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Fisheye visualization and multi-path trees for presenting clinical practice guidelines: Methods and application to Covid-19

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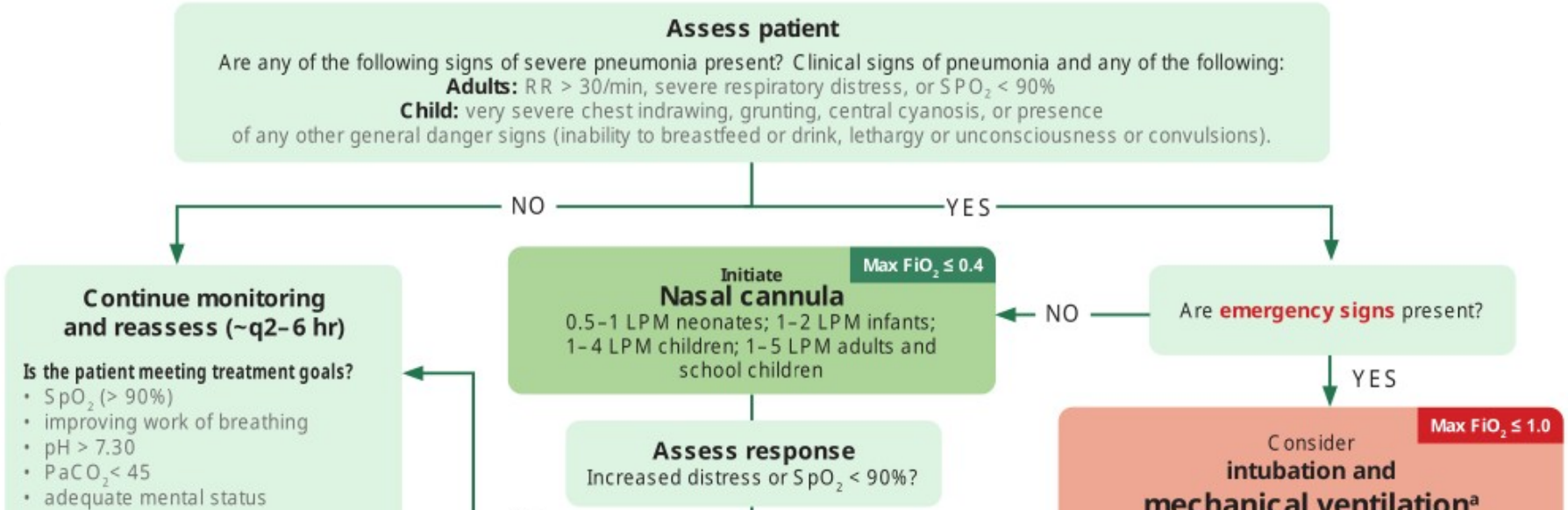
Introduction

- **Decision trees are commonly used for representing a reasoning process, in particular in the medical field**
  - from expert knowledge, *e.g.* clinical practice guidelines
  - or generated by machine-learning algorithms

Clinical Care for Severe Acute Respiratory Infection (WHO 2022)



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  - from expert knowledge, *e.g.* clinical practice guidelines
  - or generated by machine-learning algorithms
- **Advantages:**
  - Machine-interpretable if the tree is fully formalized
  - Intuitive to understand for clinicians
    - Allows **“one-click navigation”**:
      user can go from any node in the tree to any other node in a single click

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  - The size of the tree is limited by the size of the screen

