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Does inappropriate selectivity in information use relate to diagnostic errors and patient harm? The diagnosis of patients with dyspnea

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HIGHLIGHTS

- People can be subject to cognitive biases, resulting in inadequate consideration of alternatives.
- We studied whether physicians are inappropriately selective in the diagnostic reasoning.
- Inappropriate selectivity occurs frequently and is associated with adverse outcomes.
- Especially inappropriate selectivity in information-processing is related to adverse outcomes.
- Solutions include systematic feedback from peers and using more falsifying reasoning strategies.

ABSTRACT

Physicians often take shortcuts in diagnostic reasoning by being selective in the information that they gather and follow-up on. Although necessary, these shortcuts are susceptible to cognitive biases and may cause diagnostic errors. The aim of this study is to examine the occurrence of inappropriate selectivity in the information-gathering and information-processing stages of the diagnostic process and study how it relates to diagnostic errors and patient harm in clinical practice. Expert internists reviewed the patient records of 247 dyspnea patients of five acute-care hospitals in the Netherlands, to detect reasoning faults, diagnostic errors and patient harm. The cases with reasoning faults were discussed with the treating physicians. Based on the record review and the clarifications from the treating physicians, the occurrence of

inappropriate selectivity in information-gathering and information-processing was established and related to the occurrence of diagnostic errors and patient harm. Inappropriate selectivity in the diagnostic reasoning process occurred in 45.7% (113 of 247) of the cases. Specifically, selective information-gathering occurred in 33.2% of the cases and selective information-processing in 12.6% of the cases. Diagnostic errors occurred in 18.3% of the cases with selective information-gathering, and in 35.5% of the cases with selective information-processing. Patient harm occurred in 11.0% of the cases with selective information-gathering and in 38.7% of the cases with selective information-processing. The results showed that inappropriate selectivity in the diagnostic process occurred in a substantial number of cases. Particularly inappropriate selective information-processing was related to diagnostic errors and patient harm. Prevention strategies should include an increase in promoting the falsification strategies in the diagnostic process.

INTRODUCTION

The diagnostic reasoning process is a complex process that involves many different decision making skills. Since diagnostic errors are often considered to be preventable and severe, studying the diagnostic process to find ways to reduce diagnostic error is important (Baker et al., 2004; Leape et al., 1991; Zwaan et al., 2010). Many different factors are involved in the occurrence of diagnostic errors, such as lack of knowledge or atypical presentation of the disease (Kostopoulou, Mousoulis, & Delaney, 2009; Neale, Woloshynowych, & Vincent, 2001; Schiff et al., 2009; Zwaan et al., 2010). In addition, research shows that in many cases in which a diagnostic error occurred, the physician did not consider the correct diagnosis from the start, which is often caused by cognitive biases (Berner & Graber, 2008; Croskerry, 2003; Elstein, 1999). Cognitive biases are faulty beliefs that affect decision making and occur because physicians use heuristics during the diagnostic process (Bornstein & Emler, 2001; Elstein, 1999; Tversky & Kahneman, 1974). Heuristics are shortcuts in the reasoning process, which means that not all available information is gathered or used to come to a diagnosis (Wegwarth, Gaissmaier, & Gigenrenzer, 2009). These heuristics are necessary to diagnose a patient within a reasonable amount of time and without conducting many unnecessary diagnostic tests. Heuristics are usually associated with fast diagnostic reasoning, and in most cases with correct diagnoses (Orient, 2009). Actually, the use of heuristics in the diagnostic process, can even lead to better diagnoses (Wegwarth et al., 2009). Particularly experts are able to diagnose a patient after gathering little data because they rely on the heuristic of pattern recognition (Groves, O'Rourke, & Alexander, 2003).

Although the use of heuristics is important in diagnostic reasoning, they may lead to faulty data-gathering, faulty data-synthesis and diagnostic errors (Graber, Franklin, & Gordon, 2005). For example, when the physician focuses on a specific diagnosis based on his/her recent experiences, and as a consequence does not adequately evaluate the evidence pointing towards alternatives (availability bias) (Berner & Graber, 2008; Berner, Maisiak, Heuderbert, & Young, Jr., 2003; Graber, 2005). Research showed that many cognitive biases occur in diagnostic reasoning and that they occur at all levels of expertise (Dubeau, Voytovich, & Rippey, 1986; Graber, Gordon, & Franklin, 2002; Redelmeier, 2005; Voytovich, Rippey, & Suffredini, 1985). The common denominator of most of the cognitive biases is that physicians are too selective in their reasoning process and therefore overlook likely diagnoses.

