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OVERCOMING INFORMATIONAL PROBLEMS AT A CARDIO-PULMONARY FUNCTION LAB BY OFF-LINE DATA PROCESSING

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Summary

A minute analysis of the functional capacity of the cardio-pulmonary system is based on computer assisted data processing. The specialist is provided for with a bulge of data and he has to interpret the findings and draw conclusions. The medical report on these sophisticated physiologic investigations (ergometry, ergospirometry, central hemodynamics, lung function analysis) should not remain understandable to an elite only. Data transformation into informative, easily perceptible and didactical graphics will enhance the knowledge and awareness of basic pathophysiologic processes involved in cardio-pulmonary diseases.

Introduction

During the last decade sophisticated physiologic tests have been introduced into clinical routine and practice. To obtain precise informations about the functional capacity of the cardio-pulmonary system a minute acquisition of data is impracticable, unless the technics of on-line data processing are available.

At the cardio-pulmonary function lab we apply methods such as bicycle ergometry, ergospirometric stress testing, the invasive analysis of central hemodynamics at work and the comprehensive analysis of lung function (Ergo-Pneumo-Body-Test, Fa. Jäger, Würzburg, FRG). In 1974 the on-line computation of ergospirometric and hemodynamic parameters (on- and off-line) has been introduced at the lab. One year later the plotter-diagrams of ergospirometric and hemodynamic data have been added to the routine printer protocols to facilitate the observations of trends and to make better the interpretations of interrelationships of selected variables at work, such as oxygen uptake, minute-ventilation, exspiratory flow rate, cardiac output, blood pressure etc.

Due to our experience we may conclude that the computer assisted analysis of function tests at a cardio-pulmonary lab has led to a prompt interpretation of findings. The minute description of the functional capacity with regard to the onset of abnormal reactions at work and the reversibility of functional limitations (e.g. airway resistance, afterload induced pump failure) has contributed to a comprehensive clinical diagnosis (descriptive). The identification of abnormal reactions to physical stress and the detection of limiting mechanisms (anaerobic threshold - endurance performance, low output syndrome, congestive heart failure, elevated afterload and airway resistance, hypoxia etc.) have led to a rational therapy. Intervention studies can be performed subsequently and interpreted immediately by means of data processing to optimize the treatment regime which is put to the question. With regard to the cost/benefit/efficiency ratio

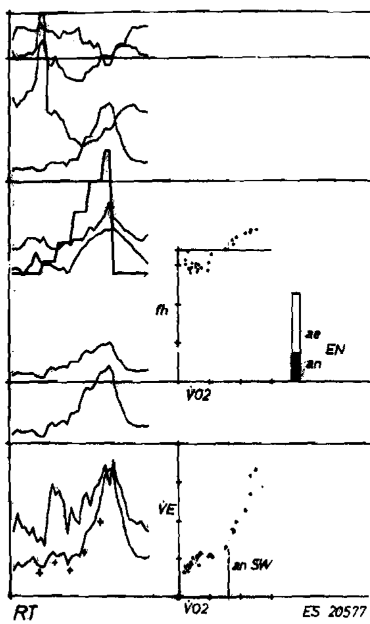

Figure 1

Plotter-diagram of ergospirometric parameters (2-min increment bicycle ergometry. + VA, 11 tracings: VE, VT, VO2, O2-P, fh, Watt, fr, VCO2, REO2, RQ, flow; correlation analysis between selected parameters: e.g. VE/VO2 to identify the anaerobic threshold - an SW)

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further investigations with more invasive technics (e.g. angiography) will be selected properly.

Unfortunately we had to learn that the results obtained by these sophisticated investigations remain unclear, even obscure to our colleagues and students, unless they were engaged with some basic training to understand and interpret the findings. To overcome the informational problems we decided to set up a computer system to transform physiologic data into graphics, which should be informative, easily perceptible and didactical. For this purpose we use a HP-85A desktop computer (Basic; 32 k memory, build in cartridge display, printer and tape cartridge). The capability of the system was enhanced by adding a plotter, a dual disk drive, a peripheral printer and a graphic tablet (Hewlett Packard, USA).