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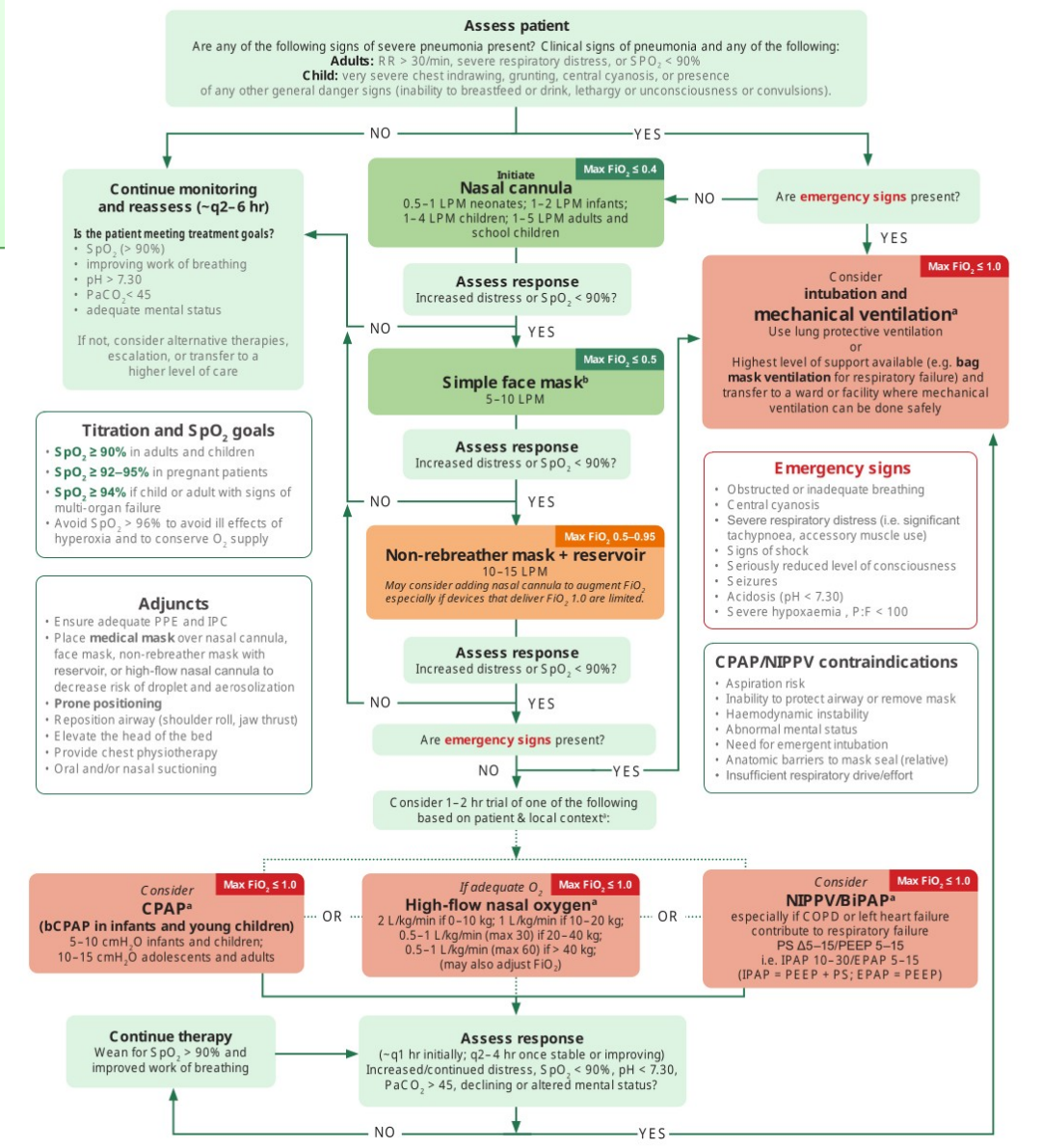

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  - Some reasoning processes are difficult to translate into tree
    - E.g. independent followup elements in clinical recommendations:
      If element A is abnormal, treat A. If element B is abnormal, treat B.

