probe detection system. We developed a system which allows the estimation of the EF on line without the use of a computer.

Material and methode:
The changes of the endsystolic and enddiastolic count rate are measured continously by a usual equipment consisting of a single probe (VAS-968, MKD robotron GDR) with a stative and

a Scope (OPD 6/3, Tesla CSSR) Fig. 1. The value of the EF can be read directly from the scope. It is necessary that the zero line of the display must be constant. The maximum of the stroke volume curve will be calibrated to a constant level (for instance 10 cm) in each patient.

In our investigations we used a cylindric collimation of 7,5 cm length and a diameter of 4 cm.

The estimation is done in equilibrium after intravenous injection of 450-550 MBq Indium-113m (In-transferrine) or injection of 250-300 MBq Technetium-99m pertechnetate (in-vivo labelled erytherocytes).

The single probe is positioned over the heart with an angle of 30 degree LAO. The position over the left ventricle is correct, if the stroke volume curve equivalent SV' reaches its maximum between systolic and diastolic difference at a stationary maximum (EDV) of the curve.

Theoretical proposals
The EF results from the equation $EF = \frac{EDV - ESV}{EDV}$

In praecordial external estimation the formula changes to

$$EF = \frac{EDV' - ESV''}{EDV'}$$

$$EDV' - ESV' = SV'$$

$$EF = \frac{SV'}{EDV'}$$

EDV' counts (cm) at enddiastole
ESV' counts (cm) at endsystole
SV' counts (cm) of difference from EDV'-ESV'

In each investigation the maximum of the EDV' is adjusted to a constant level on the scope.
The EF' can be read directly from the SV'-curve

$$EF' = \frac{SV' \cdot f}{EDV' \cdot f}$$ fig. 2

f=calibration factor for adjusted EDV'

$$EF'' = \frac{SV' \cdot f}{\text{constant}}$$

Due to the difficulties in background correction and its low reproducibility the bacground was not measured directly. We proofed the correlation and calculated the regression of the simultaneous estimated EF' by the scintillation probe and the EF measured by the scintillation camera in 30 patients. The regression is represented by the equation

$$EF = 35,76\ SV' - 35,15,\ r = 0,92$$

This regression is valid at an adjusted EDV' at 10 cm on the scope.

Correction of the heart moving during respiration.
During the inspiration and the expiration the heart moves down and up and therefore the values of the EDV' and the SV' changes in dependence on the position of the heart in the field of the collimator,fig.3.The measurement of the EF' is possible,in this respiratory phasis,in which the left ventricle is positioned within the collimator field. In these conditions the EDV'reaches the adjusted maximum.

Results
In 90 patients of different age suffering from angina pectoris syndrome, post infarction, hypertension the EF estimated by the single probe methode and the scintillation camera were compared. The results are demonstrated in fig. 4. The normal values of the EF are in the right upper field and the pathologic values in the left lower field of the figure. The space between the full and dotted horizontal and vertical lines represents the indifferent values. The figure demonstrates that in 86 of the 90 patients the EF agree within normal, pathologic and indifferent values. Only in 4 patients we find different results. Three times the EF of the scintillation camera is pathologic and of the single probe indifferent and one times indifferent with scintillation camera and normal with single probe.

Discussion
The estimation of the EF with the single scintillation probe is possible. The validity of the methode can be improved by a consideration of the heart moving due to the respiration. The dicussed new way of the estimation of the EF by the SV' has some advantages. The equipment does not need a computer, the results are received on line, the apparatus is easy to handle and to move. Due to the adjusted EDV' no correction is necessary, when using short lining radionuclides such as In-113m, even in follow up studies. The values of the EF are adapted to the scintillation camera, and therefore a direct comparison between both methodes is possible.
The correction of the heart moving induced by respiration

gives a good reproducibility of the EF. Deviations of the EF of more than 0.05 are significant. The normal value of the EF ist 0.64, the pathologic 0.60.
The methode is suitable especially for investigations in intensive care units.

