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Summarizing clinical processes from event logs by using a fuzzy linguistic approach

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Summarizing Clinical Processes from Event Logs by Using a Fuzzy Linguistic Approach

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Abstract

In order to evaluate the quality of care and improve the clinical pathways (or protocols), clinicians need to continually checking the compliance between the real process and the process designed in document. Therefore, it is important to find a way to describe the real clinical processes from event logs generated during the execution of clinical pathways (or protocols). This research implemented the linguistic summarization technique to describe clinical processes. It is a technique based on the fuzzy logic that can sum up large volume of data into simple sentences, quickly and accurately providing right information on time.

As no previous study implements linguistic summarization on clinical processes description. The goal of this study is to "*design a methodology to summarize clinical processes from event logs by using linguistic summaries approach*". The results of the summaries should be understandable and meaningful to the specialist in the clinical field. Therefore, we proposed a step by step methodology which consist as: *specify clinical pathway (protocol), specify requirements, build protoforms, generate summaries, calculate truth value and evaluation.*

In order to adapt the linguistic summarization to the process description, as well as clinical environment, we proposed three protoforms based on (L.A. Zadeh, 2002)'s work during the development of the methodology. Two of them are used to generate sentences to describe sequences. And the other protoform is used to compare the numerical attributes of two sets of objects.

The proposed methodology is validated via real-world event logs, which are gathered from the weaning process in intensive care units (ICU) in Maastricht University Medical Centre+ (MUMC+) in Netherlands. During the validity, six categories of summaries are generated based on six protoforms, within different granularities and different patient groups.

The results are evaluated by the specialists working on the weaning protocol of MUMC+. According to the feedback from specialists, the sentences of the summaries are understandable, and a certain amount of results are interesting and relevant for them, providing useful information of the weaning process in practice. The evaluation indicates that it is efficiency to apply linguistic summarization to the clinical process description.

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1. Introduction

As the demand for high quality health care services grows, clinical processes become a big concern of care providers. To standardize and manage clinical processes, protocols and clinical pathways are now widely implemented in the clinical environment.

There are some differences between clinical pathways and protocols. The clinical protocol is a detailed document outlining the steps to be followed in a specific treatment, along with the rigid criteria that support the decision making during the treatment (Ilott, Rick, Patterson, Turgoose, & Lacey, 2006). Clinical pathways take one step further. It maps the journey of a well-defined patient group with a specified disease, and it can coordinate the roles and care processes among the multidisciplinary care team (Vanhaecht, Witte, & Sermeus, 2007). Despite the differences, both of them are based on the Evidence-based medicine (EBM), aiming to provide a standardized care, optimize the quality of care and reduce the variations in practice.

However, no matter whether implementing clinical pathways or protocols in a clinical environment, clinicians are required to continually evaluate the quality of care and improve the clinical pathways (or protocols), in order to facilitate the adapting of guidelines into the local setting. One of the possible evaluation methods is checking the compliance between the real process and the process designed in document. Therefore, based on having event logs generated during the execution of clinical pathways (or protocols), it is important to find a way to describe the real clinical process from these logs.

One existing technique to describe the process of an organization operation is process mining. Process mining has been confirmed effective in business workflow management. However, when implementing in the healthcare domain, due to the complex and multidisciplinary aspect of the process, current process mining methods fail to identify precise and interpretable models. The models identified are usually spaghetti-like and lack awareness of medical knowledge.

In response of the limitation of process mining methods, this research is using linguistic summarization to describe clinical processes. Linguistic summarization can quickly and accurately provide right information from a large volume of data by summarizing them into a simple sentence. We demonstrate a methodology to summarize clinical processes from event logs by using a fuzzy linguistic approach to meet the specific clinical environment.

The rest of this chapter is as follows. Section 1.1 indicates the goal and scope of the research, following with the research questions of this project mentioned in section 1.2. In section 1.3, the expected contribution to science is identified. The research methodology is introduced in section 1.4. Finally the structure of the rest of this report is explained in section 1.5.

1.1 Goal and Scope

The goal of this study is to "*design a methodology to summarize clinical processes from event logs by using linguistic summaries approach*". As a result, the summaries should be understandable and meaningful to specialists in the health care field, in order to help they gain an insight into clinical processes. Moreover, it should be possible to build a tool to automatically summarize the clinical processes from event logs in the natural language.

There are two limitations of the study. Firstly, as different clinical environments are highly diverse, and input data we can collect are limited, the object of this study is limited to one specific clinical environment. Secondly, the study is mainly focused on the information verbalization of the actual clinical process, and it aims to provide information to specialists to gain an insight into the as-is conditions of clinical processes. Therefore, the stakeholders of this project are the specialists and care providers who conduct and manage the clinical process.

1.2 Research Questions

Based on the goal of this study, the research question is stated as follows:

How to use linguistic summarization technique to describe the clinical processes from event logs?

In order to answer the research question, the following sub-questions need to be answered:

1. Which attributes are important when describing the clinical processes?
   According to (Rebuge & Ferreira, 2012), healthcare processes are highly dynamic, highly complex, increasingly multi-disciplinary, and ad-hoc. This means it is hard to describe clinical processes in every detail. Therefore, we should first identify the important attributes of clinical processes to narrow the scope of description, as well as concentrate on the most important and representative aspects of the clinical processes. For instance, the attribute can be a specific state of patients or a specific stage of clinical processes.

2. How to extract the attributes from event logs? What is the granularity of the data when we want to extract the attributes ?
   Since event logs are the input data of this study, we need to consider if the attributes that we identified in previous sub-question can be extracted from event logs, and how to extract the attributes. Therefore, the attribute list is refined. Since the clinical process can be in different hierarchy, if necessary, the data need to be pre-processed to meet the different granular requirement of the attribute.

3. What is the basic protoform of the summaries?
   Based on the attributes we have identified and extracted in the sub-question 2, we could decide the way to summarize the attribute. According to (L. A. Zadeh, 2002), a protoform is the abstract prototype of summaries. In data mining, the basic protoform is "Qy's are F", where Q is a linguistics quantifier (e.g. most), $Y = \{y\}$ is a set of objects (e.g. employee), and F is a property (e.g. young). However, since we are going to summarize the clinical process, the protoform are different.

4. How to determine the truth and relevance of summaries?
   At this point, a number of basic summaries will be available, and each of these summaries has a truthfulness value that indicates the validity of the linguistic summary. We should decide how to calculate the truthfulness value in a numerical way and label as a linguistic value. After picking out the high validity summaries, we need to select the summaries that contain relevant information to the user.

1.3 Thesis Contribution

Some studies (A. Wilbik & Kaymak, 2015; A. M. Wilbik & Dijkman, 2015) discuss the linguistic summarization of processes. Besides, a Master thesis (Lips, 2015) implements linguistic summaries on clinical data. However, at this moment, no study has been attempted to implement linguistic summaries to describe process in clinical environment. This research will deliver such a method to the scientific world. Moreover, current analysis of clinical processes are either too external that provide very limited insight into the process (Huang et al., 2013), or has less relevance to medical knowledge, which is difficult for specialists to obtain useful information (Kaymak & Mans, 2012). Our study aims to fill the gap between two extremes, and provide understandable and meaningful information of clinical processes.

1.4 Case study

A case study is required to verify the methodology we are going to design. The event logs we used in this research are gathered from the weaning process in intensive care units (ICU) in Maastricht University Medical Centre+ (MUMC+). The dataset we are going to use is from a previous study conducted by (Boere, 2013).

ICU cater to patients with the most severe and life-threatening illness and injuries. Therefore, patient in ICU usually require constant, close invasive monitoring and supports from specialist equipment and medication to ensure normal bodily functions. One of the medical supports in ICU is mechanical ventilation. Weaning is the process that helps in discontinuing a patient from the medical ventilation. A weaning protocol is implemented on the current weaning process in ICU in MCMU+. According to (Boere, 2013), there are two different versions of weaning protocol. One for patients which receive mechanical ventilation for less than 72 hours (short-recovery) and one for patients which have more than 72 hours of mechanical ventilation (long-recovery). The dataset we have is obtained from the short version. The further information about this case study can be found in Chapter 4.

1.5 Thesis outline

The rest parts of this report is as follows. The theory of linguistic summaries are introduced in Chapter 2. The case study and the dataset we used in this research are described in Chapter 3. In Chapter 4, the research method for this study is described. The analysis result is given in Chapter 5, following the evaluation in Chapter 6. Finally, a conclusion is given in Chapter 7.

2. Linguistic summarization

Since massive data are generated and stored in the daily life, different techniques of data analysis have be developed over these years. Linguistic summaries is one of them. By summing up large volume of data into simple sentences, linguistic summaries can quickly and accurately provide right information on time. It is an efficient way to turn the vast mountain of data into knowledge.

There are two types of methods that can be used to perform the linguistic summaries. The first one is based on Natural Language Generation (NLG) system, and the second one is based on fuzzy logic. Both two types can generate sentences from input data. However, fuzzy logic based summaries are mainly focusing on the data processing, therefore the information behind the data are better discovered, while the NLG system based summaries take more account on the text generation, and more sophisticated and longer sentences are generated. According to the (Bouchon-Meunier & Moyse, 2012), fuzzy logic based linguistic summaries are more flexible and have better performance in terms of data mining and analysis. Thus, we are mainly discussing the fuzzy logic based methods.

2.1 Fuzzy Logic Based Linguistics Summaries

Fuzzy logic is an approach to approximating the way of human brains work. The term 'fuzzy logic' was first introduced in (L.a. Zadeh, 1965), where the theory of fuzzy sets was also introduced. It indicates the degree of truth that range between 0 and 1 rather than the exact truth or false. In other words, in classical logic, an object x is whether a member of a set A or not can be expressed as:

$$A(x) = \begin{cases} 1, & if\ x \in A \\ 0, & if\ x \notin A \end{cases} \qquad (1)$$

However, in fuzzy sets, the binary membership $\{0,1\}$ is extended into a continuous membership in the interval $[0,1]$. Therefore, for each object x in a universal set X, there is a membership value indicating the degree of truth that x belongs to A. The fuzzy set A can be expressed as:

$$A = \{(x, \mu_A(x)): x \in X\} \qquad (2)$$

where $\mu_A(x)$ is the degree of membership of the element x in A. An example of fuzzy set can be found in section 2.1.1. Based on the fuzzy logic, the fuzzy linguistics summaries can be used to describe the data in natural languages, filling the gap between the understandable sentences and precise data.

There are many approaches to the linguistic summarization of database based on different philosophy. Here we focus on the classical linguistic summaries method from Yager's (Yager, 1982) and the extensions. According to (Yager, 1982), we have:

- V is a quality (attribute) of interest, e.g. age in a database of employees.
- $Y = \{y_1, \dots, y_n\}$ is a set of objects (records) that manifest quality V, e.g. the set of employees; hence $V(y_i)$ are valules of quality V for object y_i,
- $D = \{V(y_1), \dots, V(y_n)\}$ is a set of data (the "database" on question).

A linguistic summary of a data set consists of:

- a summarizer P(e.g. young),
- a quantity in agreement Q (e.g. most),
- truth T (e.g. 0.7),

as, e.g., $T(most\ of\ employees\ are\ young) = 0.7$". The truth T may be meant in a more general sense, e.g. as validity of, even more generally, as some quality or goodness of linguistic summary.

Basically, given a set of data D, we can hypothesize any appropriate summarizer P and any quantity in agreement Q, and the assumed measure of truth value indicated the truth of the statement that Q data items satisfy the statement (summarizer) P.

2.1.1 On the form of the summarizer

The summarizer P is a linguistic expression semantically represented by a fuzzy set. For instance, a summarizer like "young" would be presented as a fuzzy set in the universe of discourse e.g., $\{1,2, \dots, 90\}$, i.e., containing all the possible value of human's quality 'age', and "young" could be given as e.g., a fuzzy set with a non-increasing membership function in that universe such that, in a simple case of a piece-wise linear membership function, such as:

- the age up to 30 years is for sure "young", i.e. the membership value is equal to 1.
- the age over 50 years is for sure "not young", i.e. the membership value is equal to 0.
- for the age between 30 to 50 years, the membership value is between 1 and 0. The lower the age, the higher its corresponding degree of membership .

We can use the same method to define the fuzzy set 'Middle age' and 'Old' by changing the parameters of the membership functions. Therefore, a specific age value (e.g., Age=50) can be the member of all three fuzzy sets, but the membership functions $\mu_{young}(50)$, $\mu_{Middle\ age}(50)$, $\mu_{Old}(50)$ have very different membership values for the same age (see Figure 1).

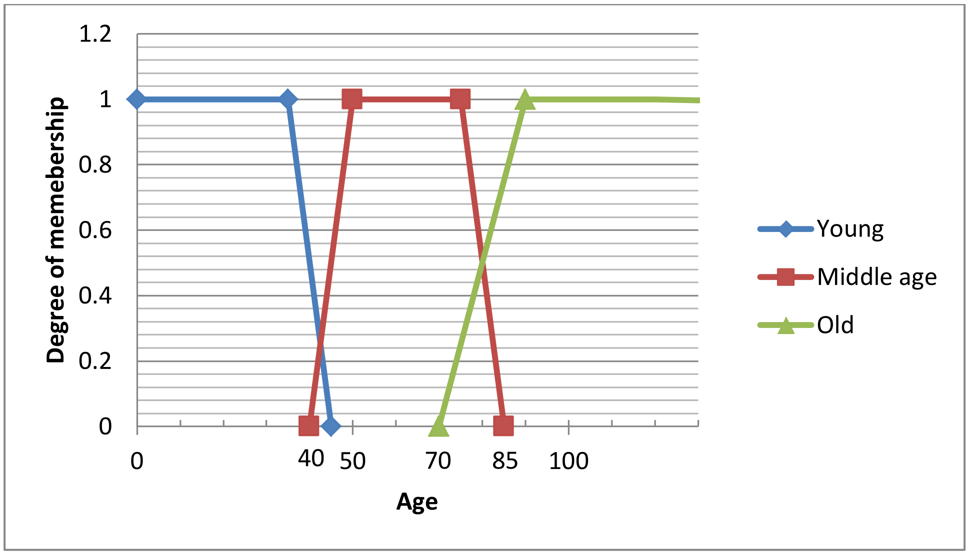

Figure 1 Membership curves for fuzzy set Young, Middle age, and Old

The summarizer can also be extended as a combination of attributes values as "*young and well paid*".

2.1.2 On the form of the quantifier

Generally, there are two kinds of linguistic quantifiers. One of them is called *absolute* quantifiers, such as "approximately 5" and "between 2 and 4". The other is called *relative* quantifiers, such as "many", "all" and "few". Since they are both fuzzy quantifiers, they are defined as possibility distributions, over the non-negative integers and the real interval [0,1], respectively.

(J Kacprzyk & Zadrozny, 2005) mentions that both fuzzy summarizers and quantity in agreements are in subjective form, which means they can be either predefined or defined by the users.

2.2 Protoforms

According to (L. A. Zadeh, 2002), a prototypical form (protoform) is defined as an abstract of prototype (template) of a linguistically quantified proposition. By implementing protoform, we can formulate many different types of linguist summaries in a uniform way. The summaries mentioned in section 2.1 may be written in the form as:

$$Q\ y\text{'s are } P \tag{3}$$

e.g., "most (Q) of the employees ($y's$) are young (P)". Or of an extended form:

$$QR\ y\text{'s are } P \tag{4}$$

e.g., "most (Q) of the new (R) employees ($y's$) are young (P)". where Q is the quantifier, P is the summarizer, $y's$ is the quality of a set of objects, and R is the qualifier.

2.3 Evaluation of a linguistic summary

The quality of linguistic summaries can be evaluated in different ways. (Delgado, Ruiz, Sánchez, & Vila, 2014) presents a comprehensive overview of properties that must be fulfilled when evaluating quantified sentences. The study also reviews a range of approaches of evaluating the quality of quantified sentences. (J Kacprzyk & Zadrozny, 2005) introduces an extension of classic Yager's approach to involve more sophisticated criteria to qualify linguistic summaries. In the following content, different criteria of measurement and relative calculation are introduced.

The truth value (a degree of truth or validity) is the basic criterion describing the degree of truth (from [0,1]) to which a linguistically quantified proposition equated with a linguistic summary is true.

Summarizer P and qualifier R are fuzzy sets in Y, and a linguistic quantifier Q is assumed to be a fuzzy set in [0,1] as, e.g.

$$\mu_Q(x) = \begin{cases} 1 & for\ x \geq 0.8 \\ 2x - 0.6 & for\ 0.3 < x < 0.8 \\ 0 & for\ x \leq 0.3 \end{cases} \tag{5}$$

According to (LA Zadeh, 1983):

$$truth\ (Qy's\ are\ P) = \mu_Q\left[\frac{1}{n}\sum_{i=1}^{n} \mu_P(y_i)\right] \tag{6}$$

$$truth\ (QRy's\ are\ P) = \mu_Q \left[\sum_{i=1}^{n} (\mu_R(y_i) \wedge \mu_P(y_i)) \middle/ \sum_{i=1}^{n} (\mu_R(y_i)) \right] \qquad (7)$$

where μ_P, μ_R and μ_Q are membership functions of fuzzy set representing summarizer, qualifier and linguistic quantifier, respectively. $\wedge$ is the minimum operation, which can be generalized as a t-norm. The expression (6) is for the basic protoform (3), and the expression (7) is for the extended protoform (4).

The protoform based linguistic summarization is the fundamental of this research. In the following chapter, we are going to propose a methodology to summarize processes based on this concept.

3. Summarizing clinical processes

In order to design the methodology, we need to answer the sub-questions defined in section 1.2. To answer the sub-questions, literature and experiences from practice are necessary. More specific, to answer question 1, literature and specialists opinions are needed. Question 2 can be answered based on the literature review. Question 3 requires the specialists to verify the results. Both literature review and specialists opinions are required to answer question 4.

Since there is no previous study implementing linguistic summaries on the clinical processes, the design approach of our research are mainly based on the previous study of summarizing database (Zadrozny & Kacprzyk, 2007), (Janusz Kacprzyk & Wilbik, 2009; A. Wilbik & Kacprzyk, 2010), (Heide & Trivio, 2009). The overview of the methodology is shown in Figure 2. It is a step by step approach starting from specifying the clinical pathway (or protocol). The following sections will introduce the details of each steps of this methodology.

Figure 2 The overview of methodology

3.1 Specify the clinical pathway (protocol)

To start a project of summaries, first we need to determine the objective clinical process. It includes determining which clinical pathway (protocol) we are going to analyze, and collecting the relevant data, i.e. event logs of chosen clinical pathway (protocol).

In this research, we adapt the definition of event logs from (Huang et al., 2013). The definition is as follows.

Definition 1 (event logs) Let E be the event logs, i.e. a set of a data that records all possible activities of patients in the clinical pathway. We have patient identifiers domain PID, activities name domain A, and time domain T. We assume that the event log includes three basic properties. They are patient identifiers, activity names and time stamps of the events. Therefore, we use function π_{pid}: $\mathrm{E} \rightarrow PID, \pi_a$: $\mathrm{E} \rightarrow A, \pi_t$: $\mathrm{E} \rightarrow T$ to denote the patient identifiers, activity names and time stamps of the events, respectively.

More specific, we denote an event as $e = (pid, a, t)$, where pid is the patient identifier of e $(pid \in PID)$, aid is the activity identifier of e $(a \in A)$, and t is the occurring time stamp of e $(t \in T)$.

3.2 Specify requirements

As we mentioned in the introduction, this methodology is designed to generate linguistic summaries of clinical process to provide information to the specialists who maintains the clinical pathway (protocol). Therefore, we only consider specialists as the **stakeholder** of the project. To avoid trivial information in the summaries, in this step we are setting the requirement of summaries, i.e. to specify what we would like to summarize, and to what extent the summarization would be.