This selectivity is inappropriate, which may result in a diagnostic error when relevant information is missed (Elstein, 1999). Inappropriate selectivity may have serious consequences depending on the stage of the diagnostic process in which it occurs and strategies to prevent inappropriate selectivity should be adapted to the specific stage (Croskerry, 2003; Kempainen, Migeon, & Wolf, 2003). Inappropriate selectivity in clinical practice and the situations in which it leads to diagnostic error and patient harm has not been studied extensively (Kostopoulou et al., 2009).
In our previously published study, we found that physicians often gathered insufficient information or lacked to follow-up on relevant findings (Zwaan, Thijs, Wagner, Van der Wal, & Timmermans, 2012). When we asked the physicians about these suboptimal decisions, we learned that most of these were deliberate decisions. However, we did not examine whether this was either due to a lack of knowledge or whether the physicians had been too selective throughout the process. Therefore, for this study we conducted further analysis on the data to determine: 1. the occurrence of inappropriate selectivity in the information-gathering and information-processing stages of the diagnostic reasoning process of dyspnea patients, and 2. to what extent inappropriate selectivity in the diagnostic reasoning process is related to diagnostic error and patient harm in clinical practice.

METHOD

Patient record reviews in combination with interviews with the treating physicians were used to determine the occurrence of inappropriate selectivity, the stages of the process in which selectivity occurred and the occurrence of diagnostic error and patient harm. See Fig. 1 for an overview of the data-gathering process of the study.

[FIGURE 1]

PATIENT SELECTION

Five acute care hospitals in the Netherlands (one university hospital, two tertiary teaching hospitals and two general hospitals) participated in the study. The start of the study was phased for practical reasons meaning that after the data-gathering process was set-up in one hospital, the next hospital started the inclusion of patients. The hospitals started about a month after each other and every hospital participated 6–8 months between May 2007 and February 2008. The study took place in seven departments of internal medicine, cardiology and pulmonology (in some hospitals the departments worked closely together and therefore both participated in the study). All eligible consecutive patients admitted to the hospital with dyspnea (shortness of breath) or who developed dyspnea during their hospital stay were recommended for inclusion by the treating physicians. Subsequently, a researcher (LZ) included the patients in the study by asking them for informed consent. By selecting dyspnea patients, we selected a homogenous patient group that has not been studied extensively in the field of diagnostic error. A total of 261 patients were included in the study of which 14 records were lost. Possible reasons for the missing records involve for example incorrect registration of the location of the patient record by the archive. Therefore, 247 patients are described in this study.

RECORD REVIEW OPTIMAL DIAGNOSTIC PROCESS

Since an exploration of the literature did not reveal any relevant guidelines for the diagnostic process when starting with dyspnea as a symptom, a two-staged Delphi method with seven experienced internists (from academic centers, tertiary teaching hospitals as well as small general hospitals) was used to determine the optimal diagnostic process for dyspnea patients. We selected internists who had recently retired and who met the following criteria: 1. at least 10 years of post-graduate work experience in internal medicine, 2. a good reputation amongst colleagues, 3. retired for no longer than 5 years at the time of selection as a reviewer. Furthermore, three people from the research group participated: two research psychologists (DT and LZ) and one internist (AT) at an academic medical center.

The goal of the Delphi study was to determine the steps that had to be considered while diagnosing a dyspnea patient, such as considering the recent medical history and involving the information of previous health care professionals. Two meetings were organized to develop the optimal diagnostic process based on cases of dyspnea patients filled out by the reviewers. All internists approved of the final version of the optimal diagnostic process.