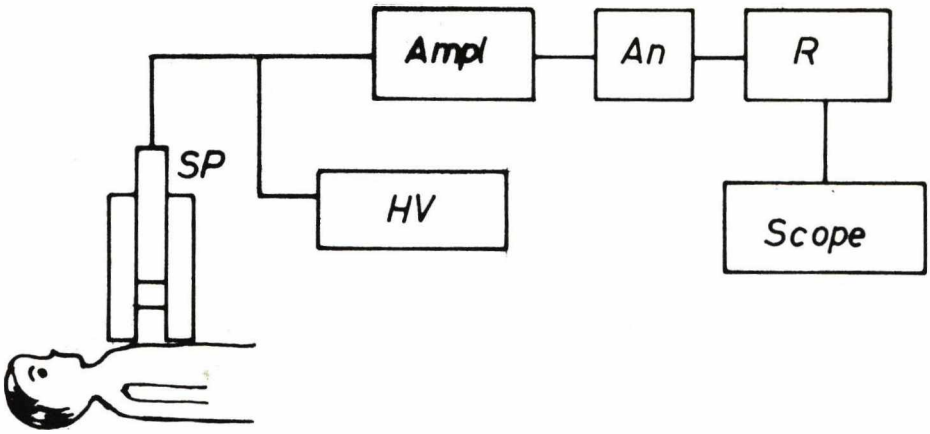


Figure 1.

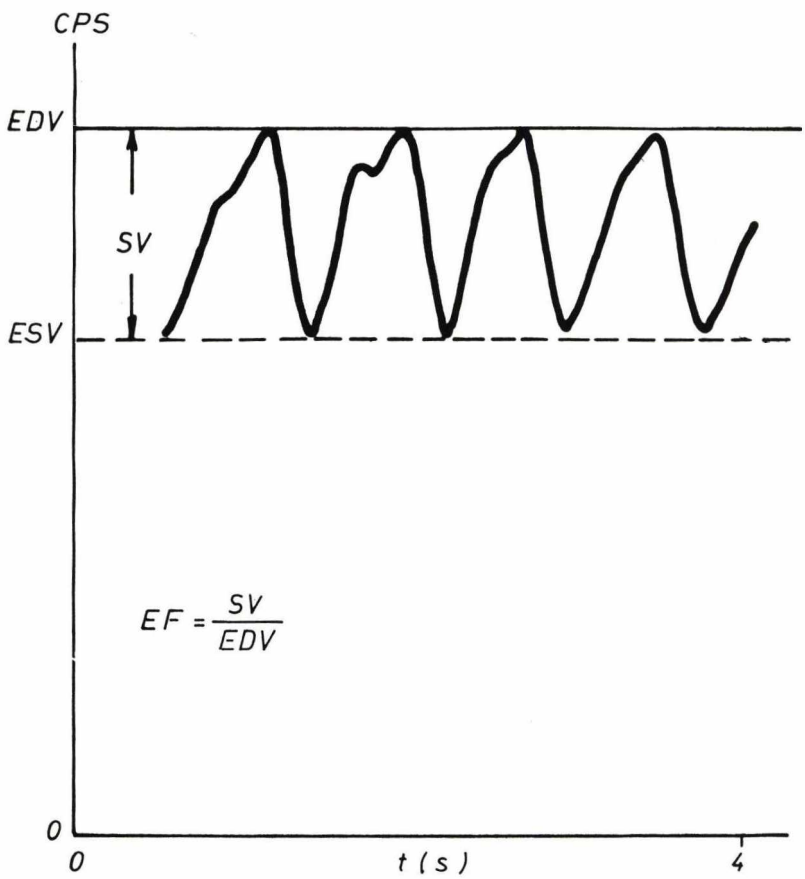


Figure 2.