As we select the clinical process as the research object, the summary content is specified as sequences and performance of process.

3.2.1 Contents of summaries

3.2.1.1 Sequences

When we have the raw data, i.e., the event logs from a specific clinical pathway (protocol), we can directly obtain the entire sequence of activities that a patient underwent from the admission to discharge. We define this sequence of activities as a *trace*, which represent as a non-empty sequence of activities that a specific patient underwent in the entire clinical pathway (protocol). The definition of trace is adapted from (Huang et al., 2013).

Definition 2 (Trace). Let E be the event logs, PID be the patient identifiers domain, A be the activities name domain, and T be the time domain. A trace is represented as a non-empty sequence of activities that a specific patient underwent in the clinical pathway. We denote a trace as $\delta = (\pi_a(e_1), \pi_a(e_2), \dots, \pi_a(e_n))$,where $\pi_{pid}(e_1) \equiv \pi_{pid}(e_2) \equiv \cdots \equiv \pi_{pid}(e_n)$, and $e_i \in E(1 \leq i \leq n)$.

Based on the definition of trace, we have the definition of sequence as follows:

Definition 3 (Sequence). Let A be the activities name domain. A sequence is an order of activity names that indicate a process. Since we have:

- A= $\{a_1, a_2, \cdots, a_m\}$ as a set of activity names, i.e. activities name domain,
- $\Delta = \{\delta_1, \delta_2, \dots, \delta_i, \dots, \delta_n\}$ as a set of traces, where $i \epsilon \pi_{pid}$, $i = 1, \cdots, n$

we denote a sequence as:

- $H = (h_1, h_2, \cdots, h_n)$, where $h_i \in A(1 \leq i \leq n)$.

Therefore, a sequence segment H from a specific patient i is the subsequence of δ_i. In other words, a trace can also defined as a sequence.

Since we have patients' traces from event logs, the practical process of the clinical pathway can be described, in the form of sequences of activities. There are several perspectives when we would like to describe a set of traces:

1. Statistic result of traces

By displaying the unique traces in the universe Δ, along with the numbers of patients follow a specific trace, we can have a comprehensive view of all the possible scenarios that patients have undergone. Besides, statistic results can help us validating whether the majority of patients followed the designed pathway.

2. Traces/sequences clustering

Cluster analysis refers to grouping a set of objects in a way that the similar objects are in the same group. When implementing in a set of traces (or sequence), clustering can provide an insight on the implicit similarity of different sequences among a set of traces.

3. Traces/sequences pattern

In the previous two perspectives, we would have an overview of entire clinical process. However, we can take one step deeper, to discover some frequent medical behaviors by recognizing pattern from the set of traces. The pattern recognizing might filter the trivial information in the traces and reveal deviation between the practice and the designed pathway (protoform).

3.2.1.2 Process performance

Generally, besides the sequence of process, people are also concerned with the performance of the process. In clinical specialists' perspective, mortality rate and time duration of patients' staying in the clinical process are usually important. Besides, the cost of a process is also a possible performance to analyze.

3.2.2 Universe of discourse

There are two reasons to specify the universe of discourse in this methodology. The first reason is that the data we are going to analyze are mainly from clinical behavior, which is usually highly complex and variable. The result of the summaries might be meaningless if we conduct all the event log without preprocess. Another reason is that the clinical treatment are diverse since every patient has its own characteristics. More information might be found when we group patients with the same characteristics.

3.2.2.1. Summary granularities

When describing a process in natural language, we mainly focus on describing the sequence of events. In order to simplify the summary sentences and to avoid sentences too long to read, we can describe the process in different granularities, i.e. ***phase level*** and ***activity level***. For activity level, the analysis is conducted on the activities inside one phase.

Phase level summaries can provide an overview of clinical process. Meanwhile, by packing the activities into one phase, we can screen trivial information which might affect us to understand the entire process.

3.2.2.2. Patient groups

By grouping patients with the same characteristics, we can have different perspectives of processes, and comparisons of the performance among different patient groups. It might provide some information about how different characteristics influnce the clinical treatment.

3.3 Build protoforms

As we introduced in section 2.2, the protoform is used to formulate linguistic summaries in a uniform way. Based on the expression (3) and (4), the protoforms for the data summaries, we can build such protoforms to describe sequences and performances of processes.

According to the requirement settled in the previous steps, there are two types of protoforms can be generated in this research.

3.3.1 Descriptive protoforms

The descriptive protoform describes a specific quality of a set of objects. As indicated in expression (3), the protoform can be written as:

$$Q\ y's\ are\ P$$

It consists of a quantifier Q, the quality of a set of objects $y's$, and a summarizer P. It can be extended by a qualifier R, as indicated in expression (4) :

$$Q\ Ry's\ are\ P$$

In this research, this type of protoforms can be used to summarize both the sequences and the performance of the process. More specific, to summarize sequences of patients, we extend the basic form of protoform into a specific one and denote it as:

$$Q\ patients\ follow\ the\ process\ S \tag{8}$$

e.g. "most (Q) patients follow *blood test, injection, discharge* (S)." An extended protoform for sequences is written as:

$$Q\ R\ patients\ follow\ the\ process\ S \tag{9}$$

e.g. "most (Q) young patients follow *blood test, injection, discharge* (S)." where Q is the quantifier, R is the qualifier and S is the summarizer for the sequences. Since we only describe the process that patients underwent, the objects $y's$ can be specified as patients. By adding R, patients are filtered into a specified group as we mentioned in section 3.2.2.2.

Therefore, based on the definition 3 in section 3.2.1.1, we define the summarizer S for the sequence as an order of activity names that indicates the sequence of activities. Then we have:

- $N = \{N_1, N_2, \cdots, N_m\}$ as a set of activity/phase names that indicates different action/phase in the process,
- $S = (s_1,\ s_2, \cdots, s_n)$, where $s_i \in N$, $i = 1, \cdots, n$,as a summarizer that indicates a sequence of activity (or phase) names.

For instance, to describe the process of anesthesia care, a summarizer S can be ("Premedication", "Induction", "Maintenance phase") (Christopher D Press, 2013). It means an anesthesia care starts from premedication phase, then it moves to induction phase. After that, a maintenance phase follows.

3.3.2 Comparative protofoms

This type of protoforms can be used to summarize the performance of the process. Comparative protoforms compare a specific quality between two object sets. The quality should be a numerical attribute (such as the average time duration of a group of patients). It can be written as:

$$For\ Q, R_1 y's\ \ are\ P\ than\ R_2\ y's \tag{10}$$

e.g. " for about a half (Q) cases, old (R_1) patients ($y's$) stay longer (P) than young (R_2) patients ($y's$) in the clinical process", where Q is the quantifier, R_1 and R_2 are two different qualifiers, and P is a comparison summarizer. The comparison summarizer is a linguistic expression, which semantically represents a fuzzy comparison (e.g. longer, smaller).

3.4 Generate summaries

After having all the protoforms, the next step is to fill components of the protoforms by processing the event logs we collected. Then we have a bunches of sentences as all the possible summarizations. To be more specific, we need to acquire the possible quantifier, the possible summarizer and possible qualifiers (if applied), from event logs.

3.4.1 Generate quantifiers

The data we have are all crisp values, while when we summarize, some of the information are expressed in fuzzy linguistic terms. Therefore, we need to transform the data set with crisp values into fuzzy set with degree of membership. More specific, we need to define the membership functions for fuzzy quantifier Q in different protoforms before generating summaries. The most frequent used membership functions are triangular and trapezoidal functions (Barua, Mudunuri, & Kosheleva, 2014).

In this research, we use the trapezoid-shaped membership function for fuzzification. It depends on four parameters a, b, c and d, and x, which are given by:

$$f(x; a, b, c, d) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ 1, & b \leq x \leq c \\ \frac{d-x}{d-c}, & c \leq x \leq d \\ 0, & d \leq x \end{cases} \tag{11}$$

3.4.2 Generate summarizers

3.4.2.1 Summarizers for the sequences cluster

The following indicates the steps to obtain the summarizers when clustering sequences.

1. Acquire the sequences of activity/phase from event logs.

This is a preprocessing step. The set of all activity/phase name (denoted by N in section 3.3.1) are first obtained from event logs. To simplify the calculation, we use identification numbers to label activity/phase names. Therefore, for each patient, the sequences of activity/phases name can be transformed into numerical sequences.

2. Calculate the distance between two arbitrary sequence

To summarize sequences, we need to compare the differences of sequences and group them in a certain method. Generally, comparing sequences can be realized by calculating and comparing the distance of different sequences. Here we implement the **Levenshtein distance** to conduct the calculation. The Levensthein distance between two sequences is the minimum number of single-character edits (i.e. insertions, deletions or substitutions) required to change one sequence into the other. Therefore, the weight of three possible edits are all equal to 1.

For each sequence, we calculate its distance between all the other sequences. Thus, we have a distance matrix which contains the distances between two arbitrary sequences.

3. Clustering sequence

Based on the distance matrix we obtained in the previous step, we can cluster sequences into groups and find the most representative sequence for each cluster. This can be realized by implementing k-medoids algorithm. When deciding the number of clusters, in other words, determining the parameter k, we implement the rule of thumb (Mardia, Kent, & Bibby, 1979) as:

$$k \approx \sqrt{n/2} \tag{12}$$

where n is the number of objects (in our case, n is the number of sequences).

3.4.2.2 Summarizer for sequence patterns

In this project, patterns are considered as common segments of at least two arbitrary sequences. The segment should contain at least two activities. To find patterns from a set of sequences, we implement an algorithm based on the longest common substring problem.

3.4.2.3 Summarizer for the performance

For both descriptive and comparative summarizers, the fuzzy membership function is required to define the different summarizers. We use the trapezoid-shaped membership function (indicated in expression (11)) to define the summarizer for the performance. To set the function parameters, consultation with specialists is required.

3.4.3 Generate qualifiers

Depending on the definition of a qualifier, a membership function might need to be implemented. For instance, if the qualifier is gender of patients, the term of the qualifier is either male or female (when we do not consider the case of sex change) i.e. a binary membership. Thus, the membership function is not applicable. If the qualifier is the age group of patients, the term of the qualifier can be 'young', 'middle age' or 'old', which are fuzzy sets based. Therefore, the membership function is required.

We use the trapezoid-shaped membership function (indicated in expression (11)) to define the fuzzy qualifiers. To set the function parameters, consultation with specialists are required.

3.5 Calculate truth value

As we introduced in Section 2.3, the quality of linguistic summarization can be validated. In our project, we use the degree of truth (LA Zadeh, 1983) for the evaluation. The expression (6) and (7) indicate the way to calculate truth value for the descriptive protoforms.

For the comparative protoforms, we assume that only numerical sets are considered as the objects of comparison. Therefore, consider two numerical sets X, Y, with the number of object m, n, respectively, we extend the Zadeh's methods to calculate the truth value as follows.

For expression (10) , when R_1 and R_2 are the qualifier with identity relations, the truth value is calculated as:

$$truth\ (For\ Q, R_1 x's\ \ are\ P\ than\ R_2\ y's) = \mu_Q\left[\frac{1}{m \times n}\sum_{i=1}^{m}\sum_{j=1}^{n}\mu_P(x_i - y_j)\right] \tag{13}$$

where μ_P, μ_Q are membership functions of fuzzy sets representing summarizer and linguistic quantifier, respectively. Therefore, the truth value is a function of the mean value of all the μ_P in the universe.

When R_1' and R_2' are the fuzzy qualifier with membership functions μ_{R1}, μ_{R2}, the formula is as follows:

$$truth\ (For\ Q, R_1'x's\ \ are\ P\ than\ R_2'\ y's)$$
$$= \mu_Q \left\{ \sum_{i=1}^{m} \left[\mu_{R1}(x_i) \wedge \left(\frac{\sum_{j=1}^{n} \left(\mu_{R2}(y_j) \wedge \mu_P(x_i - y_j) \right)}{\sum_{j=1}^{n} (\mu_{R2}(y_j))} \right) \right] \Big/ \sum_{i=1}^{m} (\mu_{R1}(x_i)) \right\} \quad (14)$$

where ∧ is the minimum operation, which can be generalized as a t-norm.

3.6 Evaluation

The evaluation should be conducted when we set the requirement of the project, as well as the protoforms we specified. The results of the summaries should also be validated by the specialists to see whether they meet the users' demands and whether the contents are reasonable. Necessary revising and refining should be conducted.

To verify the methodology we introduced above, in this research, we processed a linguistic summarization on event logs gathered from weaning protocols in MUMC+. The following chapter is the introduction of the weaning protocols and the event logs extracted from the protocol.

4 Summarizing weaning protocols

As we mentioned in section 1.4, a case study is implemented in this research. The overview of the weaning protocol is given in section 4.1 and a detailed description of weaning protocol in MUMC+ is indicated in section 4.2, along with the dataset we used in this research.

4.1 Introduction of weaning protocols

Weaning is used to describe the process of liberating the patient from mechanical ventilation support. In Intensive Care Unit (ICU), weaning is an essential and universal procedure for intubated patients. According to (Chawla, Varma, & Sharma, 2012) weaning process begins when specialists assess readiness to wean. If the patient is considered ready to wean, a spontaneous breath trial (SBT) is executed. In this stage, the patient is disconnected or half-disconnected to the mechanical ventilator. During the SBT, patient comfort and all the vital and respiratory parameters should be closely monitored. If SBT succeeds, the patient can be extubated from mechanical ventilator and breathe independently. However, when SBT fails, the patient should re-connected to the mechanical ventilator until another assessment of probability to execute an SBT. There is also a possibility that a patient is re-intubated after the extubation. (Boles et al., 2007) recommended that weaning should be considered as early as possible. The long-time weaning might bring unnecessary discomfort to the patient, increasing risk of complications, affecting the successful extubation, and increasing the cost of care.

Weaning protocols are intended to reduce the duration of mechanical ventilation, standardizing the weaning process and improving the efficiency of practice. Typically, a weaning protocol consists of three components: a list of objective criteria to assess readiness to wean; guidelines to reduce ventilation support; a list of criteria to extubate (Blackwood et al., 2011). Many studies provide evidence that weaning protocol can expedite liberating from mechanical ventilation in adult patients in ICU. (Blackwood et al., 2011) conducted a review and meta-analysis among several best evidences on weaning protocols. It shows that the implementation of weaning protocols were associated with 25% reduction in total duration of medical ventilation when comparing the weaning process without protocols.

Physicians, respiratory care practitioners, and ICU nurses are involved in the weaning process. The implementation of weaning protocols, on one hand, can reduce variations produced by individual judgment and experience (Blackwood et al., 2011). On the other hand, protocols should also be tailored to different population of patients (Epstein & Walkey, 2013). Therefore, clinical professionals and staffs should modify the protocol for application to different patient groups. Based on this perspective, our study is intended to provide a comprehensive view of weaning process by implementing linguistic summarization techniques on the event logs extracted from weaning protocols application. Thus, clinical practitioners could gain an insight into requirements for different patients and adjust protocols.

4.2 Weaning protocols in MUMC+

In this study, we choose the weaning protocols from the ICU of Maastricht University Medical Center+ (MUMC+) as the object of our case study. A previous study from (Boere, 2013) demonstrates an analysis of this weaning protocol by applying process mining techniques. Our study, on the other hand, provides an alternative method to analyze the event logs extracted in Boere's study.

There are two different versions of weaning protocols in ICU of MUMC+, one is for patients who receive mechanical ventilation less than 72 hour before weaning, and another is for patients who have more than 72 hours ventilation support. Here we choose the short version to analyze, since more patients are involved in the short version therefore event logs from short version is easier to collect. The protocol is developed based on the weaning guidelines by (Van Leeuwen, 2003). The overview of the protocol is shown in Figure 3. It is a translated version from (Boere, 2013).

4.2.1 Phases of weaning

The weaning process consists of three phases, namely BIPAP phase, ASB phase and Extubation phase. In the following, the description of three phases will be given.

1. BIPAP phase

Before the start of the weaning process, patients are full mechanical ventilation dependent. At this stage, the mechanical ventilation applied on patients is named Bi-level Positive Airway Pressure (BiPAP). It provides the oxygen support and pressure control for the patient's respiration, since the patient cannot be self-sufficient during this stage. We use 'BIPAP phase' to represent the full ventilation dependent stage for patients. When a patient is sent to the ICU with mechanical ventilation support, we can consider the patient is at BIPAP phase. During the stay of the patient in ICU, a daily check is conducted to assess if patient's condition meets all the criteria to wean. This is where the protocol starts (indicated by Note A in Figure 3).

2. ASB phase

When all the criteria are met by the patient and the patient can trigger breaths, the weaning can be processed. In this stage, the patient's respiratory more depends on him/herself instead of the mechanical ventilation. The mechanical ventilation mode on this stage is called Assisted Spontaneous Breathing (ASB). We use 'ASB phase' to present the half ventilation dependent stage for patients. During this phase, the patient is gradually liberated from ventilation support by adjusting the pressure from ventilator. In this protocol, one criterion is decreasing the P-ASB value to 6. When the value reaches 6 and the patient remains stable for 30 minutes (indicated by Note B in Figure 3), the patient can be considered suitable to disconnect from the ventilator. If any deviation happens, a consultation is necessary to determine whether raising ASB support (i.e. remain in ASB phase) or resuming full ventilation support (i.e. send back to BIPAP phase) is needed. The patient who is considered adequate to extubate should have an Arterial Blood Gas (ABG) , a blood test to check whether all the extubation criteria (indicated by Note C in Figure 3) are met.

3. Extubation phase

When the result of extubation criteria is positive, the patient can be disconnected from ventilation and breath independently. At that moment, we consider that patient is in the 'Extubation phase'. There is a possibility that the patient fails the weaning within 48 hour after extubating. Then the patient should be re-intubated for the full mechanical ventilation support (i.e. back to BIPAP phase).

