

# A Causal Loop Approach to the Study of Diagnostic Errors

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**Abstract.** Missed, wrong or delayed diagnosis has a direct effect on patient safety. Diagnostic errors have been discussed at length, however it still lacks a systematic approach. This study proposed a more systematic way of studying diagnostic errors by using a causal loop diagram. A systematic review was used to find the key factors which may cause diagnostic errors and their interrelationships. A causal loop diagram, as a qualitative model at the first stage of system dynamics modeling, was produced to map all the factor and interrelationships. The diagram provides not only the direct and indirect factors affecting correct diagnosis, but also a clear view of how the change of one factor in the model triggers changes of other factors and then the change of the number of final diagnostic errors.

**Keywords.** Diagnostic errors, clinical diagnosis, causal loop diagram, system dynamics, patient safety

## Introduction

Diagnostic errors cause severe harm to patient safety, as well as high payouts of extra medical cost [1]. However, it is widely believed this could be potentially reduced [2]. Current research findings are mostly limited to partial analysis, and the results are diverse and limited [3,4]. Errors which happen at any stage of the diagnostic process may lead to a diagnostic error directly or indirectly. [5] Thus, diagnostic errors need to be researched in a systemic way through the whole picture of diagnostic system instead of using piecemeal solutions. A Causal Loop Diagram (CLD) is the essential and fundamental model in the system dynamics approach, which maps the key factors affecting the problem, as well as how these interrelated factors affect each other [6]. It visualizes the interrelationships using loops with arrows. The aim of this study was to create a CLD model from a systematic study of diagnostic errors. The purpose of building a CLD model was to understand the diagnostic process, analyze root causes of diagnostic errors, map interrelations of relevant factors, and then provide a clear view of how relevant variables in the system are changed by the change of one variable. In this study, a systematic review was conducted to seek out the leading causes of diagnostic errors, and identifying the key inputs of the CLD model.

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## 1. Methods

A CLD was created based on the following steps: 1, identify the purpose of the model; 2, identify key variables; 3, developing the reference modes; 4 developing the causal map of the feedback processes. [7]

A systematic review was carried out to establish the key factors that affect correct diagnosis. Paper published in English between 2002 and 2012, using the following databases were covered in the search: PubMed, CINAHL with Full Text, EMbase, PsycINFO, Web of Science, IEEE Xplore, using search phrases: Diagnostic Error, Delayed Diagnosis, Misdiagnosis, Reduce diagnostic errors, Prevent diagnostic errors, Manage diagnostic errors. Papers were excluded if: 1, the paper was a commentary or general review paper; 2, the paper was used for medical disease study. Relevant papers were viewed and provided the information of possible factors affecting diagnosis.

An initial CLD was developed to reflect on the factors collected from the systematic review and to map the important feedback loops or interrelationships among the factors which are responsible for the problem. The initial model was shown to 7 clinicians to increase model trustability and acceptability. After the model was explained in details, a number of semi-structured questions were asked in terms of the suitability of the variables in the model and the causal-effect interrelationships. Clinicians provided their feedback and suggestions based on their knowledge and experience. At last, the initial causal loop diagram was further refined based on the information collected from experts.

## 2. Results

57 papers were selected from the systematic review. There were 10 papers out of 57 focusing on diagnostic errors with possible suggestions to reduce errors. 26 out of 57 papers researched solutions by changing one or a few factors which affect diagnosis. 21 out of 57 papers related to specific diseases, but still focused on diagnostic errors instead of the medical disease point of view.

### 2.1. Key factors contributing to diagnostic errors

The main factors which affect a correct/incorrect diagnosis based on the selected papers, includes:

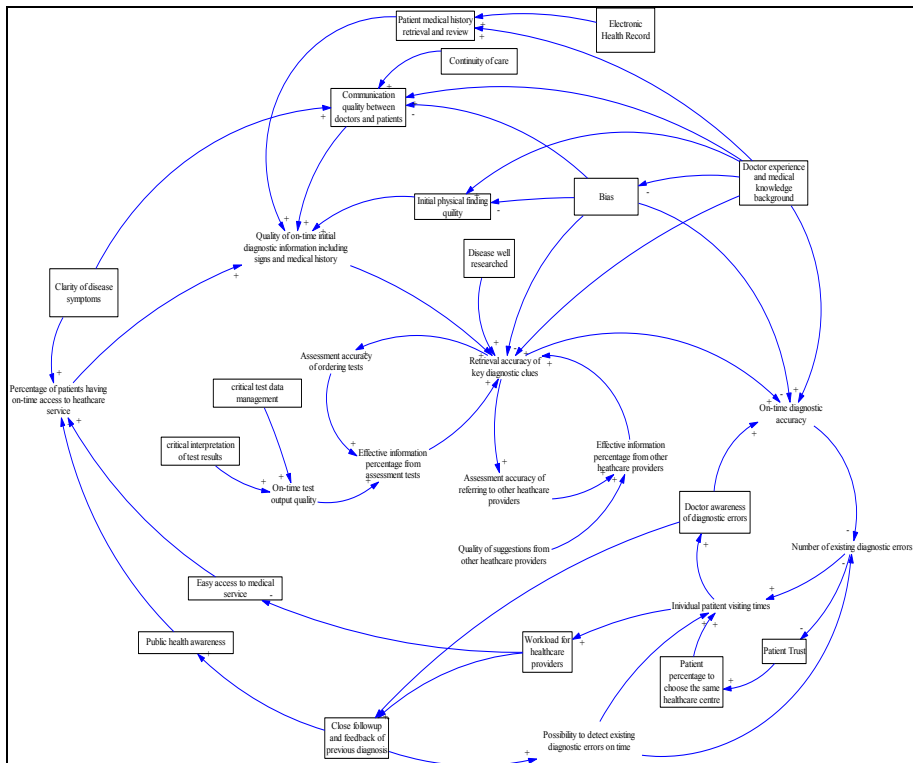
- Clinical disease features: This includes whether a disease is well researched [8] and the clarity of disease symptoms or presentations [9].
- Education background of patients or doctors: Patient education background was shown it could affect patient health awareness in terms of whether proper actions could be carried out after a symptom was presented [10]. Doctor experience and knowledge and background cover doctor abilities to observe clinical signs, understand collected clinical information, reason clinical reasoning of the information and organizing treatment plans.[11]
- Clinical reasoning in retrieving key diagnostic clues [12]: Diagnostic clues are the evidential information used to make diagnostic decisions. Clinical reasoning involves using doctors' knowledge to retrieve key clues from