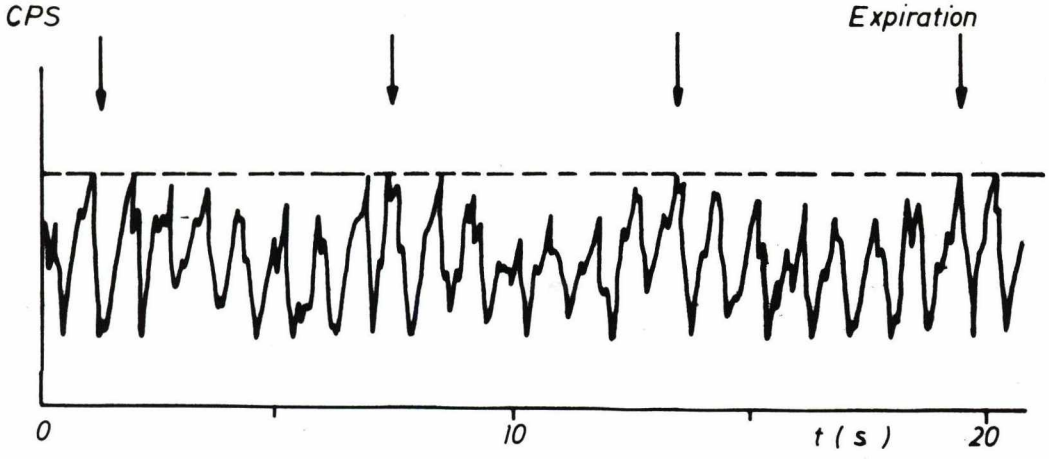


Figure 3.

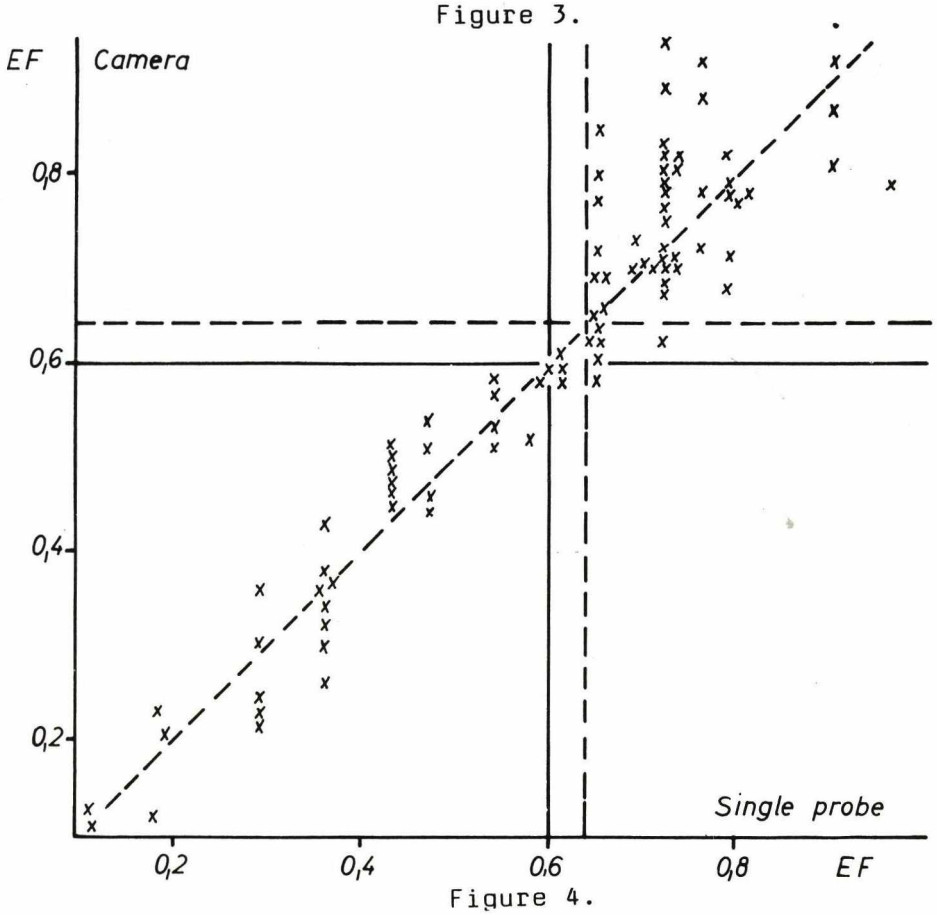


Figure 4.