Reviewers Four expert internists, who also participated in the Delphi study, participated in the record review process. Based on this optimal process the record review questionnaire to study the diagnostic reasoning process was developed by the researcher in collaboration with the internist reviewers. The participating internists attended a training program (2 days) about the study protocol, the review questionnaire and the computer program in which the questionnaire was programmed. After having reviewed several records, another training session was organized to discuss questions and difficulties.

Review process and questionnaire After the patients were discharged from the hospital and informed consent was obtained, their patient records were reviewed, identifying faults in the diagnostic reasoning process. Because of the large variety of diagnoses among patients presenting with dyspnea, we relied on the clinical expertise of the expert internist reviewers to determine whether faults occurred. The internist reviewers also took the clinical context into account when reviewing the patient records. These reasoning faults were defined as suboptimal decisions that contributed or could have contributed to the occurrence of a diagnostic error such as incomplete data gathering or incorrect interpretation of a test result. Thus, these reasoning faults were identified with a low threshold. The record review also identified diagnostic errors, i.e. a diagnosis that was unintentionally delayed, wrong or missed as judged from the eventual appreciation of more definitive information (Graber et al., 2005).

The record review questionnaire assessed all steps of the diagnostic process. The information-gathering stage involved: history taking, physical examination, laboratory requests and imaging techniques. The information-processing stage consisted of: the interpretation of the results found in the information-gathering stage, outlining a diagnosis, starting the treatment and verification of diagnosis, and treatment during the patients' stay. For the information-gathering stages the review questionnaire first inquired whether all aspects that were considered to be relevant according to the optimal diagnostic process and the clinical expertise of the reviewers (such as family history, EKG, D-dimer) were identified or checked by the treating physician. If an aspect was considered to be relevant by the reviewer, but not checked/performed by the treating physician, this was considered a fault in the

information-gathering stage. For the information-processing stages the treating physicians' interpretation of the findings was assessed, i.e. whether correct conclusions were drawn from the findings. If the reviewers considered the interpretation by the treating physician to be incorrect, this was considered to be a fault in the information processing stage. By studying the information gathering and information interpretation stages thoroughly while often having access to more definitive information such as the patient record of a subsequent hospital admission, the internist reviewers determined whether a diagnostic error occurred. In some cases it was not possible to determine the correct diagnosis if the treating physician did not gather sufficient information to establish a diagnosis with certainty. These cases were defined as most likely a diagnostic error, but in the analysis included as diagnostic errors. For the reasoning faults as well as the diagnostic errors additional questions were answered about (possible) patient harm, namely, any disadvantage for the patient that led to prolonged or strengthened treatment, temporary or permanent impairment or death (Zegers et al., 2009).

An inter-rater reliability analysis was conducted in which 25 randomly selected cases were reviewed by two out of the four reviewers. The reliability between the reviewers for the determination of patient harm was fair, $\kappa = 0.34$; 95% CI 0.0–1.0; 88% agreement. For the determination whether the diagnosis was correct or incorrect, the reliability was moderate, $\kappa = 0.51$; 95% CI 0.06–0.95; 84% agreement. The reliability for the reasoning faults was fair, $\kappa = 0.28$; 95% CI 0.00–0.76; 76% agreement (Zwaan et al., 2012).

This study is part of a larger study and a more detailed description of the method can be found in the design paper and the results of the occurrence of reasoning faults (Zwaan, Thijs, Wagner, Van der Wal, & Timmermans, 2009; Zwaan et al., 2012).

Interviews with treating physicians A researcher (LZ) interviewed the treating physicians about the presumed reasoning faults that they were involved in. The interviews completed the information that was missing from the patient record. We were able to conduct an interview with 48 out of the 58 residents that were involved in reasoning faults. A total of 144 of the 163 cases with faults were discussed. 19 interviews (11%) were missing because the treating physician could not be contacted for the interview (Zwaan et al., 2012). The goal of the interview was to find out the causes of the faults and to verify whether there was another reason for the occurrence of the fault that was not described in the patient record, e.g. lack of documentation in the patient record. The interviews consisted of clear-cut questions such as: “Pulmonary embolism was a possible diagnosis, why did you decide not to conduct any further tests to establish or rule out PE?” or “Why did you decide not to perform an EKG to check for heart rhythm disorder?” The answers of the treating physicians were checked with the expert record reviewer to determine whether the fault was still valid. Both the record review and the answers of the treating physicians about the faults were used to evaluate whether inappropriate selectivity in information use occurred.