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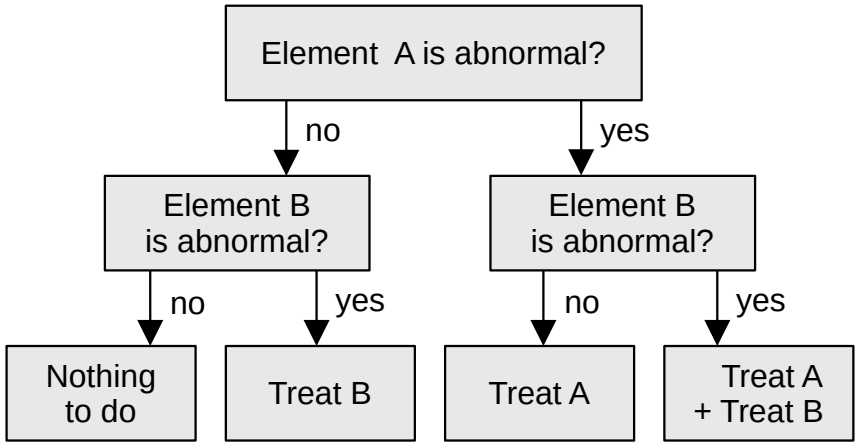


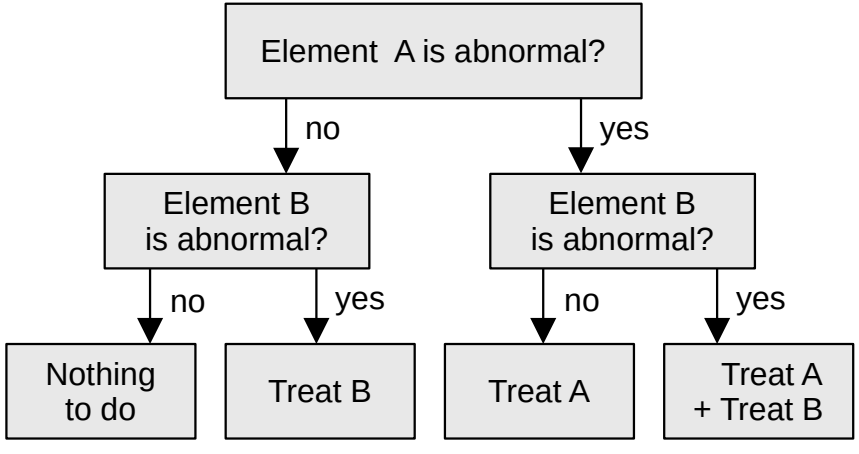
The tree has at least 2^n leaves,
where *n* is the number of elements A, B, etc.

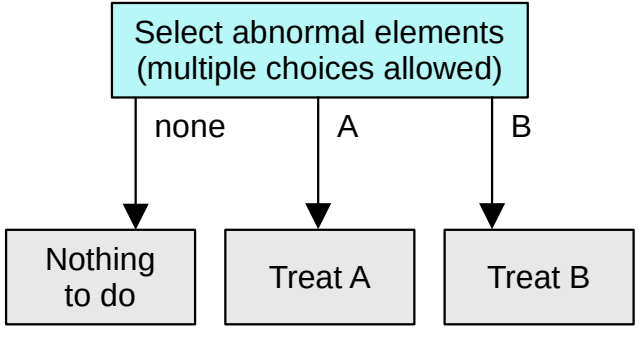
Introduction

- **In machine learning, *multi-path* decision trees have been proposed:**
  - For a given sample, several paths can be selected simultaneously [Guo 2013]
  - But it has not been formalized for the user presentation of decision tree
- **In this work, we propose a dynamic and interactive visualization tool for a multi-path decision tree**
  - Including algorithms adapting the one-click navigation
  - With an application to the clinical management of Covid-19 patients

Multi-path decision tree model

- **We consider 2 types of nodes:**
  - Single-choice question nodes, corresponding to the usual behavior of nodes in a decision tree
  - Multiple-choice question nodes, for which one or more child can be selected
    - Multiple-choice question nodes may have a special “none” child





The multi-path tree has at least n+1 leaves, where n is the number of elements A, B, etc.