SOME NEW SUGGESTIONS ABOUT THE NUCLEAR STETHOSCOPE

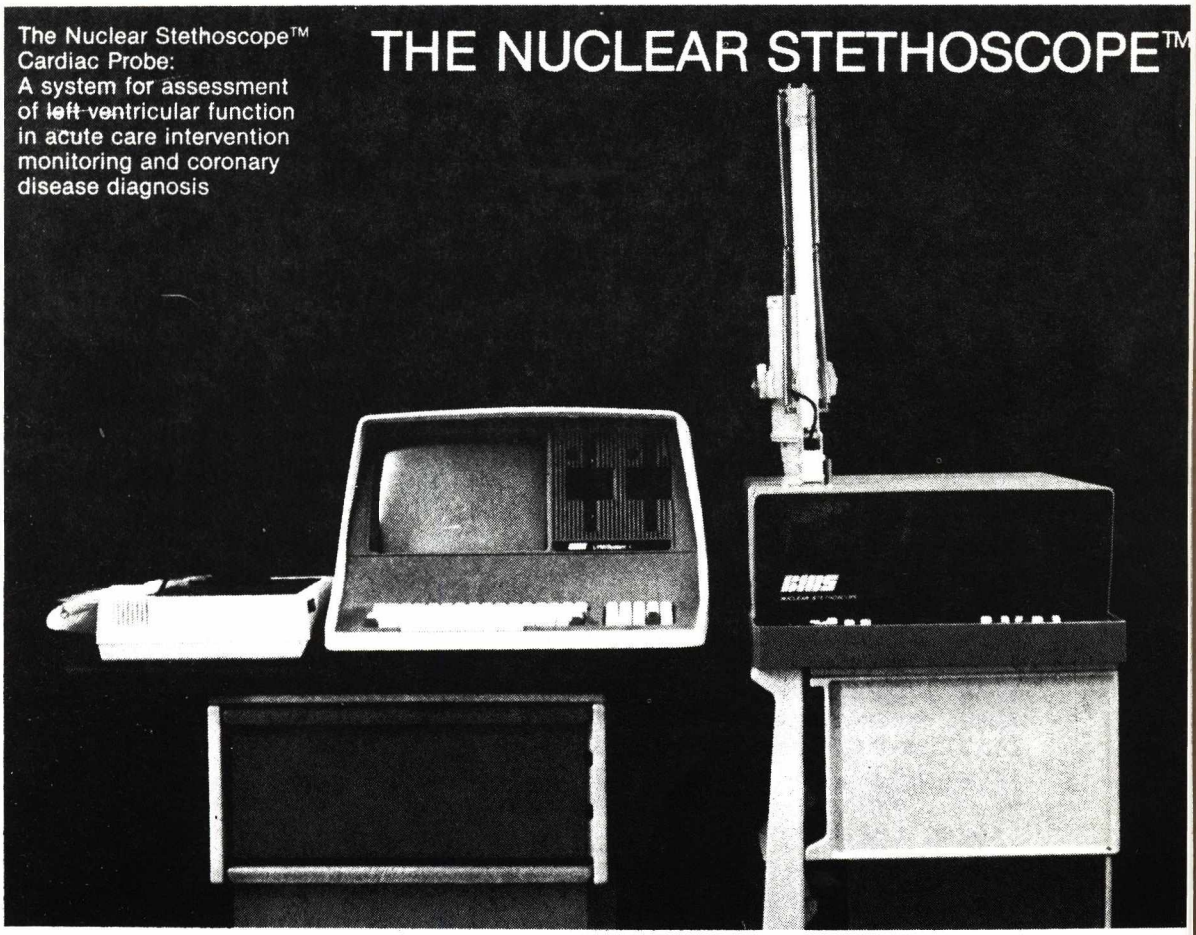
Dr. W. H. Frenkel, USSR

As user of the NS-bios, I emphasize two points which could improve the possibilities of the instrument.