DETERMINING INAPPROPRIATE SELECTIVITY IN DIAGNOSTIC REASONING

Inappropriate selectivity in the diagnostic reasoning process was defined as: cases in which a probable diagnosis (as judged by the reviewer) was not sufficiently considered and therefore not confirmed or ruled out. The cases were examined using three steps: 1. The cases in which faults were found in the information-gathering and/or information-processing stages in the record review were selected (163 of 247 cases).

2. By using the findings in the record review and the interview with the treating physician, LZ (research psychologist) and AT (internist) evaluated whether the faults involved inappropriate selectivity i.e., for each patient case it was evaluated whether all probable diagnoses (according to the record reviewers) were sufficiently considered to be confirmed or ruled out. Faults in which a diagnosis was insufficiently precise (e.g. the type of pneumonia was not established) or faults indicating that a diagnosis that should have been established following different diagnostic criteria (e.g. an immediate CTa to confirm pulmonary embolism without a preceding, less invasive, D-dimer), were not considered to be inappropriate selectivity because the diagnoses were considered.

3. In the information-gathering stage all faults identified by the reviewers were checked with the treating physicians and, based on their answer, categorized as inappropriate selectivity or not. For example, a fault in the information-gathering stage such as “the physician did not apply for a D-dimer when pulmonary embolism was likely”, could have the following answer from the treating physician: “I did not consider PE as a likely option”. This was considered as inappropriate selectivity. While the following answer: “I did perform a D-dimer test, but I did not write down a non-deviating test result in the patient record” was considered a ‘record error’, but was not classified as inappropriate selectivity because the treating physician did consider pulmonary embolism. When the physician was not available for an interview, LZ and AT determined whether inappropriate selectivity took place based on the record review only.

4. The information-processing stage was distinguished into two different types of inappropriate selective information-processing: Selective information-integration and selective review of test results. Selective information-integration was defined as: inappropriate selective integration and/or interpretation of the gathered information while forming the working diagnosis, thus the treating physician did not use all relevant information while determining the diagnosis according to the reviewers. Selective interpretation of the test results was categorized as such if the treating physician did not follow up on deviating laboratory and other test results needed to confirm or rule out a diagnosis according to the reviewers.

If in one case both selective information-gathering and selective information-processing occurred, for simplicity we classified this hierarchically as selective information-processing. The two types of selective information-processing did not co-occur.

STATISTICAL ANALYSIS

Descriptive statistics were used for most of the analyses. To compare the occurrence of diagnostic error and patient harm in cases with versus without the different types of inappropriate selectivity χ^2 tests and tests for comparison of proportions in two independent samples were used. For all tests the continuity correction was applied.

CONFIDENTIALITY AND ETHICAL APPROVAL

The ethical review board of the VU University Medical Centre approved of the research protocol, and all participating hospitals granted approval to participate. The internist reviewers and researchers involved in the data collection signed a confidentiality agreement to maintain the secrecy of the data. Patients included in the study gave informed consent to review their patient record.

RESULTS PATIENT SAMPLE

The patient characteristics are described in Table 1.

[TABLE 1]

PHYSICIANS

The physicians who included the patients in the study and who were interviewed involved 72 medical residents who were supervised by a medical specialist. The residents had on average 29 months (SD = 26.5) of work experience.

INAPPROPRIATE SELECTIVE DIAGNOSTIC REASONING

In 45.7% (113 of 247 cases) inappropriate selectivity occurred. This involved selective information-gathering in 33.2% (82 of 247) of the cases while selective information-processing was identified in 12.6% (31 of 247) of the cases (see Table 2). Within the information-processing stage, selective information-integration involved 4.9% (12 of 247) of the cases while selective interpretation of test results occurred in 7.7% (19 of 247) of the cases. For examples of the cases, see Table 3. Please note that the examples are simplified case descriptions, the clinical context of the cases was more complex.

