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SEKI-PROJEKT

SEKI MEMO

Overview on MED1: A Heuristic Diagnostics System with an Efficient Control-Structure

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MEMO SEKI-83-02

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A Heuristic Diagnostics System
with an Efficient Control-Structure

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Abstract:

MED1 is a fully implemented tool for constructing diagnosis systems especially in the medical area. A model to diagnose diseases provoking chest pain has been completed. It tries to simulate the way physicians diagnose and is capable of explaining every reasoning step.
From other diagnosis systems using the techniques of Artificial Intelligence for representation of heuristic expert knowledge, MED1 differs mainly regarding more flexibility in hypothesis generation, reasoning with uncertainty and deciding the necessity of technical diagnostic procedures.
The comfortable knowledge-acquisition facility enables the expert familiar with the structure of MED1 to communicate his knowledge to the system without knowing anything about LISP.

1. Introduction

The goal of the MED-project (MED stands for Meta - Ebenen Diagnosesystem or Meta Level Diagnostics System) is the development of a medical diagnostics system for a broad domain of human diseases. The system should provide assistance to the physician in making the rapidly increasing medical knowledge available for a particular case at hand, avoiding overlooking rare diseases and minimizing diagnostic inconveniences and costs.

We have now finished the development of a first model (MED1) for diagnosing diseases associated with chest pain. This paper presents an overview on the design criteria (chapter 2), their implementation (chap. 3 and 4), and system-performance (chap.5). An example is given in the appendix. For detailed description see [Pup 83a], [Pup 83b].

Because structure and functioning of MED1 are not specific for its domain, it can be used as a tool for constructing diagnostic systems in any domain, which was demonstrated by MODIS [Bor 83] in the area of car-engine defects.

2. Design Criteria

MED1 is based on the experience with the AIM (Artificial Intelligence in Medicine) programs already completed. An excellent review of these is given in [Szo 82]. They (including MED1) are characterized by a set of heuristic rules associating findings with diagnoses without using a complicated causal model. Our design criteria were set up with respect to specific deficiencies reported.
One of the major problems is to facilitate the expert's interaction with the computer. To do without a "knowledge engineer" requires (first design criterium):

1.1 a comfortable knowledge-acquisition facility
1.2 a comprehensive explanation facility

The second design criterium was to improve the weak control structures of the known AIM systems. The backward-reasoning of MYCIN [Sho 76] resp. EMYCIN [Mel 79] usually results in thoroughly investigating all disease-hypotheses. Towards the other extreme CASNET [WKAS 78] resp. EXPERT [WK 79] mainly rely on forward-reasoning, thereby completely reevaluating the knowlegde base when processing a new finding. Both pure strategies are increasingly inefficient in larger domains. The strict hierachy of MDX [CGMS 79] can only be applied to well-structured diagnostic problems. INTERNIST1 [MPM 82] examines all of the diagnoses explaining at least one of the symptoms initially presented to the system. PIP [PGKS 76] seperates between active, semiactive and dormant hypotheses, but the simple trigger mechanism activating hypotheses is not selective enough.
The consequences of a weak control structure are not wrong diagnoses. Instead they restrict these systems to rather small (EMYCIN and EXPERT) or specialized (CASNET and MDX) domains or yield unsatisfying diagnostic styles (PIP and especially INTERNIST1). MED1 should be able:

2.1 to efficiently deal with a large knowledge base
2.2 to ask questions in a reasonable order
2.3 to arrive at the right diagnosis avoiding unneccary questions and tests

The judgemental knowledge of experts (as opposed to statistical data) has been proven to be a sound base of reasoning with uncertainty. To support the expert in formalizing his knowledge, MED1 should provide powerful categorical and probablistic reasoning concepts [SP 78]. That requires

3.1 representation schemes for structuring the way from the initial findings to the final diagnosis.

3.2 avoiding imposing any restrictions on the expert when quantifying his knowledge by providing reasoning

schemes making no a-priori assumptions about the independence of rules (like MYCIN as shown in [Ada 76]).

3. System Architecture and Execution Cycle

To meet the second design criterium, we chose a meta-level system architecture:

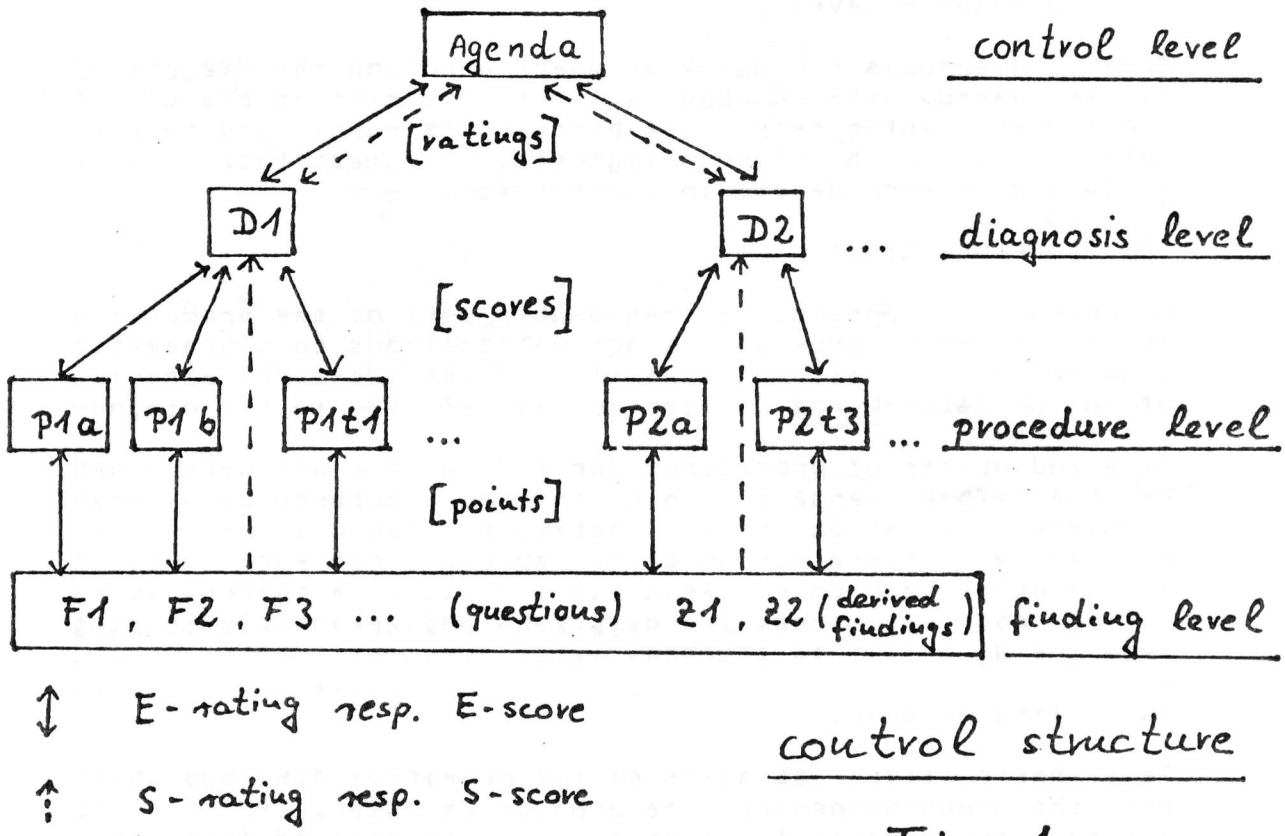


Fig 1

Explanation:

(1) Control Level:

The core of MED1 is the agenda, a list of all active diagnoses ranked according to their ratings.
Two different ratings may be assigned to each diagnosis:

- an S-rating for suggesting disease hypotheses
- an E-rating representing the result of detailed evaluation

The S-rating is computed by forward-rules accumulating suggestive evidence thereby providing much more selectivity than PIP's trigger mechanism.
Upon every execution-cycle (see fig. 2) the top diagnosis of the agenda is activated and further explored. An execution-cycle results in:

- elimination of the S-rating and computation of a new E-rating.
- several updated S-ratings of other diagnoses if the system hit upon suggestive evidence.

(2) Diagnosis Level

Once a diagnosis (actually an agent handling the diagnosis) is activated, the diagnosis in turn activates one of its procedures, interpretes the procedure's result and handles interactions with other diagnoses. The last task will be explained in more detail in chapter 4.3.

(3) Procedure Level

A procedure contains a reasonable part of the production rules of one diagnosis. Its activation leads to a schematic examination of its rules similar to the backward-reasoning of MYCIN. Afterwards the control is returned to the diagnosis level.
Size and number of procedures for a diagnosis are determined by the expert enabling him to find a compromise between complete evaluation of an activated diagnosis at the one extreme and reevaluation of the agenda after each question at the other (design criteria 2.2 and 2.3). We thereby avoid asking possibly unneccary questions and frequently jumping from one diagnosis to another.

(4) Finding Level

This basic level consists of the primitive findings which are the conditions of the production rules. Findings are either asked directly from the user or derived from other findings (e.g.: shock-index = heart beat frequency divided by blood pressure).

The execution-cycle has already been mentioned. It is best illustrated in a scheme:

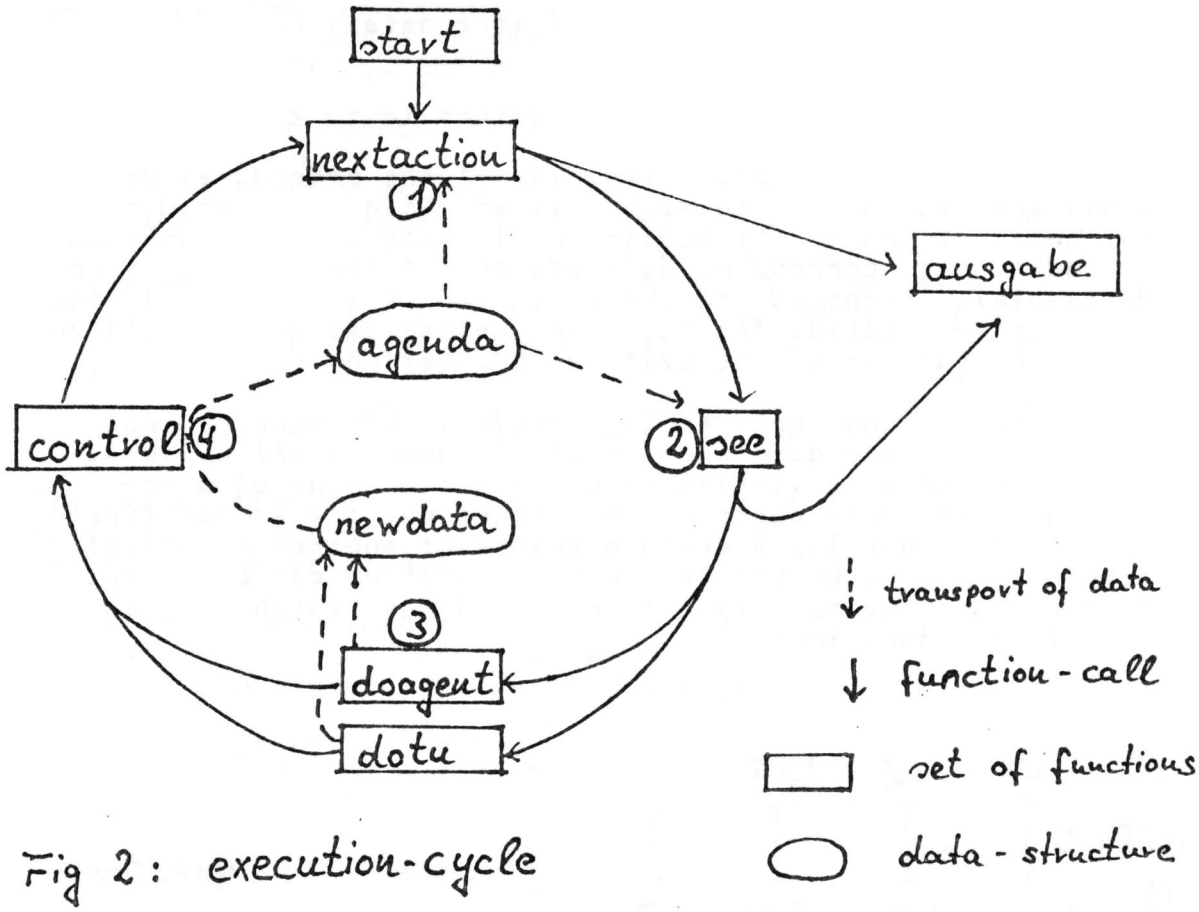


Fig 2: execution-cycle

Explanation

The systems starts with a set of survey-questions evaluated by forward rules to initiate the agenda before entering the execution-cycle, which is divided into four phases:

Phase 1: Check of the termination criteria (true, when one diagnosis is rated much higher than the rest.)
Phase 2: Activation of the top-ranking diagnosis or technical investigation (see later explanation). If there is none, the system has to terminate too.
Phase 3: Exploration of the activated diagnosis. What happens here will be explained in more detail in the next section. The results are buffered in a variable "newdata".
Phase 4: Incorporation of the data from "newdata" in the agenda.

After termination the system informs the user about the results (ausgabe).