The main feature of the NS is the monitoring of heart functions before and after different influences: drugs, operations, physical effort, etc. I think the graph trends should be calculated in percents to the basic study. Now the dramatic changes in the graphs are not always justified by the really small changes of the actual values, because they are presented at full scale.

Monitoring studies were performed every half an hour after administration of Sustac. By patients with less serious ischaemic heart lesion, a temporary increase of the stroke volume and a less pronounced increase of the EDV have been observed, with result to a significant increase ot the EF. The PFR and TPFR were clearly increased. With more serious lesion the Sustac administration had no or little influence on the EF, but these ineffective efforts were accompanied by a decrease of PFR and with increase of the TPFR. Without the proposed new calculations of the graph trends, the mentioned changes are by far less visible.

The second remark is directed to the study of the so called extravascular lung water, which can be studied by two-tracer technique with diffusable and non-diffusable agents. The difference between the two transit times enabled us to calculate the relative or absolute value of the ELW, up to day by manual procedure. It seems to be advisable to have adequate software incorporated as a standard feature. The corresponding formula can easily be programed.



System

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OPTIMIZATION THEORY APPROACH TO POSITRON EMISSION TOMOGRAPHY

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Abstract

We discuss the relationship between the optimization criterion and the algorithm to achieve the "optimal" reconstruction in positron emission tomography (PET). As an illustration we compare two optimization criteria: maximum likelihood (ML) and maximum a posteriori probability (MAP). Both of these can be achieved by the general algorithm called expectation maximization (EM), but MAP is preferable, since it provides greater smoothness and accuracy, and the convergence of EM is faster for MAP than it is for ML.

Optimization criteria and algorithms

In the optimization theory approach to PET we wish to find an object which is "optimum" in some sense, given the observed data, the known statistical behavior of the data collection device, and (possibly) some prior knowledge. We give a mathematically precise definition of the term "optimum", by selecting one of many possible optimization criteria. In this way we turn a clinical problem into a mathematical one. The most important question regarding this stage of the process is: "Does the optimization criterion we have chosen reflect accurately clinical efficacy?"

Once the optimization criterion has been selected, we need to provide an algorithm (a computer procedure) which amongst all the possible objects selects the one which is optimum according to our chosen criterion. Here we need to provide a mathematical proof that the algorithm does optimize as intended. We also need to investigate the in practice important question of speed of optimization by the chosen algorithm.

In what follows we compare two optimization criteria, ML and MAP, both of which can be achieved by the EM algorithm. The results that are referred to in the discussion of these criteria and algorithm appeared in (1), the reader should look at that publication for the details.

The properties of the ML EM and MAP EM approaches

In this section we briefly discuss the properties of two approaches: the maximum likelihood (ML) and maximum a posteriori probably (MAP) criteria with the expectation maximization (EM) algorithm applied to achieve the optimum in both cases. Wo leave for the next section the precise definition of these criteria and the precise description of the algorithms.

The pictures which satisfy the ML criterion are very noisy-looking. The EM algorithm converges in the limit to the picture satisfying the ML criterion, but it does so slowly. In a typical PET application the iterative process determined by the EM algorithm keeps noticably changing the estimate even after 100 cycles through the data (100 iterative steps). Interestingly, provided we start the iterative process with a smooth picture, early iterates tend to be improvements over the starting picture, but as iterations go on and the iterates approach the ML picture, they tend to become noisier and noisier and, consequently, a less and less accurate representation of the object to be reconstructed.

On the other hand, pictures which satisfy and appropriately chosen MAP criterion tend to be a smooth and more accurate representation of the objects to be reconstructed in PET. For this criterion, the EM algorithm converges relatively fast. In a typical PET application, no appreciable changes were noted after about the 30th iterate (1).