[TABLE 2] [TABLE 3]

DIAGNOSTIC ERROR AND PATIENT HARM

Cases in which the record review revealed inappropriate selectivity ($N = 113$), diagnostic errors and patient harm occurred more often compared to cases without inappropriate selectivity: diagnostic error 23.0% vs. 6.0%; $\chi^2(1) = 13.6$; $p = <0.001$; patient harm 18.6% vs. 5.2%; $\chi^2(1) = 9.6$; $p = <0.01$. There were cases in which inappropriate selectivity was related to both a diagnostic error and patient harm (5 cases). However, we also found cases in which selectivity was related to a diagnostic error but did not lead to patient harm (21 cases), as well as cases in which selectivity was related to patient harm, while the diagnosis was correct (16 cases). An example of the latter group involves a patient whose renal insufficiency was not noticed and

diagnostic tests were performed that harmed the patient. The main diagnosis was correct, but the patient suffered from renal failure. If renal insufficiency was considered earlier, these diagnostic tests would most likely not have been performed. When specifying the types of inappropriate selectivity (see also Table 2), we found that diagnostic errors occurred significantly more often in cases with selective information-gathering compared to cases without selectivity. There was no significant difference in the occurrence of patient harm. Both diagnostic error and patient harm occurred significantly more often in cases with selective information-processing when compared to cases without inappropriate selectivity: diagnostic error 35.4 vs. 6%, $z = 4.31$, $p < 0.01$; patient harm 38.7 vs. 5.2, $z = 4.96$, $p < 0.01$. In cases with selective interpretation of test results, diagnostic errors did not occur significantly more often than in cases without selectivity, but patient harm did (See Table 2).

DISCUSSION

Inappropriate selectivity occurred frequently in the diagnostic reasoning process and was associated with the occurrence of more diagnostic errors and patient harm compared to cases without it. Inappropriate selective information-gathering occurred more often than inappropriate selective information-processing. However adverse outcomes were more often associated with selective information-processing than with selective information-gathering.

There are some limitations of this study. First, during the record review, we relied on the retrospective judgment of the expert internists. Although they were well trained and had extensive experience in the medical field, subjectivity as well as hindsight bias might have had an effect on the data. Second, the evaluation of inappropriate selectivity was based on the record review and the interview with the treating physician. Because it was a retrospective explanation of the reasoning faults their answers might have been different from what actually happened. Furthermore, the final evaluation of inappropriate selectivity was based on a review of the patient's case by an internist and a research psychologist and might therefore have been influenced by subjectivity as well. We tried to make the evaluation procedure as explicit as possible, but the kappa's suggest that subjectivity did play a role in the evaluation. Thirdly, the patient records could not always provide a definitive measure of a diagnostic error. Therefore, the occurrence of a diagnostic error could not always be established with certainty. In addition, the treating physicians were aware of the general aims of the study (examination of the diagnostic process) which may have caused selective inclusion of patients. This selection bias, has most likely led to an underestimation of the percentage of diagnostic errors and patient harm. Lastly, due to the rather small number of cases with inappropriate selectivity (particularly in the information-processing stages) and the rather low kappa scores, the conclusions should be interpreted with caution.

Inappropriate selectivity was found in all stages of the diagnostic process. It most frequently occurred during the information-gathering process. IAS during the information-gathering stages was related to diagnostic errors and patient harm in only a minority of the cases.

Most of the information is gathered early in the diagnostic process when tentative diagnoses are considered. This is probably the stage of the diagnostic process in which fast decision-making is the most important and gathering of limited

information might save valuable time. Physicians may reason that the benefit of gathering additional data is small, since the most likely and the most severe diagnoses are examined first. In addition, for the less urgent diseases, the patient could be examined later in the process. In general, this is a good strategy, because it allows diagnosing the patient in the most efficient manner. However, physicians should be aware that they might become too selective and gather information too strongly in light of their existing hypotheses. They may gather information that supports their hypothesis while information about alternative diagnoses is not gathered (Russo et al., 1996). Consequently, the information about the patient may be biased towards the physician's existing beliefs.

