

# Controlled Natural Language for Clinical Practice Guidelines<sup>\*</sup>

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**Abstract.** Clinicians would benefit from decision support systems incorporating the knowledge of clinical practice guidelines. However, the unstructured form of the guidelines makes them unsuitable for formal representation. To remedy this shortcoming we translated a set of pediatric guidelines into Attempto Controlled English (ACE). An experienced pediatrician and a knowledge engineer assessed that ACE can accurately represent the clinical concepts and the proposed actions of the guidelines. Currently, we are developing a systematic and replicable approach to authoring guideline recommendations in ACE.

## 1 Introduction

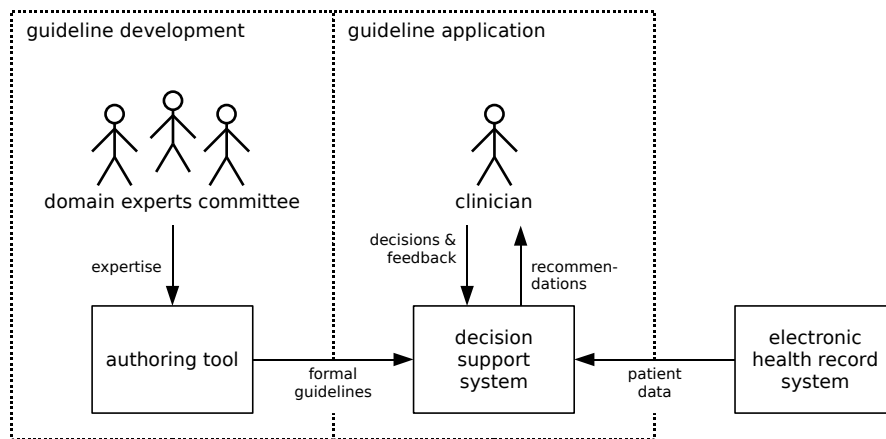
Clinical practice guidelines are defined as “systematically developed statements to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances” [2]. Guidelines are developed by teams of clinical experts who systematically review and appraise the relevant biomedical literature and apply rigorous methods to link recommendations about appropriate care to the supporting scientific evidence. More than 4000 guidelines have been published by various organizations. The large number of guidelines impedes their practical application by clinicians who would profit from computerized decision support.

However, there is a mismatch between the unstructured narrative form of the published guidelines and the formality that is necessary for the operationalization of guideline knowledge [4]. Uncritical translation of such recommendations into computable statements risks distortion of the guideline authors’ intent [8, 9].

In order to address this problem, we investigate writing guidelines in Attempto Controlled English (ACE) [3]. ACE is a controlled natural language, i.e.

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**Fig. 1.** This diagram shows the general architecture of our approach. It shows the information and data flows between systems (in rectangular shapes) and users. The focus of the ERGO project lies on the guideline development part.

a precisely defined subset of English with restrictions on vocabulary and grammar. These restrictions result in increased terminological consistency, reduced ambiguity, consistent vocabulary, potentially templated phrases, and a generally simplified sentence and text structure. ACE has the additional benefit of being supported by a parsing engine that translates ACE texts into first-order logic, thereby providing a computable format and supporting automatic reasoning.

In the initial phases of the ERGO Project (Effective Representation of Guidelines with Ontologies)<sup>3</sup> we will demonstrate the feasibility of translating guideline knowledge into rules. We propose to use ACE as an intermediary representation between the implicit knowledge contained in the minds of the domain experts and the representation of that knowledge in an explicit computable form. Our goal is to develop an authoring tool that helps guideline authors to reduce ambiguity, vagueness, incompleteness, and inconsistency, and facilitates the translation of guideline recommendations into logic statements that can be implemented in decision support systems. These systems generally depend on production rules derived from guideline recommendations to create a knowledge base. The decision support system compares an individual patient's characteristics (demographic descriptors and clinical findings) against these rules to guide a health provider by offering patient-specific and situation-specific advice. A second goal is to demonstrate that ACE is a good candidate controlled natural language for writing recommendations. Figure 1 shows the general architecture of our approach.

<sup>3</sup> <http://gem.med.yale.edu/ergo/>

**Table 1.** A comparison of three of the eleven original natural language guidelines together with their ACE equivalents

Original guideline	Attempto Controlled English
The presence of UTI should be considered in infants and young children 2 months to 2 years of age with unexplained fever (strength of evidence: strong).	If the patient is a young child who has an unexplained fever then the clinician must consider UTI.
In infants and young children 2 months to 2 years of age with unexplained fever, the degree of toxicity, dehydration, and ability to retain oral intake must be carefully assessed (strength of evidence: strong).	If the patient is a young child who has an unexplained fever then the clinician must assess the degree of Toxicity and must assess the degree of Dehydration and must assess the Ability-to-retain-oral-intake.
If an infant or young child 2 months to 2 years of age with unexplained fever is assessed as being sufficiently ill to warrant immediate antimicrobial therapy, a urine specimen should be obtained by SPA or transurethral bladder catheterization; [...] (strength of evidence: good).	If the patient is a young child who has an unexplained fever and the patient is sufficiently-ill then the clinician should analyze a culture of a urine-specimen that is obtained-by SPA or that is obtained-by Transurethral-catheterization.

