# VitalSimML – A Well-Formed Data Structure to Capture Patient Monitoring Scenarios to Facilitate the Training of Nurses via Computer-Based Simulation

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## Abstract

*Introduction: Patient monitoring is both a prevalent and critical nursing duty. Given that it requires the interpretation of vital signs and intricate decision-making, nurses could benefit from simulation-based training. Currently there is a lack of an open data structure for capturing training scenarios that can be used to augment simulation software and virtual reality applications.*

*Methods: Twenty patient monitoring scenarios were analysed to identify the key common elements that are used to provide simulation. These elements aided the development of a data structure for storing training scenarios.*

*Results: A well-formed eXtensible Markup Language (XML) data structure, currently titled VitalSimML, has been developed for capturing patient monitoring scenarios, which can be used for simulation-based training using dynamic intelligent software solutions.*

*Conclusion: VitalSimML is the first attempt at a digital format for capturing patient monitoring scenarios.*

## 1. Introduction

Patient monitoring is a critical nursing duty that raises patient safety implications when sub-optimally performed [1]–[4]. Research shows that not all nurses record and interpret patient vital signs correctly or frequently [5]. One identified factor for this lack of competency is the knowledge and decision-making skill of the individual [6]. A safe method of combating a low level of competency is using simulation-based training [7]–[9] given that it poses no harm to any patient. It should also allow the trainee to frequently rehearse clinical scenarios until adequate competency is achieved. This training could be delivered via an intelligent software-based solution [10][11] and an open human/machine readable data format can (1) help capture and distribute scenarios (2) share the scenarios and (3) control a dynamic software or virtual reality system [12]. However, there is a gap in the literature for an open format for capturing patient monitoring scenarios. Such a format would allow instructors to build bespoke scenarios that would be parsed and visualized into a simulated scenario using software. Clinical staff could use the software for both training and assessment.

## 2. Methods

A literature review was conducted for simulation-based training in patient monitoring. The key search terms were: patient monitoring, healthcare simulation, e-simulation, patient safety and virtual patient. Twenty patient monitoring scenarios were identified (provided by nursing experts at Ulster University and literature on critical care nursing [2]) and analyzed (using thematic analysis) for the required elements.

**Panel 1 - Example scenario**

*"Fred is a 47 year old, previously independent man who was admitted to the medical ward yesterday morning. He complained of a 2-day history of vomiting and diarrhea at home and his admission was triggered by his sister who visited him and found him unwell. He has a history of binge drinking and has been frequent attender of A&E as a result of this. It is now 15:00 and you are working in the bay where he is being cared for in a side room. On assessment he appears unkempt and restless."*

The presentation of the scenario would be followed with questions for the trainee:

1. **Reviewing the EWS (early warning score) and fluid balance charts – what information do they give you?** *In this scenario we would see stable vital signs, $SpO^2$ reducing slowly, respiratory rate increasing slowly, some peripheral cyanosis and CRT (capillary refill time) of 3 seconds.*
2. **What action would you take?** *Start head to toe assessment. He has been diagnosed with basal pneumonia.*
3. **What action you take upon learning this?** *Assess him – Heart Rate (124bpm, irregular), Blood Pressure (88/52), Respiratory Rate (18bpm), $SpO^2$ (92%). Report results to doctor on ward immediately. Non-rebreather mask to deliver oxygen. ECG has shown atrial fibrillation.*

## 3. Results

By using the scenarios in patient monitoring we developed a well-formed data structure using the XML. XML has previously been used for capturing scenarios in other projects [12], [13] however limitations were noted in these cases. It was designed for the entire spectrum of medical education (which left the medical staff involved unsure about its specific use). Drawing from this, it can be argued that a specific data structure designed for a specific training area is likely to be more effective in creating software training scenarios. A tailored structure will be more accessible to healthcare staff and educators (and therefore, more likely to be used). The data structure has been named **VitalSimML** and its elements and attributes have been illustrated in Figure 1. The goal is to provide a structure that captures as much data as possible for a simulated patient monitoring scenario, without allowing it to become bloated and lacking of focus. An attempt has been made to capture as much 'state' data within element attributes as possible. This will leave room for textual explanations (or interpretations) as string data within the element body, provided by the author of the monitoring scenario.