Inappropriate selectivity in the information-processing stage of the diagnostic process was probably more often related to adverse outcomes because the probability of missing relevant information at this stage was higher. Specifically, the information had already been selected, or a test had been ordered, because the physician thought it was relevant earlier in the diagnostic process. When this information is missed or not followed-up on later in the process, it is more likely to cause a diagnostic error. Selectivity in the information-processing stages may occur because at this stage the physicians might be less open to new information that suggests an alternative diagnosis, compared to earlier in the process when they are still exploring several possible diagnoses (Russo, Husted Medvec, & Meloy, 1996). Research showed that once physicians have established a working diagnosis, they are likely to confirm their existing hypothesis rather than trying to refute them (Russo et al., 1996; Simon, Snow, & Read, 2004). This might be related to premature closure (failure to considering reasonable alternatives after an initial diagnosis was reached) or overconfidence (physicians' under-appreciation of the likelihood that their diagnoses are wrong) (Berner & Graber, 2008; Kempainen et al., 2003). Physicians may also incorrectly evaluate information as not relevant. Physicians adapt their ideas about the relevance of information based on their ideas about the diagnosis. Information consistent with their working diagnosis is more easily considered to have important diagnostic value, while inconsistent information is more easily evaluated as having little diagnostic value (Kostopoulou et al., 2009). This might particularly be the case for the interpretation of laboratory results, because (some of the) laboratory results arrive after the physician has established a firm differential diagnosis. Studies of Singh and colleagues showed that for many patients who were diagnosed with colon cancer or lung cancer, an abnormal test result was available earlier in the process (Singh et al., 2009, 2010). While the studies of Singh and colleagues were retrospective, the present study demonstrated that these abnormalities could be detected earlier in the process before knowing the final diagnosis.

To improve the diagnostic reasoning process and reduce the occurrence of diagnostic error and patient harm, two types of prevention strategies could be helpful. First, more systematic feedback may be useful. Physicians can learn from their own incorrect considerations and this should be systematically integrated in the diagnostic process, e.g. discussing it more specifically during the moments of supervision and handovers. Second, to reduce the effect of inappropriate selectivity, the application of falsification strategies is potentially helpful. Research on logical reasoning has shown that in order to consider a statement as correct, the hypotheses should be confirmed and at the same time alternatives should be ruled out. Only verification of the hypothesis is insufficient and thus a combination of a verification and

falsification strategies is needed (Johnson-Laird & Wason, 1970). This should be more consistently applied to the diagnostic reasoning process. Physicians should be taught that it is important not only to verify whether the established diagnosis can explain all of the main complaints and symptoms, but that alternative diagnoses should be considered and falsified. A more systematic review of available information could be a relatively simple way to detect other relevant information that should be followed up. This includes considering the presence of co-morbidity. Furthermore, more research to study the occurrence of inappropriate selectivity as well as on the ways to reduce inappropriate selectivity in clinical practice is needed.

CONCLUSIONS

Inappropriate selectivity in the diagnostic reasoning process occurs frequently and is related to diagnostic error and patient harm. This is especially true for inappropriate selectivity in the information-processing stages of the diagnostic process. In order to improve diagnostic reasoning and reduce the occurrence of diagnostic errors and patient harm systematic feedback during supervision and handovers could be helpful. Furthermore, more falsifying reasoning strategies may help to detect a correct diagnosis or co-morbidity.

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TABLES AND FIGURES

Table 1
Patient characteristics ($N = 247$).