4.2.2 Event logs of weaning process

The event log we acquire for this study is not automatically created by the information system in the hospital. Instead, it is manually transformed from process state file by (Boere, 2013). The original state file are extracted from Intellispace Critical Care and Anesthesia (ICCA) system in hospital. The system records all the data generated by the patient, along with a time

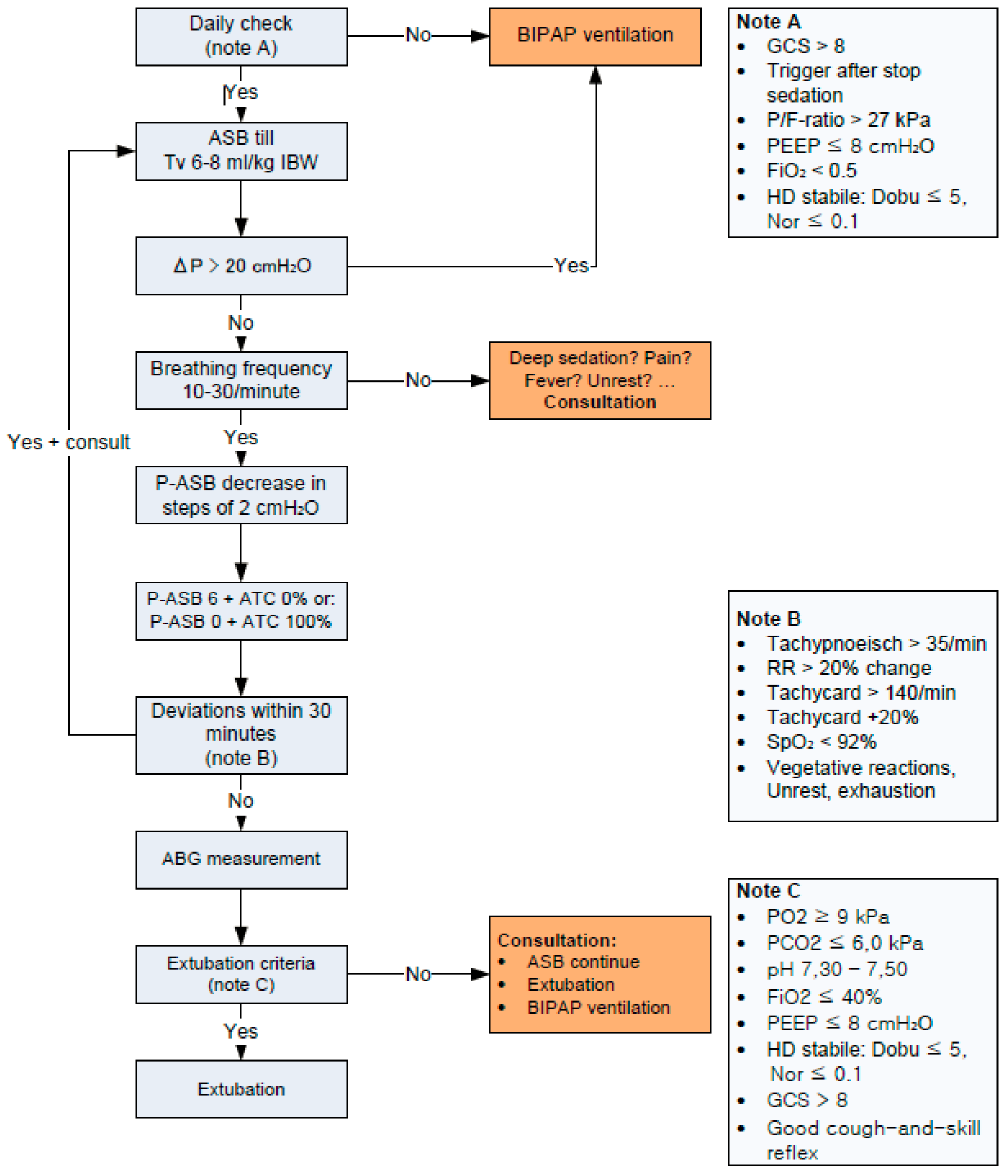

Figure 3 Weaning protocol from MUMC+ , translated by (Boere, 2013)

stamp for each state. The timespan of this data is from 2009 until June, 2012.

A total of 65 patients cases have been collected in this event log. The patients are with different age and gender, and all underwent the short version of weaning procedure. The raw data consisted of five types of data.

1) Characteristics of patients (e.g. patient with COPD (Chronic Obstructive Pulmonary Disease)). Further information can be found in section 4.2.2.1.
2) Event: time stamps of activity in the process (e.g. patient records and its start and end time). The activities list of events can be found in section 4.2.2.2.
3) Mode of mechanical ventilation (e.g. BIPAP ventilation).
4) Vital signs: continuously monitored data (e.g. heart rate). See Appendix I Other data types of event logsfor more detail.
5) Medications: medications that patients received during the weaning process (e.g. Tranexamic acid). See Appendix I Other data types of event logsfor more detail.
6) Personal data: age, weight, gender etc.

4.2.2.1 Characteristics of patients

Three medical characteristics of patients are considered by specialists in MUMC+ as patient with one or more of these characteristics may have different weaning process or performance. Therefore they are recorded in the event log. The first one is COPD (Chronic Obstructive Pulmonary Disease). Patients who suffer from this chronic incurable lung disease may have more difficulties to be extubated. The second characteristic is whether tranexamic acid and desmopressin acetate are applied on the patient. Both two medicines are used to prevent excessive blood loss during the surgery. The third characteristic is liquid balance of a patient. This is an indicator of the patient liquid condition. If a patient have abnormal liquid balance, it means the patient has difficulties in recovering. The possible value of these characteristics are indicated in Table 1.

Other patients characteristics are also concerned, such as gender, age and BMI (Body Mass Index).

Table 1 Characteristics of patients

Characteristic	Possible value in dataset
COPD	0 :the patient does not have COPD; 1, 2 :patient suffer from light COPD; 3, 4 :patient suffer from severe COPD.
Medication	0 : no medicine is applied; 1 : medicine is applied during the process.
Liquid group	1 indicates liquid (ml) < 0; 2 indicates liquid (ml) 1- 500; 3 indicates liquid (ml) 500 – 1000; 4 indicates liquid (ml) > 1000.
Gender	Men; Women
Age	Integer from 0 to 100
BMI	from 18.9 to 37.5

4.2.2.2 Activities in Event logs

According to (Boere, 2013), some assumptions have been made to translate states into activities. For instance, the activity named ‘patient record’ and ‘operation blood’ are not shown in the protocol, but in practice, these activities happen for recording patients’ general and medical information before arriving at ICU. To ensure every activity belongs to a specific phase, we use ‘Pre-BIPAP phase’ to represent this stage in which the patient has not arrived at

ICU. The complete activities list are showed in Table 2, accompanied with phases they belong to, and assumptions are described if applied.

Table 2 Phases and Activities list

Phase name	Activity name	Description
Pre-BIPAP phase	Patient record	These two tasks are executed before patient arriving at the ICU. They are the start of the process and the entry of patient data in the ICCA system.
	Operation blood	
BIPAP phase	BIPAP ventilation **OR** BIPAP/ASB ventilation **OR** IPPV/autoflow ventilation	Three different modes of mechanical ventilation for full ventilation support. Practitioners decide which mode is applied according to the vital signs of patient.
	BIPAP check	The check criteria are indicated in Node A in Figure 3. This is the assessment of readiness to wean.
	Temperature	This activity is not shown in the protocol but it is added since temperature is an assessing criterion for patient state (Boere, 2013).
	Blood test*	This activity is not shown in the protocol. It is added since the blood value is the important parameter to observe during the weaning process.
ASB phase	Setup ASB ventilation	Indicates two events in protocol, ‘ASB till Tv 6-8 ml/kg IBW’ and ‘$\Delta P > 20$ cmH_2O’.
	ASB ventilation **OR** CPAP/ASB ventilation **OR** CPAP ventilation	Three different modes of ASB-type ventilation applied during the weaning process. Practitioners decide which mode is applied according to the vital signs of patient.
	Check breathing frequency	Indicates the event “Breathing frequency 10-30/minute” in protocol in Figure 3.
	Decrease P-ASB **OR** Increase P-ASB **OR** Continue P-ASB	There is only ‘decrease P-ASB’ indicated in protocol, but in practice, this value could also be increased or remain stable depending on the condition of patient. Therefore they are added as activities.
	30 min. deviation check	The criteria is indicated in Node B in Figure 3.
	Blood test *	This activity is not shown in the protocol. It is added since the blood value is the important parameter to observe during the weaning process.
	Final blood	Indicates the event ‘ABG measurement’
Extubation phase	Extubation criteria	The criteria is indicated in Node C in Figure 3.
	O2 probe	This event is executed after the uncoupling of the ASB-type ventilation.
	Breathing stop	End of the process.

* Both BIPAP phase and ASB phase have blood test task.

After specifying the weaning protocol and the relevant event logs we analyzed, the implementation of the methodology is demonstrated in detail in the next chapter.

5 Implementation

After we specified the pathway and the requirements of summaries in Chapter 4, the protoforms of summaries can be formulated. Based on the protoforms we specified in section 5.1, all the possible summaries are generated by filling the required components in protoforms. The components are Qualifiers, Summarizers and Quantifiers. They will be introduced in section 1, 5.4 and 6, respectively. After that, the truth value of each summary is calculated and only the summaries with truth value higher than 0.7 are reserved.

5.1 Protoforms of summaries

According to the requirement in section 3.2, we discuss both the data performance (e.g. "time duration") and the sequence of activities (e.g. "blood test, BIPAP ventilation, temperature, Setup ASB ventilation…"). There are two different types of summarization. One is fuzzy (e.g. "longer" for time duration) , and another one is crisp (a sequence of events). Therefore, more than one protoform are needed to fulfill the requirement.

As we introduced (Yager, 1982) in section 2.1, the summarization approach are based on three components, i.e. :

- a quality (attributes) of interest (denoted by V),
- a set of objects (denoted by Y) that manifest quality,
- and a set of data (denoted by D) that include the object and its attributes.

In our case, we consider V is the requirements we specified in section 3.2.2, and Y is the universe of discourse we specified in section 3.2.1. Table 3 give a comprehensive view of the summaries that we plan to produce in this research, with the protoforms involved. Not all the requirement are discussed in each level with a specific patient group. For instance, all the possible sequence of activities are highly divers, and it might hardly find two patients with exactly the same sequence of activities. Therefore we only consider this part in Phase level.

Table 3 Summaries content

Type	Descriptions	Protoforms
Phase Level	Statistic results of all possible trace in phase level, among all patients as well as patients in a specific group.	Q patients with C follow the process S.
Activity Level Clustering	Clustering results of activity sequences in a specific phase, among all patients as well as patients in a specific group.	Q patients with C follow process S in phase H.
Activity Level Patterns	Patterns recognized from the activity sequences in a specific phase, among all patients and in a specific patient group.	Q patients with C follow process S (pattern) in phase H.
Cost comparison between 2 phases	Comparing costs between 2 phases, the cost is the sum of all patients costs in one specific phase.	For Q cases, the cost of H_1 is P than the cost of H_2
Cost comparison between 2 patient groups	Comparing costs between 2 patient groups in a specific phase.	For Q cases, patients with C_1 have P costs in H than patients with C_2.

Time Comparison	Comparing time durations in weaning protocol between 2 patient groups.	For Q cases, patients with C_1 spend P times than patients with C_2.

Different protoforms are introduced in the following sections.

5.1.1 Phase level

In this level, we summarize all the possible trace of phases and provide statistic results of those traces. These summaries can be conducted in the entire range of patients, but also in a group of patients. From the results, we might discover the most representative trace of phases in the weaning protocol. **Protoform 1** is implemented to generate this kind of summaries.

Protoform 1: To describe the sequence of phases, we have protoform as:

Q patients with C follow the process S.

where Q is a quantifier, C is the characteristic of patients, S is the sequence of phases.

Examples:

1) *Most* **patients with level 1 COPD** follow the process "pre-BIPAP phase", " BIPAP phase", "ASB phase", "Extubation phase".
2) *A bout a half* **patients with level 1 COPD** follow the process "pre-BIPAP phase", "BIPAP phase", "ASB phase", "BIPAP phase", "ASB phase", "Extubation phase".

The characteristic of patient C can be considered as the qualifiers. It indicates the feature of the patient group. C can be null when we summarize entire range of patients. When discussing a group of patients, it can be specified as "patients with COPD" or to further detail as "patient with Level 1 COPD", etc..

As we only summarize phase sequence in this part, the trace of phases P is the sequence of the phase's names which indicates the treatment procedure that a group of patients underwent. The way to conduct the summarization will be discussed in section 5.4.

5.1.2 Activity level

After we have a comprehensive view from the Phase level summaries, we can gain an insight into one specific phase to see what happened among a group of patients. In the activity level, the sequences of activities are highly diverse for each patients. Therefore, it is difficult to discuss all the possible traces in one time. Instead, we implement clustering and recognize patterns from the activity sequences to have a deep view of the process. **Protoform 2** is used to formulate the results into linguistic summaries.

We find that **Protoform 2** is similar to **Protoform 1;** the only difference is it adds "in phase H" at the end of the protoform. Since we analyze a small dataset with 65 patients in our case, the sequence clustering is not conducted in the phase level. However, if the dataset is larger, the **Protoform 2** can also be used to formulate the clustering result in phase level.

Protoform 2: In order to describe the sequence of activities, we have protoform as:

Q patients with C follow process S in phase H.

where Q is a quantifier, C is the characteristic of patients, S is the activity sequence, and H is a phase of protocol.

Examples:

1) *All* ***patients*** follow the process "patient records", " operation blood" in (*Pre-BIPAP phase)*.
2) *Most* **patients with level 1 COPD** follow the process "BIPAP ventilation", "blood test", "blood test", "blood test", "blood test" in (*BIPAP phase)*.

5.1.3 Performance comparison

According to Boere (2013), there are currently no performance criteria of any sort used or even known for the Weaning protocol. Therefore, we gain a basic relevant insight in the performance of the overall process in this analysis stage. The performance includes the duration of treatment and costs spent on the overall process / different phases. There is also a performance comparison of different phases in same patient group, or a performance comparison of different patient groups in same phases. Therefore, we abstract **Protoform 3, 4** and **5** to formulate the summaries. They are indicated as below.

Protoform 3: To compare the duration of processes among the patients with different condition, we have protoform as:

For Q case, Patients with C_1 spend P time than patients with C_2.

where Q is a quantifier, C_1 ,C_2 are characteristics of patients, P is a summarizer

Examples:

1) For *most* cases, **Patients in liquid group 4** spend more time than **patients in liquid group 3**.
2) **Patients with Level 1 COPD** spend same time as **patients with level 2 COPD**.

Protoform 4: To compare the costs of different phases, we have protoform as:

For Q cases, the cost in H_1 is P than the cost in H_2

where Q is a quantifier, P is a summarizer, H_1, H_2 are different phases in weaning protocol.

Example:

1) For a *few* cases, the costs of (BiPAP phase) is lower than the costs of (ASB phases).

Protoform 5: To compare the costs of different condition of patients, we have protoform as:

For Q cases, patients with C_1 have P costs than patients with C_2 in H.

where Q is a quantifier, P is a summariezer, C_1 ,C_2 are characteristics of patients, H is the phase of protocol

Example:

1) For *most* cases, the costs of **Patients with medication support** are higher than the **Patient without medical support .**

We do not discuss the performance in activity level because the result would be trivial, and it is meaningless to compare the cost or time duration of different activities as they are usually fixed and for different purposes.

5.2 Quantifier and Truth value

For a specific summarizer, the truth value is the membership value of a specific quantifier when using it to describe the summarizer.

A quantifier is a fuzzy set in [0,1]. There are 10 quantifiers in this project. The quantifiers we implement here follow trapezoid membership function indicated in expression (11). The label and its parameters are indicated in Table 4, and more clearly shown in Figure 4. For a specific summarizer, we calculate its membership value (in a range from 0 to 1) to different quantifiers, and select the quantifier with the highest membership value to label the summarizer.

For instance, for a specific summarizer, if its membership value in the quantifier 'About a half' is 0.42 (in the range of $[a, b]$), we can label the summarizer as 'About a half' with the truth value 0.8. If its membership value in the quantifier 'About a half' is 0.5 (in the range of $[b, c]$), then the summarizer can be labeled with truth value as 1, which means the quantifier can exactly describe the summarizer. However, if its membership value of 'About a half' is 0.7, which is beyond the range of $[a, d]$, then the truth value is 0, and the quantifier cannot describe the summary.

Table 4 Quantifiers

Quantifier label	Parameters			
	a	b	c	d
'Most'	0.8	0.85	1	1
'About 3/4'	0.67	0.72	0.78	0.83
'About 2/3'	0.57	0.62	0.7	0.75
'About a half'	0.35	0.45	0.55	0.65
'About 1/3'	0.23	0.3	0.36	0.42
'About 1/4'	0.18	0.23	0.27	0.32
'About 1/5'	0.12	0.17	0.23	0.28
'About 1/10'	0.04	0.07	0.13	0.16
'A few'	0.01	0.03	0.05	0.07
'Almost No'	0	0	0.005	0.02

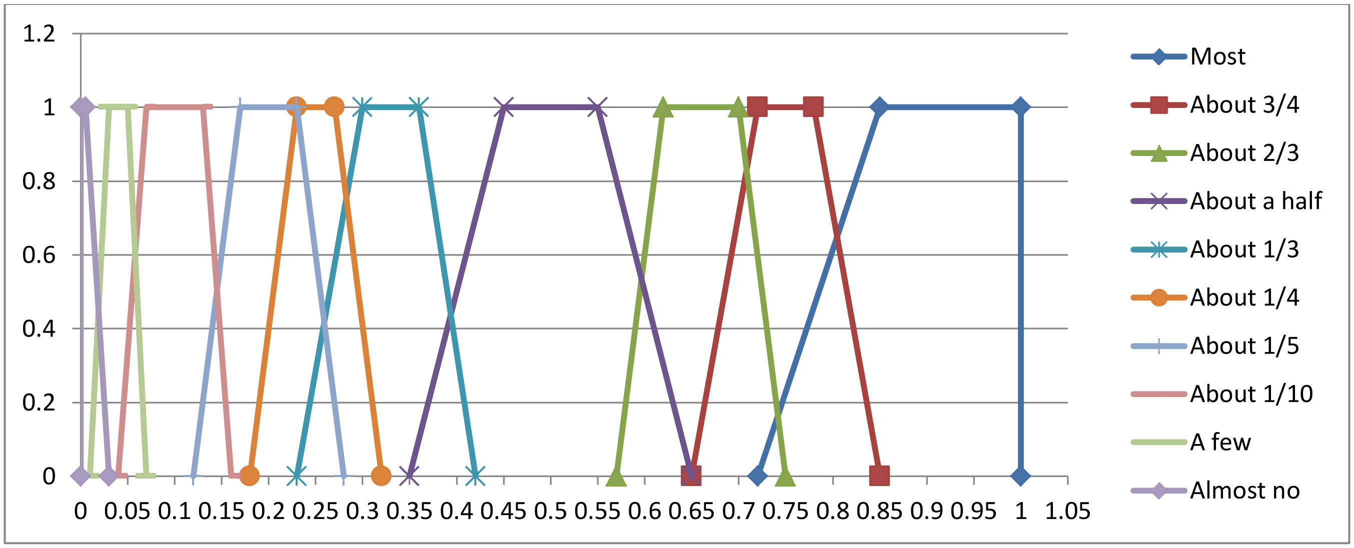

Figure 4 Membership curves for quantifiers

5.3 Patient groups

Patients are grouped by characteristics. There are 6 types of characteristics involved, which are COPD, liquid level, medication, gender, age and BMI. For each type, the possible characteristics are indicated in Table 5. The characteristics are considered as the Qualifier (denoted by C in the protoform) in the summary.

When we compare the performance between 2 patient groups, we only compare the groups within one type of characteristics. For instance, we compare the time duration between patients with COPD and patients without COPD (both characteristics are from type COPD), but we do not compare the time duration between patients with COPD (characteristic from type COPD) and patients with middle age (characteristic from type Age).

Table 5 Patient Groups

Type	Description	Possible characteristics (patient groups)
COPD	Whether the patient have COPD (Chronic Obstructive Pulmonary Disease). If applies, in which level.	1. with COPD (1.1 COPD level 1; 1.2 COPD level 2) 2. without COPD;
Liquid Level	Liquid level of the patients.	1. Liquid level 1; 2. Liquid level 2; 3. Liquid level 3; 4. Liquid level 4
Medication	Whether medication is applied on the patient.	1. with Medication; 2. without Medication
Gender	The gender of patients.	1. Male; 2. Female

Age	The age level of patients.	1. Young age; 2. Middle age; 3 Old age
BMI	BMI (Body Mass Index) level of patients.	1. Normal BMI; 2. Obese BMI

For the characteristics like COPD, liquid level, Medication and gender, patients can be explicitly divided by different groups without any overlap. The characteristics Age and BMI, on the other hand, are defined by trapezoid membership function (which is indicated in expression (11)), and the calculation of the truth value should followed function (6) instead of (7). The labels and parameters of these two characteristics are indicated in Table 6 (which are from (Lips, 2015)), and more clearly shown in Figure 5 and Figure 6.