Interaction with a multi-path decision tree

- **Adapting one-click navigation to multi-path decision tree is challenging:**
  - some current paths may be affected by the user interaction and others not
  - some previous nodes must remain open
    (*e.g.* multiple-choice question nodes, in order to let the user choose another answer, unless “none” has been chosen)

Algorithm 1 Algorithm partitioning nodes in four subsets, C, P, A and I, the subsets of current, past, accessible and inaccessible nodes.

function ancestors($n \in \mathcal{N}$):
  if $n = root$: return $\emptyset$
  return $\{parent(n)\} \cup$ **ancestors**$(parent(n))$

function accessible_descendants($n \in \mathcal{N}$, $C \subset \mathcal{N}$, $P \subset \mathcal{N}$):
  if $(n \in \mathcal{M})$ and $(multi(n) \cap (C \cup P) \neq \emptyset)$: return $\emptyset$
  return $children(n)$
    $\cup \bigcup_{k \in children(n)}$ **accessible_descendants**(k, C, P)

function make_partition($C \subset \mathcal{N}$):
  $P = \bigcup_{n \in C}$ **ancestors**(n)
  $A = \bigcup_{n \in C}$ **accessible_descendants**$(n, C, P) \setminus C$
  $I = \mathcal{N} \setminus (P \cup A \cup I)$
  return C, P, A, I

Algorithm 2 Algorithm applying the user interaction and computing the new set of current nodes.

function descendants($n \in \mathcal{N}$):
  return $\{n\} \cup \bigcup_{k \in children(n)}$ **descendants**(k)

function multiple_choice_ancestors($n \in \mathcal{N}$):
  if $n = root$: return $\emptyset$
  if $parent(n) \in \mathcal{M}$ and $n \in multi(parent(n))$:
    return $\{parent(n)\} \cup$ **ancestors**$(parent(n))$
  return **ancestors**$(parent(n))$

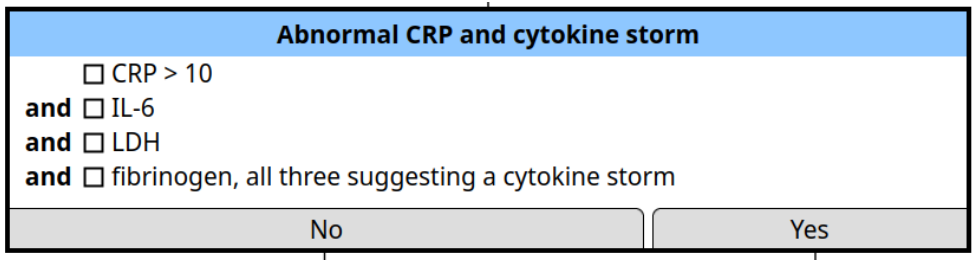
function apply_user_interaction($C \subset \mathcal{N}$, $P \subset \mathcal{N}$, $n \in \mathcal{N}$):
  $x = n$
  while not $((x = root)$ or $(parent(x) \in C \cup P))$:
    $x = parent(x)$
  if $x = root$:
    $C' = \{root\}$
  else if not $((parent(x) \in \mathcal{M})$
      and $(x \in multi(parent(x))))$:
    $C' = (C \setminus$ **descendants**$(parent(x))) \cup \{n\}$
  else if $(n \in C)$ and $(x = n)$:
    $C' = (C \setminus$ **descendants**$(x))$
  else:
    $C' = \Big(C \setminus \bigcup_{k \in none(parent(x)) \cup \{x\}}$ **descendants**$(k)\Big)$
      $\cup \{n\}$
  $C' = C' \cup$ **multiple_choice_ancestors**(n)
  return C'

Formalization of the decision tree

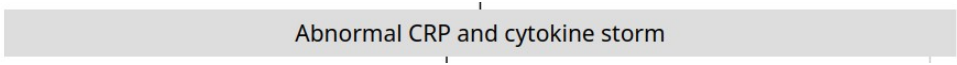
- **Decision trees were formalized using an OWL ontology**
  - May include coded medical criteria, using medical reference terminologies :
    - ICD10 (International Classification of Disease, release 10)
    - ATC (Anatomical Therapeutical Chemical classification of drugs)
    - LOINC (Logical Observation Identifiers Names & Codes, for lab tests)
  - Nodes that are fully coded can be executed automatically

