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ABSTRACT

In this study Dutch subjects with four different levels of expertise (24 second-year, 24 fourth-year, 24 sixth-year medical students, and 24 internists with at least 4 years of experience) studied, diagnosed, and explained four clinical cases. Diagnostic accuracy increased with the increasing level of expertise. The number of concepts used and the number of detail concepts in the explanation protocols showed an inverted U-shaped relationship with level of expertise, whereas the experts' protocols matched better with canonical explanations of the cases. Constraining the processing time did not affect diagnostic accuracy but did affect the elaborateness of the explanations. It was concluded that advanced students applied more and better detailed biomedical knowledge than experts in clinical reasoning. Four figures, two appendixes (case study and chart of decisions) are included. (Contains 17 references.) (Author/SLD)

Differences in knowledge application by students and medical experts in clinical reasoning

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Abstract

In the present study subjects of four different levels of expertise studied, diagnosed and explained four clinical cases. Diagnostic accuracy increased with level of expertise. The number of concepts used and the number of detail concepts in the explanation protocols showed an inverted U-shaped relationship with level of expertise, whereas the experts' protocols matched better with canonical explanations of the cases. Constraining processing time did not affect diagnostic accuracy, but affected the elaborateness of the explanations. It was concluded that advanced students applied more, and more detailed biomedical knowledge than experts in clinical reasoning.

In the process of acquiring medical expertise an extensive knowledge base of biomedical and pathophysiological knowledge is required. Researchers in medical expertise, however, do not agree what role the biomedical knowledge plays in clinical reasoning by expert physicians. Some suppose that even for experts biomedical knowledge has an integrating function in constructing a problem representation of a clinical case (Feltovich & Barrows, 1984; Kuipers & Kassirer, 1984; Hassebrock & Prietula, 1992; Lesgold, 1984; Lesgold et al., 1988). In the opposing view medical experts mainly use clinical knowledge[1] instead of biomedical knowledge to represent and diagnose a clinical case, whereas the application of biomedical knowledge is rather considered as a characteristic of non-expert reasoning (Boshuizen & Schmidt, 1992; Patel, Evans & Groen, 1989).

These different positions concerning the application of biomedical knowledge in clinical reasoning directly refer to the different ways the researchers conceptualize the organization of medical knowledge. In contrast to the view that clinical experiences are structured and integrated around a central base of biomedical knowledge (Feltovich & Barrows, 1984; Hassebrock & Prietula, 1992; Lesgold, 1984), Patel, Evans and Groen (1989) suppose that biomedical and clinical knowledge are separately organized as two different worlds. A position between these two extremes (Boshuizen & Schmidt, 1992; Schmidt & Boshuizen, 1992), assumes that with clinical experience biomedical knowledge becomes encapsulated into higher level clinical concepts. Central to their view is the restructuring of knowledge in the development from student to expert. During medical training, students rapidly develop rich, elaborated causal networks explaining causes and consequences of disease in terms of general underlying biological or pathophysiological processes. However, through extensive and repeated application of acquired knowledge, and particularly through exposure to patient problems, clusters of detailed concepts in these causal networks become encapsulated into a few higher level concepts or diagnostic labels.

Empirical support for this position has been found in think-aloud protocols (Boshuizen & Schmidt, 1992; Joseph & Patel, 1990; Lemieux & Bordage, 1986), in post-hoc pathophysiological explanations (Patel et al., 1989; Schmidt & Boshuizen, 1993) and in recall protocols (Patel & Groen, 1991; Patel & Medley-Mark, 1986; Schmidt & Boshuizen, 1993; Schmidt, Boshuizen & Hobus, 1988) of subjects of different levels of expertise. The think-aloud protocols showed that subjects of an intermediate level of expertise applied more biomedical concepts than experts in diagnosing a clinical case. In addition, the post-hoc explanation studies revealed that protocols of intermediates contained more, and more detailed

[1] Clinical knowledge is defined as knowledge of attributes of sick people, and biomedical knowledge as attributes of entities such as organs, bacteria or viruses (Patel et al., 1989).

pathophysiological concepts than those of experts, while expert protocols were more coherent. Since it is supposed that the pathophysiological explanation reflects the knowledge activated during case processing (Patel & Groen, 1986; Schmidt & Boshuizen, 1993), it was concluded that intermediates activated elaborate causal knowledge underlying a case in clinical reasoning. This in contrast to medical experts who activated more comprehensive, high-level concepts encapsulating basic science knowledge. Moreover, recall protocols of intermediates were more extensive and literal than those of experts, which can be interpreted as more elaborate case representations by intermediates resulting from their more elaborate processing of case information. A priming experiment (Schmidt & Boshuizen, 1993), in addition, showed that the amount of activation of pathophysiological knowledge strongly determined the recall performance of students of an intermediate level of expertise, whereas clinicians' recall was not affected.