**Panel 2 Annotation**

E.g. the author wishes to set the initial patient state as a high respiratory rate, albeit stable. We can set the random variance for change per minute to 1.0 and the rate itself to 25 respirations per min. This allows a textual description/interpretation to be stored within the element:

```
<RespiratoryRate random_variance="1.0"
rate="25">High-stable.</RespiratoryRate>
```

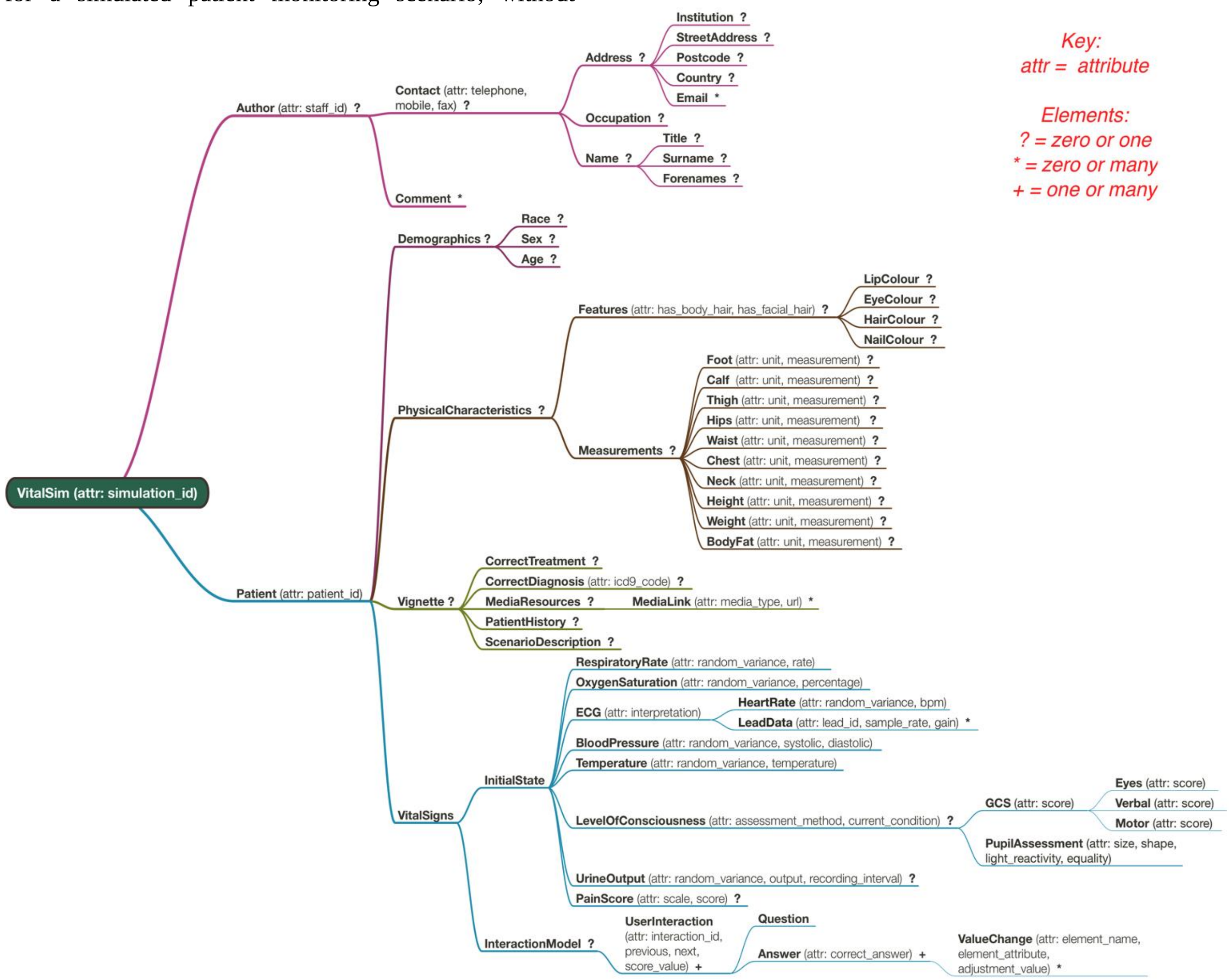


**Figure 1 - VitalSimML overview**

## 3.1. VitalSimML

The root element will have an attribute `simulation_id` that allows a scenario to have a unique identifier, for searching or retrieval on any potential database retrieval system.
**Author** contains descriptive data regarding the creator of the scenario (i.e. name, occupation, contact information, any comments regarding the simulation).

**Table 1 - Patient Elements**

| Element | Description |
|---|---|
| Demographics | Captures the patient's race, gender and age. |
| PhysicalCharacteristics | Provides the detail including features and measurements to potentially take advantage of 3D graphic technology to visually represent a patient on screen. |
| Vignette | Captures the descriptive elements of the monitoring scenario. Including scenario description, patient history, correct diagnosis (along with the exact ICD9 code), treatment and links to media that can be used in the simulation. |
| VitalSigns | Refer to Table 2. |

**Patient**, as seen in Figure 1 and Table 1 contains all patient related data (descriptive and physiological) and includes the patient vital signs, which are essential for the simulation.