4. Specific Mechanisms

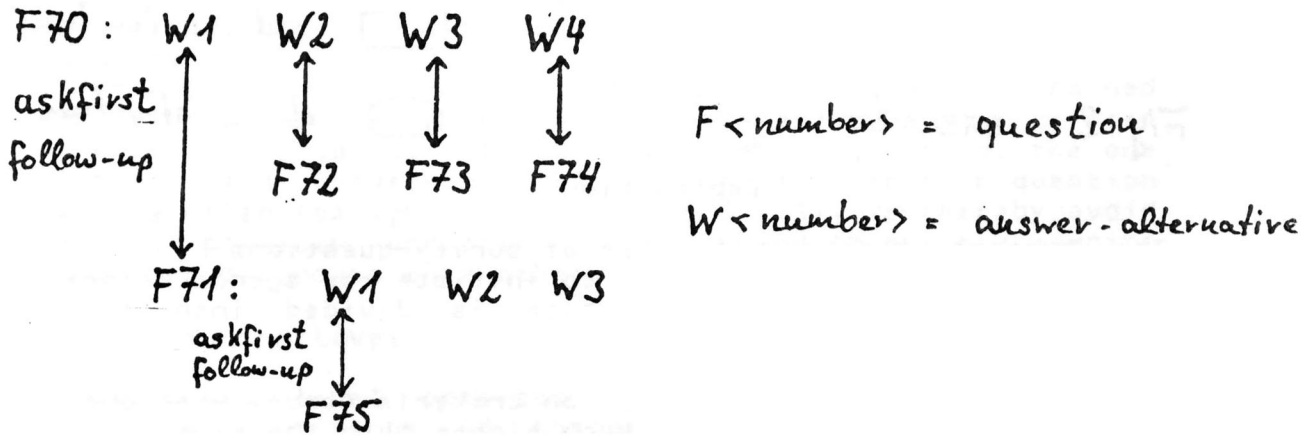
In this section we describe in more detail how we achieve the design-criteria (d. c.).

4.1. Strategy of asking questions (d.c. 2.2)

Generally the backward reasoning of the procedures determines the sequence of questions asked. When the system tries to apply a rule the condition of which is still unknown, it asks the corresponding question (if the finding is not derivable). Compared to the physician this strategy is too much goal-directed. The following mechanisms enable MED1 to cover the context of the symptom in question, too:

- We usually do not employ yes/no, but more general multiple-choice questions. Multiple answers are allowed.
- MED1 posesses facilities to build a hierarchy of questions. For every question the expert may fix an "askfirst"-condition (usually a certain answer of another question) which has to be met before this question can be asked.
- The expert may specify answers (findings) which trigger follow-up questions.

Example:



Explanation:

The system evaluates a rule containing as condition (F71 = W1). The askfirst-condition of F71 is (F70 = W1). If the user's answer to F70 is W1 and W4, the system asks in addition to F71 the question F74 as follow-up of (F70 = W4).

Apart from asking related questions together, these mechanisms greatly increase the chance to discover unexpected findings. These are evaluated by forward rules suggesting new hypotheses as mentioned above (explanation of control level).

4.2 Reasoning with Uncertainty (d. c. 3.2)

Our model for reasoning with uncertainty is a modified version of the model introduced by MYCIN. The main features of our model are (1. and 2. similiar to MYCIN):

1. Positive and negative evidence is evaluated by different rules.
2. The correlation between findings and conclusions (e.g. diagnoses) is expressed in rules based on estimations of experts. The rules specify how many points (representing diagnostic importance) the findings or combinations of findings contribute to the disease accounts. The higher its score, the higher the probability of the diagnosis.
3. For interpreting the score of a disease account, the expert specifies an evaluation scheme to calculate the total probability (rating) of the conclusion.

The last feature deserves attention. All other diagnosis systems following the approach of MYCIN use a strict combining scheme, e.g.:

Let P = the combined evidence-value of a conclusion
P1 = the old evidence-value
P2 = the evidence-value of a new rule

MYCIN calculates the combined evidence-value by a formula:

$$P = P1 + (1 - P1) * P2 \quad \text{if } P2 \geq 20\,\%$$
$$P = P1 \quad \text{if } P2 < 20\,\%$$

CASNET uses a different formula:

$$P = \text{maximum } (P1, P2)$$

A strict combining scheme is only correct if certain assumptions hold about the relations of several rules belonging to one conclusion, e.g. complete independence (MYCIN) or dependence (CASNET).
To avoid such assumptions MED1 transforms the score of a disease account into one of several (currently seven) probability classes (ratings) from "excluded" to "confirmed" This evaluation scheme may be specific to each conclusion.

Besides, we think this model facilitates the difficult task of quantifying medical knowledge by dividing it into two steps (the expert can specify some score for each individual rule and the evaluation scheme seperately).

4.3 Structuring the Knowledge-Base (d.c. 2.1 and 3.1)

Usually the diagnostician does not relate findings directly to specific diagnoses. Instead he first recognizes pathophysiologic states connecting the findings with the specific diagnoses by causal or hierarchical relations.

In MED1 these concepts are represented as intermediate diagnoses while their relations are expressed in diagnosis to diagnosis rules. Flexibility results from the different types of rules: forward or backward-activation, adding points to the S- or E-score.
Example: To build up a hierarchy MED1 provides two mechanisms: the parent diagnosis may transfer an arbitrary amount of points to the S- or E-score of its children. A resulting high S-rating only initiates exploration, whereas an increased E-score additionally represents some belief in the child-diagnosis.

But there is one important difference to the ordinary finding-to-diagnosis rules: MED1 explores diagnoses in several steps (procedures). The E-rating of a diagnosis may change during a session. Therefore the condition of a diagnosis-to-diagnosis rule can be true or false depending on the time when the rule is checked. We have addressed this problem by making sure that conclusions can only be drawn from the E-rating of a diagnosis when the score is unlikely to change considerably, i.e. when a special score representing the degree of diagnostic completeness has surpassed a threshold. Vary rarely major changes happen even afterwards, making the conclusion wrong. Currently MED1 has no thruth maintenance system to correct premature conclusions but only prints a warning to the user.

4.4 Technical Investigations (d. c. 2.3)

Technical investigations (tech. invest.) are powerful diagnostic means but often expensive, risky or inconvenient. Their use requires special justification. MED1 reflects this by treating them as independent entities and incorporating them in the agenda, where they are ranked according to a score representing strength of indication. Only upon reaching the top position they are proposed by the system.

When it is desirable or necessary to make a tech. invest. (laboratory test, x-ray etc) to clarify a diagnostic problem, the suspected diagnosis indicates (activates) it by transferring a certain amount of points (representing strength of indication) on an account of this tech. invest. Other rules score the involved risks and costs. Additionally, there is a check on contraindications. The resulting balance of the account determines the position of the tech.

invest. in the agenda.

The goal and effect of this complex mechanism is to delay tech. invest. until no other diagnostic options are left while the problem is still unresolved. However, its full power would result from the introduction of therapeutic options in the agenda to compete with tech. invest.