Visualization and fisheye

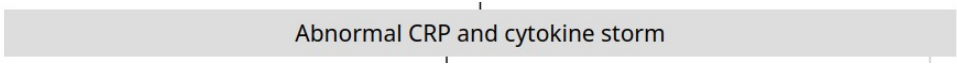
- **Detail on demand: at a given time, four categories of nodes, displayed differently:**
  - Current node(s), with full details



  - Past nodes, in gray with only the title



  - Accessible nodes, in gray with only the title



  - Inaccessible nodes, in white with only the title and shrunken

Visualization and fisheye

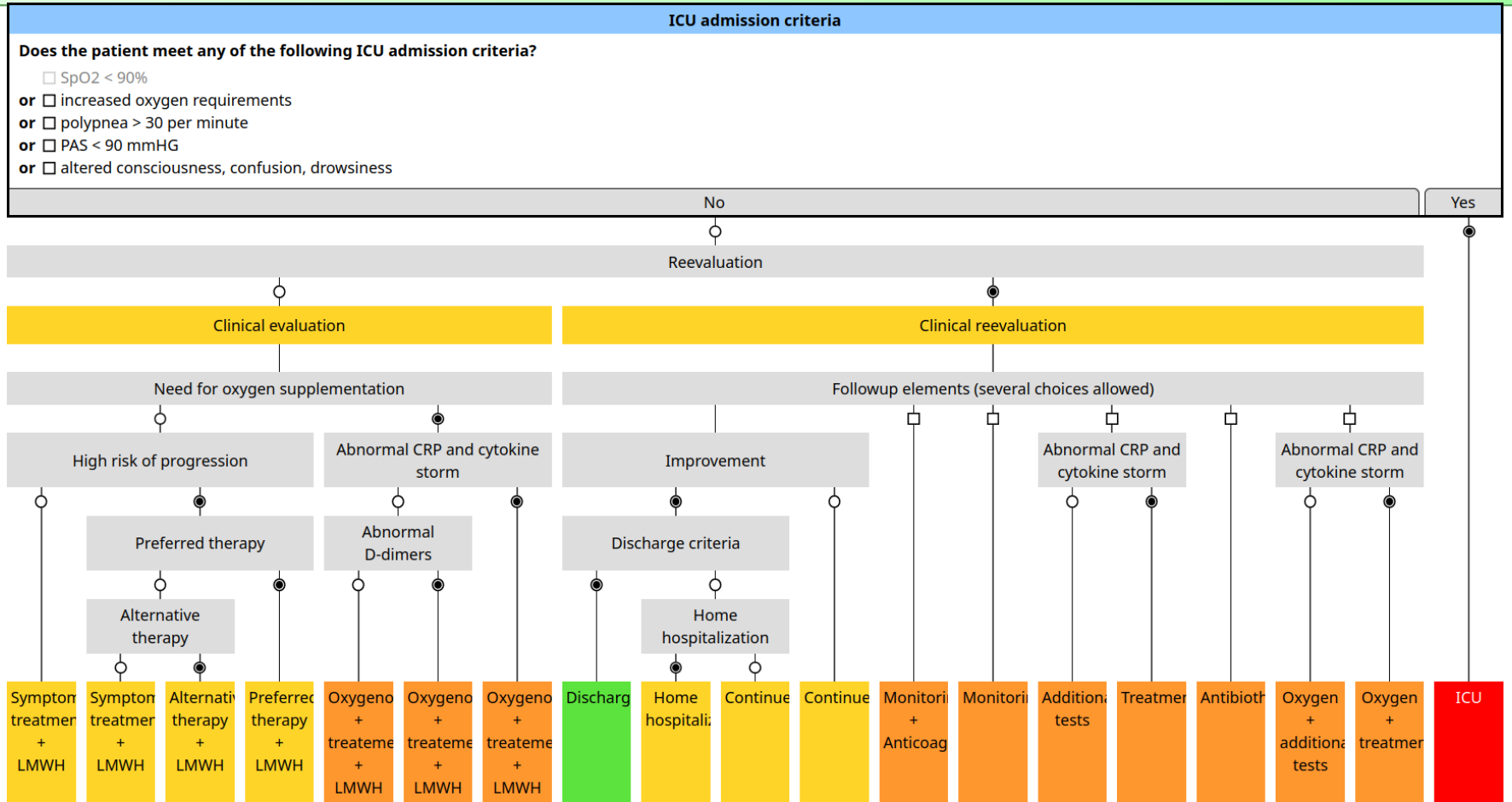
- **Fisheye: parts of the tree that are inaccessible are shrunken**
  - At least half of the available horizontal space is devoted to accessible leaf nodes
  - Smooth transitions are used for opening/closing node boxes, and changing the node horizontal sizes