In a recent experiment, however, we found a positive linear relationship between recall and level of expertise in four cases from internal medicine (Van de Wiel, Boshuizen, Schmidt & de Leeuw, 1993). This finding suggests that the expert physicians constructed more elaborate case representations than students. However, since it has been discussed that task perception (Norman, Brooks & Allen, 1989) and motivation of subjects (Patel & Groen, 1991) could influence the recall task, we cannot completely rule out that the latter of these variables could be responsible for the higher recall performance of experts. Therefore we verified if evidence for more elaborate case representations is also found in experts' pathophysiological explanations of these four internal cases.

In the experiment we conducted, subjects of four levels of expertise were asked to study, diagnose, and explain the signs and symptoms of each case. As in the studies of Schmidt & Boshuizen (1993) and Van de Wiel et al. (1993) study time was manipulated. Based on the notion of knowledge encapsulation (Boshuizen & Schmidt, 1992) it was assumed that students need to elaborate on their biomedical knowledge in order to construct a coherent representation of a clinical case, in contrast to expert physicians who automatically activate higher level knowledge in encapsulated form. Therefore, we expected the explanation protocols of advanced students to be more extensive and detailed than those of experts. In addition, we hypothesized that constraining processing time has no effect on experts' protocols, whereas students' protocols will become less extensive, since students will be restricted in the elaboration of their representations.

Method

Subjects. Subjects were 96 students and physicians of the University of Limburg: 24 second-year, 24 fourth-year and 24 sixth-year medical students[1] and 24 internists with at least 4 years of experience in internal medicine. Each group of 24 was randomly subdivided into three groups of eight who were assigned to three time constraint conditions. Subjects received a small compensation for their participation.

Material. The materials consisted of four booklets, each containing a description of a clinical case and two blank response sheets. Each clinical case description reported some contextual information, the complaint, findings from history taking and physical examination, the relevant laboratory data and some additional findings. The case descriptions were about half a page in length and consisted of 33, 42, 43, and 35 propositions respectively. The four clinical cases, pheohromocytoma, stomach carcinoma, heart failure and liver cirrhosis, were based on actual patients and were presented as a narrative. Except for pheochromocytoma, these cases are fairly common in medical practice. The translated text the case of heart failure is provided in Appendix A.

Procedure. Subjects were asked to study each case in order to produce a diagnosis and to provide a pathophysiological explanation of the signs and symptoms in the case. An example case was presented to familiarize them with the case format in this experiment and to experience the reading time allowed. Depending on the experimental condition subjects were given the opportunity to read each case for 3 minutes (3'00"), 1 minute and 15 seconds (1'15"), or 30 seconds (30"). Subjects were free to use as much time as they needed for the assignments. The order of case presentation was balanced.

Analysis. Diagnoses were scored on a scale ranging from 0 (completely inaccurate diagnosis) to 6 (completely accurate diagnosis) for each case: points were attributed to accurate diagnostic elements which, for each case, summed up to 6. Based on propositional analysis (Patel & Groen, 1986), the pathophysiological explanations were schematized as semantic networks of small meaningful concepts. The total number of concepts in these schematized explanations was counted. For each case a canonical explanation was constructed by the first two authors, a family physician and an internist. This explanation contained the minimal set of pathophysiologically and clinically relevant concepts

[1] The program at the University of Limburg contains in the first two years subjects on basic science knowledge to a good understanding of physiology, anatomy and general pathophysiology. In the third and fourth year education is centered around clinical problems addressing pathophysiological knowledge of disease, and the fifth and sixth year consists of different clerkships in the clinic.

necessary to explain the signs and symptoms in the case (see Appendix B for a canonical explanation of the case of heart failure). The subjects' explanations were matched against the canonical explanations: The number of overlapping concepts (model concepts) and the number of more detailed concepts (detail concepts) were counted. Reliabilities of these procedures exceeded .90. All data were analyzed by means of repeated measures Manova. Polynomial contrast analysis was used to test specific hypotheses.