Table 6 Qualifiers and their parameters

Type of characteristic	Label of summarizer	Parameters			
		a	b	c	d
Age	Young age	0	0	35	45
	Middle age	40	50	75	85
	Old age	70	90	+ ∞	+ ∞
BMI	Normal	0	0	25	30
	Obese	25	30	+ ∞	+ ∞

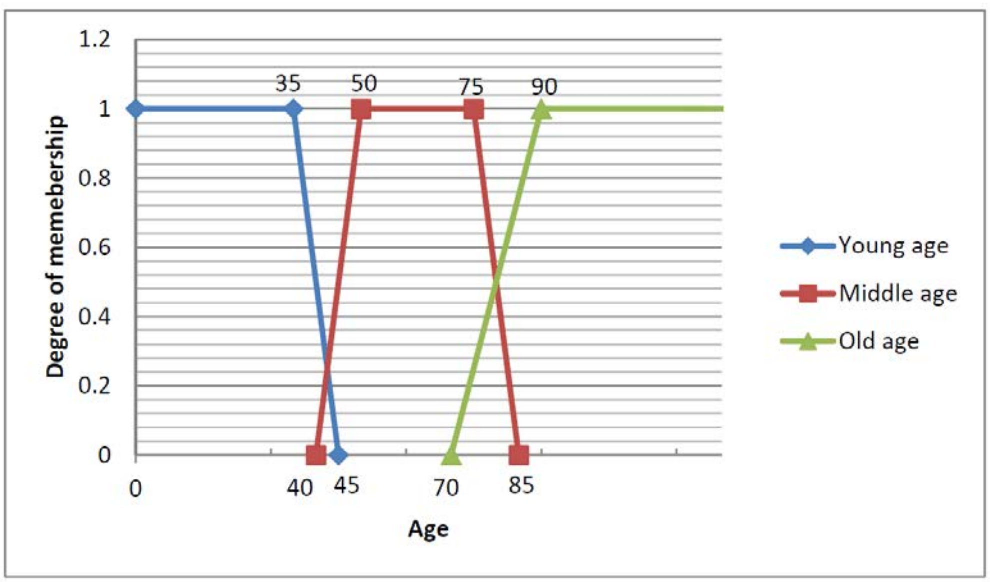

Figure 5 Membership curves for Age groups

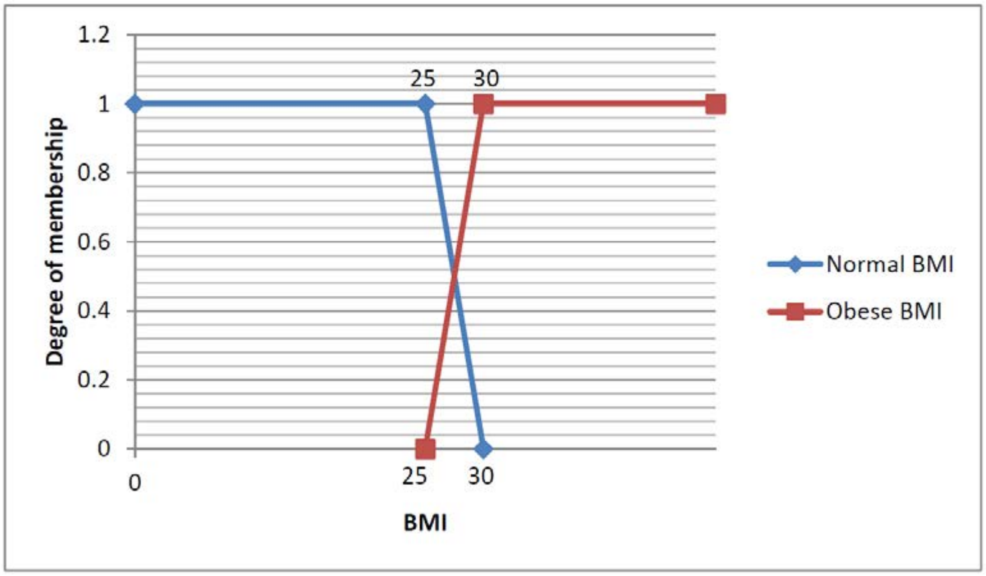

Figure 6 Membership curves for BMI

5.4 Generate summarizers

In this section, we demonstrate the algorithms that are applied during the implementation. For easier understanding, an example of event logs is used to describe the summary process. The sample data is shown in Figure 7.

There are 6 patient traces in the sample data. We denote the patients with ID 1 to 6. Therefore, the trace of the patients can be denoted as δ_1 ... δ_6. Instead of using activity name, we use different characters (Activity ID) to represent the activities. There are 18 different activities involved in this sample data. The character and the associated activity name can be found in the bottom of Figure 7.

Based on the description in Table 2, the activities belongs to different phases. We use four different colors to highlight the phases. Activities $\{a, b\}$ are from Phase 1 ; $\{c, d, e, q\}$ are from Phase 2; $\{e, f, g, h, i, j, k, l, m, n\}$ are from Phase 3; and $\{o, p, r\}$ are from Phase 4. Activity e (blood test) can be either in Phase 2 or 3 as we mentioned in Table 2.

According to the notations of color, the traces are divide into segments based on the Phase. They are highlighted in the table in Figure 7.

5.4.1 Generate sequence summarizer

In this section, different methods and algorithms to generate sequences summarizers are introduced. The summarizer can be filled in Protoform 1 or 2 when generating summaries.

5.4.1.1 Generate phase level summarizer

As the example given in Figure 3, the original patients trace are activity level sequences. To have the statistic result of phase level sequences, we should first divide activity trace into segments, and group up the activities in segment by labeling phase id. The weaning protocol is a chain like process with no parallel path, and most activities belong explicitly to one specific phase. We can easily segment the trace by comparing the phases of two adjacent activities.

P_ID	Activity Sequences
1	a c d q e d d d o r
2	a c d q e d d f h j c d e d f h j c d f h j e i l m l m l m n o p
3	a b c d q d e d d d e d d d d e d f g j c d f g j m l m n o p
4	a b c d q e d d d d e d d e d d d d d d e d d d f h j l m l m e l m l m l m l m n o p
5	a b c d q d e d d d e d d d f h j l l e k l l k m n o r
6	a b b c d q d d d e d d d d d e d d e f h j c d d d d e d f h j c d d d d d e f h j k m n o r

Phase 1 Phase 2 Phase 3 Phase 4

Activity ID a b c d e e f g h i j k l m n o p q r

a: Patient record	g: ASB ventilation	m: 30 min. deviation check
b: Operation blood	h: CPAP/ASB ventilation	n: Final blood
c: Bipap ventilation	i: CPAP ventilation	o: Extubation criteria
d: Bipap check	j: Check breathing frequency	p: O2 probe
e: Blood test	k: Decrease P-ASB	q: Temperature
f: Setup ASB ventilation	l: Continue P-ASB	r: Breathing stop

Figure 7 Example event logs

Consider the example from Figure 7. When we are segmenting the trace of patient 1, the first two activities $\{a, c\}$ do not belong to the same phase (a is from phase 1, while c is from phase 2), a segment applied between these two activities. Therefore $\{a\}$ will be a segment and it can be represented by phase 1. In the same way, both activities c and d are from phase 2, then nothing need to be done but to continue the comparison with d and q, etc.

After the segmentation working on all the traces in example data, we have now the trace of phases indicated in Figure 8

P_ID	Phase Level							
1	1	2	4					
2	1	2	3	2	3	2	3	4
3	1	2	3	2	3	4		
4	1	2	3	4				
5	1	2	3	4				
6	1	2	3	2	3	2	3	4

Figure 8 Example of phase level segments

We can find that there are four possible phase sequences among the 6 patients. Two patients followed phase 1,2,3,4 during weaning. It aligns with the standard process of weaning protocol. Besides, one patient skipped the phase 3, and three others have some loops between phase 2 and 3.

5.4.1.2 Summarizer from clustering

Algorithm 1 is used to generate clustering result among a set of sequences. It is based on the k-medoid clustering. Therefore, the center of the cluster is one of the sequence among the cluster set. We use the center sequence to represent the other sequences in a specific cluster, i.e. the center sequence is the summarizer.

The basic concept and the step of the algorithm are explained in section 3.4.2.1.

Algorithm 1:

Procedure *SequenceClustering* (L, k)
Input:
L, A set of sequences $L = \{ H_1, H_2, \cdots, H_n\}$.
k, Number of clusters, $k < n$
Output:
$center$, The index of clustering center
$index$, The index of clusters for all the sequences segment
D, distance matrix among the sequences in set L.
Steps:
Initialize D to $\emptyset$; $center$ to $\emptyset$
Initialize $e = 1$; $energy = 0$
Initialize $index$ to a zero vector with n dimensions
Set $D \Leftarrow$ *SequenceDistance*(L)
Set C to a vector containing k different integers randomly chosen from $[1, n]$
$D' \Leftarrow$ select row c_i in D, where $c_i \in C, 1 \le i \le k$
For each column j of $D', 1 \le j \le n$
find the smallest value and save its row index to $index(j)$
End For
While $e > 0$
For each cluster i
gather the distance between each non-center sequence and center sequence from $distance\ matrix$, and sum up all the distances
For each center c_i, for each non-center sequence H_k
switch c_i and H_k, re-computing the total distance
If the total distance in cluster i is increasing, undo the switch.
End If
End For
End For
$energy =$ sum up all the total distance
If $energy$ is smaller than the previous
replace the new $center$ and $index$.
Else stop the iteration
$e = 0$
End If
End While
End procedure

Procedure *SequenceDistance* (L)

37. **Input**:
38. L, A set of sequences $L = \{ H_1,\ H_2, \cdots, H_n\}$
39. **Output**:
40. D, a $n \times n$ matrix records distances between two arbitrary sequences in L.
41. **Steps**:
42. **Let** D be a $n \times n$ zero matrix
43. **For** each $H_i, H_j \in L$
44. calculate Levenshtein distance between H_i and H_j, and save the result in $D(i,j)$. ($1 \le i \le n$, $1 \le j \le n$, and $i \ne j$)
45. **End for**
46. **Return** D
47. **End Procedure**

As the input of the algorithm, the value of k is explicated based on the function (12) . However, due to the similar processes among the Pre-Bipap Phase and

Before the calculation, as we can find from Figure 7, the activity sequence in the examples usually contain many duplicated activities. More specific, the duplicated activity is 'Bipap check', which is a routine check in weaning process. Since we are more concerned about the transition among different activities, to simplify the calculation, we group up the repeated activity sequence and represent it by one activity. For instance, we simplify the sequence $\{c, d, q, e, d, d, d\}$ from the trace of patient 1 into $\{c, d, q, e, d\}$. This is the pre-processing on input data L.

The distance matrix D among the set of sequences L is first generated. We implement Levenshtein distance during the calculation (as indicated from line 42 to 44 in **Algorithm 1**). The Levenshtein distance between two sequences $H_1,\ H_2$ (with length m, n respectively) is given by $lev_{H_1,H_2}(m,n)$ where

$$lev_{H_1,H_2}(i,j) = \begin{cases} \max(i,j), & if \ \min(i,j) = 0 \\ min \begin{cases} lev_{H_1,H_2}(i-1,j)+1 \\ lev_{H_1,H_2}(i,j-1)+1 \\ lev_{H_1,H_2}(i-1,j-1)+1_{(H_{1_i} \neq H_{2_j})} \end{cases} & otherwise \end{cases} \tag{15}$$

where $1_{(H_{1_i} \neq H_{2_j})}$ is the indicator function equal to 0 when $H_{1_i} = H_{2_j}$, and equal to 1 otherwise.

After generating the distance matrix, the matrix can be considered as an input of the clustering. When clustering, firstly we randomly choose k centers as the initial centers from the sequences set (Line 13). After that, for each sequence in the set, the closed initial center c_i can be found by retrieving the minimal value from c_ith row in distance matrix D (line 14 to 17). This is the first round of clustering. Following the line 18 to 24, the center of each cluster might be reset if the total distance from each sequence to the current center is higher than the value of a non-center sequence. Otherwise the center will be recorded as the final center of the cluster.

5.4.1.3 *Summarizer from pattern recognition*

The clustering results provide approximate overview of the process in activity level. However, we still need to gain insight into the medical behavior in real data. Therefore, we implement patterns recognition on the activity level sequences.

We define the pattern as a consecutive sequence (with at least two activities) which exist in at least two different sequences, in other words, the common segment of two sequences.

For instance, assuming two sequences are $ABCAC$ and $ABAC$. We consider AB and AC are the patterns recognized from these two sequences. However, ABC, ABA, BC, $ABAC$ etc. cannot be considered as patterns, since they are not consecutive in original sequences.

Algorithm 2 is used to recognize patterns from a set of sequences. The main concept of this algorithm is to recognize patterns from two arbitrary sequences in the set. When all the patterns are gathered, we retrieve patterns from the set of sequences to calculate the number of patients that followed a specific pattern. The statistic results is used to settle the quantifier and calculate the truth value when generating summaries.

Algorithm 2:

Procedure *PatternsRecognized* $(L, patient\_list)$
Input:
    L, A set of sequences $L = \{H_1, H_2, \cdots, H_n\}$.
    $patient\_list$, a vector with n dimensions. It is the list of patients who underwent the sequences in L
Output:
    $patterns$, a list of patterns, each pattern is a sequence segment
    $pattern\_matrix$, record whether the patterns is underwent in patient traces
    p_list, t the list of patients who underwent the sequences in L, without any duplicated records.
Steps:
        Initialize $patterns\ to\ \emptyset$; $p\_M\ to\ \emptyset$; $ind\ to\ \emptyset$
        Initialize k to 0
        Initialize D to the list of patient id that appeared two or more time in $patient\_list$
        For two different arbitrary sequences H_i H_j from L ($1 \le i \le n$, $1 \le j \le n$, and $i \ne j$)
            run $SequencePattern$ (H_i, H_j) and record the patterns to the list $patterns$
        End For
        Delete the duplicated records from $patterns$
        Set k to the number of patterns
        Initialize $pattern\_matrix$ to a $n \times k$ zero matrix
        For each sequences H_i from L ($1 \le i \le n$)
            For each sequences P_j from $patterns$ ($1 \le j \le k$)
                Set $pattern\_matrix(i,j)$ to the $issub$ value from SequencePattern (H_i, P_j)

End For
End For
For each d_i in D
Set ind to the index of d_i found from $patient\_list$
Set p_M to the $pattern\_matrix$ contains only the rows indicated in ind
For each column in p_M
If there is any nonzero value
Set all the value in this column as 1
End If
Keep the first row of p_M and delete the remains
End For
for the rows in $pattern\_matrix$ that ind indicated, replace the first row by p_M, and remove the remains.
End For
Remove all the duplicated id from $patient\_list$ and save it as p_list
End procedure

Procedure *SequencePattern* $(H_1,\ H_2)$
Input:
$H_1,\ H_2,$ two sequences
Output:
$patterns,$ a list of patterns found from H_1 and H_2, each pattern is a sequence segment
$issub,$ a notation that denote whether H_1 is the subsequences of H_2, or vice versa.
$label,$ if $issub$ is true, the $label$ records which sequence is the subsequence.
Steps:
Initialize $patterns\ to\ \emptyset$
Initialize M to a zero $(m+1, n+1)$ matrix, where n, m are the length of $H_1,\ H_2$ respectively.
Initialize $issub$ to 0; $label$ to 0; A to 0
For $i = 2\ to\ n$+1
For $j = 2\ to\ m + 1$
compare $(j-1)th$ character in H_2 to the $(i-1)th$ character in H_1
If $(i-1)th$ character in H_1 is the same as $(j-1)th$ character in H_2
set $M(j,i)$ to $M(j-1, i-1) + 1$
End If
End For
End For
set A as the maximum value in M , and record the position of A as (a_1, a_2)
If A is equal to either $n, m,$ it means one of the two sequences is the subsequence of the other one.

```
58.             set  issub to 1
59.             set  label  to the subscript of the subsequence(either 1 or 2)
60.             set  patterns as the subsequence
61.         End If
62.         If A is not equal to 1 ,and issub is 0  (which means there is a least one pattern
            between H_1 and H_2
63.             While A > 1
64.                 the longest pattern is saved in patterns , which is the segment of H_1
                    from  (a_1 − A + 1)th character to  (a_2 − 1)th character
65.                 set  the diagonal from M(a_1, a_2) to M(a_1 − A + 1, a_2 − A + 1) to zeros
66.                 A=A-1
67.             End While
68.         End If
69. End Procedure
```

There are three steps to recognize the patterns from a set of sequences. Firstly, we collect the patterns from two different arbitrary sequences and save them to a list (from line 13 to 15 in Algorithm 2). The procedure is given in the SequencePattern (from line 36 to 69 in Algorithm 2) in detail. After that, the duplicated records are removed from the list. Then a second round comparison between patterns and original sequences are processed (from line 19 to 23 in Algorithm 2). The Boolean matrix, $pattern\_matrix$, is used to record whether a specific patterns exist in each sequence.

Since the sequences set are gathered from patient traces, there is a possibility that one patient underwent several sequences in the set. For the further summarizing, we need to calculate the number of patient that underwent a specific pattern, rather that the number of sequences containing the pattern. Therefore, it is required to build a new matrix to record whether a specific pattern executed for patients. Since we do not consider how many times a pattern is executed for one patient, we can simply remark the existence by combining all the records that belong to the same patients. This procedure is indicated from line 24 to line 34.

As the patterns we defined previously, we implement an algorithm based on the longest common substring problem. It is different from the longest common sequence (LCS) problem, where the subsequence are not required to occupy constitutive positions in the original sequence. However, as we would like to find all the possible patterns between two or more sequences, we have extended the algorithm as indicated in **Algorithm 2**.

Here we give an example based on the data from Figure 7 to explain how the algorithm works.

Let $H_1 = cdqedd$ from Patient 2, i.e. the first Phase 2 process segment.

Let $H_2 = cddded$ from Patient 6, i.e. the second Phase 2 process segment.

As we can see, there are some repetitive activities in both two sequences. For more efficiency, we combine the repetitive activity sequence into one activity to simplify the calculation. Therefore, the updated sequences are:

$$H_1 = cdqed, \text{ with length } n = 5$$

$$H_2 = cded, \quad \text{with length } m = 4$$

Therefore, following the Algorithm 2 line 46 we have a 5×6 zero matrix M. Then we operate M by following the line 48 to line 55, which is also indicated as an example from step 1 to step 4 in Figure 9. For each step, M is demonstrated in the white square. For easier tracking the process of generating M, we leave the un-operated part of the matrix in blank. As we can see in step 4, the two different colors highlights the patterns we found between H_1 and H_2.

The maximum value in M is 2, and it is not equal to either m or n, which means there is no subsequence relation between H_1 and H_2 . After that, we record the patterns by retrieving M (line 62 to line 68 in **Algorithm 2**). The procedure for this example can be found in step 5 and 6 in Figure 9. After retrieving and recording one pattern, we set the value of associate diagonal into 0 to avoid duplicated records in the next turn. Eventually, the patterns we found between H_1 and H_2 are $[e, d]$ and $[c, d]$.