4.5 Differential Diagnosis and Multiple Diseases

High ratings of more than one diagnosis can be due to multiple diseases or reflect the similarity of several competing disease-hypotheses. INTERNIST1 solves the latter problem by defining problem areas consisting of diagnoses explaining the same findings (of which only one may be true). PIP provides for each diagnosis a list of differential diagnoses. Our approach is somewhat similiar to PIP: we use diagnosis-to-diagnosis rules to increase the difference between competing diagnoses. However, if upon termination there is more than one probable hypothesis, MED1 lets the user interpret the result.

4.6 Termination Criteria

MED1 terminates if

- one diagnosis is confirmed. or
- one diagnosis is very probable and no other diagnosis appears to be likely (in both cases the user has the option to have MED1 continue its diagnostic course). or
- the agenda is empty (no promising diagnostic options are left).

These criteria are adequate for our domain (chest-pain), where multiple diseases are rare. Extension of the domain requires more sophisticated termination criteria (e.g. INTERNIST1). However substantial improvement can only result from a deeper causal understanding and incorparation of therapeutic options.

4.7 Explanation Facility (d. c. 1.2)

The explanation facility illustrates and explains every reasoning-step taken by MED1, thereby reflecting its architecture.
The main explanatory options are:

- State of agenda
- Explanation of both E- and S-ratings of each diagnosis in terms of all rules evaluated as "true"
- Steps of reasoning from the current question to the hypothesis under investigation

In addition, the user can ask questions concerning the underlying medical knowledge:

- The meaning of a finding, in terms of all rules drawing conclusions from this finding
- The profile of a diagnosis, i.e. all the findings contributing various amounts of evidence (points) to this diagnosis
- The indication-mechanism of technical investigations

4.8 Knowledge-Acquisition Facility (d. c. 1.1)

The knowledge-acquisition requires the expert to be familiar with the structure of MED1, but not with LISP. To facilitate the expert's work, well structured and readable listings of the knowledge base are printed by the computer. If you visualize the knowledge-base as a network, the expert first specifies the nodes (questions, intermediate states, technical investigations and diagnoses and its procedures) guided by the computer. Then he establishes the links (the various kinds of rules) by using shorthands to refer to the nodes. Because syntax-checks and proper updating are done by the computer, this part is little time-consuming. A special service is the possibility to change the knowledge base during a session enabling the correction of faults immediately after detecting them. This will be demonstrated in the example.

5. Performance

MED1 is fully implemented in Interlisp and runs on a Siemens computer under the operating system BS 2000. Currently the medical knowlege base enables MED1 to diagnose diseases provoking chest pain. All of the about 20 diagnoses have been tested with simulated patient's records yielding satisfying results with respect to finding the right diagnosis and diagnostic style. We have no psychological problems with the response time even when interpreting the LISP-code.

A second model for diagnosing car-engine defects has been implemented using MED1 as tool. The experience with MODIS has shown that even a doubled knowledge base doesn't substantially lengthen the response time.
The storage requirements for MED1 are about 300 K bytes for the general system (including the knowledge-acquisition facility) and 300 K bytes (chest pain model) or 600 K bytes (car engine model) for the knowledge base, respectively.

6. Conclusions

MED1 introduces several innovations over other AIM systems:

- Its powerful meta-level control structure can deal with large knowledge bases and secures a reasonable diagnostic style.

- MED1's mechanisms for reasoning with uncertainty avoid any a-priori assumptions and facilitate the difficult task of quantifying medical knowledge by dividing it into two steps.

- MED1 has a special mechanism for indicating technical investigations, treating them as independant entities.

It also demonstrates the need of additional mechanisms like a truth-maintenance system and the incorporation of therapeutic options before making the final diagnosis.
Like the other first generation AIM systems MED1 lacks adequate representation of causality, time and anatomy. Further improvements require progress in these areas and will characterize the second generation.