	Cases with inappropriate selectivity ($N = 113$)	Cases without inappropriate selectivity ($N = 134$)	All cases ($N = 247$)
Male patients	47 (41.6%)	68 (50.7%)	115 (46.6%)
Average age (SD)	72.8 (13.0)	67.5 (16.0)	69.9 (14.9)
Median length of stay in days (inter quartile range)	10 (9)	9 (12)	10 (11)
Correct diagnosis			
1. Heart failure	26 (23.0%)	25 (18.7%)	51 (20.6%)
2. Chronic obstructive pulmonary disease/Bronchitis/Asthma	23 (20.4%)	36 (26.9%)	59 (23.8%)
3. Pneumonia	20 (17.7%)	27 (20.1%)	47 (19.0%)
4. Malignancy	7 (6.2%)	9 (6.7%)	16 (6.5%)
5. Pulmonary embolism	6 (5.3%)	8 (6.0%)	14 (5.7%)
6. No diagnosis	2 (1,8%)	1 (0.7%)	3 (1,2%)
7. Other (e.g.: meningitis, cholecystitis, anemia, septic shock, pneumothorax, viral infection, hyperventilation, hepatorenal syndrome, bronchiolitis, pancreatitis)	29 (25.7%)	28 (20.9%)	57 (23.1%)
Relevant co-morbidity (can be more than one diagnosis per patient)	61 (54.0%)	55 (41.0%)	116 (51%)
1. Heart failure	7 (8.9%)	11 (10.3%)	18 (15,5%)
2. Atrial fibrillation	10 (12.7%)	5 (4.7%)	15 (12.9%)
3. Pneumonia	2 (2.5%)	11 (10.3%)	13 (11.2%)
4. Chronic obstructive pulmonary disease/Bronchitis/Asthma	11 (13.9%)	9 (8.4%)	20 (17.3%)
5. Renal insufficiency	3 (3.8%)	8 (7.4%)	11 (9.5%)
6. Ischemic heart disease without heart failure	2 (2.5%)	9 (8.4%)	11 (9.5%)
7. Malignancy	2 (2.5%)	6 (5.6%)	8 (6.9%)
8. Hypoglycemia	3 (3.8%)	6 (5.6%)	9 (7.8%)
9. Anemia	3 (3.8%)	2 (1.9%)	5 (4.3%)
10. Other (e.g.: aorta valve stenosis, meningitis, septic shock, viral infection, lung fibrosis, urinary tract infection, liver failure, HIV, hypertension, pulmonary embolism, thrombosis)	34 (43.0%)	40 (37.4%)	74 (63.8%)

Note. Percentages use the frequency of the column as denominator.

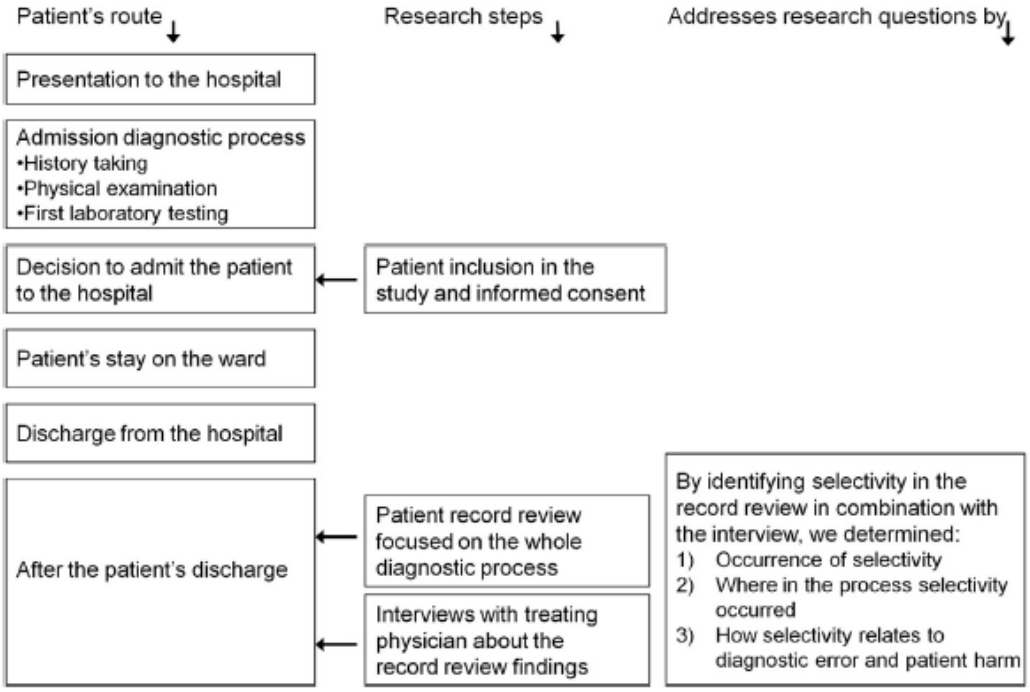

Fig. 1. Overview of the patient's route, the steps of the study and the addressed research questions.