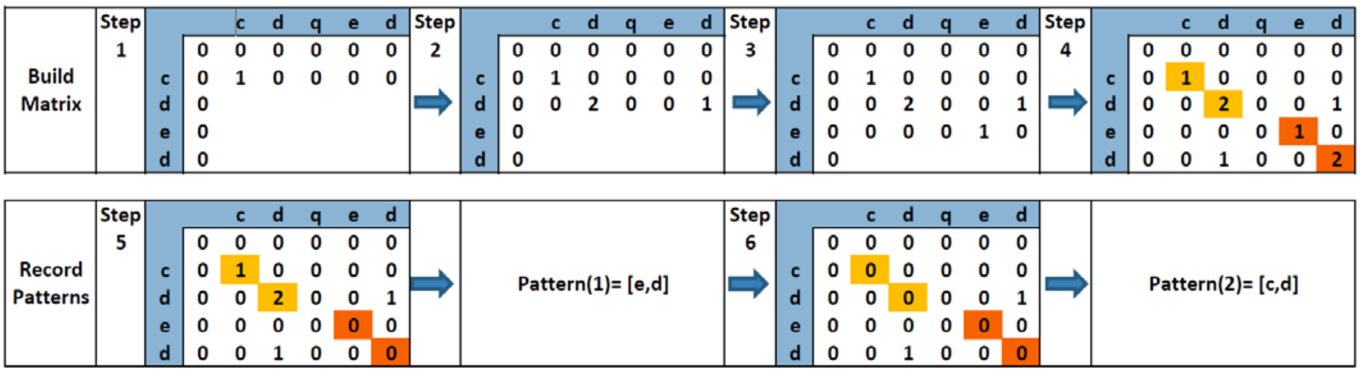

Figure 9 Example for pattern recognition

5.4.2 Generate comparative summarizer

When comparing two sets of data, it is not precise to simply compare average or standard deviation values between two sets. Instead, we implement a comparison by fuzzy summarizer indicated in section 3.4.2.3. According to the assumptions, only numerical sets are considered, such as the costs or time durations in our case.

The comparative summarizer are a set of membership functions. We use trapezoid function to define summarizers. There are two types of comparison, one is for costs and another is for time durations. We define two different sets of summarizer. The label and parameters are indicated in Table 7. The calculation of the membership value is indicated in function (19) in the previous section.

Table 7 Comparison Summarizer

Type of summarizer	Label of summarizer	Parameters			
		a	b	c	d
cost (comparison)	same	-100	-50	50	100
	higher	40	100	+ ∞	+ ∞
	lower	- ∞	- ∞	-100	-40
time (comparison) (in seconds)	same	-7200	-3600	3600	7200
	more	3600	10800	+ ∞	+ ∞

	Less	- ∞	- ∞	-10800	-3600

The **Algorithm 3** is about comparing the cost between two patient groups in a specific phase level. This algorithm can also be implemented to comparing the time durations between two patient groups, or costs between two phases. The only change is the input of the algorithm. As we indicated in

Algorithm 3:

Procedure CostComparison $(P_1, P_2, s, M_1, M_2, Q)$
Input:
  P_1, P_2, two sets of cost records from two different patient groups (with length $|P_1|$, $|P_2|$ respectively)
  s, the membership functions of n summarizers
  Q, the membership functions of quantifiers
  M_1, M_2, two set of membership values of qualifier that might applied in two patient groups respectively.
Output:
  $list$, the summary results
Steps:
  Initialize $list$ to $\emptyset$;
  Initialize qq to n zero vector for recording the quantifier value
  Initialize $comparematrix$ to a $|P_1| \times |P_2|$ zero matrix to save the comparing result.
  Initialize $index$ to a zero vector with n dimensions
  For each element p_{1_i} in P_1 $(1 \leq i \leq |P_1|)$,
    For each element p_{2_j} in P_2 $(1 \leq j \leq |P_2|)$
      $comparematrix(i, j) = p_{1_i} - p_{2_j}$
    End For
  End For
  For each summarizer in s
    Calculate the membership value for each element in $comparematrix$ by using trapezoid function, set the new matrix as CM_i $(1 \leq i \leq n)$
  End For
  For each CM_i
    If the qualifiers do not have membership value
    Set the i element in qq, $qq_i = sum(CM_i)/(|P_1| \times |P_2|)$
    Else
    For j = 1: $|P_2|$
      $CM_i' = minimum(CM_i, M_{2_j})$
    End For
      CM_i'' =sum each columns in CM_i' and divided them by sum(M_2)

30. $qq_i = \ sum\ (minimum(CM_i'', M_1)) / \text{sum}(M_1)$
31. **End For**
32. **For** each Q_i in Q
33. Calculate the membership value on quantifier for qq_i by using trapezoid function, record the highest results as the truth value and corresponding quantifier label as the quantifier of the summaries.
34. **End For**
35. Generate the list of summaries by filling Quantifier , Summarizer, Qualifier and the truth value.
36. **End procedure**

The algorithm has three steps. In order to explain the Algorithm 3 more explicitly, we use the example data as shown in Table 8. The data contains the cost of 6 patients in phase 2, along with the condition of COPD (where 0 mean non COPD, and 1 mean with COPD). Therefore, we have two patients groups. As the input of the algorithm, the P_1, P_2 are as follows:

$$P_1 = \{1486,2974,4582,6730\},$$

$$P_2 = \{3778, 2518\}$$

Table 8 Example data for cost comparison

P_ID	Cost	COPD
1	1486	0
2	2974	0
3	3778	1
4	4582	0
5	2518	1
6	6730	0

Following the line 14 to 18 in Algorithm 3, we can build the compare matrix indicated as the white square in the Step 1 in Figure 10.

For each value of the compare matrix, we are going to calculate its membership value under the membership function of each summarizer (indicated in Table 7). This step is demonstrated from line 19 to 21 in the Algorithm 3. Then we have the result as shown in Step 2 in Figure 10. We can find that the membership values for the summarizer 'same' are all zeros. Therefore, by retrieving the Quantifiers membership in Table 4, we can state that the quantifier with label 'Almost no' have the highest truth value when describing the summarizer 'same'. Thus, by filling the Protoform 5, we have the sentence of summary says " For almost no case, patient without COPD have the same cost as the patient with COPD in phase 2."

For the other two summarizer, we can calculate the quantifier value by following line 23 to 24, since COPD is the characteristic without membership function. The quantifier value for summarizer 'Higher' is $\frac{5}{4\times 2} = 0.625$, and the value for summarizer 'Lower' is $\frac{3}{4\times 2} = 0.375$. By implement membership function of quantifier, the two summarizer can be labeled by 'About 2/3' and 'About 1/3' , respectively.

Step 1

Calculation		
	3778	2518
1486	-2292	-1032
2974	-804	456
4582	804	2064
6730	2952	4212

Step 2

Same		
	3778	2518
1486	0	0
2974	0	0
4582	0	0
6730	0	0

Higher		
	3778	2518
1486	0	0
2974	0	**1**
4582	**1**	**1**
6730	**1**	**1**

lower		
	3778	2518
1486	**1**	**1**
2974	**1**	0
4582	0	0
6730	0	0

Figure 10 Comparison examples

6 Results

We have implemented and tested the proposed approach using MATLAB. There are in total 625 sentences generated by running the program after the automatic filtering. During the first step filtering, only sentences with truth value higher than 0.7 are retained, which are considered as true enough. Besides, if one summary describes the same content as the other one (i.e. with same quantifier and summarizer), while in which the patient group is the sub-group of the other's, then we delete the summary for the smaller dataset. For instance, if there is a summary says 'About 1/4 patients with COPD follow Patient record, Operation blood, in Pre-BIPAP Phase.', While another summary says 'About 1/4 patients follow Patient record, Operation blood, in Pre-BIPAP Phase.', then we delete the first sentence as it does not provide new information. The entire results list can be found in Appendix II Original results of summaries.

6.1 Filtering the results

After the automatic filtering, there are still too many sentences as the results of summary. Not all of the results are informative or of interest to clinical specialists. To select the relevant sentences, different filter rules are implemented for different summaries categories.

Since the phase level results provide an overview of process in weaning protocol, we keep all the sentences summarized from entire patients range. While for the results generated from different patient groups, if the process described in the sentence has deviations from the designed protocol, we think the sentence is relevant.

For the clustering results, it provides an overview of process in activity level, but in an approximate way. Therefore, the sentences summarized from entire patients range with the quantifier lower than 'about 1/3' are removed. One exception is applied if there is a transition of ventilation within a process. For a specific group of patients, Exceptions are applied when there are uncommon activities (e.g. 'IPPV/autoflow ventilation') and there exists a transition between two ventilation types.

For the pattern results, sentences with the quantifier higher than or equal to 'about 1/5' are retained. Exceptions are applied when there are uncommon activities (e.g. 'IPPV/autoflow ventilation') and there exists a transition between two ventilation types.

For the comparison summaries, firstly, we removed all the sentences with the summarizer 'same'. For the rest of the sentences, the sentences with quantifier lower than 'about a half' are removed. One exception is applied for time comparison between the groups of patients with and without COPD. It remained as an example of complete comparison results for a specific characteristic.

After the filtering, only 57 sentences were selected as the final results. There are 38 sentences describing the sequence of the Weaning process. The remaining 19 sentences are describing the performance of the process. The results are in 6 categories, which are indicated in Table 3.

6.2 Sequence summary

In this section, the sequence summaries are indicated. The summaries have two different granularity. Phase level summaries give a comprehensive view of the process, while the activity level summaries gain an insight into the process in each phase.

6.2.1 Phase level summaries

For all the patients, as indicated by sentence No. 1-3, the most general process in phase level is consistent with the designed protocol. There is an exception that a few patient skip the ASB phase during the weaning (No. 1-4), and according to No. 1-7, we can learn that 1/5 patients with liquid level 2 follow this path . In a few cases, patients return from ASB phase to BIPAP phase several times (No.1-1,1-2), and it happened in greater degree in patients with COPD level 1 (No. 1-5), or liquid level 1(No. 1-6), or with medication support (No.1-8).

Table 9 Sequence summary results in phase level

Phase Level	
No.	Summary
1-1	A few patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
1-2	About 1/10 patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
1-3	Most patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.
1-4	A few patients follow Pre-BIPAP Phase, BIPAP Phase, Extubation Phase.
1-5	About 1/4 patients with COPD level follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
1-6	About 1/10 patients with Liquid level 1 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
1-7	About 1/5 patients with Liquid level 2 follow Pre-BIPAP Phase, BIPAP Phase, Extubation Phase.
1-8	About 1/5 patients with Medication support follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.

6.2.2 Activity level summaries

Since the sequences in activity level have a massive deviation from each other, the clustering results can not be the exact description for a batch of sequences, but a representative process that patients follow it in a certain degree. To be more precise, we recognize some patterns from a set of sequences. The patterns are more accurat to describe the process in activity level.

As we can see, the patterns results indicate that the process in Pre-BIPAP Phase is concrete (No. 3-1). For the Extubation phase, the proportions of two possible sequences are equivalent (No. 3-20,3-21).

In BIPAP phase, there are some cases that ventilation type is changed during the process (No. 2-3,2-4,2-5,3-2,3-3,3-5,3-10,3-11). It also happens in ASB phase (No. 3-17,3-18), where ASB ventilation is changed into CPAP/ASB ventilation. There are few cases that IPPV/autoflow ventilation are implemented (No.2-3,3-6,3-8). Besides, the results show some general process that patients underwent during the weaning. They are consistent with the designed protocol.
The remaining sentences describe several general cases when patients are in the weaning procedure.

Table 10 Sequence summary results in activity level

Activity Level --- Clustering

No.	Summary
2-1	About 1/3 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
2-2	About 1/5 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
2-3	About 1/4 patients with COPD level 2 likely follow IPPV/autoflow ventilation, Bipap check, Temperature, Blood test, Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
2-4	About 1/5 patients with COPD level 1 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
2-5	A few patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
2-6	About 1/5 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
2-7	About 1/4 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.
2-8	About 1/5 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
2-9	About 1/5 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
Activity Level --- Patterns	
No.	Summary
3-1	Most patients follow Patient record, Operation blood, in Pre-BIPAP Phase.
3-2	About 1/3 patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.
3-3	About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
3-4	About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
3-5	About 1/10 patients follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
3-6	A few patients follow IPPV/autoflow ventilation, Bipap check, Temperature, in BIPAP Phase.
3-7	A few patients with obese BMI follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
3-8	About 1/10 patients with old age follow IPPV/autoflow ventilation, Bipap check, Temperature, in BIPAP Phase.
3-9	Most patients with Liquid level 2 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
3-10	About 1/5 patients with Liquid level 3 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.

3-11	About 1/5 patients with old age follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
3-12	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
3-13	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, in ASB Phase.
3-14	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
3-15	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Final blood, in ASB Phase.
3-16	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
3-17	A few patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
3-18	About 1/10 male patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
3-19	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
3-20	About a half patients follow Extubation criteria, O2 probe, in Extubation Phase.
3-21	About a half patients follow Extubation criteria, Breathing stop, in Extubation Phase.

6.3 Performance summary

As no data are provided for the cost comparison in this case study, the cost of each activity is randomly generated. Therefore, results of cost comparison is not precise and relevant to the weaning protocol from MUMC+. However, the result can be considered as a proposal to specialists if they are concerned about the costs. The list of cost is shown in Table 11.

From the time duration comparison results (shown in Table 12), we can learn that the time durations is dramatically different between patients with COPD level 1 and COPD level 2. It also happens between patients with liquid level 1 and liquid level 4.

Table 11 Cost list for activities (in Euro)

No.	Activity name	Cost	No.	Activity name	Cost
1	Patient record	6	12	Check breathing frequency	265
2	Operation blood	273	13	Decrease P-ASB	15
3	Bipap ventilation	448	14	Increase P-ASB	111
4	Bipap/ASB ventilation	59	15	Continue P-ASB	59
5	IPPV/autoflow ventilation	60	16	30 min. deviation check	447
6	Bipap check	220	17	Final blood	113
7	Blood test	152	18	Extubation criteria	40
8	Setup ASB ventilation	224	19	O2 probe	348
9	ASB ventilation	494	20	Temperature	6

10	CPAP/ASB ventilation	118	21	Breathing stop	3
11	CPAP ventilation	31			

Table 12 Comparison results

Cost comparison ---- between 2 phases	
No.	Summary
4-1	For Most cases, the cost of Pre-BIPAP phase is lower than the cost of BIPAP phase in weaning protocol
4-2	For Most cases, the cost of Pre-BIPAP phase is lower than the cost of ASB phase in weaning protocol
4-3	For About a half cases, the cost of Pre-BIPAP phase is higher than the cost of Extubation phase in weaning protocol
4-4	For About 2/3 cases, the cost of BIPAP phase is higher than the cost of ASB phase in weaning protocol
4-5	For Most cases, the cost of BIPAP phase is higher than the cost of Extubation phase in weaning protocol
4-6	For Most cases, the cost of ASB phase is higher than the cost of Extubation phase in weaning protocol
Cost comparison ---- between 2 patient groups	
No.	Summary
5-1	For About 2/3 cases, the cost of patients with COPD is higher than the cost of patients without COPD in BIPAP phase
5-2	For Most cases, the cost of patients with COPD level 1 is higher than the cost of patients with COPD level 2 in BIPAP phase
5-3	For Most cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in BIPAP phase
5-4	For About 2/3 cases, the cost of patients with COPD level 1 is higher than the cost of patients with COPD level 2 in ASB phase
5-5	For About 2/3 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 4 in ASB phase
5-6	For About 2/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 4 in ASB phase
5-7	For About a half cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in ASB phase
Time comparison	
No.	Summary
6-1	For About 1/3 cases, patients with COPD spend more time than patients without COPD in weaning protocol
6-2	For About a half cases, patients with COPD spend less time than patients without COPD in weaning protocol
6-3	For Most cases, patients with COPD level 1 spend more time than patients with COPD level 2 in weaning protocol
6-4	For About 2/3 cases, patients with Liquid level 1 spend less time than patients with Liquid level 2 in weaning protocol
6-5	For About 3/4 cases, patients with Liquid level 1 spend less time than patients with Liquid level 4 in weaning protocol

7 Evaluation

According to the goal and scope indicated in section 1.1, the summaries that we generated in chapter 6 should be understandable and meaningful to specialists. Therefore, an interview based evaluation is conducted with one doctor and one nurse from MUMC+. Both the doctor and the nurse are participating the weaning protocol implementation and execution. The record of the interview can be found in Appendix III Feedback from specialists.

7.1 Content evaluation

All the results shown in section 6 are delivered to the specialists. Due to the time limitation, only 11 sentences were discussed in detail during the evaluation. For each category of summaries, 2 sentences were discussed (except the cost comparison between 2 phases, in which only one result was discussed). For each sentence, we asked experts whether the sentence is:

- understandable
- relevant
- interesting

According to the feedback from interviewees, all the sentences are understandable, though some explanations of activities need to be recalled. Besides, the majority of the results are relevant and interesting for the experts to study the weaning process.

However, the experts indicated that summaries about cost comparison are not interesting to them. The main reason is that they are not concerned much about the cost during the weaning process. The associated cost is negligible, which means there is no much reduction on cost when improving the weaning process.

With regards to the patients groups division, experts indicate that they are more interested in the COPD, liquid level, age of patients and BMI. The implementation of medication and the gender of patients are less interesting to them.

The detail of the feedback is demonstrated according to the category in Table 13. The number of the summary is referring to the results sentences shown in Chapter 6.

Table 13 Feedback from experts

No. of summary	Feedback
1-3,1-2	An overview of the weaning process is first given from the phase level summaries. Experts think 1-3 provides useful information that most patients were following the process without any iterations, which is compliant with the designed protocol. For the 1-2, experts think it is an interesting summary. It shows there are the cases that iterations happened between BIPAP and ASB phases.
2-1,2-7	Since the clustering results is an approximation description of the activity level process, we did not request the feedback according the relevant and interesting criteria.

3-3,3-17	These two sentences are chosen as they show the transition of ventilation type in a specific phase. Experts said these sentences are interesting because they indicate the iteration within one phase. They are also interested to know how many times the iteration (e.g. the iteration between Blood test and Bipap check) happens within one phase. Besides, they would like to know what the process that other patients followed in the same phase (which actually indicated in the full version of results).
4-4,5-3,5-7	For the costs comparison results, experts were not interested on the cost (as explained above). Therefore , the sentences are understandable but not interesting or useful in this case study.
6-1,6-2	Experts showed a particular interest on the time comparison results. They considered the results are useful to check whether they followed the settled rule in the practice. They mention that more efforts were made on earlier discharging the patient with COPD, and the summary 6-2 indicates it. However they are also surprised that only half of the cases meet the requirement.

7.2 Expression evaluation

The expression evaluation is based on the content evaluation. The evaluation is used to check whether improvements are required with regards to the sentence organization. It includes simplifying the sequences summary and relabel the quantifiers.

Firstly, we proposed a simplified sentence in activities level summaries to ask if it is easier to understand or gain useful information. The simplification should be conducted by pre-defining the key activities.

The original sentence is 3-3 in chapter 6. Here we suppose *Bipap ventilation*, *Temperature*, and *Bipap/ASB ventilation* are the key activities, and we remove the *Bipap check* and *Blood tests* from the sentence 3-3. Therefore, the sentence is rewritten as:

> **About a half patients follow Bipap ventilation, Temperature, Bipap/ASB ventilation, in BIPAP Phase.**

Different opinions are given from the doctor and the nurse. In doctor's opinion, the original sentence is readable, while after being simplified, some valuable information is being lost. He indicated that, for this particular example, the simplification can be processed only if the iteration always happened between *Bipap check* and *Blood tests.* While the nurse preferred the simplified sentences as it is more obvious.

Regarding the label of quantifiers, experts preferred the approximate label (e.g. about 1/3) rather than the abstract label (e.g. more, a few).

7.3 Summary

Generally, the evaluation is positive. The summaries are understandable, and majority of them are relevant and interesting according to the feedback from specialists. One exception is that the specialists are not concerned about the cost of the weaning protocol. Besides, as the clustering results is an approximation of the real process, it does not provide much relevant information to the specialists. However, it can be considered as an attempt to discovery the similarity of sequences, and it can be further studied.