Comparative description of the ML EM and MAP EM approches

Let I be the number of the detector pairs used and y_i be the number of the observed coincidences for the i'th detector pair ($1 \leq i \leq I$). Let J be the number of pixels (picture elements) in the reconstructed image and let x_j be the mean activity in the j'th pixel during the observation ($1 \leq j \leq J$). Let a_{ij} denote the probability that an observed activity in the j'th pixel is observed by the i'th detector pair. Then the picture x we are seeking is determined by the optimization criterion: maximize

$$\sum_{i=1}^{L} \left(y_i \ln \Big/ \sum_{j=1}^{J} a_{ij} x_j \Big/ - \sum_{j=1}^{J} a_{ij} x_j \right) - \frac{y}{2} \sum_{u,v=1}^{J} (x_u - m_u) H_{uv} (x_v - m_v).$$

Here n denotes the natural logarithm.

The ML optimization criterion is the special case of the one given above with $\gamma=0$. In this case only the first term matters and all symbols in the criterion are already defined. The optimizer depends on the data (y) and on our knowledge of our data collection device (a), but on nothing else.

The MAP optimization criterion is another special case, the one given by $\gamma \geq 0$. In this case m_j is the expected value in the j'th pixel prior to the measurements and H_{uv} is the (u,v)'th entry of the IxJ covariance matrix of our a priori expectation. γ plays the role of a noise-to-signal ratio determining the relevance of prior knowledge as opposed to the data that are collected.

For either of these optimization criteria the EM algorithm is applicable. It is an iterative process which leads from the k'th estimate $x^{(k)}$ to the (k+1)'st estimate $x^{(k+1)}$ by the following rule. Define, for $1 \leq j \leq J$.

$$\hat{x}_j^{(k+1)} = x_j^{(k)} \sum_{i=1}^{I} \frac{a_{ij} y_i}{\sum_{n=1}^{J} a_{in} x_n^{(k)}}$$

In the case of ML, for $1 \leq j \leq J$,

$$x_j^{(k+1)} = \hat{x}_j^{(k+1)}$$

In the case of MAP we give the algorithm only for the special case when H is a diagonal matrix and $H_{uv} = h_u$, for $1 \leq u, v \leq J$.
Then, for $1 \leq j \leq J$,

$$x_j^{(k+1)} = \left(\gamma h_j m_j - 1 + \sqrt{/\gamma h_j m_j - 1/^2 + 4\gamma h_j \hat{x}_j^{(k+1)}}\right) / 2\gamma h_j.$$

So the $x_j^{(k+1)}$ of the MAP approach can be obtained at a small extra expense over that of obtaining the $x_j^{(k+1)}$ of the ML approach.

Conclusions

In discussing optimization theory approaches to PET, one must carefully distinguish between the adopted optimization

criterion and the algorithm proposed to achieve it. In particular, the EM algorithm can be used to achieve either the ML or the MAP optimum. Nevertheless, MAP is preferable, since it provedes pictures of greater smoothness and accuracy, and the EM algorithm converges faster for MAP than it does for ML.

Acknowledgements

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Reference

(1) E. Levitan and G.T. Herman:

"A maximum a posteriori probability expectation maximization algorithm for image reconstruction in emission tomography". Technical Report MIPG 115, Medical Image Processing Group, Dept. of Radiology, Univ. of Pennsylvania, 1986. (Revised version to appear in IEEE Transactions on Medical Imaging, 1987.)

ASSESSMENT OF VALVULAR REGURGITATION BY GATED BLOOD POOL TOMOGRAPHY

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The quantitative assessment of valvular regurgitation on planar blood pool radionuclide ventriculography (RVG) introduces certain pitfalls. Right and left ventricular storke volumes are highly affected by measuring geometry mainly depending on the attenuation and scattering (1). Gated blood tomography (GBPT) helds a more precise to measure left to right stroke volumes (2).

The aims of our study were to evaluate the use of this new technique in clinical routine and to estimate the left to right stroke volume ratio as a measure of valvular regurgitation index.