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A P P E N D I X

Kommentierte Auszuege aus einem Sitzungsprotokoll
(Kommentare stehen in Klammern)

```
(OUT)    DIESES MEDIZINISCHE EXPERTENSYSTEM STELLT DIAGNOSEN FUER PATIENTEN MIT DEM
(OUT)    LEITSYMPTOM BRUSTSCHMERZ.

Diagnostisches Problem:   Es handelt sich um einen 35-jaehrigen Mann,
                          der ueber ploetzlich aufgetretenes links-
                          thorakales Stechen klagt.

(OUT)    DER DIALOG BEGINNT MIT CA. 15 UEBERSICHTSFRAGEN ZUR VERDACHTSGENERIERUNG.

         (Nach einer Reihe von Fragen stellt das System die folgenden:)

(OUT)    F26 = SCHMERZBEGLEITSYMPTOME
(OUT)    WELCHE KRANKHEITSZEICHEN SIND SCHMERZBEGLEITEND AUFGETRETEN?
(OUT)    1    = DYSPNOE
(OUT)    2    = EXANTHEM.IM.SCHMERZAREAL
(OUT)    3    = DYSPHAGIE
(OUT)    4    = HUSTENREIZ
(OUT)    5    = BLUTIGES.SPUTUM/AUSWURF
(OUT)    6    = ERBRECHEN
(OUT)    7    = ANHALTENDE.HEISERKEIT
(OUT)    8    = STRIDOR
(OUT)    0   = NEIN / KEINE DER BISHERIGEN ALTERNATIVEN
(OUT)    ?
(IN)-----1    (Benutzereingaben sind durch Striche am linken Rand hervorgehoben.)
(OUT)
(OUT)    BEZUG DER FRAGE:   SCHMERZBEGLEITSYMPTOME  =  DYSPNOE
         (Die beiden folgenden Fragen sind keine obligatorischen
          Uebersichtsfragen; sie sind durch die Antwort "1" auf
          die Frage F26 ausgeloest worden zur weiteren Erforschung
          der Dyspnoe: "follow-questions").

(OUT)    F134 = DYSPNOE-CHARAKTERISIERUNG
(OUT)    CHARAKTERISIEREN SIE DIE DYSPNOE GENAUER!
(OUT)    1    = NICHT.RICHTIG.DURCHATMEN.KOENNEN
(OUT)    2    = FLACHE.BESCHLEUNIGTE.ATMUNG
(OUT)    3    = BELASTUNGSDYSPNOE
(OUT)    4    = RUHEDYSPNOE
(OUT)    5    = ORTHOPNOE
(OUT)    6    = * NAECHTLICHE.PAROXYSMALE.DYSPNOE
(OUT)    7    = VON.DEN.LUNGEN.AUSGEHENDES.BRODELN
(OUT)    8    = BLUTIGER.SCHAUM.VOR.DEM.MUND
(OUT)    0   = NEIN / KEINE DER BISHERIGEN ALTERNATIVEN
(OUT)    ?
(IN)-----3
(OUT)
(OUT)    BEZUG DER FRAGE:   SCHMERZBEGLEITSYMPTOME  =  DYSPNOE
(OUT)    F200 = DYSPNOE-AKUITAET
(OUT)    IST DIE LUFTNOT ALT ODER NEU AUFGETRETEN?
(OUT)    1    = ALT
(OUT)    2    = * NEU-PLOETZLICH.NACH.BRUSTSCHMERZEN
(OUT)    3    = NEU-10.MIN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN
(OUT)    4    = NEU-3.STD.BIS.24.STD.NACH.BRUSTSCHMERZEN
```

```
(OUT)     5    = NEU.1-7.TAGE.NACH.BRUSTSCHMERZEN
(OUT)     6    = NEU,NACH.SUBCLAVIA-PUNKTION
(OUT)     0   = NEIN / KEINE DER BISHERIGEN ALTERNATIVEN
(OUT)     ?
(IN)-----3

(IN)-----w f200.w    (Der Benutzer fragt nach der Bedeutung der Ant-
                      wortalternativen der Frage F200; das System
                      druckt darauf die Regeln aus, deren Bedingungs-
                      teil diese Antwortalternativen enthaelt; hier
                      wird nur ein Teil davon wiedergegeben.
                      Regeln zur Verdachtsgenerierung (S-rating) sind
                      durch das Schluesselwort "SPEC" gekennzeichnet,
                      Regeln zur Verdachtsueberpruefung (E-rating) durch
                      "ADD". Es werden zunaechst nur die 'SPEC"-Regeln
                      ausgewertet.)

(OUT)     F200 = DYSPNOE-AKUITAET HAT FOLGENDE BEDEUTUNG:
(OUT)     (= 2)      200    SPEC D1 = PNEUMOTHORAX
(OUT)                   4    ADD  Z9 = LUEMBO-HINWEIS-ZAEHLER
(OUT)     (= 3)         3    ADD  Z9 = LUEMBO-HINWEIS-ZAEHLER
(OUT)     (4 5)        10    ADD  P1A = PNEUMOTHORAX-A
(OUT)     (= 4)         2    ADD  Z9 = LUEMBO-HINWEIS-ZAEHLER
(OUT)     (2 3)       300    SPEC D3 = LUNGENEMBOLIE
(OUT)     (2 4)       100    SPEC D20 = KREISLAUFSCHOCK
(OUT)     (= 6)        80    ADD  P1A = PNEUMOTHORAX-A
(OUT)                 300    SPEC D1 = PNEUMOTHORAX
(OUT)     (3 4)       100    SPEC D1 = PNEUMOTHORAX
(OUT)     (= 5)        50    SPEC D7 = PERICARDERGUSS
(OUT)     (= 1)        50    SPEC D7 = PERICARDERGUSS
(OUT)     R250         10    ADD  P20B = SCHOCK-UEBERPRUEFUNG
(OUT)                                                (F134 W2) (F200 3 4)
(OUT)     R69          20    ADD  P1A  = PNEUMOTHORAX-A     (F134 W3) (F200 = 3)
(OUT)     R11          -4    ADD  P1A = PNEUMOTHORAX-A      (F26 NON W1) (F130 NON W7)
(OUT)                                              ODER  (F200 = 1)

          (Abbruch der Regelauflistung)

(IN)-----R69    (Benutzer fragt nach einer ausfuehrlichen Erlaeuterung
                 der Regel R69.)

(OUT)     WENN    F134 W3          DYSPNOE-CHARAKTERISIERUNG  =  BELASTUNGSDYSPNOE
(OUT)             F200 = 3         DYSPNOE-AKUITAET = NEU-10.MIN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN
(OUT)     DANN  ADD P1A = PNEUMOTHORAX-A    20

          (Als naechstes zeigen wir die Passage nach Auswertung der Uebersichtsfragen.)

(OUT)     NACH AUSWERTUNG DER STEUERSYSTEMFRAGEN ERGEBEN SICH FOLGENDE PRIORITAETEN:

(OUT)     3. KLASSE:                D3 = LUNGENEMBOLIE
(OUT)                               D1 = PNEUMOTHORAX
(OUT)                               D4 = PLEURITIS.SICCA

(OUT)     7. KLASSE:                D20 = KREISLAUFSCHOCK
(OUT)                               D15 = ANGINA-PECTORIS
(OUT)                               D11 = INTERKOSTALNEURALGIE
(OUT)                               D12 = HERPES.ZOSTER
```

```
(OUT)     NEXT:                        D3 = LUNGENEMBOLIE
          (Die Ueberpruefung der Verdachtsdiagnosen beginnt mit der
           Lungenembolie, da diese in der hoechsten Verdachtsklasse
           steht und aufgrund ihrer Gefaehrlichkeit Prioritaet vor
           den anderen gleichbewerteten Verdachtsdiagnosen hat.)