8 Conclusion

In this chapter, the conclusion of the project is given, followed by the limitation of the project and the direction of the future work.

8.1 Conclusions

The goal of this research was to "*design a methodology to summarize clinical processes from event logs by using linguistic summaries approach*". The results of the summaries should be understandable and meaningful to the specialist in the clinical field. To approach the goal, based on the literature study on the linguistic summaries, we answer the sub question by proposing a step by step methodology which consist as: *specify clinical pathway (protocol), specify requirements, build protoforms, generate summaries, calculate truth value and evaluation.* The requirement specifying is used to answer the research sub question 1 and 2. Sub question 3 was answered by the step build protoforms, while the calculation of truth value and evaluation steps answered the sub question 4.

To emphasis, an extension of basic protoforms from (L.A. Zadeh, 2002) are proposed during the development of the methodology. The extended protoforms (8) and (9) are adapted to generate sentences to describe sequences. Besides, we also proposed a comparative protoform (10) that can used to comparing the numerical attributes of two sets of objects. Based on the concept of truth value (LA Zadeh, 1983), two extended functions (13) and (14) are proposed to calculate the degree of truth for the fuzzy comparison summarizer.

After that, the methodology was applied during the case study of weaning protocol from MUMC+, in order to test whether the methodology can be implemented in practice. During the case study, we made more effort on building protoforms and generating summaries, including generating the sequence summarizer and performance summarizer. Based on the event logs we obtained, different methods (clustering and pattern recognition, etc.) are implemented to generate the summaries in both phase level and activity level, as well as in different patient groups.

The results of the case study are evaluated by the specialists working on the weaning protocol of MUMC+. The summaries are understandable, and majority of them are relevant and interesting according to the feedback from specialists. The negative feedback is the summaries of cost comparison. The specialists are indicates they are not much concerned on the cost of weaning protocol as the associated cost is negligible.

According to the result, we realized that for some cases, a ventilation transferring within a phase happened. Therefore, we recommend doctors to gain an insight into the criteria of ventilation selecting. It might happen that for some specific patient group, different ventilation modes are applied. If a standardized selecting rule can be generated based on the patient condition, less transition of ventilation might happen. As a result, the patient might be discharged from the weaning protocol earlier.

8.2 Limitations

The main limitation of this research is that only one protocol is implemented and evaluated as the case study. The weaning protocol is a sequential process that do not have any parallel process. Therefore, it is unclear that the methodology can be implemented into clinical process with parallel paths. Another limitation is the clustering summaries, which can only provide approximation descriptions of processes. Besides, a small dataset with only 65 cases is implemented due to the limitation of time.

8.3 Future works

The next step of this study is implementing large dataset based on the case study, therefore more accurate and precise results will be generated to help the specialists gain an insight into the weaning process. With regards to the methodology we developed, another useful future work is to extend the methodology to other protocols or clinical pathways.

9 Reference

Barua, A., Mudunuri, L. S., & Kosheleva, O. (2014). Why trapezoidal and triangular membership functions work so well: Towards a theoretical explanation. *Journal of Uncertain Systems*, *8*(3), 164–168.

Blackwood, B., Alderdice, F., Burns, K., Cardwell, C., Lavery, G., & O'Halloran, P. (2011). Use of weaning protocols for reducing duration of mechanical ventilation in critically ill adult patients: Cochrane systematic review and meta-analysis. *BMJ (Clinical Research Ed.)*, *342*, c7237. doi:10.1136/bmj.c7237

Boere, J.-J. (2013). *An analysis and redesign of the ICU weaning process using data analysis and process mining (Unpublished Master's Thesis)*. TU/e, Eindhoven, University of Technology.

Boles, J.-M., Bion, J., Connors, a, Herridge, M., Marsh, B., Melot, C., … Welte, T. (2007). Weaning from mechanical ventilation. *The European Respiratory Journal*, *29*(5), 1033–56. doi:10.1183/09031936.00010206

Bouchon-Meunier, B., & Moyse, G. (2012). Fuzzy linguistic summaries: Where are we, where can we go? In *2012 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr)* (pp. 1–8). Ieee. doi:10.1109/CIFEr.2012.6327810

Chawla, R., Varma, V., & Sharma, R. (2012). ICU Protocols, 57–64. doi:10.1007/978-81-322-0535-7

Christopher D Press. (2013). General anesthesia. *medscape.com*. Retrieved September 10, 2013, from http://emedicine.medscape.com/article/1271543-overview#aw2aab6b4

Delgado, M., Ruiz, M. D., Sánchez, D., & Vila, M. A. (2014). Fuzzy quantification: a state of the art. *Fuzzy Sets and Systems*, *242*, 1–30. doi:10.1016/j.fss.2013.10.012

Epstein, S., & Walkey, A. (2013). Methods of weaning from mechanical ventilation. *UpToDate*. Retrieved from http://www.uptodate.com/contents/methods-of-weaning-from-mechanical-ventilation

Heide, A. Van Der, & Trivio, G. (2009). Automatically generated linguistic summaries of energy consumption data. In *Intelligent Systems Design and Applications, 2009. ISDA '09. Ninth International Conference on* (pp. 553 – 559).

Huang, Z., Lu, X., Duan, H., & Fan, W. (2013). Summarizing clinical pathways from event logs. *Journal of Biomedical Informatics*, *46*(1), 111–27. doi:10.1016/j.jbi.2012.10.001

Ilott, I., Rick, J., Patterson, M., Turgoose, C., & Lacey, A. (2006). What is protocol-based care? A concept analysis. *Journal of Nursing Management*, *14*(7), 544–552.

doi:10.1111/j.1365-2934.2006.00703.x

Kacprzyk, J., & Wilbik, A. (2009). Towards an Efficient Generation of Linguistic Summaries of Time Series Using a Degree of Focus. In *Fuzzy Information Processing Society, 2009. NAFIPS 2009. Annual Meeting of the North American* (pp. 1–6). Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5156430

Kacprzyk, J., & Zadrozny, S. (2005). Linguistic database summaries and their protoforms: towards natural language based knowledge discovery tools. *Information Sciences*, *173*(4), 281–304. doi:10.1016/j.ins.2005.03.002

Kaymak, U., & Mans, R. (2012). On process mining in health care. In *Systems, Man, and Cybernetics (SMC), 2012 IEEE International Conference on* (pp. 1859–1864). Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6378009

Kaymak, U., Mans, R., Steeg, T. Van De, & Dierks, M. (2012). On process mining in health care. *2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 1859–1864. doi:10.1109/ICSMC.2012.6378009

Lips, R. (2015). *Linguistic summarization of clinical data - an analysis of theory and a proof of concept at the ICU (Unpublished Master's Thesis)*. Eindhoven University of Technology.

Mardia, K. V., Kent, J. T., & Bibby, J. M. (1979). *Multivariate analysis*. Academic press.

Rebuge, Á., & Ferreira, D. R. (2012). Business process analysis in healthcare environments: A methodology based on process mining. *Information Systems*, *37*(2), 99–116. doi:10.1016/j.is.2011.01.003

Van Leeuwen, H. (2003). *Concept richtlijn ontwenning van beademing. Protocollencommissie Nederlandse vereniging voor intensive care.*

Vanhaecht, K., Witte, K. De, & Sermeus, W. (2007). *The impact of clinical pathways on the organisation of care processes*. PhD dissertation KULeuven.

Wilbik, A., & Kacprzyk, J. (2010). On the evaluation of the linguistic summarization of temporally focused time series using a measure of informativeness, 155–162.

Wilbik, A., & Kaymak, U. (2015). Linguistic Summarization of Processes – a research agenda. In *International Joint Conference IFSA-EUSFLAT : 16th World Congress of the International Fuzzy Systems Association (IFSA) and 9th Conference of the European Society for Fuzzy Logic and Technology (EUSFLAT)* (pp. 1636–1643). Gijon, Spain: Atlantis Press. Retrieved from http://purl.tue.nl/570750991414371.pdf

Wilbik, A. M., & Dijkman, R. M. (2015). Linguistic summaries of process data. In *IEEE International Conference on Fuzzy Systems (IEEE-FUZZ 2015)*. Istanbul, Turkey.

Yager, R. R. (1982). A New Approach to the Summarization of Data. *Information Sciences*, *28*, 69–86.

Zadeh, L. (1983). A computational approach to fuzzy quantifiers in natural languages. *Computers & Mathematics with Applications*, *9*(I), 149–184.

Zadeh, L. a. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338–353. doi:10.1016/S0019-9958(65)90241-X

Zadeh, L. A. (2002). A prototype-centered approach to adding deduction capability to search engines-the concept of protoform. University of California, Berkeley: BISC Seminar,2002.

Zadrozny, S., & Kacprzyk, J. (2007). Summarizing the Contents of Web Server Logs: A Fuzzy Linguistic Approach. In *2007 IEEE International Fuzzy Systems Conference* (pp. 1–6). IEEE. doi:10.1109/FUZZY.2007.4295649

Appendix I Other data types of event logs

The following data types event logs are not considered during the case study in this project.

Vital signs

The most significant difference between clinical process and general organization process is that patients' characteristics and vital signs can lead to different decision making from specialists (Kaymak, Mans, Steeg, & Dierks, 2012). Therefore, the clinical process is incorporated with these medical signals, which should be considered as a part of event logs. Table 14 indicates all the vital signs in the event logs.

Table 14 Vital signs

Name	Description
HF	Heartbeat
Freq	The percentage of changes of respiratory rate (breath frequency)
O_2sat (O_2 saturation)	O_2 saturation in blood
Temp	Temperature of patient
PH	Blood PH
PCO_2	Blood PCO_2
PO_2	Blood PO2
FIO_2	Blood FIO_2
ASB	Pressure of ASB
PEEP	Positive end-expiratory pressure
P-ASB	PEEP minus ASB
GSC	Glasgow coma score, indicates the level of coma, the lower the score , the severer the coma

Medications

There are some medications that might be applied on patients during the weaning process. They are different from the medication mentioned in section 4.2.2.1, which are applied before the weaning process. The content of some medications in patients' blood is the criteria of weaning (e.g. $Dobu \leq 5$ in Note A in Figure 3). Therefore, they are included in the event logs. Table 15 indicates all the medications in the event logs.

Table 15 Medications

Name	Description
Prop	Propofol, a kind of anaesthetic
mid	Midazolam, for sedation
dobu	Dobutamine, to treat heart failure and cardiogenic shock
NOR	Noradrenaline
Desmo	Desmopressin acetate
Trans	Tranexamic acid

Appendix II Original results of summaries

The original 625 results of summaries are indicated in this section. There are selected as their truth value is above 0.7. Besides, if one summary describes the same content as the other one (i.e. with same quantifier and summarizer), in which the patient group is the sub-group of the other's, then we delete the summary for smaller dataset. For instance, if there is a summary says 'About 1/4 patients with COPD follow Patient record, Operation blood, in Pre-BIPAP Phase.', While another summary says 'About 1/4 patients follow Patient record, Operation blood, in Pre-BIPAP Phase.', then we delete the first sentence as it does not provide new information.

Phase level

Table 16 Original results for phase level summaries

No.	Summaries
1	A few patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
2	About 1/10 patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
3	Most patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.
4	A few patients follow Pre-BIPAP Phase, BIPAP Phase, Extubation Phase.
5	About 1/4 patients with COPD level 1 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
6	About 3/4 patients with COPD level 1 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.
7	About 1/10 patients with Liquid level 1 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
8	About 1/10 patients with Liquid level 1 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
9	About 1/10 patients with Liquid level 2 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
10	About 2/3 patients with Liquid level 2 follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.
11	About 1/5 patients with Liquid level 2 follow Pre-BIPAP Phase, BIPAP Phase, Extubation Phase.
12	About 1/5 patients with Medication support follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
13	A few female patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
14	About 1/10 female patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.
15	About 3/4 female patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.
16	Most patients with young age follow Pre-BIPAP Phase, BIPAP Phase, Extubation Phase.

Activity level--- clustering

Table 17 Original results for activity level clustering

No.	Summaries
1	Most patients likely follow Patient record, Operation blood, in Pre-BIPAP Phase.
2	About 1/5 patients likely follow Patient record, in Pre-BIPAP Phase.
3	About 1/3 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
4	About 1/4 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
5	About 1/10 patients likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
6	About 1/10 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
7	About 1/10 patients likely follow Bipap ventilation, Bipap check, in BIPAP Phase.
8	About 1/4 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
9	About 1/10 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
10	About 1/4 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.
11	About 1/5 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
12	About a half patients likely follow Extubation criteria, O2 probe, in Extubation Phase.
13	About a half patients likely follow Extubation criteria, Breathing stop, in Extubation Phase.
14	About 1/5 patients without COPD likely follow Bipap ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
15	About 1/5 patients without COPD likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
16	A few patients without COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
17	About 1/4 patients without COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
18	About 1/5 patients without COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
19	About 3/4 patients with COPD likely follow Patient record, Operation blood, in Pre-BIPAP Phase.

20	About a half patients with COPD likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
21	About 1/10 patients with COPD likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Decrease P-ASB, 30 min. deviation check, in BIPAP Phase.
22	About 1/5 patients with COPD likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
23	About 1/10 patients with COPD likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
24	About 1/5 patients with COPD likely follow CPAP/ASB ventilation, Continue P-ASB, Final blood, in ASB Phase.
25	About 1/10 patients with COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
26	About 1/5 patients with COPD likely follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
27	About 1/10 patients with COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
28	About 1/3 patients with COPD likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
29	About 1/4 patients with COPD level 1 likely follow Patient record, in Pre-BIPAP Phase.
30	About 3/4 patients with COPD level 1 likely follow Patient record, Operation blood, in Pre-BIPAP Phase.
31	About 1/5 patients with COPD level 1 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Decrease P-ASB, 30 min. deviation check, in BIPAP Phase.
32	About 1/5 patients with COPD level 1 likely follow Bipap ventilation, Bipap check, in BIPAP Phase.
33	About 1/3 patients with COPD level 1 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
34	About 1/3 patients with COPD level 1 likely follow CPAP/ASB ventilation, Continue P-ASB, Final blood, in ASB Phase.
35	About 1/5 patients with COPD level 1 likely follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
36	About 3/4 patients with COPD level 1 likely follow Extubation criteria, O2 probe, in Extubation Phase.
37	About 1/4 patients with COPD level 1 likely follow Extubation criteria, Breathing stop, in Extubation Phase.

38	About 1/4 patients with COPD level 2 likely follow Operation blood, Patient record, in Pre-BIPAP Phase.
39	About 3/4 patients with COPD level 2 likely follow Patient record, Operation blood, in Pre-BIPAP Phase.
40	About a half patients with COPD level 2 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
41	About 1/4 patients with COPD level 2 likely follow IPPV/autoflow ventilation, Bipap check, Temperature, Blood test, Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
42	About a half patients with COPD level 2 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
43	About 1/4 patients with COPD level 2 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
44	About 1/4 patients with COPD level 2 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
45	About 1/4 patients with COPD level 2 likely follow Extubation criteria, O2 probe, in Extubation Phase.
46	About 3/4 patients with COPD level 2 likely follow Extubation criteria, Breathing stop, in Extubation Phase.
47	About 1/10 patients with Liquid level 1 likely follow Patient record, in Pre-BIPAP Phase.
48	About 1/10 patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
49	About 1/10 patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, in BIPAP Phase.
50	About 1/5 patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, in BIPAP Phase.
51	About 1/3 patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
52	About 1/5 patients with Liquid level 1 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
53	About 1/10 patients with Liquid level 1 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
54	About 1/10 patients with Liquid level 1 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, CPAP ventilation, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
55	About 1/3 patients with Liquid level 1 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
56	About 1/3 patients with Liquid level 1 likely follow Setup ASB ventilation, CPAP/ASB

	ventilation, Check breathing frequency, in ASB Phase.
57	About 1/10 patients with Liquid level 1 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
58	About 1/10 patients with Liquid level 2 likely follow Patient record, in Pre-BIPAP Phase.
59	About 1/10 patients with Liquid level 2 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
60	About a half patients with Liquid level 2 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
61	About 1/10 patients with Liquid level 2 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
62	About 1/10 patients with Liquid level 2 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
63	About 1/10 patients with Liquid level 2 likely follow Bipap ventilation, Bipap check, in BIPAP Phase.
64	About 1/5 patients with Liquid level 2 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
65	About 1/10 patients with Liquid level 2 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
66	About 1/3 patients with Liquid level 2 likely follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, Continue P-ASB, in ASB Phase.
67	About 1/5 patients with Liquid level 3 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
68	A few patients with Liquid level 3 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Decrease P-ASB, 30 min. deviation check, in BIPAP Phase.
69	About 1/5 patients with Liquid level 3 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, in BIPAP Phase.
70	About 1/5 patients with Liquid level 3 likely follow Bipap ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
71	About 1/10 patients with Liquid level 3 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.

72	About 1/10 patients with Liquid level 3 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
73	A few patients with Liquid level 3 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, Decrease P-ASB, 30 min. deviation check, Decrease P-ASB, 30 min. deviation check, Decrease P-ASB, 30 min. deviation check, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
74	About a half patients with Liquid level 3 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
75	About 3/4 patients with Liquid level 3 likely follow Extubation criteria, Breathing stop, in Extubation Phase.
76	About 1/4 patients with Liquid level 3 likely follow Extubation criteria, O2 probe, in Extubation Phase.
77	About 1/4 patients with Liquid level 4 likely follow Patient record, in Pre-BIPAP Phase.
78	About 3/4 patients with Liquid level 4 likely follow Patient record, Operation blood, in Pre-BIPAP Phase.
79	About 1/3 patients with Liquid level 4 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
80	About 1/3 patients with Liquid level 4 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
81	About 1/4 patients with Liquid level 4 likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
82	About 1/10 patients with Liquid level 4 likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
83	About 1/10 patients with Liquid level 4 likely follow Setup ASB ventilation, CPAP ventilation, Check breathing frequency, CPAP/ASB ventilation, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
84	About 1/10 patients with Liquid level 4 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
85	About 1/3 patients with Liquid level 4 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
86	About 1/10 patients with Liquid level 4 likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, in ASB Phase.

87	About 1/5 patients without Medication support likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
88	About 1/3 patients without Medication support likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
89	About 1/5 patients without Medication support likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
90	About 1/5 patients without Medication support likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
91	About 1/5 patients without Medication support likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
92	About 1/5 patients without Medication support likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
93	About 1/10 patients without Medication support likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
94	About a half patients with Medication support likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
95	About 1/4 patients with Medication support likely follow Bipap ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
96	About 1/10 patients with Medication support likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
97	About 1/10 patients with Medication support likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
98	About a half patients with Medication support likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
99	About 3/4 female patients likely follow Patient record, Operation blood, in Pre-BIPAP Phase.
100	About 1/4 female patients likely follow Patient record, in Pre-BIPAP Phase.
101	About 1/5 female patients likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
102	About 1/5 female patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.

103	A few female patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
104	A few female patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
105	About 1/3 female patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
106	About 1/10 female patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
107	About 1/5 female patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
108	About 1/3 female patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.
109	About 3/4 female patients likely follow Extubation criteria, Breathing stop, in Extubation Phase.
110	About 1/3 female patients likely follow Extubation criteria, O2 probe, in Extubation Phase.
111	About 1/10 male patients likely follow Patient record, in Pre-BIPAP Phase.
112	About 1/5 male patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, in BIPAP Phase.
113	About 1/5 male patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
114	About 1/5 male patients likely follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, in BIPAP Phase.
115	About 1/5 male patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
116	About 1/3 male patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
117	About 1/5 male patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.
118	A few male patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
119	About 1/5 male patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.