Application of graphics

1. Ergometry and computer assisted ergospirometry

We have introduced a 2-min increment test (bicycle ergometry) for exercise testing, a test model which has been accepted as a standard procedure for cardiologic patients in Austria. We apply this test model in lung patients and in atheletes as well. The findings of symptom-limited maximal stress-testing should become more conclusive by graphic presentations. Figure 2 informs about the maximal load tolerated (% of predicted maximum), the type of loading (Watt, minutes/load), the heart rate and blood pressure regulation (systolic blood pressure) and the onset of any abnormal reaction (e.g. subjective complaints, arrhythmias, ischemic ECG-changes; see black arrow). The hardcopy of the graph is attached to a standard form, on which the maximal values of pertinent parameters (e.g. heart rate, blood-pressure; oxygen uptake, minute ventilation, tidal volume, respiratory frequency, alveolar ventilation, functional dead-space ventilation ratio, anaerobic threshold, anaerobic energy, metabolic acidosis, blood gas analysis) are listed. The medical report is closed by a comment on basic findings, such as the physical capacity, subjective complaints (angina pectoris, dyspnea), the ECG, heart rate and blood-pressure regulation and on promising medical treatment or further investigations.

2. Central hemodynamics

At rest, during volume loading and at work ergospirometric and blood pressure data (art. pulm., art. rad.) are processed on-line, using the direct Fick's principle to calculate the cardiac output and derived parameters. During the test selected para-

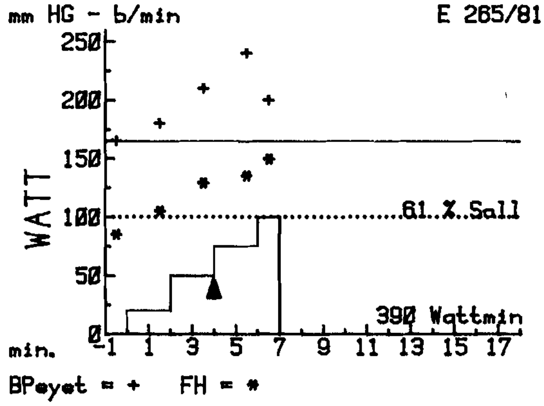

Figure 2

Selfexplaining graph of ergometric stress-testing: work capacity reduced (61% max) by abnormal reactions (starting with end of the second load: angina pectoris and ST-depression, maximum 0.3 mV; no arrhythmias; decrease of systolic blood pressure at break off.

meters (s. fig. 3; VO2, fh) and pressure data (PAsyst, PApm, PAEDP) are plotted. For the final report only data obtained during steady-state periods will be stored off-line on a data bank and documented by a print out. The graphical display of the function curve of the heart (plotting the cardiac index as the parameter of the volume transport capacity versus the index of the left ventricular filling pressure - PAEDP , pulmonary artery enddiastolic pressure) is added to the report. Figure 4 shows the reactions of the patient to volume loading (first intervention) and to two subsequent steady-state work loads in the recumbent position. The label NP characterizes the findings in normals at rest, under volume loading and at 20, 50 and 100 Watt. Any effects of acute medical intervention (e.g. Nitroglyzerin; see on-line computer plot of pharmacological intervention in figure 3) can be rated in terms of normalizing the patients functional state.

3. Lung function analysis

At our lab lung-function tests such as spirometry, flow-volume-analysis, body-plethysmography, estimation of the CO - transfer factor and of the alveolar ventilation, blood gas analysis, ergospirometric data at work can be performed easily by means of computer assisted on-line analysis. Nevertheless it has turned out to be of practical importance to add off-line data processing (graphic tablet to measure distances and calculate areas) to improve the evaluation of the lung mechanics (integrated airway resistance, instantaneous airway resistance during the forced