(IN)------w d3.v    (Welche Verdachtsmomente fuer Lungenembolie liegen vor?)

(OUT)     D3 = LUNGENEMBOLIE
(OUT)     ES GIBT FOLGENDE VERDACHTSMOMENTE FUER LUNGENEMBOLIE (D3):

(OUT)     100    R306    F1 W1            SCHMERZVERLAUFSTYP  =  AKUT.ERSTMALIG
(OUT)                    F2 W1            SCHMERZENTWICKLUNGSGESCHWINDIGKEIT  =  IN.WENIGEN.SEKUNDEN
(OUT)      50            F6 W1           SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)      50            F11 W1          SCHMERZQUALITAET  =  STECHEND
(OUT)     300            F200 2 3        DYSPNOE-AKUITAET   VON NEU-PLOETZLICH.NACH.BRUSTSCHMERZEN BIS
(OUT)                                    NEU-10.MIN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN

(IN)------d1.v    (Welche Verdachtsmomente liegen fuer Pneumothorax vor?)

(OUT)     D1 = PNEUMOTHORAX
(OUT)     ES GIBT FOLGENDE VERDACHTSMOMENTE FUER PNEUMOTHORAX (D1):

(OUT)      50            F6 W1           SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)      50            F11 W1          SCHMERZQUALITAET  =  STECHEND
(OUT)     100            F15 W6          SCHMERZVERSTAERKUNG  =  FORCIERTES.EINATMEN
(OUT)     100            F16 W4          SCHMERZABSCHWAECHUNG  =  ATEM.ANHALTEN
(OUT)      50    R300    F1 W1            SCHMERZVERLAUFSTYP  =  AKUT.ERSTMALIG
(OUT)                    F2 W1            SCHMERZENTWICKLUNGSGESCHWINDIGKEIT  =  IN.WENIGEN.SEKUNDEN
(OUT)     100            F200 3 4        DYSPNOE-AKUITAET   VON NEU-10.MIN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN BIS
(OUT)                                    NEU-3.STD.BIS.24.STD.NACH.BRUSTSCHMERZEN
(OUT)      50    R302    F6 W1            SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)                    F7 W2            SCHMERZLOKALISATION  =  LINKSTHORAKAL

(IN)------e    (Fortsetzung der Diagnostik: MED1 stellt Fragen zur Ueberpruefung des Verdachtes
               auf Lungenembolie. Nach der Durcharbeitung der ersten Lungenembolie-Prozedur
               wird eine Zwischenbewertung vorgenommen, in der die Lungenembolie als "neutral"
               eingestuft wird. Deswegen wird die Lungenembolie-Diagnostik unterbrochen; MED1
               wendet sich dem neuen Spitzenreiter der Agenda zu.

(OUT)     NEXT:                        D1 = PNEUMOTHORAX
(OUT)     NEXT:                        D1 = PNEUMOTHORAX

(OUT)     F73 = PHYSIKALISCHER.LUNGENBEFUND
(OUT)     HABEN SIE BEI DER LUNGENUNTERSUCHUNG MIT PALPATION, PERKUSSION UND
(OUT)     AUSKULTATION EINEN RELEVANTEN BEFUND ERHOBEN?
(OUT)     1    = NEIN
(OUT)     2    = BEI.PALPATION
(OUT)     3    = BEI.PERKUSSION
(OUT)     4    = BEI.AUSKULTATION
(OUT)     0    = NEIN / KEINE DER BISHERIGEN ALTERNATIVEN
(OUT)     ?
(IN)------1

(IN)------w 1    (Warum wird die Frage F73 gestellt?)

(OUT)     DIE FRAGE DIENT DER UEBERPRUEFUNG DER DIAGNOSE  PNEUMOTHORAX (D1)
(OUT)     PROZEDUR:            PNEUMOTHORAX-B (P13)
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(OUT)    AKTIVE REGEL:
(OUT)          20   R12    F76 W3          LUNGENAUSKULTATIONSBEFUND  =  ABGESCHWAECHTES.ATEMGERAEUSCH
(OUT)                       F116 W3         ABGESCHWAECHTES-AG-ORT  =  HAUPTSAECHLICH.RECHTE.LUNGE
(OUT)                       F74 W1          LUNGENPERKUSSIONSBEFUND  =  PERKUSSION.O.B.
(OUT)    FRAGE:               LUNGENAUSKULTATIONSBEFUND (F76)
(OUT)    ASKFIRST:             F73 W4          PHYSIKALISCHER.LUNGEBEFUND  =  BEI.AUSKULTATION
(OUT)    FRAGE:               PHYSIKALISCHER.LUNGEBEFUND (F73)

         (Vor der Indikation technischer Untersuchungen wird
          zunaechst die 3. Diagnose mit der hoechsten Verdachts-
          klasse, Pleuritis sicca, ueberprueft.)

(OUT)    NEXT:                      D4 = PLEURITIS SICCA
(OUT)    NEXT:                      D4 = PLEURITIS SICCA

(OUT)    NEXT:                     T3 = ROENTGEN-THORAX
         (Die Symptome aus Anamnese und koerperlicher Untersuchung,
          die fuer die Pl. sicca relevant sind, sind aufgrund der
          abgelaufenen Diagnostik bereits bekannt. MED1 indiziert
          jetzt eine technische Untersuchung zur weiteren
          Ueberpruefung der Diagnose.)

(OUT)    ZUR KLAERUNG FOLGENDER DIAGNOSEN:
(OUT)    PLEJRITIS.SICCA
(OUT)    SOLLTE DIE TECHNISCHE UNTERSUCHUNG:   ROENTGEN-THORAX
(OUT)    DURCHGEFUEHRT WERDEN.

(IN)-----w 8     (Frage nach dem Stand der Agenda)

(OUT)    PRIORITAET DER DIAGNOSEN UND TECHNISCHEN UNTERSUCHUNGEN:

(OUT)    3. KLASSE:                 T3 = ROENTGEN-THORAX

(OUT)    4. KLASSE:                 D1 = PNEUMOTHRAX
(OUT)                               D3 = LUNGENEMBOLIE

(OUT)    7. KLASSE:                 D20 = KREISLAUFSCHOCK
(OUT)                               D15 = ANGINA-PECTORIS
(OUT)                               D11 = INTERKOSTALNEURALGIE
(OUT)                               D12 = HERPES ZOSTER

(IN)-----7    (Frage nach dem Zwischenstand der Diagnostik)

(OUT)    DERZEITIGE ORDNUNG DER DIAGNOSEN:

(OUT)    WAHRSCHEINLICH:            D4 = PLEJRITIS.SICCA
(OUT)                               D1 = PNEJMOTHORAX

(OUT)    NEUTRAL:                   D3 = LUNGENEMBOLIE

(IN)-----d4.b    (Warum ist die Pl. sicca "wahrscheinlich"?)

(OUT)    D4 = PLEURITIS.SICCA
(OUT)    BEGRUENDUNG VON D4 = PLEURITIS.SICCA

(OUT)    27 PUNKTE = WAHRSCHEINLICH

(OUT)      4          F6 W1           SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
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(OUT)     20   R61     F6 W1          SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)                  F7 W2          SCHMERZLOKALISATION  =  LINKSTHORAKAL