120	About 1/3 patients with young age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
121	About 1/4 patients with young age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
122	About 1/10 patients with young age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
123	About 1/3 patients with young age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.
124	About 1/3 patients with young age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
125	A few patients with young age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
126	About 1/10 patients with young age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
127	About 1/4 patients with middle age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
128	About 1/10 patients with middle age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
129	About 1/4 patients with old age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
130	About 1/10 patients with old age likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
131	A few patients with old age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
132	About 1/4 patients with old age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
133	About 1/4 patients with old age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
134	About 1/5 patients with old age likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
135	About 1/3 patients with normal BMI likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.

136	About 1/4 patients with normal BMI likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
137	About 1/10 patients with normal BMI likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
138	About 1/5 patients with normal BMI likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
139	About 1/3 patients with obese BMI likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
140	About 1/5 patients with obese BMI likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
141	A few patients with obese BMI likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.

Activity level --- patterns

Table 18 Original results for activity level patterns

No.	Summaries
1	Most patients follow Patient record, Operation blood, in Pre-BIPAP Phase.
2	About 1/3 patients follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
3	About 1/3 patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.
4	About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
5	About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
6	About 1/5 patients follow Bipap ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
7	About 1/10 patients follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
8	A few patients follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
9	A few patients follow IPPV/autoflow ventilation, Bipap check, Temperature, in BIPAP Phase.

10	A few patients follow Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
11	A few patients follow Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
12	A few patients follow Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
13	A few patients follow CPAP/ASB ventilation, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
14	A few patients follow Check breathing frequency, CPAP/ASB ventilation, in ASB Phase.
15	A few patients follow Decrease P-ASB, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
16	A few patients follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
17	A few patients follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
18	A few patients follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
19	A few patients follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
20	A few patients follow Continue P-ASB, Final blood, in ASB Phase.
21	A few patients follow Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
22	A few patients follow Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
23	A few patients follow Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
24	A few patients follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
25	A few patients follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
26	A few patients follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
27	A few patients follow Blood test, CPAP ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
28	About 1/10 patients follow Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
29	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
30	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.

31	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
32	About 1/10 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
33	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, in ASB Phase.
34	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, in ASB Phase.
35	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
36	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Final blood, in ASB Phase.
37	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
38	About 1/10 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Final blood, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
39	About 1/5 patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
40	A few patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, Continue P-ASB, in ASB Phase.
41	A few patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
42	A few patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
43	About a half patients follow Extubation criteria, O2 probe, in Extubation Phase.
44	About a half patients follow Extubation criteria, Breathing stop, in Extubation Phase.
45	A few patients without COPD follow Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
46	A few patients without COPD follow Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
47	A few patients without COPD follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
48	About 1/5 patients without COPD follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
49	About 1/5 patients without COPD follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, in ASB Phase.

50	About 1/5 patients without COPD follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
51	About 1/5 patients without COPD follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
52	About 2/3 patients with COPD follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
53	About 1/3 patients with COPD follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, in BIPAP Phase.
54	About 1/4 patients with COPD follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
55	About 1/3 patients with COPD follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
56	About 1/4 patients with COPD follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, in ASB Phase.
57	About 1/4 patients with COPD follow Blood test, Decrease P-ASB, in ASB Phase.
58	About 1/3 patients with COPD follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
59	About 1/10 patients with COPD follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, in ASB Phase.
60	About 3/4 patients with COPD level 1 follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
61	About a half patients with COPD level 1 follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
62	About a half patients with COPD level 1 follow Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
63	About a half patients with COPD level 1 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, in ASB Phase.
64	About 1/4 patients with COPD level 1 follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, in ASB Phase.
65	About 3/4 patients with COPD level 1 follow Extubation criteria, O2 probe, in Extubation Phase.
66	About 3/4 patients with COPD level 2 follow Patient record, Operation blood, in Pre-BIPAP Phase.
67	About a half patients with COPD level 2 follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.

68	About a half patients with COPD level 2 follow Bipap check, Temperature, Blood test, in BIPAP Phase.
69	About a half patients with COPD level 2 follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
70	About 3/4 patients with COPD level 2 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
71	About 3/4 patients with COPD level 2 follow Extubation criteria, Breathing stop, in Extubation Phase.
72	About 1/4 patients with Liquid level 1 follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, in BIPAP Phase.
73	About a half patients with Liquid level 1 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
74	About 1/4 patients with Liquid level 1 follow Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
75	About 1/10 patients with Liquid level 1 follow Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
76	About 1/5 patients with Liquid level 1 follow Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
77	About 1/10 patients with Liquid level 1 follow Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
78	About 1/10 patients with Liquid level 1 follow Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
79	About 1/10 patients with Liquid level 1 follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
80	About 1/10 patients with Liquid level 1 follow Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
81	About 1/10 patients with Liquid level 1 follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
82	About 1/10 patients with Liquid level 1 follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
83	About a half patients with Liquid level 1 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
84	About 1/3 patients with Liquid level 1 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, in ASB Phase.
85	About 1/3 patients with Liquid level 1 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
86	About 1/3 patients with Liquid level 1 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
87	Most patients with Liquid level 2 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
88	About 1/5 patients with Liquid level 2 follow Bipap/ASB ventilation, Bipap check, in BIPAP

	Phase.
89	About 1/5 patients with Liquid level 2 follow CPAP/ASB ventilation, Continue P-ASB, in ASB Phase.
90	About 1/5 patients with Liquid level 2 follow Decrease P-ASB, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
91	About 1/5 patients with Liquid level 2 follow 30 min. deviation check, Blood test, in ASB Phase.
92	About 1/5 patients with Liquid level 2 follow Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
93	About a half patients with Liquid level 2 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, in ASB Phase.
94	About 1/3 patients with Liquid level 2 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, in ASB Phase.
95	About 1/10 patients with Liquid level 2 follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, Continue P-ASB, in ASB Phase.
96	About 1/5 patients with Liquid level 2 follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, in ASB Phase.
97	About a half patients with Liquid level 3 follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
98	About 1/5 patients with Liquid level 3 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.
99	About 1/3 patients with Liquid level 3 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
100	About 1/10 patients with Liquid level 3 follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
101	About 1/10 patients with Liquid level 3 follow Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
102	About 1/10 patients with Liquid level 3 follow Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
103	About 1/10 patients with Liquid level 3 follow Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
104	About 1/10 patients with Liquid level 3 follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
105	About 1/10 patients with Liquid level 3 follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
106	About 1/10 patients with Liquid level 3 follow Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
107	About 1/10 patients with Liquid level 3 follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.

108	About 1/10 patients with Liquid level 3 follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
109	About 1/10 patients with Liquid level 3 follow Final blood, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
110	About 1/10 patients with Liquid level 3 follow Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
111	About 1/4 patients with Liquid level 3 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
112	About 1/4 patients with Liquid level 3 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
113	About 1/4 patients with Liquid level 3 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
114	About 1/3 patients with Liquid level 3 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, in ASB Phase.
115	About 1/4 patients with Liquid level 3 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
116	About 1/4 patients with Liquid level 3 follow Extubation criteria, O2 probe, in Extubation Phase.
117	About 3/4 patients with Liquid level 3 follow Extubation criteria, Breathing stop, in Extubation Phase.
118	About 1/3 patients with Liquid level 4 follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
119	About 2/3 patients with Liquid level 4 follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
120	About 1/10 patients with Liquid level 4 follow Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
121	About 1/10 patients with Liquid level 4 follow CPAP/ASB ventilation, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
122	About 1/5 patients with Liquid level 4 follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
123	About 1/10 patients with Liquid level 4 follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
124	About 1/10 patients with Liquid level 4 follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
125	About 1/10 patients with Liquid level 4 follow Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.

126	About 1/10 patients with Liquid level 4 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, in ASB Phase.
127	About 1/10 patients with Liquid level 4 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, in ASB Phase.
128	About 1/5 patients with Liquid level 4 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, in ASB Phase.
129	About 1/10 patients with Liquid level 4 follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, in ASB Phase.
130	About 1/10 patients with Liquid level 4 follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
131	About 1/3 patients without Medication support follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
132	A few patients without Medication support follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
133	A few patients without Medication support follow Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
134	A few patients without Medication support follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
135	About a half patients with Medication support follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
136	About 1/3 patients with Medication support follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
137	About 1/3 patients with Medication support follow Bipap ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
138	About 1/3 patients with Medication support follow Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
139	About 1/3 patients with Medication support follow Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
140	About a half patients with Medication support follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
141	About 1/3 patients with Medication support follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
142	About 1/3 patients with Medication support follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
143	About a half patients with Medication support follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, in ASB Phase.

144	About a half patients with Medication support follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
145	About 1/3 female patients follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
146	About 1/5 female patients follow Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
147	About 1/10 female patients follow Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
148	About 1/10 female patients follow Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
149	About 1/10 female patients follow Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
150	About 1/10 female patients follow CPAP/ASB ventilation, Continue P-ASB, in ASB Phase.
151	About 1/10 female patients follow Decrease P-ASB, Continue P-ASB, in ASB Phase.
152	About 1/5 female patients follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
153	About 1/10 female patients follow Decrease P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
154	About 1/10 female patients follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
155	About 1/10 female patients follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
156	About 1/10 female patients follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
157	About 1/10 female patients follow Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
158	About 1/5 female patients follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
159	About 1/10 female patients follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, in ASB Phase.
160	About 1/10 female patients follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
161	About 1/10 female patients follow Blood test, CPAP ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
162	About 1/10 female patients follow Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
163	About 1/3 female patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
164	About 1/3 female patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, in ASB Phase.

165	About 1/4 female patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
166	About 1/5 female patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, in ASB Phase.
167	About 1/3 female patients follow Extubation criteria, O2 probe, in Extubation Phase.
168	About 3/4 female patients follow Extubation criteria, Breathing stop, in Extubation Phase.
169	About 1/5 male patients follow Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
170	About 1/10 male patients follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
171	A few male patients follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
172	A few male patients follow Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
173	A few male patients follow Continue P-ASB, 30 min. deviation check, Final blood, Continue P-ASB, 30 min. deviation check, in ASB Phase.
174	A few male patients follow Continue P-ASB, Blood test, Continue P-ASB, in ASB Phase.
175	About 1/10 male patients follow 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
176	A few male patients follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
177	A few male patients follow Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
178	About 1/5 male patients follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
179	About 1/10 male patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
180	Most patients with young age follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.
181	Most patients with young age follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.
182	Most patients with young age follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
183	Most patients with young age follow Extubation criteria, Breathing stop, in Extubation Phase.
184	A few patients with middle age follow Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
185	A few patients with middle age follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB

	Phase.
186	A few patients with middle age follow Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
187	About 1/5 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
188	About 1/10 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, Blood test, in ASB Phase.
189	About 1/10 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
190	About 1/10 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, in ASB Phase.
191	About 1/10 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
192	About 1/5 patients with middle age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
193	About 3/4 patients with old age follow Patient record, Operation blood, in Pre-BIPAP Phase.
194	About 1/4 patients with old age follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
195	About 1/5 patients with old age follow Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
196	About 1/5 patients with old age follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
197	About 1/10 patients with old age follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
198	About 1/10 patients with old age follow IPPV/autoflow ventilation, Bipap check, Temperature, in BIPAP Phase.
199	About 1/10 patients with old age follow Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
200	About 1/10 patients with old age follow Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
201	About 1/10 patients with old age follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
202	About 1/10 patients with old age follow Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.

203	About 1/10 patients with old age follow Blood test, CPAP ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.
204	About 1/4 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
205	About 1/4 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, Blood test, in ASB Phase.
206	About 1/5 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Decrease P-ASB, Continue P-ASB, Blood test, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
207	About 1/4 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
208	About 1/5 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, in ASB Phase.
209	About 1/5 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
210	About 1/4 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
211	About 1/5 patients with old age follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Final blood, Decrease P-ASB, 30 min. deviation check, in ASB Phase.
212	About 3/4 patients with normal BMI follow Patient record, Operation blood, in Pre-BIPAP Phase.
213	About a half patients with normal BMI follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
214	About 1/10 patients with normal BMI follow Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
215	About 1/10 patients with normal BMI follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
216	About 1/10 patients with normal BMI follow Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
217	About 1/10 patients with normal BMI follow Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, in BIPAP Phase.
218	A few patients with normal BMI follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
219	A few patients with normal BMI follow 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, in ASB Phase.
220	About 1/10 patients with normal BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, Blood test, in ASB Phase.

221	About 1/10 patients with normal BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
222	About 1/5 patients with normal BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
223	About 1/5 patients with obese BMI follow Bipap ventilation, Bipap check, Temperature, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
224	About 1/5 patients with obese BMI follow Bipap ventilation, Bipap check, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.
225	A few patients with obese BMI follow Bipap/ASB ventilation, Bipap check, Bipap ventilation, Bipap check, in BIPAP Phase.
226	A few patients with obese BMI follow Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, Blood test, in BIPAP Phase.
227	A few patients with obese BMI follow Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, Blood test, Bipap check, in BIPAP Phase.
228	A few patients with obese BMI follow Check breathing frequency, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
229	About 1/10 patients with obese BMI follow Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
230	About 1/10 patients with obese BMI follow Decrease P-ASB, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, in ASB Phase.
231	About 1/10 patients with obese BMI follow 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.
232	About 1/5 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Decrease P-ASB, 30 min. deviation check, Blood test, in ASB Phase.
233	About 1/5 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, 30 min. deviation check, in ASB Phase.
234	About 1/10 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Decrease P-ASB, in ASB Phase.
235	About 1/10 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Continue P-ASB, Blood test, Continue P-ASB, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
236	About 1/10 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, 30 min. deviation check, Blood test, Continue P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, in ASB Phase.
237	About 1/10 patients with obese BMI follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, Blood test, Decrease P-ASB, 30 min. deviation check, Continue P-ASB, 30 min. deviation check, Final blood, in ASB Phase.

Cost comparison --- two phases

Table 19 Original results for cost comparison between two phases

No.	Summaries
1	For Most cases, the cost of Pre-BIPAP phase is lower than the cost of BIPAP phase in weaning protocol
2	For A few cases, the cost of Pre-BIPAP phase is same as the cost of ASB phase in weaning protocol
3	For Most cases, the cost of Pre-BIPAP phase is lower than the cost of ASB phase in weaning protocol
4	For About 1/10 cases, the cost of Pre-BIPAP phase is same as the cost of Extubation phase in weaning protocol
5	For About a half cases, the cost of Pre-BIPAP phase is higher than the cost of Extubation phase in weaning protocol
6	For About 1/3 cases, the cost of Pre-BIPAP phase is lower than the cost of Extubation phase in weaning protocol
7	For A few cases, the cost of BIPAP phase is same as the cost of ASB phase in weaning protocol
8	For About 2/3 cases, the cost of BIPAP phase is higher than the cost of ASB phase in weaning protocol
9	For About 1/3 cases, the cost of BIPAP phase is lower than the cost of ASB phase in weaning protocol
10	For Most cases, the cost of BIPAP phase is higher than the cost of Extubation phase in weaning protocol
11	For Most cases, the cost of ASB phase is higher than the cost of Extubation phase in weaning protocol

Cost comparison --- between two patient groups

Table 20 Original results for cost comparison between two patient groups

No.	Summaries
1	For About a half cases, the cost of patients with COPD is same as the cost of patients without COPD in Pre-BIPAP phase
2	For About 1/5 cases, the cost of patients with COPD is higher than the cost of patients without COPD in Pre-BIPAP phase
3	For About 1/3 cases, the cost of patients with COPD is lower than the cost of patients without COPD in Pre-BIPAP phase
4	For About a half cases, the cost of patients with COPD level 1 is same as the cost of patients with COPD level 2 in Pre-BIPAP phase
5	For About a half cases, the cost of patients with COPD level 1 is lower than the cost of patients with COPD level 2 in Pre-BIPAP phase
6	For About 2/3 cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 2 in Pre-BIPAP phase

7	For About 1/5 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 2 in Pre-BIPAP phase
8	For About 1/5 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 2 in Pre-BIPAP phase
9	For About 1/5 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 3 in Pre-BIPAP phase
10	For About a half cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 4 in Pre-BIPAP phase
11	For About 1/3 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 4 in Pre-BIPAP phase
12	For About 1/4 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 4 in Pre-BIPAP phase
13	For About 1/4 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 3 in Pre-BIPAP phase
14	For About 1/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 3 in Pre-BIPAP phase
15	For About a half cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 4 in Pre-BIPAP phase
16	For About 1/3 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 4 in Pre-BIPAP phase
17	For About 1/5 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 4 in Pre-BIPAP phase
18	For About 1/3 cases, the cost of patients with Liquid level 3 is same as the cost of patients with Liquid level 4 in Pre-BIPAP phase
19	For About 1/4 cases, the cost of patients with Liquid level 3 is lower than the cost of patients with Liquid level 4 in Pre-BIPAP phase
20	For About 1/5 cases, the cost of patients with Medication support is same as the cost of patients without Medication support in Pre-BIPAP phase
21	For About 3/4 cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in Pre-BIPAP phase
22	For About a half cases, the cost of patients female is same as the cost of patients male in Pre-BIPAP phase
23	For About 1/3 cases, the cost of patients female is higher than the cost of patients male in Pre-BIPAP phase
24	For About 1/4 cases, the cost of patients female is lower than the cost of patients male in Pre-BIPAP phase
25	For About 1/3 cases, the cost of patients with young age is same as the cost of patients with middle age in Pre-BIPAP phase
26	For Most cases, the cost of patients with young age is lower than the cost of patients with middle age in Pre-BIPAP phase
27	For About a half cases, the cost of patients with young age is same as the cost of patients with old age in Pre-BIPAP phase
28	For Most cases, the cost of patients with young age is lower than the cost of patients with old age in Pre-BIPAP phase

29	For About a half cases, the cost of patients with middle age is same as the cost of patients with old age in Pre-BIPAP phase
30	For About 1/3 cases, the cost of patients with middle age is higher than the cost of patients with old age in Pre-BIPAP phase
31	For About 1/4 cases, the cost of patients with middle age is lower than the cost of patients with old age in Pre-BIPAP phase
32	For Most cases, the cost of patients with middle age is higher than the cost of patients with young age in Pre-BIPAP phase
33	For About 1/5 cases, the cost of patients with old age is same as the cost of patients with young age in Pre-BIPAP phase
34	For About 3/4 cases, the cost of patients with old age is higher than the cost of patients with young age in Pre-BIPAP phase
35	For About 3/4 cases, the cost of patients with old age is same as the cost of patients with middle age in Pre-BIPAP phase
36	For About a half cases, the cost of patients with old age is higher than the cost of patients with middle age in Pre-BIPAP phase
37	For About a half cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in Pre-BIPAP phase
38	For About 1/3 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in Pre-BIPAP phase
39	For About 1/4 cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in Pre-BIPAP phase
40	For About a half cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in Pre-BIPAP phase
41	For About 1/3 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in Pre-BIPAP phase
42	For About 1/4 cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in Pre-BIPAP phase
43	For A few cases, the cost of patients with COPD is same as the cost of patients without COPD in BIPAP phase
44	For About 2/3 cases, the cost of patients with COPD is higher than the cost of patients without COPD in BIPAP phase
45	For About 1/3 cases, the cost of patients with COPD is lower than the cost of patients without COPD in BIPAP phase
46	For A few cases, the cost of patients with COPD level 1 is same as the cost of patients with COPD level 2 in BIPAP phase
47	For Most cases, the cost of patients with COPD level 1 is higher than the cost of patients with COPD level 2 in BIPAP phase
48	For A few cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 2 in BIPAP phase
49	For About 1/3 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 2 in BIPAP phase
50	For A few cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 3 in BIPAP phase