Material and methods

In this both fomographic and planar detections of stroke volumes and ejection fraction were evaluated in 23 patients. Standard technetium planar blood ventriculography was acquired at a temporal resolution of 24 frames per cardiac cycle for a total acquisition of 10 Mc. A Siemens LFOV(ZLC) gamma camera with a high sensitivity collimator was used. The data were collected onto a small digital computer (PDP-1134, GAMMA-11). All measurements were done in the "best" MLAO-projection. Both the right and left ventricular stroke volumes and ejection fractions were calculated using the RPAH-cardiac program package (3).

Immediately after the planar imaging a gated blood pool tomography was made. A GE 400 A/T gamma camera with a low energy all purpose collimator was used to record data at 32 angles over 180° from LPO to RAO. The data were acquired for 45 seconds per angles into a 65 x 65 pixel matrix. The energy window was centered on the 140 keV photon peak of Tc-99m with a 20 % window. No camera's digital flood field uniformity correction was used. Each cardiac cycle was divided into 12 or 16 frames with the tolerance of 10 %. The total measuring time was 24 minutes.

Transaxial and sagittal sections (12 mm thick) were reconstructed by filtered backprojection technique using the HECT-program (4). Resulting sagittal voxels total were directly converted to ventricular volumes (EDV and ESV) using the lo-

wer treshold setting of 40% of the maximal ventricular counts. So the right and left ventricular end-diastolic and end-systolci images with the "3-D" ejection fraction maps were shown on the monitor (Fig. 1). The total reconstruction time was 90-110 minutes using the floating point processor, FP11.

J. T. Kuikka, L. Németh, K. Tahvainen, M. Kármán, M. Horváth, E. Länsimies: Assessment of valvular regurgitation by gated blood pool tomography. Nuklearmedizin 1987. 10-12

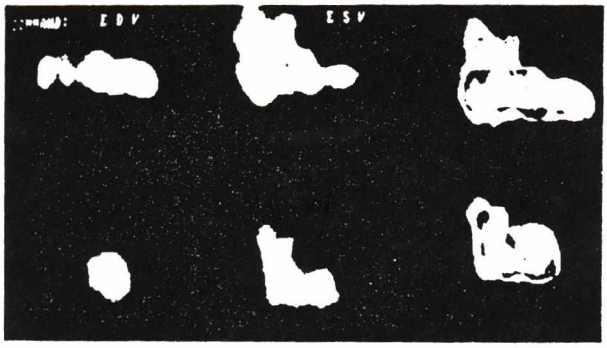

Fig. 1. End-diastolic (left) and end-systolic (right) tomographic slices through the mid portion of the right (top) and the left (bottom) ventricle. The "3-D" ejection fraction maps show normal right ventricular contractility and akinetic apical and hypokinetic inferior regions of the left ventricle. The patient has suffered an inferoposterior myocardial infarction.

Results

The normal value of the left to right ventricular stroke volume ratio from the tomographic study was 1.08 (range: 0.85 - 1.26). There was an excellent agreement between the tomographic and planar LVEFs (r = 0.93), except of 3 cases (LVEDV 300 ml or over) as we have preveiously published (5). In the normal subjects the mean LVEF was 65% (range: 53-73%) at rest. There was a highly significant correlation between the tomographic and catheterization results whereas the planar study introduced a poorer correlation.

Conclusions

GBPT provides a clear four chamber view with well visualized valve planes to assess both wall motion and ventricular volumes. GBPT is more accurate to indentify regional asynergy in patients with inferior wall asynergy. GBPT also shows atrial and ventricular dilatation more precisely than planar imaging. The real voxel' method provides accurate estimates of valvular regurgitations without any attenuation or geometric corrections. This method is more reliable than the planar techniques.

However, there are several limitations of GBPT. Limitations

include both the enormous amount of data that are collected and the time of reconstruction (1.5 hours). The newer HECT-versions benifit the use of array preocessors by reducing the reconstruction time up to 1/5 to 1/10. Also, the use of exercise studies is lost oving to the relatively long measuring time (20-30 minutes). Tomographic study should be done to carefully selected patients.

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