(OUT)      4          F11 W1         SCHMERZQUALITAET  =  STECHEND
(OUT)     18          F15 W6         SCHMERZVERSTAERKUNG  =  FORCIERTES_EINATMEN
(OUT)     18          F16 W4         SCHMERZABSCHWAECHUNG  =  ATEM_ANHALTEN
(OUT)    -10          F2 W1          SCHMERZENTWICKLUNGSGESCHWINDIGKEIT  =  IN_WENIGEN_SEKUNDEN
(OUT)     -7          F59 W1         FIEBER  =  NEIN
(OUT)    -20   R69    F76 NON W7     LUNGENAUSKULTATIONSBEFUND UNGLEICH PLEURAREIBEN
         (Die Regel R69 wird anschliessend geaendert.)

         (Der medizinische Experte ist der Meinung, dass die Pl. sicca
          in Anbetracht der bekannten Symptomatik mit "wahrscheinlich"
          als zu hoch eingeschaetzt wird. Insbesondere findet er, dass
          das Nichtvorhandensein des Symptoms "Pleureiben" nicht stark
          genug gegen eine moegliche Pl. sicca ausgewertet wurde.  Mo-
          mentan subtrahiert die Regel R69 (ihre Bedingung lautet:
          NON-Pleurareiben) 20 Punkte vom Punktekonto der Pl. sicca.
          Der Experte will die Regel R69 verschaerfen, so dass 40 Punkte
          subtrahiert werden.)

(IN)-----mutabo   (Kommando, das den Aenderungsmodus (Aenderungen der
                   knowledge base) einschaltet.)

(OUT)     SIE KOENNEN JETZT DAS SYSTEM FUETTERN!

(OUT)     A = EINGABE VON ALPHAS
(OUT)     R = EINGABE VON REGELN
(OUT)     F = EINGABE VON FIRST (UEBERSICHTSFRAGEN UND -REGELN)
(OUT)     S = ***        SAFEN = ABSPEICHERN ALLER DATEN        ***
(OUT)     L = EINGABE DES LEXIKONS
(OUT)     E = ENDE DER EINGABE
(OUT)     T = TEXT DER EINLEITUNG
(OUT)     D = LOESCHEN VON DATEIEN

(IN)-----r

(OUT)     SIE HABEN FOLGENDE OPTIONEN:
(OUT)     N      = NEUEINGABE VON REGELN
(OUT)     E      = ENDE DER REGELEINGABE
(OUT)     A      = AUFLISTEN DER VORHANDENEN REGELNUMMERN
(OUT)     P      = AENDERN VON PUNKTBEWERTUNGEN IN REGELN
(OUT)     L      = LOESCHEN VON REGELN
(OUT)
(IN)-----p

(OUT)     REGELNUMMER EZW (SNUMMER WNUMMER) ANGEBEN, WO IM AKTIONSTEIL EINE AENDERUNG DER
(OUT)     PUNKTBEWERTUNG DURCHGEFUEHRT WERDEN SOLL.(E = ENDE)
(OUT)
(IN)-----r69

(OUT)     1 (ADD P48 -20)    (zu aendernde Regel)
(OUT)     BITTE JETZT (<NUMMER DER AKTION> <NEUE PUNKTZAHL>) Z.B.(1 10) EINGEBEN!
(OUT)
(IN)-----(1 -40)    (die geaenderte Regel R69: (ADD P48 -40) )
(IN)-----e e e    (Kommandofolge, die vom Aenderungsmodus zur Diagnosesitzung zurueckfuehrt.)

(IN)-----w 8    (Frage nach dem neuen Stand der Agenda, in der Verschiebungen auf-
                 grund der vorgenommenen Regelaenderung beruecksichtigt sind.)
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(OUT)     PRIORITAET DER DIAGNOSEN UND TECHNISCHEN UNTERSUCHUNGEN:

(OUT)     3. KLASSE:              T4 = ROENTGEN-THORAX.IN.EXSPIRATION

(OUT)     4. KLASSE:              D3 = LUNGENEMBOLIE
(OUT)     6. KLASSE:              D4 = PLEURITIS.SICCA
(OUT)     7. KLASSE:              D20 = KREISLAUFSCHOCK
(OUT)                             D15 = ANGINA-PECTORIS
(OUT)                             D11 = INTERKOSTALNEURALGIE
(OUT)                             D12 = HERPES.ZOSTER
(OUT)
(IN)-----7   (Zwischenstand der Diagnostik)

(OUT)     DERZEITIGE ORDNUNG DER DIAGNOSEN:

(OUT)     WAHRSCHEINLICH:         D1 = PNEUMOTHORAX

(OUT)     NEUTRAL:                D4 = PLEURITIS.SICCA
(OUT)                             D3 = LUNGENEMBOLIE

          (Die Regelaenderung hat sich dahingehend ausgewirkt, dass
           die Diagnose Pl. sicca, die vorher als "wahrscheinlich"
           eingestuft wurde, jetzt als "neutral" eingeschaetzt wird.
           Dies hat zur Folge, dass die Ueberpruefung der Pl. sicca
           unterbrochen wird (vorher wurde zur weiteren Diagnostik
           eine Roentgen-Aufnahme vorgeschlagen) und statt dessen eine
           technische Untersuchung zur Abklaerung des als "wahrschein-
           lich" eingestuften Pneumothorax indiziert wird.)

(OUT)     F319 = ROENTGEN-THORAX.IN.EXSPIRATION.AUF.PNEUMOTHORAX
(OUT)     BEURTEILEN SIE DEN ROENTGEN-THORAX IN EXSPIRATION IM HINBLICK AUF PNEUMOTHORAX!
(OUT)     1    = BEWEISEND
(OUT)     2    = NAHEZU.BEWEISEND
(OUT)     3    = NAHEZU.AUSSCHLIESSEND
(OUT)     4    = AUSSCHLIESSEND
(OUT)     0    = NEIN / KEINE DER BISHERIGEN ALTERNATIVEN
(OUT)     ?
(IN)-----1   (Das Untersuchungsergebnis ist beweisend fuer die Diagnose "Pneumothorax".)

(OUT)     *****                   ERGEBNISSE:                    *****
(OUT)
(OUT)     1. UEBERSICHT UEBER ENDDIAGNOSEN:

(OUT)     GESICHERT:              D1 = PNEUMOTHORAX

(OUT)     UNWAHRSCHEINLICH:       D4 = PLEURITIS.SICCA

(OUT)     NAHEZU.AUSGESCHLOSSEN:  D3 = LUNGENEMBOLIE
(OUT)
(OUT)     2. GROB- UND ZWISCHENDIAGNOSEN:
(OUT)
(OUT)     FOLGENDEN (SCHWACHEN) HINWEISEN WURDE NICHT VOLLSTAENDIG NACHGEGANGEN:
(OUT)     7. KLASSE:              D20 = KREISLAUFSCHOCK
(OUT)                             D15 = ANGINA-PECTORIS
(OUT)                             D11 = INTERKOSTALNEURALGIE
(OUT)                             D12 = HERPES.ZOSTER
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(OUT)     SIE HABEN FOLGENDE MOEGLICHKEITEN:
(OUT)     F = FORTSETZUNG DER SITZUNG (ABARBEITUNG ALLER HINWEISE)
(OUT)     W = WARUM-OPTION
(OUT)     B = BEENDIGUNG DER SITZUNG
(OUT)     EINGABE EINER DIAGNOSENUMMER = AUFLISTUNG ALLER RELEVANTEN BEFUNDE
(OUT)
(IN)------w d1.b    (Begruendung der Diagnose: Pneumothorax = gesichert)

(OUT)     D1 = PNEUMOTHORAX
(OUT)     BEGRUENDUNG VON D1 = PNEUMOTHORAX
(OUT)     200 PUNKTE = GESICHERT

(OUT)       3    R1      F1 W1          SCHMERZVERLAUFSTYP  =  AKUT.ERSTMALIG
(OUT)                    F2 W1          SCHMERZENTWICKLUNGSGESCHWINDIGKEIT  =  IN.WENIGEN.SEKUNDEN