collected diagnostic information. This information could come from initial physical examinations, patient-doctor communication [13] and patient medical history [6], as well as further diagnostic information collected from tests [14] or consulting from other healthcare providers.

- Psychological factors: This mainly involves cognitive errors [15], bias[16] and doctor awareness of high risk cases.
- Follow-up after a diagnosis: Careful follow-up helps to discover and correct existing diagnostic errors before they can have a server affect on patients [17].

## 2.2. Causal loop diagram

Further to the systematic review, 7 clinicians reviewed the findings and gave suggestions about key factors and their inter-relations in terms of: continuity of care, workload for healthcare providers, easy access to medical services, and patient trust of the healthcare provider. The final CLD is illustrated in Figure 1. Causal loop diagram of diagnostic errors after the initial model was refined.

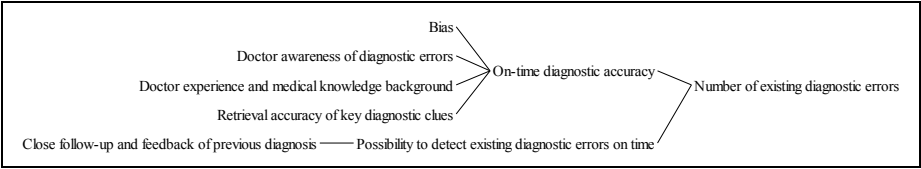


**Figure 1.** Causal loop diagram of diagnostic errors.

The CLD shows the research-level factors which affect diagnosis and their interrelationships. All factors and loops are based on the findings from the systematic review and the expert reviews.

The arrows in the diagram indicate a causal-effect interrelationship. The “effect variable” is the variable adjacent to the arrowhead, and the “cause variable” is at the opposite end of the arrowhead. Arrows with a positive polarity indicate the “effect variable” changes in the same direction with “cause variable”; while arrows with a negative polarity indicate the variables move in an opposite direction[7]. These arrows are linked into twelve loops in the diagram.

Each variable in the model has a clear view of different levels of causes by following its input arrows. The diagnostic errors are reflected as “Number of existing diagnostic errors” in the diagram, and its input arrows indicate the first-level factors which have direct causal effect on it. Additionally, a causes tree could be illustrated to show different level of factors. Figure 2 shows the first and the second level of factors of “Number of existing diagnostic errors” as an example.



**Figure 2.**Causes tree of “Number of existing diagnostic errors”.

Furthermore, following paths of loops, it is clear to see that a factor could pass one or more loops to affect the “Number of existing diagnostic errors”. A change of a factor in the diagram triggers one or more changes of relevant variables, and then causes the change of “Number of existing diagnostic errors” directly or indirectly.

**3. Discussion**

The CLD shows many factors could potentially affect making a correct diagnosis and these multiple factors also have close interrelations with each other. A factor can appear to have a direct positive effect on diagnostics errors based on a partial view, but from a whole picture point of view in a CLD, it may actually produce negative outputs by affecting other factors essentially via other loops. It makes a CLD, as a systemic analysis, is important for the study of diagnostic errors. At the same time, the change of a factor could be caused by introducing an external intervention, thus a CLD also provides a potential way of visualizing the consequent influence of a new external intervention.

Current methods of reducing diagnostic errors can be divided into two groups, “Non-electronic methods” and “Electronic methods”, based on whether individuals carrying out the diagnosis use computer technology to solve the problem. Non-electronic methods include improving education of patients or doctors, improving clinical guidelines and other creative ideas from other high-risk, high-reliability professions, like aviation. [18] Electronic methods work in the following two instances. The first is introducing advanced electronic laboratory equipments. The second is introducing other electronic interventions which work specifically in three ways: helping predict a diagnosis, providing information to doctors making a diagnosis, or helping to detect diagnostic errors in time after a diagnosis. [19]

A CLD is a qualitative analysis to understand what the key factors are and how they work from a systemic viewpoint. A quantitative model would be executed as a

next step in the future to transfer the CLD into a stock and flow diagram. This would provide a simulation of how much the output of diagnostic errors changes if one or more factors inside of the model are changed, as well as understanding the dominant factor(s) working inside of the model.

This model promotes patient safety in many ways. It gives suggestions of possible strategies to reduce diagnostic errors via finding how individual factors working inside of the model and discovering domain factors by performing sensitivity analysis. Also, it potentially provides a way of visualizing the consequent influence of a new external intervention. Furthermore, it could propose guidelines on how to reduce diagnostic errors.

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