Results and discussion

Diagnosis. Figure 1 shows diagnostic accuracy as a function of level of expertise and processing time. A significant main effect of level of expertise on diagnostic accuracy was found, $F(3,84) = 68{,}68$, $p = .0001$. Polynomial contrast analysis revealed a significant linear trend ($F(1,84) = 211.58$), $p = .0001$), and a nonsignificant quadratic trend ($F(1,84) = .004$), $p = .95$): Thus, the more experienced the subjects, the better diagnoses they made.

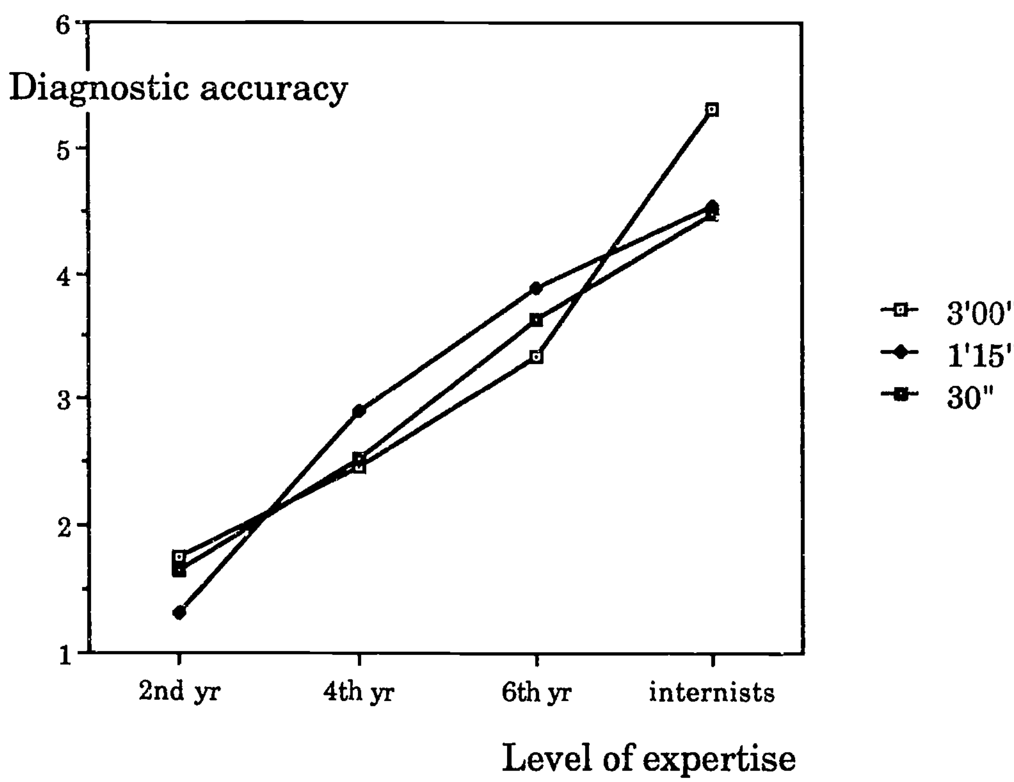

Figure 1. Average accuracy of diagnoses as a function of expertise level and processing time.

An increase in diagnostic accuracy is considered one of the most stable effects of medical expertise. Therefore, we can conclude that the subjects' tasks in this experimental setting were ecologically valid. The effect of processing time was not significant $F(3,84) = .29$, $p = .75$. The same effect was found by Schmidt et al. (1988). This suggests that processing a clinical case in order to formulate a diagnosis directs the attention of the subjects in such a way that they are equally capable or incapable of fulfilling this task in 3'.00", 1'.15" or 30".

Pathophysiological explanations. Considering the assumptions of knowledge encapsulation the first variable of interest in the pathophysiological explanation protocols is the total number of concepts applied. Figure 2 depicts the relationship between the average number of concepts produced and level of expertise. Both a significant main effect of level of expertise ($F(3,84) = 9.26$, $p = .0001$), and a significant main effect of processing time ($F(3,84) = 4.14$, $p = .015$) was found. The sixth-year students used more concepts in their pathophysiological explanations than internists, which we interpret as more elaborate processing by advanced students. In contrast to what we expected total number of concepts in 6th year

