A Constraint Logic Programming Approach to Identifying Inconsistencies in Clinical Practice Guidelines for Patients with Comorbidity

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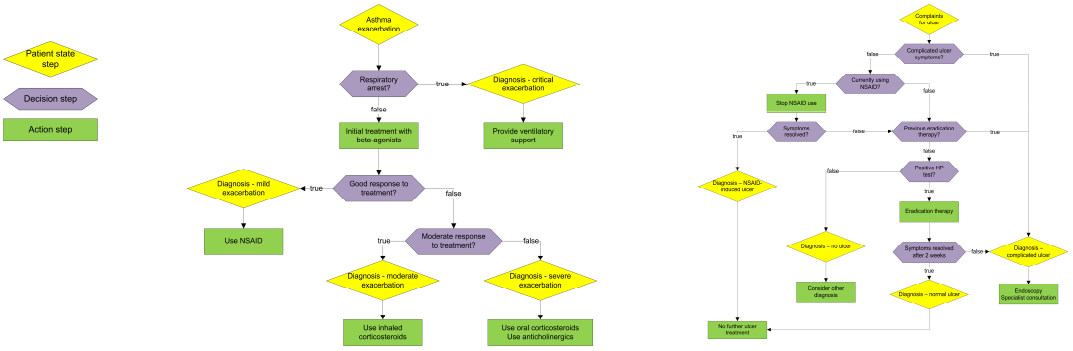
Problem Statement

How to create a computable guideline model that can be applied to a patient with comorbidity?

Rationale
- Most of the attention has been paid to translating evidence into a guideline and representing an individual CPG
- 50% of people 65 years old or older have a co-morbid condition [Institute of Medicine, 2001]
- A need for personalized medicine

Clinical Practice Guidelines

CPG: systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances



Asthma **Ulcer**

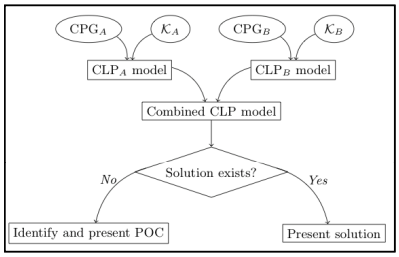
Methodology: Constraint Logic Programming

CLP model is composed of:
•A set of variables V = {V_1,V_2,...,V_n} and their respective value domains D = {D_1,D_2,...,D_n}
•A set of constraints C = {C_1, C_2,..., C_n} that restrict the possible combinations of values assigned to each variable
•A set of clauses CL = {CL_1, CL_2,..., CL_n} that define the logic program, a disjunction of n-ary predicates (literals)

Variables = decision and action steps from the CPG
Constraints = restrictions on variables' values derived from a CPG

Solving a CLP model provides:
- A therapy if one exists or lack of hereafter
- The ability to identify inconsistencies that we call *points of contention* (POC)
- The ability to use CPG for scenarios with incomplete patient data

Modeling and Combining Multiple CPGs



Proposed modeling and solving process

1. $CUS \rightarrow SC$
2. $\neg CUS \wedge CNSAID \rightarrow \neg NSAID$
3. $\neg CUS \wedge \neg CNSAID \wedge PET \rightarrow SC$
4. $\neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge PHPT \rightarrow ET$
5. $\neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge \neg PHPT \rightarrow OD$

1. $\neg OC$
2. $\neg NSAID$
3. $\neg(ET \wedge IC)$

Rules and Knowledge Base derived from ulcer CPG

$$\mathcal{V} = (CUS, SC, CNSAID, NSAID, PET, PHPT, ET, OD, OC, IC)$$
$$\mathcal{D} = \{D_1, .., D_{10}\}, \text{ where } D_i = \{true,\ false\}\ \forall i = \overline{1..10}$$
$$\mathcal{CL} = \left\{ \begin{array}{c} CUS \rightarrow SC \equiv true \\ \neg CUS \wedge CNSAID \rightarrow \neg NSAID \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge PET \rightarrow SC \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge PHPT \rightarrow ET \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge \neg PHPT \rightarrow OD \equiv true \\ \neg OC \equiv true \\ \neg NSAID \equiv true \\ \neg(ET \wedge IC) \equiv true \end{array} \right\}$$

Individual CLP-CPG model representing the ulcer CPG

- Solving CLP-CPG model implies assigning a value to each variable such that no constraints are violated
  - Use open source constraint programming system ECLiPSe
- When solving the combined CLP-CPG model two scenarios exist:
  1. If a solution exists, there are no adverse or contradictory actions
  2. If solution **doesn't** exist, then *points of contention* (POC) need to be identified

- Points of contention
  - *A set of variables T in the combined CLP-CPG model whose domains are annihilated (reduced to the empty set) during search, resulting in no found solution.*
  - Represent adverse or contradictory actions resulting from concurrent use of multiple CPGs
  - Flags sources of the adversities and contradictions

$$\mathcal{V} = (CUS, SC, CNSAID, NSAID, PET, PHPT, ET, OD, OC, IC, GR, MR)$$
$$\mathcal{D} = \{D_1, .., D_{12}\}, \text{ where } D_i = \{true,\ false\}\ \forall i = \overline{1..12}$$
$$\mathcal{CL} = \left\{ \begin{array}{c} CUS \rightarrow SC \equiv true \\ \neg CUS \wedge CNSAID \rightarrow \neg NSAID \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge PET \rightarrow SC \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge PHPT \rightarrow ET \equiv true \\ \neg CUS \wedge \neg CNSAID \wedge \neg PET \wedge \neg PHPT \rightarrow OD \equiv true \\ \neg OC \equiv true \\ \neg NSAID \equiv true \\ \neg(ET \wedge IC) \equiv true \\ GR \rightarrow NSAID \equiv true \\ \neg GR \wedge MR \rightarrow IC \equiv true \\ \neg GR \wedge \neg MR \rightarrow OC \equiv true \end{array} \right\}$$

Combined CLP-CPG model of the asthma and ulcer CPGs

Results and Discussion

Results

- We proposed method to build a computable CPG model that can be solved for co-morbid condition

- An executable CPG model is an active support tool that
  - Provides solutions for incomplete information
  - Helps physician identify POC

Future Research

- Richer model representation allowing to:
  - Represent temporal actions
  - Combine and constraint medication dosages
  - Represent physician's preferences, along with weighting actions and probabilities in path nodes
- Method to identify and flag "critical" variables
  - In some instances, it is inadvisable to assign values to unknown variables
- Provide more informative advice to physician
  - Augment suggested paths with more information
  - Expand external knowledge