Application to Covid-19

- **3 scenarios were considered:**
  - a phone hotline receiving a call from a patient with confirmed or suspected Covid-19
  - the home care management of a Covid-19 patient, including oxygen therapy if needed
  - the hospitalization of a Covid-19 patient
- **Thorough synthetic review of practice guidelines from:**
  - World Health Organization
  - Centers for Disease Control and Prevention – USA
  - International Society for Infectious Diseases – USA
  - Haute Autorité de Santé – France
- **Multidisciplinary panel of medical experts**

Demo

http://www.lesfleursdunormal.fr/appliweb/orient_covid



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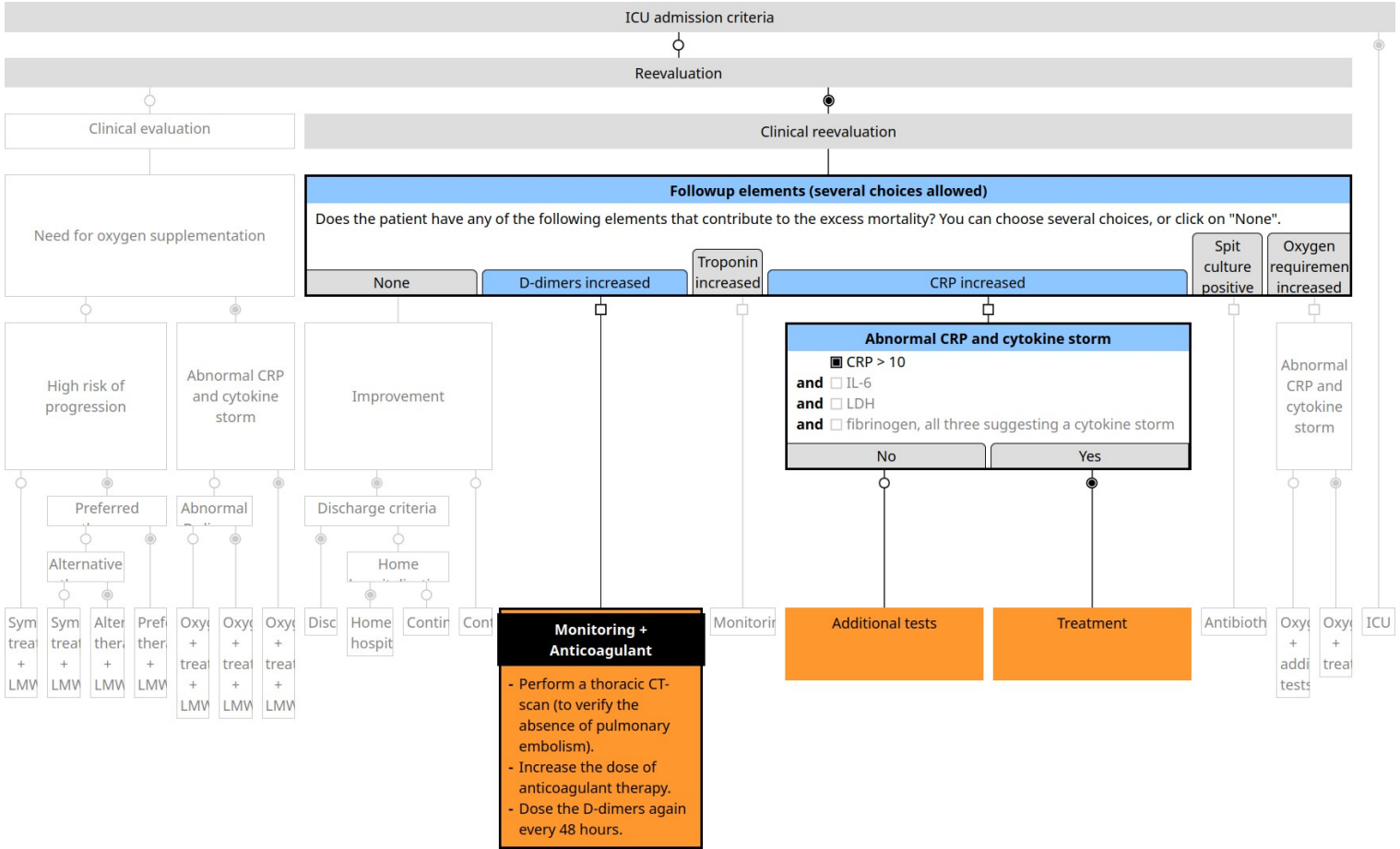
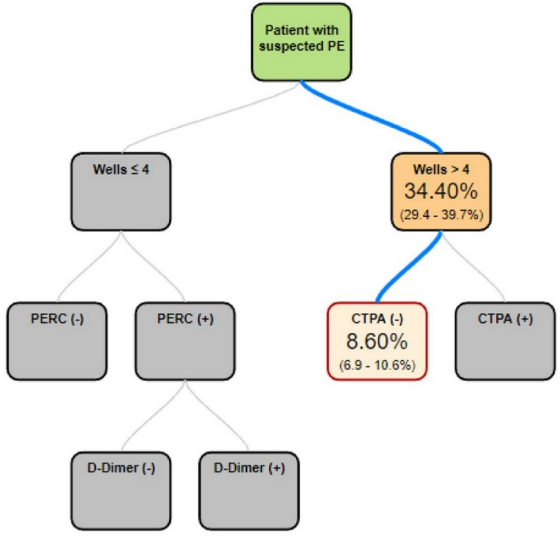