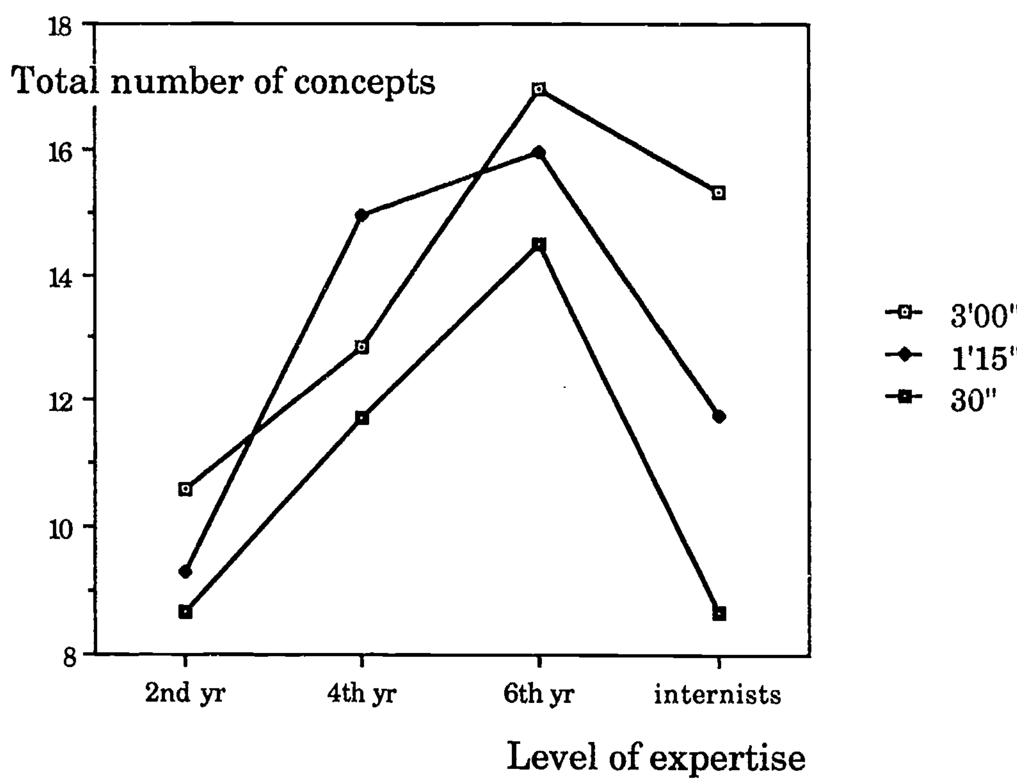

Figure 2. Total number of concepts in the pathophysiological explanation protocols as a function of expertise level and processing time.

students' protocols was not affected by processing time constraints, while those in internists' protocols in fact were ($F(2,21) = 5.27$, $p = .014$). This seems to be in contradiction with the hypothesis of elaborate processing of clinical cases by subjects of an intermediate level of expertise.

The second variable we measured was the number of model concepts in subjects' protocols. In order to circumvent an effect of the extensiveness of protocols we transformed this variable to the percentage of model concepts of the total number of concepts in the protocols. The main effect of level of expertise on the percentage of model concepts was significant ($F(3,84) = 16.52$, $p = .0001$), as well as the main effect of processing time ($F(3,84) = 3.26$, $p = .043$). The relationship between percentage of model concepts and level of expertise (figure 3) was positively linear as indicated by a strong linear component ($F(1,84) = 45.50$, $p = .0001$) and a weak quadratic component ($F(1,84) = 3.24$, $p = .076$). This means that the explanations of the internists matched better with the canonical explanations. The significant effect of processing time should be atrributed to the poor quality of the students' explanations in the 30" condition. The quality of experts' explanations was not affected by processing time conditions; this suggests that experts automatically activate the relevant knowledge.