## 3.2. VitalSigns

**VitalSigns** is the key child element of **Patient** and provides the scenario with the initial physiological data for interpretation and any set interactions that the author wishes to impose on the user during the simulation. This includes the vital signs deemed critical for monitoring [2], [5] (see Table 2).

### 3.2.1. InitialState

These vital signs are set within the **InitialState** element and as a basic function can provide a simulated monitoring scenario on screen. Key elements and attributes are:

- `random_variance` – fluctuation of vital signs over time (e.g. set to '1.0' = random movement of +1 or -1).
- **LeadData** – element should store comma-separated values (CSV) for ECG trace.
    - `lead_id` – id for angles of measurement.
    - `sample_rate` – recordings per second.
    - `gain` – regulates height or size of ECG waveform.
- `assessment_method` - for neurological assessment, there are different methods to assess. E.g. AVPU (Alert, Voice, Pain, Unresponsive).
- **GCS** – Glasgow Coma Scale – assessment for head trauma.

**Table 2 - Vital Signs Definitions**

| Element | Definition |
|---|---|
| RespiratoryRate | Rate of breathing over a full minute period. |
| OxygenSaturation | Indicator of tissue oxygenation. |
| ECG (electrocardiogram) | Tracing of the electrical activity of the heart over a period of time. |
| BloodPressure | Pressure exerted by blood against the arterial wall. |
| Temperature | Difference of heat lost and produced by the body. |
| LevelOfConsciousness | Grading on a scale for the patient's neurological condition. |
| PainScore | Self-reported measure of pain on a provided scale. |
| UrineOutput | Indirect reflection of renal function and fluid status. |

### 3.2.2. InteractionModel

**InteractionModel** is where on-screen user activities are captured - a question with possible solutions prompted to the user (see section 2). One or many **UserInteraction** elements capture an `interaction_id` and the identifiers of the `previous` and `next` interactions; allowing intelligent software to stack the interactions appropriately. The `score_value` for completing the interaction correctly is also set. **Question** stores the prompt to the user and is accompanied by one or many values in **Answer** – with the attribute `correct_answer` that is set to true or false (only one set to "true"). **ValueChange** will make a change to the vital signs set in the **InitialState**. This element will have set attributes for the element that can be changed, the attribute that can be changed and the adjustment that can be made. This element of course can be recorded many times, for different vital signs for the same correct or wrong answer. One wrong answer could set off a chain of deteriorating or improving vital signs.

**Panel 3 – Example definition**

```
<ChangeValue element_name=”Temperature”
attribute_name=”temperature”
adjustment_value=”+0.5”>Increase
temperature</ChangeValue>
```

## 4. Discussion and Future Work

VitalSimML could be used to capture scenarios that could augment intelligent software to provide simulation-based training. A software interface could provide a configuration of the parameters for the scenario and then generate the valid XML file. Visualization of the displaying monitor could be presented using Scalable Vector Graphics (SVG) or other suitable technology as shown in Figure 2. This example would allow a practical device-agnostic simulation on any screen and the captured physiological data would replicate a bedside monitor.
Future work would include implementation of a software interface (scenario builder) that allows a user to build their own scenarios using nursing expertise using VitalSimML as validation.

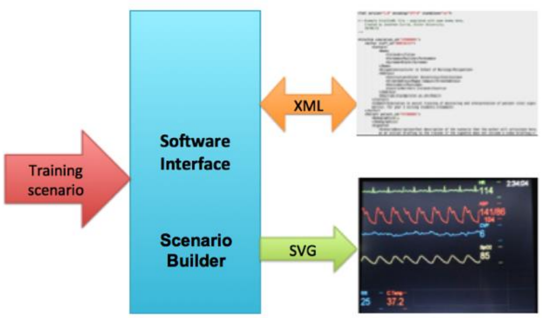


**Figure 2 - Fundamental software use of VitalSimML**

## 5. Conclusion

VitalSimML is the first digital format for capturing patient monitoring scenarios for training nurses. If adopted it could provide consistent and interoperable training content amongst instructors in various institutions. Trainees could continually rehearse a broad range of scenarios and safely practice their decision-making skills within software simulators. This can complement the traditional laboratory based simulations that occur infrequently, at inflexible set times and usually require expensive equipment.

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