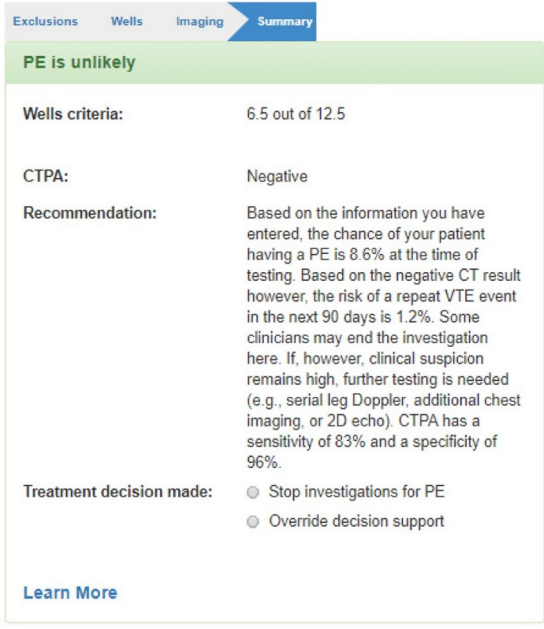
Preliminary evaluation

- **Two internists validated the medical content of the trees**
- **Visual trees were presented to 6 clinicians not involved in the conception**
  - SUS (System Usability Scale) score: 92.5% – “excellent”
  - Qualitative remarks were collected
    - The system was described as “user-friendly” (4 times), “good and clear visuals”, “simple and practical”
    - 5 clinicians said it can improve adherence to guidelines

Discussion

- **Many clinical guidelines include informal decision trees**
  - Some of them being multi-path in spirit, but not formalized as such
  - Classical approach for viewing big decision tree is to display the tree in a panel, and the details of the current node in another panel
    - But it is not suited for multi-path trees