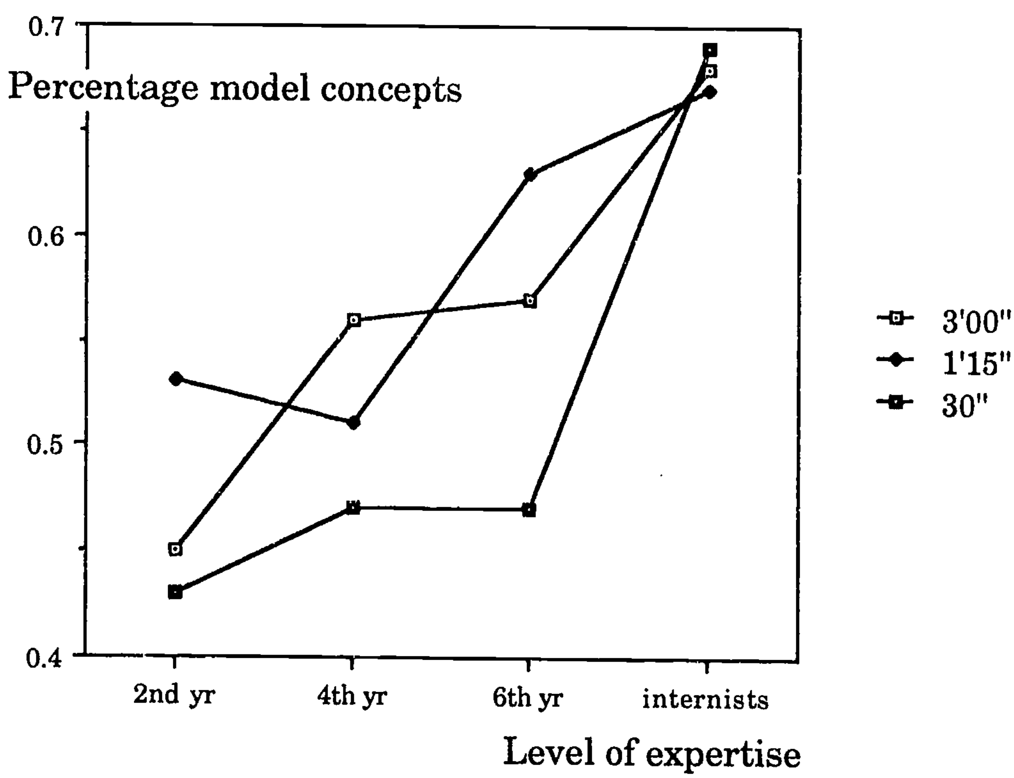

Figure 3. Percentage model concepts of the total number of concepts in the pathophysiological explanation protocols as a function of expertise level and processing time.

Finally, the third variable was the number of concepts of a more detailed level than the concepts in the canonical explanations. An overall effect of expertise on level of detail of explanations was significant ($F(3,84) = 6.72$, $p = .0004$). The graph depicting the relation between the number of detail concepts, level of expertise and processing time (figure 4) shows an inverted U-shaped function with expertise ($F(1,84) = 18.34$, $p = .0001$). This supports our hypothesis that advanced students activate detailed biomedical knowledge in clinical reasoning, while experts do not. The main effect of processing time, however, was not significant, ($F(3,84) = .26$, $p = .8$). Thus constraining processing time had no effect on the level of detail of explanations.