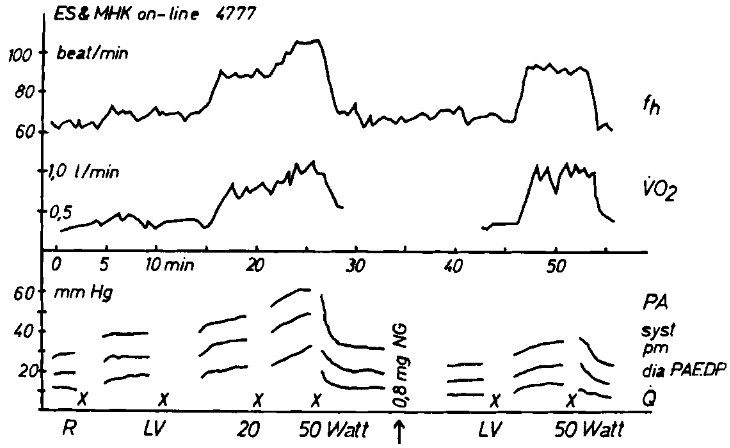

Figure 3

On-line computation and plotting of ergospirometric (fh, VO2) and hemodynamic parameters (pressure art. pulm.) in a patient with ischemia induced abnormal pressure increase at 50 Watt, which is abolished after nitroglycerin. The tracing of pressure data is interrupted during the sampling periods of mixed venous blood via the catheter. As soon as the oxygen content is known (blood gas analysis) the data are fed into the computer to calculate the cardiac out put due to the Fick's principle.

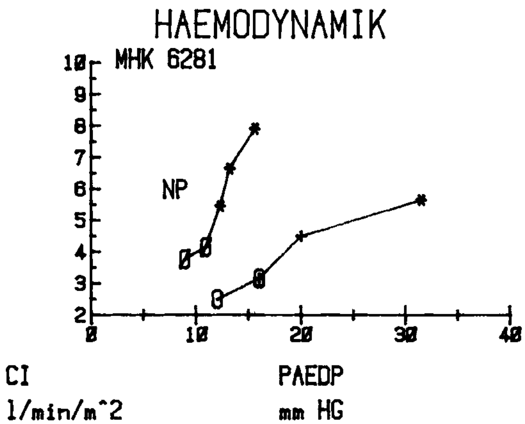

Figure 4

Selfexplaining graph of the ventricular function curve of a patient (at rest, volume loading, 20 and 50 Watt steady-state work) in comparison to normals (NP).

vital capacity maneuver. On the other hand it is often difficult to select proper data in disabled patients for on-line processing, especially if the test depends on the correct cooperation of the patient. Off-line graphics are attached to the medical report to illustrate the lung volume relationship (residual volume, vital capacity, total lung capacity) and the volume related mechanical properties of the lung. Indicating the exspiratory flow-rates at 50% and 25% of the forced vital capacity maneuver in comparison to normal ranges should visualize the functional dynamic capacity of the lung in relation to the effort applied. The instantaneous airway resistance data can be calculated, if flow, volume and pressure values during the forced vital capacity maneuver in the body chamber box are stored simultaneously. Studing the graph a functional concept of the lung mechanics should become evident by relating flow and resistance to absolute lung volumes. In figure 5 a patient with small airway disease is unable to create normal flow rates at 25% of the vital capacity despite a very high degree of effort (alveolar pressure). As a result the pertinent airway resistance Ri exceeds four-fold the normal range.

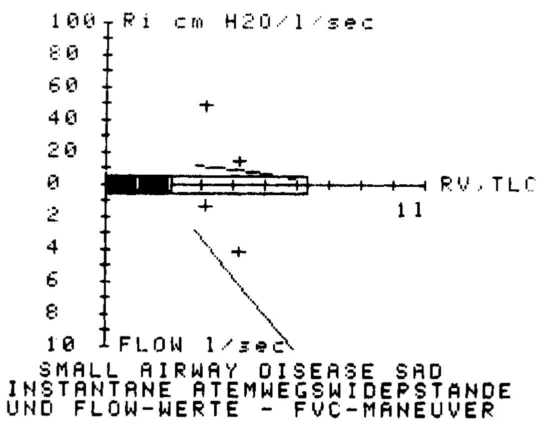

Figure 5

Selfexplaining graph on lung volumes (RV = residual volume, TLC = total lung capacity) and pertinent flow and resistance values during the forced vital capacity maneuver.

The standard form of medical reports about investigations at our cardio-pulmoary lab now comprises a) a print-out of selected data with a short comment on the findings and b) a hard copy of normal physiologic values, which are overlaid by actual patient's data. In any case at the end of each test a prompt interpretation of the findings can be performed to draw conclusions on the functional capacity of the cardio-pulmonary system, to recommend the most powerful treatment and to stimulate further investigations if needed.

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