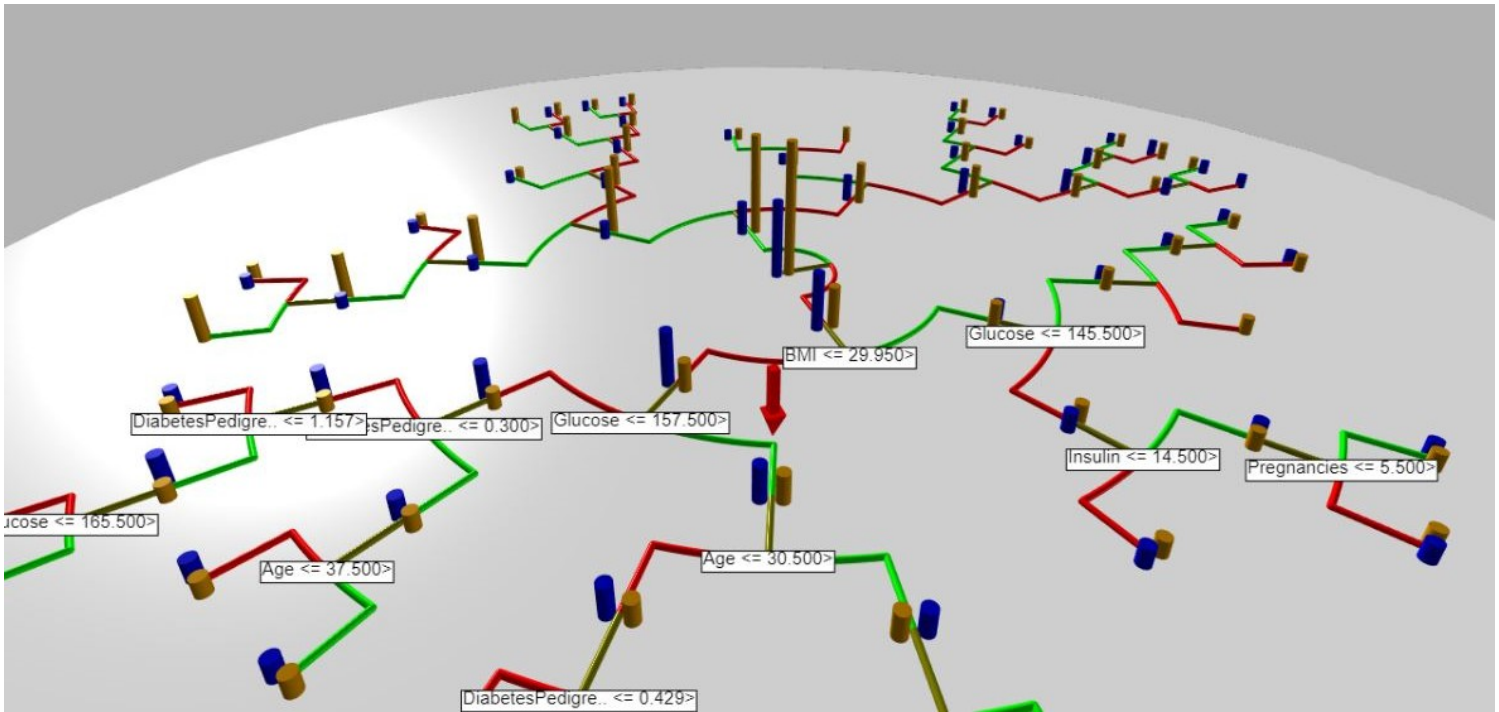




[Babione 2020]

Discussion

- **Fisheye have already been applied to trees in various manners**
  - Radial 3D visualization [Mrva 2019]



Conclusion

- **We proposed methods for visualizing big decision trees, relying on a multi-path tree model, Fisheye and details-on-demand**
  - We adapted one-click navigation to multi-path decision trees
  - We applied these methods to the presentation of decision trees for the clinical management of Covid-19 patients
- **Perspectives:**
  - Clinical validation of the Covid-19 application
  - Connection to hospital electronic health records
  - Application to larger decision trees
  - Implementation of other guidelines (medical or not) or machine-learned decision trees

Thank you!

- **Email for questions and remarks:**

  jiba@lesfleursdunormal.fr

- **Online demo:**

  http://www.lesfleursdunormal.fr/appliweb/orient_covid

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