A SUMMARY

Today, hospitals and general practitioners are requested to compute dramatically increasing numbers of healthcare quality indicators to monitor and to improve the quality of their delivered care, and to be compared with each other. This computation is mostly performed manually, which is time-consuming, expensive and error-prone because indicators are typically released in inherently ambiguous natural language. A concurrent development is the rapid adoption of Electronic Medical Records, resulting in increased volumes of routinely recorded healthcare data, and opening the door to the automated computation of quality indicators. Therefore, the main research question tackled in this thesis is:

> *Under which conditions can healthcare quality indicators be computed automatically by reusing data already collected during the clinical care process?*

We demonstrated that the automated computation of healthcare quality indicators by reusing data already collected during the clinical care process is feasible. However, several conditions must be met:

I) Indicators and their formalisation

Indicators need to be formalised to be automatically computable. Based on a literature study and a requirements analysis, we developed CLIF, a method to formalise quality indicators into unambiguous queries that can be run against patient data. We created a web-based tool that implements the formalisation method to lead users through the formalisation process, and thereafter examined the method's reproducibility in a case study, and its generalisability by formalising the entire set of Dutch indicators for general practitioners. Our studies confirmed that CLIF can lead to maximally reproducible results and that it is generalisable to a broad set of Dutch quality indicators, but that unambiguous indicators and the cooperation of trained experts are required. Both the tool and the sets of formalised indicators have been made available online.[1]

II) Patient data and its (re)usability

1 https://github.com/kathrinrin/clif, http://figshare.com/authors/Kathrin_Dentler/452665

Regarding the secondary use of patient data, we conducted our research in the clinical setting of the GIOCA, the Gastro-Intestinal Oncology Centre Amsterdam. To automatically compute quality indicators, patient data needs to be available. We attempted to gather all raw source data that is required to compute the set of indicators relevant for the GIOCA. We identified barriers that impede the secondary use of patient data and provided recommendations on how to prevent them. Patient data needs to be of adequate quality to be reused. We assessed the data quality inside our hospital by comparison to data submitted to the DSCA, the Dutch Surgical Colorectal Audit, and its influence on quality indicator results by a statistical analysis. We demonstrated that data quality can have a significant impact on quality indicator results. High quality implies the use of well-established healthcare standards, so that the meaning of data becomes machine-processable. To integrate data from various heterogeneous sources, and also to bridge the semantic gap between indicators and patient data, standard information models and large, lightweight, logics-based terminologies such as SNOMED CT play an important role. We represented both the data and the indicators based on the standard information model *open*EHR archetypes, and proved the concept by automatically computing the formalised indicators.

III) Semantic interoperability

Automated reasoners provide support to meaningfully use logics-based terminologies, for example by selecting not only certain concepts, but also their sub-concepts. Based on a literature study, we defined characteristics of reasoning engines, and categorised eight reasoners along these characteristics. Our results show that reasoners can vary substantially, and that their characteristics should be taken into account when choosing a reasoner for a specific application scenario. Finally, the quality of medical terminologies must be ensured by automated auditing methods, as these terminologies are typically too large to be audited manually. A relevant quality factor is non-reduncancy. We extended and operationalised an already existing definition to detect intra-axiom redundancies in SNOMED CT and showed that 12% of concepts in the employed SNOMED CT version contained redundant elements.

The presented results are a basis to support clinical practice and further areas of research where quality indicators are used to improve health outcomes of patients.