## 2 Expressing Clinical Practice Guidelines in ACE

We plan to use ACE to encode the summary recommendation statements that form the backbone of guideline documents. Often published in boldface, these recommendation statements embody the critical knowledge about appropriate practice that is amplified by supporting text. A first critical step is to establish whether clinical guidelines can be adequately expressed in ACE, and to identify potential barriers to the effective translation. To answer this question we decided to manually “ACE’ify” the set of recommendations contained in the guideline “Diagnosis, Treatment, and Evaluation of the Initial Urinary Tract Infection in Febrile Infants and Young Children” (UTI) [1]. UTI was chosen because (1) it includes a sufficient number of recommendations to exercise the translation process, (2) its recommendations involve a variety of action types and levels of obligation, (3) some recommendations incorporate a temporal sequence, (4) while others contain sentences related by anaphoric references. This guideline demonstrates many challenges in translating recommendations in spite of its small size. All eleven UTI guidelines could be successfully translated into ACE. Table 1 shows three of the original natural language guidelines together with their ACE equivalents.

The recommendations were translated by 3 members of the ACE team at the University of Zurich. Once translated into ACE, the recommendations were reviewed by a pediatrician with expertise in clinical guidelines and by a knowledge engineer. Judgements were made regarding the accuracy of translation, the naturalness of the ACE statements, and potential solutions to encountered impediments of the translation. Altogether, the reviewers concluded that ACE is capable of accurately stating the clinical concepts and the actions described

in the guideline’s recommendations. Nevertheless, the reviewers identified some problem areas.

The example guidelines use specialized medical terms that are not part of the basic lexicon of the ACE parser. Though many of these terms can be found in lexicons like UMLS and SNOMED, the problem remains that terms — such as “ability to retain oral intake,” “sufficiently ill” and “SPA” — require clear and consistent specifications by guideline authors. We plan to solve this problem by providing an authoring tool that accepts only terms that are known to the system and that have a clearly defined meaning.

Considerable uncertainty accompanies most medical decision making. Evidence validity as well as the accuracy of clinical observations and measurements contribute to this uncertainty. Guideline authors express the uncertainty by using deontic modals and by including coded representations of evidence quality and recommendation strength with their recommendations. Strength of recommendation is a judgment based on the anticipated benefits, risks, harms, and costs of the proposed actions.

The modals “can” and “must” originally offered by ACE are not sufficient to capture the levels of obligation imposed by recommendations. In guideline recommendations “should” is the most frequently used modal with a level of obligation between “can” and “must”. To adequately represent the required levels, ACE was extended by the modal “should”. This is already reflected in the examples of table 1.

While “ACE’ifying” UTI, we noticed that a systematic approach is needed to consistently author clinical guidelines, and to adequately support clinicians in the use of guidelines. All knowledge should be made explicit, all terms should be used consistently, and guidelines should be rendered operational to be executed under the control of the responsible clinician — who ultimately must decide whether, or not, to follow the recommendations of a guideline.

To make all knowledge explicit and to enforce a consistent use of this knowledge we introduce a domain-specific lexicon and a background ontology. Here is a sample of the UTI background ontology:

Every child is a person.  
SPA is a method.  
No analysis confirms X and excludes X.  
Every antimicrobial-therapy is a therapy.  
...

To make the guidelines operational we express them as linked rules that are executed under the control of the clinician. Every rule (see Table 1) consists of preconditions that must be fulfilled to trigger the rule, and conclusions that are true after the rule fired, and that can be used as preconditions for other rules. To get the rule machinery running, a number of initial facts are asserted that originate from the patient’s electronic health record or that are manually asserted by the clinician, for instance:

The patient is a young child.  
The patient’s age is 1.5 years.

The patient has an unexplained fever.

...

The firing of a guideline rule can enable other rules, so that potentially every rule can be fired at some point.

### 3 Conclusions and Future Work

We showed that ACE can be used to adequately express clinical practice guidelines. Furthermore, we prototypically developed a systematic approach to author and to transparently use clinical practice guidelines stated in ACE.

Our immediate plan is to build a “look-ahead” editor for clinical practice guidelines expressed in ACE that dynamically displays the knowledge defined so far and the specific options available for extending or revising it, similiar to the existing ACE Editor<sup>4</sup>. This approach was described by Scott et al. [6], and has been used by Schwitter [7] and by Kuhn [5] working with controlled language grammars. Furthermore, in the future, we plan to embed rules created with the ACE editor in a decision support system that advises clinicians. That system will combine the rules with clinical observations derived from an electronic health record system to provide guidance about best practices for care.

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<sup>4</sup> <http://attempto.ifi.uzh.ch/aceeditor>