Table 2
Occurrence and consequences of inappropriate selective information-gathering and information-processing as determined by the record review.

	Cases	Cases with diagnostic error[a]	Cases with patient harm[a]	Cases with diagnostic error and patient harm
Inappropriate selective information-gathering	82 (33.2%)	18.3% (15 out of 82) 95%CI: 10–27% *	11.0% (9 out of 82) 95%CI: 4–18%	3.6% (1 of 82)[b]
Inappropriate selective information-processing: interpretation of test results	19 (7.7%)	26.3% (5 out of 19)* 95%CI: 7–46%	42.1% (8 out of 19)* 95%CI: 20–64%	5.3% (1 out of 19)[b]
Inappropriate selective information-processing: information-integration	12 (4.9%)	50% (6 out of 12)* 95%CI: 22–78%	33,3% (4 out of 12)* 95%CI: 7–60%	25% (3 out of 12)[b]
No inappropriate selectivity	134 (54.2%)	6.0% (8 out of 134) 95%CI: 2–10%	5.2% (7 out of 134) 95%CI: 1–9%	0.7% (1 out of 134)[b]

*Significantly more diagnostic errors or patient harm when compared to cases without inappropriate selectivity; $p < 0.01$.
[a] These also include the cases with a diagnostic error and patient harm.
[b] No statistics conducted because of the small numbers.

Table 3
Examples of inappropriate selective information-gathering and information-processing.

	Examples including short explanation of the physician
Inappropriate selective information-gathering	The patient's history suggested pulmonary embolism (patient with breast cancer and previous pulmonary embolisms), however no information was gathered nor tests were performed to determine this. The physician said he/she considered pneumonia was more likely and decided it was not necessary to examine pulmonary embolism as well. For patient with an exacerbation of COPD, heart failure was not investigated while likely (no check for oedema and central venous pressure, no CT thorax). The physician explained that this patient came to the hospital regularly and always had an exacerbation of COPD and therefore did not examine her further. Breast examination was not performed while relevant because of a possible breast carcinoma. The physician indicated that since the patient came with a abdominal problem he/she considered it not necessary to examine the breasts as well.
Inappropriate selective information-processing: Information-integration	In a patient with both pneumonia and heart failure, the heart failure was missed. The physician did not consider heart failure as a possibility while the patients' recent medical history included mitral insufficiency and atrial fibrillation. The physician realized during the interview that his/her diagnostic process was focused on confirming pneumonia and therefore he/she completely overlooked the possibility that heart failure was also present. Cholescystitis was missed because of incorrect interpretation of abdominal pain and the patient's history. The physician said that urosepsis was a plausible explanation for the patients' symptoms and complaints and therefore did not consider cholescystitis. A lung tumor was initially missed, while it was detectable on the CT thorax. Although the patient's condition did not substantially improve no control CT thorax was ordered and no other diagnoses were considered and explored. The physician did not consider a tumor since the complaints of the patient were pointing towards her heart. The physician therefore considered the main problem to be cardiac.
Inappropriate selective information processing: interpretation of test results	Laboratory results showed anaemia (low hemoglobin levels), which was not further investigated. The physician explained that since the results of the tests were not available immediately he/she forgot to look at them later. Cholangitis with sepsis was missed. The physician explained that the patient did not arrive at the hospital with abdominal pain, but presented with symptoms of bronchitis. The laboratory results were abnormal later in the process and the physician did not notice this. He/she thinks he/she should have been more alert and should have noticed and followed-up on this abnormality. Liver abnormalities were not further investigated. The physician said that when he/she is working in the department of cardiology he/she is focused on the heart. Therefore, he/she does not specifically examine laboratory results not related to the main (heart) problem.
No inappropriate selectivity	A sputum test was conducted for a patient with a suspicion of pneumonia. The test was conducted after giving antibiotics to the patient. Therefore the test result was not reliable and the patient was treated with unnecessary antibiotics. A patient had overload disease, which was not detected by the physician. The physician considered it, but it was not recognized in the CT thorax. The diagnosis of COPD was initially missed. This is a complex diagnosis to detect and everything was done correctly to examine the patient and the information was interpreted correctly. After 5 days the correct diagnosis was established.