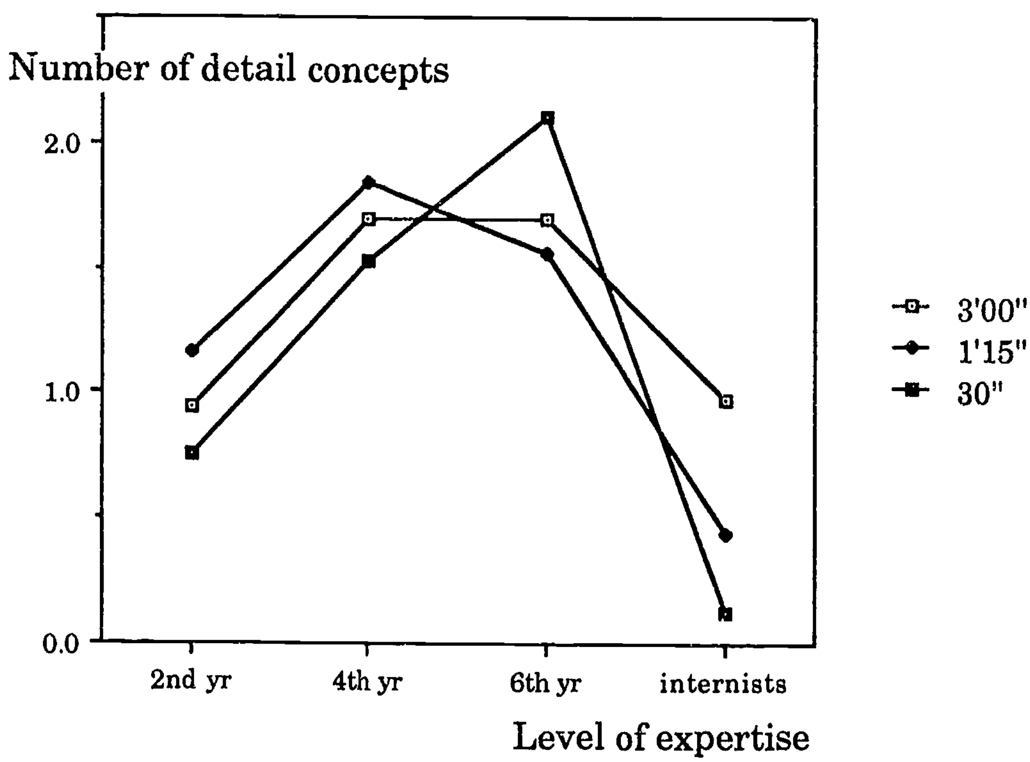

Figure 4. Number of detail concepts in the pathophysiological explanation protocols as a function of expertise level and processing time.

Overall, the data comparing expertise levels support the view of Boshuizen and Schmidt (1992) that in clinical reasoning advanced students process case information more elaborately and in more detail than experts. Students have to invoke their detailed biomedical knowledge when they try to diagnose a clinical case. Expert physicians, in contrast, automatically activate the relevant knowledge on an encapsulated level.

The effect of processing time, however, was not consistent with the results of Schmidt & Boshuizen (1993). In our study elaborateness and level of detail of advanced students' explanations was not affected by constraining processing time, whereas experts' explanation protocols were significantly longer when more study time was available. However, the quality of the students' explanations was significantly poorer in the short processing time condition as indicated by the lower percentage of model concepts in their protocols. The quality of experts' protocols, in contrast, remained stable over all processing time conditions. Thus, the quality results are in line with our hypothesis that students' explanations would be negatively affected by constraining processing time, whereas experts' explanations would not be affected. However, our hypothesis does not hold for the extensiveness of explanation protocols, and we found the opposite of what we expected. An explanation for this finding could be that the pathophysiological explanation does not only reflects the knowledge activated during case processing, as we assumed, but also reflects knowledge processed during providing the pathophysiological explanation itself. The representation constructed during studying the case is the starting point, on which can be elaborated in the explanation phase. Thus, when students had shorter time to study a case, the initial representation would be less elaborate and coherent, providing a weaker base for high-level pathophysiological reasoning. Experts, in contrast, immediately activated the relevant knowledge in case processing, but could feel more stimulated to give an explanation when they studied a case for a longer time.

In further research we will explore the nature and development of knowledge structures in the medical domain with different methods and in different subject groups. On the one hand, we will focus on the knowledge restructuring process in students with abundant practice in a specified domain; on the other we will investigate what kind of knowledge medical experts use in diagnosing a case outside their specific domain of expertise.

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Appendix A

<u>Case of heart failure</u>

A 70-year-old female is admitted into hospital because of increasing shortness of breath. History taking reveals that the patient has been very tired lately and tolerates her food badly. Sometimes she has chest pain, especially after dinner. Physical examination shows a pale and tired woman. She has an irregular, unequal pulse of 100/min. The blood pressure is 110/70 mmHg and jugular venous pressure is elevated. The patient has wide-spread peripheral edema, and positive jugular venous pulsations. The heart is enlarged to all sides, and auscultation reveals a holosystolic murmur at the apex radiating towards the axilla. Lungs: at both sides rales at lung bases. Liver and spleen not palpable. Laboratory results shows a ESR of 2 mm/u (normal: < 12 mm/u), a Hemoglobine-level of 10.8 mmol/l (normal: 7.5-10.0 mmol/l) and a PCV of 0.54 (normal: 0.36-0.47). Electrolytes normal. Creatinine 85 µmol/l (normal: 53-97 µmol/l), CPK 40 U/l (normal: 40-200 U/l). pH is 7.50 (normal: 7.35-7.45), PO_2 11,6 kPa (normal: 8.7-13.1 kPa), pCO_2 3.6 kPa (normal: 4.5-5.9 kPa), HCO_3^--concentration 21 mmol/l (normal: 22-28mmol/l) and O_2-saturation 97% (normal: 93-98%).
The thoracic X-ray shows congestion of the lungs and an enlarged heart. Echocardiography shows an enlarged left atrium and ventricle. And ECG reveals atrial fibrillation.

Appendix B

Canonical explanation of heart failure