51	For About 1/4 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 3 in BIPAP phase
52	For About 3/4 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 3 in BIPAP phase
53	For A few cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 4 in BIPAP phase
54	For About 1/5 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 4 in BIPAP phase
55	For About 3/4 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 4 in BIPAP phase
56	For A few cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 3 in BIPAP phase
57	For About 1/3 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 3 in BIPAP phase
58	For About 2/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 3 in BIPAP phase
59	For A few cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 4 in BIPAP phase
60	For About 1/3 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 4 in BIPAP phase
61	For About 2/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 4 in BIPAP phase
62	For A few cases, the cost of patients with Liquid level 3 is same as the cost of patients with Liquid level 4 in BIPAP phase
63	For About a half cases, the cost of patients with Liquid level 3 is higher than the cost of patients with Liquid level 4 in BIPAP phase
64	For About a half cases, the cost of patients with Liquid level 3 is lower than the cost of patients with Liquid level 4 in BIPAP phase
65	For Most cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in BIPAP phase
66	For About 1/10 cases, the cost of patients with Medication support is lower than the cost of patients without Medication support in BIPAP phase
67	For A few cases, the cost of patients female is same as the cost of patients male in BIPAP phase
68	For About 1/3 cases, the cost of patients female is higher than the cost of patients male in BIPAP phase
69	For About 1/5 cases, the cost of patients with young age is higher than the cost of patients with middle age in BIPAP phase
70	For Most cases, the cost of patients with young age is lower than the cost of patients with middle age in BIPAP phase
71	For About 1/4 cases, the cost of patients with young age is same as the cost of patients with old age in BIPAP phase
72	For About 1/10 cases, the cost of patients with young age is higher than the cost of patients with old age in BIPAP phase

73	For Most cases, the cost of patients with young age is lower than the cost of patients with old age in BIPAP phase
74	For A few cases, the cost of patients with middle age is same as the cost of patients with old age in BIPAP phase
75	For About 2/3 cases, the cost of patients with middle age is lower than the cost of patients with old age in BIPAP phase
76	For Most cases, the cost of patients with middle age is higher than the cost of patients with young age in BIPAP phase
77	For About 1/10 cases, the cost of patients with middle age is lower than the cost of patients with young age in BIPAP phase
78	For About 1/10 cases, the cost of patients with old age is same as the cost of patients with young age in BIPAP phase
79	For Most cases, the cost of patients with old age is higher than the cost of patients with young age in BIPAP phase
80	For A few cases, the cost of patients with old age is lower than the cost of patients with young age in BIPAP phase
81	For About 1/10 cases, the cost of patients with old age is same as the cost of patients with middle age in BIPAP phase
82	For Most cases, the cost of patients with old age is higher than the cost of patients with middle age in BIPAP phase
83	For About 2/3 cases, the cost of patients with old age is lower than the cost of patients with middle age in BIPAP phase
84	For About 1/10 cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in BIPAP phase
85	For About 2/3 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in BIPAP phase
86	For About a half cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in BIPAP phase
87	For About 1/10 cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in BIPAP phase
88	For About 2/3 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in BIPAP phase
89	For About a half cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in BIPAP phase
90	For A few cases, the cost of patients with COPD is same as the cost of patients without COPD in ASB phase
91	For About a half cases, the cost of patients with COPD is higher than the cost of patients without COPD in ASB phase
92	For About a half cases, the cost of patients with COPD is lower than the cost of patients without COPD in ASB phase
93	For About 1/10 cases, the cost of patients with COPD level 1 is same as the cost of patients with COPD level 2 in ASB phase
94	For About 2/3 cases, the cost of patients with COPD level 1 is higher than the cost of patients with COPD level 2 in ASB phase

95	For About 1/4 cases, the cost of patients with COPD level 1 is lower than the cost of patients with COPD level 2 in ASB phase
96	For A few cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 2 in ASB phase
97	For About a half cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 2 in ASB phase
98	For About 1/10 cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 3 in ASB phase
99	For About a half cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 3 in ASB phase
100	For About a half cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 3 in ASB phase
101	For About 1/10 cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 4 in ASB phase
102	For About 1/3 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 4 in ASB phase
103	For About 2/3 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 4 in ASB phase
104	For About 1/10 cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 3 in ASB phase
105	For About a half cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 3 in ASB phase
106	For A few cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 4 in ASB phase
107	For About 1/3 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 4 in ASB phase
108	For About 2/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 4 in ASB phase
109	For About 1/10 cases, the cost of patients with Liquid level 3 is same as the cost of patients with Liquid level 4 in ASB phase
110	For About 1/3 cases, the cost of patients with Liquid level 3 is higher than the cost of patients with Liquid level 4 in ASB phase
111	For About 1/10 cases, the cost of patients with Medication support is same as the cost of patients without Medication support in ASB phase
112	For About a half cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in ASB phase
113	For About 1/3 cases, the cost of patients with Medication support is lower than the cost of patients without Medication support in ASB phase
114	For A few cases, the cost of patients female is same as the cost of patients male in ASB phase
115	For About a half cases, the cost of patients female is higher than the cost of patients male in ASB phase
116	For About a half cases, the cost of patients female is lower than the cost of patients male in ASB phase

117	For A few cases, the cost of patients with young age is same as the cost of patients with middle age in ASB phase
118	For Most cases, the cost of patients with young age is lower than the cost of patients with middle age in ASB phase
119	For About 1/4 cases, the cost of patients with young age is same as the cost of patients with old age in ASB phase
120	For Most cases, the cost of patients with young age is lower than the cost of patients with old age in ASB phase
121	For About 1/10 cases, the cost of patients with middle age is same as the cost of patients with old age in ASB phase
122	For About a half cases, the cost of patients with middle age is higher than the cost of patients with old age in ASB phase
123	For About a half cases, the cost of patients with middle age is lower than the cost of patients with old age in ASB phase
124	For Most cases, the cost of patients with middle age is higher than the cost of patients with young age in ASB phase
125	For About 1/10 cases, the cost of patients with old age is same as the cost of patients with young age in ASB phase
126	For Most cases, the cost of patients with old age is higher than the cost of patients with young age in ASB phase
127	For About 1/5 cases, the cost of patients with old age is same as the cost of patients with middle age in ASB phase
128	For About 3/4 cases, the cost of patients with old age is higher than the cost of patients with middle age in ASB phase
129	For About 3/4 cases, the cost of patients with old age is lower than the cost of patients with middle age in ASB phase
130	For About 1/10 cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in ASB phase
131	For About a half cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in ASB phase
132	For About a half cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in ASB phase
133	For About 1/10 cases, the cost of patients with normal BMI is same as the cost of patients with obese BMI in ASB phase
134	For About a half cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in ASB phase
135	For About a half cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in ASB phase
136	For About a half cases, the cost of patients with COPD is same as the cost of patients without COPD in Extubation phase
137	For About 1/3 cases, the cost of patients with COPD is higher than the cost of patients without COPD in Extubation phase
138	For About 1/5 cases, the cost of patients with COPD is lower than the cost of patients without COPD in Extubation phase

139	For About 1/3 cases, the cost of patients with COPD level 1 is same as the cost of patients with COPD level 2 in Extubation phase
140	For About a half cases, the cost of patients with COPD level 1 is higher than the cost of patients with COPD level 2 in Extubation phase
141	For About 1/10 cases, the cost of patients with COPD level 1 is lower than the cost of patients with COPD level 2 in Extubation phase
142	For About a half cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 2 in Extubation phase
143	For About 1/5 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 2 in Extubation phase
144	For About 1/4 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 2 in Extubation phase
145	For About a half cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 3 in Extubation phase
146	For About 1/3 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 3 in Extubation phase
147	For About a half cases, the cost of patients with Liquid level 1 is same as the cost of patients with Liquid level 4 in Extubation phase
148	For About 1/5 cases, the cost of patients with Liquid level 1 is higher than the cost of patients with Liquid level 4 in Extubation phase
149	For About 1/3 cases, the cost of patients with Liquid level 1 is lower than the cost of patients with Liquid level 4 in Extubation phase
150	For About a half cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 3 in Extubation phase
151	For About 1/3 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 3 in Extubation phase
152	For About 1/10 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 3 in Extubation phase
153	For About a half cases, the cost of patients with Liquid level 2 is same as the cost of patients with Liquid level 4 in Extubation phase
154	For About 1/5 cases, the cost of patients with Liquid level 2 is higher than the cost of patients with Liquid level 4 in Extubation phase
155	For About 1/3 cases, the cost of patients with Liquid level 2 is lower than the cost of patients with Liquid level 4 in Extubation phase
156	For About a half cases, the cost of patients with Liquid level 3 is same as the cost of patients with Liquid level 4 in Extubation phase
157	For About 1/10 cases, the cost of patients with Liquid level 3 is higher than the cost of patients with Liquid level 4 in Extubation phase
158	For About a half cases, the cost of patients with Liquid level 3 is lower than the cost of patients with Liquid level 4 in Extubation phase
159	For About a half cases, the cost of patients with Medication support is same as the cost of patients without Medication support in Extubation phase
160	For About 1/3 cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in Extubation phase

161	For About 1/5 cases, the cost of patients with Medication support is lower than the cost of patients without Medication support in Extubation phase
162	For About a half cases, the cost of patients female is same as the cost of patients male in Extubation phase
163	For About 1/3 cases, the cost of patients female is higher than the cost of patients male in Extubation phase
164	For Most cases, the cost of patients with young age is same as the cost of patients with middle age in Extubation phase
165	For Most cases, the cost of patients with young age is lower than the cost of patients with middle age in Extubation phase
166	For Most cases, the cost of patients with young age is same as the cost of patients with old age in Extubation phase
167	For Most cases, the cost of patients with young age is lower than the cost of patients with old age in Extubation phase
168	For About a half cases, the cost of patients with middle age is same as the cost of patients with old age in Extubation phase
169	For About 1/4 cases, the cost of patients with middle age is higher than the cost of patients with old age in Extubation phase
170	For About 1/4 cases, the cost of patients with middle age is lower than the cost of patients with old age in Extubation phase
171	For About a half cases, the cost of patients with middle age is same as the cost of patients with young age in Extubation phase
172	For About a half cases, the cost of patients with middle age is higher than the cost of patients with young age in Extubation phase
173	For About a half cases, the cost of patients with old age is same as the cost of patients with young age in Extubation phase
174	For About a half cases, the cost of patients with old age is higher than the cost of patients with young age in Extubation phase
175	For Most cases, the cost of patients with old age is same as the cost of patients with middle age in Extubation phase
176	For About a half cases, the cost of patients with old age is lower than the cost of patients with middle age in Extubation phase
177	For About 1/4 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in Extubation phase
178	For About 1/3 cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in Extubation phase
179	For About 1/4 cases, the cost of patients with normal BMI is higher than the cost of patients with obese BMI in Extubation phase
180	For About 1/3 cases, the cost of patients with normal BMI is lower than the cost of patients with obese BMI in Extubation phase

Time comparison --- between two patient groups

Table 21 Original results for time comparison between two patient groups

No.	Summaries
1	For About 1/3 cases, patients with COPD spend more time than patients without COPD in weaning protocol
2	For About a half cases, patients with COPD spend less time than patients without COPD in weaning protocol
3	For About 1/10 cases, patients with COPD level 1 spend same time as patients with COPD level 2 in weaning protocol
4	For Most cases, patients with COPD level 1 spend more time than patients with COPD level 2 in weaning protocol
5	For A few cases, patients with COPD level 1 spend less time than patients with COPD level 2 in weaning protocol
6	For About 1/5 cases, patients with Liquid level 1 spend same time as patients with Liquid level 2 in weaning protocol
7	For About 1/5 cases, patients with Liquid level 1 spend more time than patients with Liquid level 2 in weaning protocol
8	For About 2/3 cases, patients with Liquid level 1 spend less time than patients with Liquid level 2 in weaning protocol
9	For About 1/4 cases, patients with Liquid level 1 spend more time than patients with Liquid level 3 in weaning protocol
10	For About a half cases, patients with Liquid level 1 spend less time than patients with Liquid level 3 in weaning protocol
11	For About 1/10 cases, patients with Liquid level 1 spend same time as patients with Liquid level 4 in weaning protocol
12	For About 1/10 cases, patients with Liquid level 1 spend more time than patients with Liquid level 4 in weaning protocol
13	For About 3/4 cases, patients with Liquid level 1 spend less time than patients with Liquid level 4 in weaning protocol
14	For About a half cases, patients with Liquid level 2 spend more time than patients with Liquid level 3 in weaning protocol
15	For About 1/3 cases, patients with Liquid level 2 spend less time than patients with Liquid level 3 in weaning protocol
16	For About 1/5 cases, patients with Liquid level 2 spend same time as patients with Liquid level 4 in weaning protocol
17	For About 1/3 cases, patients with Liquid level 2 spend more time than patients with Liquid level 4 in weaning protocol
18	For About a half cases, patients with Liquid level 2 spend less time than patients with Liquid level 4 in weaning protocol
19	For About 1/10 cases, patients with Liquid level 3 spend same time as patients with Liquid level 4 in weaning protocol
20	For About 1/3 cases, patients with Liquid level 3 spend more time than patients with Liquid level 4 in weaning protocol

21	For About a half cases, patients with Liquid level 3 spend less time than patients with Liquid level 4 in weaning protocol
22	For About 1/10 cases, patients with Medication support spend same time as patients without Medication support in weaning protocol
23	For About 1/4 cases, patients with Medication support spend less time than patients without Medication support in weaning protocol
24	For About 1/10 cases, patients with young age spend same time as patients with middle age in weaning protocol
25	For Most cases, patients with young age spend less time than patients with middle age in weaning protocol
26	For About 1/10 cases, patients with young age spend same time as patients with old age in weaning protocol
27	For Most cases, patients with young age spend less time than patients with old age in weaning protocol
28	For About 1/5 cases, patients with middle age spend same time as patients with old age in weaning protocol
29	For About a half cases, patients with middle age spend less time than patients with old age in weaning protocol
30	For A few cases, patients with middle age spend same time as patients with young age in weaning protocol
31	For Most cases, patients with middle age spend more time than patients with young age in weaning protocol
32	For A few cases, patients with old age spend same time as patients with young age in weaning protocol
33	For Most cases, patients with old age spend more time than patients with young age in weaning protocol
34	For About 1/3 cases, patients with old age spend same time as patients with middle age in weaning protocol
35	For About 3/4 cases, patients with old age spend more time than patients with middle age in weaning protocol
36	For About 2/3 cases, patients with old age spend less time than patients with middle age in weaning protocol
37	For About 1/5 cases, patients with normal BMI spend same time as patients with obese BMI in weaning protocol
38	For About a half cases, patients with normal BMI spend more time than patients with obese BMI in weaning protocol
39	For About 1/5 cases, patients with normal BMI spend same time as patients with obese BMI in weaning protocol
40	For About a half cases, patients with normal BMI spend more time than patients with obese BMI in weaning protocol

Appendix III Feedback from specialists

The feedback session was conducted on October 12th, 2015 in MUMC. The specialists are one doctor and one nurse, There are totally 11 summaries shown to the specialists. For each category of protoforms, two sentences are presented, except the protoform for comparing the cost between 2 phases (only one sentence is shown). For each summary, we asked specialists whether the sentence is:

- understandable
- relevant (useful)
- interesting

According to the feedback session, all sentences are understandable, though some explanations of activities need to be recall. The following is the detail of the feedback, along with the sentences.

Phase level

The most common sequence in phase level is shown to doctors, which is:

1-3: Most patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, Extubation Phase.

Specialists said it provides a useful information that most patient were following the protocol without any iterations.

An deviation sequence in phase level is also presented:

1-2: About 1/10 patients follow Pre-BIPAP Phase, BIPAP Phase, ASB Phase, BIPAP Phase, ASB Phase, Extubation Phase.

Specialists think it is an interesting summary. It shows there are the cases that iterations happened between BIPAP and ASB phases.

Activity level clustering

There are two clustering results shown to the doctors:

2-2: About 1/3 patients likely follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, in BIPAP Phase.

2-8: About 1/4 patients likely follow Setup ASB ventilation, CPAP/ASB ventilation, Check breathing frequency, in ASB Phase.

I skip it as it is an overview of activity level but the accuracy of the sentences is not as high as the pattern result.

Activity level patterns

Two summaries are picked as they shows the transition of ventilation type in a specific phase.

3-3: About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.

3-17: A few patients follow Setup ASB ventilation, ASB ventilation, Check breathing frequency, 30 min. deviation check, CPAP/ASB ventilation, Continue P-ASB, 30 min. deviation check, in ASB Phase.

Doctor said these sentences are interesting because they indicate the iteration within one phase. They are also interested to know how many times the iteration (e.g. the iteration between blood test and bipap check) happens within one phase. Besides, they would like to know what the process that other patients followed in the same phase (which actually indicated in the full version of results).

Costs comparison

Three sentences about costs comparison are shown to the doctors:

4-4: For about 2/3 cases, the cost of BIPAP phase is higher than the cost of ASB phase in weaning protocol.

5-3: For most cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in BIPAP phase.

5-7: For about a half cases, the cost of patients with Medication support is higher than the cost of patients without Medication support in ASB phase.

Thought they are from two different protoforms, regards to the doctors feedback, they are not interested in the costs of weaning protocol. Therefore, these sentences are understandable but not useful.

They think if the costs is dramatically changed during the change or improvement of processes (e.g., the reducing the laboratory test or the reducing the duration of stay), the information would be useful. However, for the weaning protocol (or for the MUMC+), this is not the case they are concerned.

Meanwhile the doctors mentioned that the cost comparison might be interesting for our study.

Time comparison

Two sentences are presented to the doctors:

6-1: For about 1/3 cases, patients with COPD spend more time than patients without COPD in weaning protocol.

6-2: For about a half cases, patients with COPD spend less time than patients without COPD in weaning protocol.

Doctors think they are interesting information to study. The results can used to check whether the practice follows the rule they settled (they mentions that they put more effort on earlier discharging the patient with COPD, and the summary convince it.)

Question from the interviewer

Whether we should simplify the sentences for the activity level by pre-defining the key activities?

For instance, to simplify the sentence:

About a half patients follow Bipap ventilation, Bipap check, Temperature, Blood test, Bipap check, Blood test, Bipap check, Blood test, Bipap check, Bipap/ASB ventilation, Bipap check, in BIPAP Phase.

by pre-defining the key activities (highlight in red), to make the sentence shorter and more readable.

About a half patients follow Bipap ventilation, Temperature, Bipap/ASB ventilation, in BIPAP Phase.

In doctor's opinion:

- The original sentences is readable.
- Some value information are lost after simplifying.
- If the iteration in each phase is always the same (e.g. blood test is always followed by bipap check) then the simplify can be processed.

In nurse's opinion:

- He prefer the simplify sentence as it is more obvious.

Other feedbacks

1. In nurse's opinion, he was more concerned of the patient group of following characteristics :
- COPD
- Liquid level
- Age
- BMI

while the medication implementation and gender are less interesting for the nurse.

2. For the quantifiers, the specific label (e.g. about 1/3) is better than the abstract label (e.g. more, a few).
3. The numbers of the summaries (57 sentences) is reasonable, but it can be less if possible.
4. Currently, there is no more other content of summaries the specialists are interested in.