(OUT)       3            F6 W1          SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)      10    R2      F7 W2          SCHMERZLOKALISATION  =  LINKSTHORAKAL
(OUT)                    F6 W1          SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)       4            F11 W1         SCHMERZQUALITAET  =  STECHEND
(OUT)      10            F15 W6         SCHMERZVERSTAERKUNG  =  FORCIERTES.EINATMEN
(OUT)      10            F16 W4         SCHMERZABSCHWAECHUNG  =  ATEM.ANHALTEN
(OUT)      20    R57     F134 W3        DYSPNOE-CHARAKTERISIERUNG  =  BELASTUNGSDYSPNOE
(OUT)                    F200 = 3       DYSPNOE-AKUITAET = NEU-10.¶IN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN
(OUT)
(OUT)     -10    R20     F76 NON W3     LUNGENAUSKULTATIONSBEFUND UNGLEICH ABGESCHWAECHTES.ATEMGERAEUSCH
(OUT)                    F76 NON W2     LUNGENAUSKULTATIONSBEFUND UNGLEICH AUFGEHOBENES.ATEMGERAEUSCH
(OJT)     150            F319 = 1       ROENTGEN-THORAX.IN.EXSPIRATION.AUF.PNEUMOTHORAX = BEWEISEND


(IN)------d3.b    (Warum ist die Lungenembolie nahezu ausgeschlossen?)

(OUT)     D3 = LUNGENEMBOLIE
(OUT)     BEGRUENDUNG VON D3 = LUNGENEMBOLIE
(OUT)     -50 PUNKTE = NAHEZU.AUSGESCHLOSSEN

(OUT)     -15            Z8 = 1         LUEMBO-PRAEDISPO-EVALU = KEIN.VERDACHT
(OUT)      45            Z13 = 5        LUEMBO-HINWEIS-EVALU = SEHR.STARKER.VERDACHT
(OUT)     -40    R44     F40 20 39      ALTER   VON 20 BIS 39
(OUT)                    F14 NON W4     SCHMERZAUSLOESUNG UNGLEICH TAGELANGE.BETTLAEGERIGKEIT
(OUT)                    F14 NON W5     SCHMERZAUSLOESUNG UNGLEICH NACH.GROESSERER.OPERATION*
(OUT)                    F14 NON W6     SCHMERZAUSLOESUNG UNGLEICH PERI-.ODER.POSTPARTAL
(OUT)                    F146 NON W5    BEINVENENERKRANKUNGEN UNGLEICH SICHERE.PHLEBOTHROMBOSE
(OUT)                    F146 NON W6    BEINVENENERKRANKUNGEN UNGLEICH FRAGLICHE.PHLEBOTHROMBOSE
(OUT)
(OUT)     -40    R402    D1 6 7         PNEUMOTHORAX   VON HOECHSTWAHRSCHEINLICH BIS GESICHERT

(IN)------d4.b    (Warum ist die Pl. sicca unwahrscheinlich?)

(OUT)     D4 = PLEURITIS.SICCA
(OUT)     BEGRUENDUNG VON D4 = PLEURITIS.SICCA
(OUT)     -33 PUNKTE = UNWAHRWSCHEINLICH

(OUT)       4            F6 W1          SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)      20    R61     F5 W1          SCHMERZKATEGORIE  =  BRUSTWANDSCHMERZ
(OUT)      -             F7 W2          SCHMERZLOKALISATION  =  LINKSTHORAKAL
(OUT)       4            F11 W1         SCHMERZQUALITAET  =  STECHEND
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(OUT)      18          F15 W6          SCHMERZVERSTAERKUNG  =  FORCIERTES.EINATMEN
(OUT)      18          F16 W4          SCHMERZABSCHWAECHUNG  =  ATEM.ANHALTEN
(OUT)     -10          F2 W1           SCHMERZENTWICKLUNGSGESCHWINDIGKEIT  =  IN.WENIGEN.SEKUNDEN
(OUT)
(OUT)      -7          F59 W1          FIEBER  =  NEIN
(OUT)     -40   R59     F76 NON W7       LUNGENAUSKULTATIONSBEFUND UNGLEICH PLEURAREIBEN
(OUT)
(OUT)     -40   R403    D1 6 7           PNEUMOTHORAX   VON HOECHSTWAHRSCHEINLICH BIS GESICHERT
(OUT)
(IN)      e
(OUT)     SIE HABEN FOLGENDE MOEGLICHKEITEN:
(OUT)     F = FORTSETZUNG DER SITZUNG (ABARBEITUNG ALLER HINWEISE)
(OUT)     W = WARUM-OPTION
(OUT)     B = BEENDIGUNG DER SITZUNG
(OUT)     EINGABE EINER DIAGNOSENUMMER = AUFLISTUNG ALLER RELEVANTEN BEFUNDE
(OUT)
(IN)-----b
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Es folgt eine vollstaendige Zusammenfassung der Symptomatik. Die Fragen sind in der Reihenfolge aufgelistet, wie sie vom System gestellt wurden.

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F40 = ALTER                                          35
F41 = GESCHLECHT?                                    W1   MAENNLICH
F130 = PRIMAERE.ASPEKTDIAGNOSTIK                     W1   GUTER.ALLGEMEINZUSTAND
F1 = SCHMERZVERLAUFSTYP                              W1   AKUT.ERSTMALIG
F2 = SCHMERZENTWICKLUNGSGESCHWINDIGKEIT              W1   IN.WENIGEN.SEKUNDEN
F3 = SCHMERZDAUER                                    W5   6.BIS.24.STUNDEN
F6 = SCHMERZKATEGORIE                                W1   BRUSTWANDSCHMERZ
F7 = SCHMERZLOKALISATION                             W2   LINKSTHORAKAL
F11 = SCHMERZQUALITAET                               W1   STECHEND
F12 = SCHMERZINTENSITAET                             W3   ERTRAEGLICH
F14 = SCHMERZAUSLOESUNG                              W2   KOERPERLICHE.ANSTRENGUNG
F15 = SCHMERZVERSTAERKUNG                            W6   FORCIERTES.EINATMEN
F16 = SCHMERZABSCHWAECHUNG                           W4   ATEM.ANHALTEN
F26 = SCHMERZBEGLEITSYMPTOME                         W1   DYSPNOE
F134 = DYSPNOE-CHARAKTERISIERUNG                     W3   BELASTUNGSDYSPNOE
F200 = DYSPNOE-AKUITAET                              3   NEU-10.MIN.BIS.3.STUNDEN.NACH.BRUSTSCHMERZEN
F136 = PULSPALPATIONSBEFUND                          W1   O.B.
F140 = PULSFREQUENZ                                  84
F142 = SYSTOLISCHER.BLUTDRUCK                        150
F144 = DIASTOLISCHER.BLUTDRUCK                       70
F46 = AKUTERKRANKUNGEN                               W0   NEIN/SONSTIGES
F48 = CHRONISCHE.ERKRANKUNGEN                        W0   NEIN/SONSTIGES
F146 = BEINVENENERKRANKUNGEN                         W0   NEIN/SONSTIGES
F59 = FIEBER                                         W1   NEIN
F73 = PHYSIKALISCHER.LUNGEBEFUND                     W1   NEIN
F319 = ROENTGEN-THORAX.IN.EXSPIRATION.AUF.PNEUMOTHORAX
                                                     1   BEWEISEND
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