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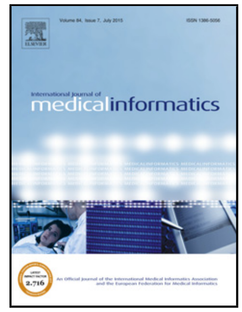

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Obstructive sleep apnoea: improving healthcare services by combining process modelling and population analysis

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Obstructive sleep apnoea: improving healthcare services by combining process modelling and population analysis

Highlights

- Graphical representing healthcare process allows to build an understandable model.
- Population analysis highlights key factors for identification and management of OSA.
- Graphical modelling and population analysis help improving healthcare services.
- The adoption of UML® allows to formalise patient care processes through a standard language useful to develop an ICT system to support the execution of the modelled processes.

ABSTRACT

Context – Disease management broke through in the early 1990s to counterbalance hyper-specialization with a more comprehensive approach. Its role became immediately relevant in chronic conditions and, consequently, in Obstructive Sleep Apnoea (OSA). This is a common chronic condition for which is important to organise services at the local level, taking into account organisational factors and the characteristics of the assisted population.

Objectives - The aim of this work is to propose and apply, coherently with a disease management approach, a combination of healthcare process modelling and population analysis as a way to identify critical issues and explore shared solutions.

Methods – A multidisciplinary working group was created with scholars who are skilled in process analysis, statistics and medicine. Through semi-structured interviews and on-site meetings, healthcare processes were represented with a standard graphical language: *Unified Modeling Language*^{TM}. Population analysis was based on statistical analysis performed on a 5-year retrospective cohort assisted by a Community Pulmonary Service.

Results – A shared graphic presentation of the current healthcare process and the results of the statistical analyses constituted the knowledge base to identify critical issues and recommend corresponding solutions, which include: a) refine the local patient database with additional details on comorbidities and risk factors; b) support a greater involvement of "gate-keepers" in the screening phase; c) provide practical tools for the definition of strategies to increment the adherence to therapy; d) include recommendations for physical exercise and interdisciplinary cooperation; and e) define process indicators for measuring the quality of the screening and therapeutic phases.

Conclusion – The concomitant analyses of formalised processes and critical risk factors represent a useful approach for systematically identifying areas of improvement in healthcare processes and allow us to discuss solutions. Moreover, the specific adoption of UML® for graphical modelling and representation of patient care processes allows us to formalise them by adopting a standard language that can be taken as the basis for implementing web services to support the execution of the modelled processes.

KEY WORDS

Sleep Apnea, Obstructive; Disease management; Healthcare process assessment; Process modelling; Predictive model

ABBREVIATIONS

AHI – Apnea Hypopnea Index

ASL-BR – Local Health Unit of Brindisi (Italy)

BMI - Body Mass Index

BQ - Berlin Questionnaire

CCA - Care Continuum Alliance

CNR - National Research Council

CPAP - Continuous positive airway pressure

COPD - Chronic obstructive pulmonary disease

DM – Disease Management

ESADA - European Sleep Apnoea Database

ESS - (Epworth Sleepiness Scale)

OR - Odds Ratio

OSA - Obstructive sleep apnoea

PCP - Primary Care Provider

ROC - Receiver Operating Characteristics

UML® - Unified Modeling Language™

1 Introduction

Disease management (DM) broke through in early 1990s to counterbalance the hyper-specialization of physiological disciplines with a more comprehensive, integrated, and systematic, patient-centred approach [1]. Collaborative models, evidence-based practices, population identification processes, and healthcare process evaluation and management are recognized as key components for DM [2].

This approach is particularly relevant in chronic conditions that require ongoing management of treatments and problems, such as residual symptoms, deficits, and co-morbidities and where the active role of patients is crucial, which is the case of Obstructive Sleep Apnoea (OSA), as specifically acknowledged in the dedicated guideline issued by the American Academy of Sleep Medicine [3].

OSA is a common chronic condition characterized by recurrent episodes of partial (hypopnoea) and complete (apnoea) airway obstructions during sleep, repetitive episodes of intermittent hypoxemia, intrathoracic pressure changes, arousals, and excessive daytime sleepiness [4,5]. Prevalence of Apnea Hypopnea Index (AHI) ≥ 5 events/h ranges between 9% and 38% and is higher in men [6]. OSA is associated with comorbidities: cardiovascular disease [7], metabolic syndrome [8], type 2 diabetes mellitus [9], obstructive lung diseases [10], and mood disorders [11]. Moreover, OSA is associated with deficits in the areas of psychomotor speed and executive function, and, even if at a lesser extent, in memory functions, motor control, construction, attention, and speed of processing abilities, with a resulting increase in injury rate and productivity loss [12,13]. Therefore, OSA is an important public health issue with implications for society and the healthcare system [14,15].

Several factors are known to increase the risk of OSA: male gender, increasing age, craniofacial and upper airway abnormalities, increases in Body Mass Index (BMI), and having a large neck [16].

In addition to the internationally recognized guidelines for assisting practitioners and patients on appropriate management of OSA [3,17–19], further efforts are required to ensure the best strategies at the local level, taking into account organisational factors and the specificity of the assisted population (i.e. the subjects referred to a pneumology service with a suspicion of OSA). As stated by Heatley and colleagues, if the field of sleep medicine does not evolve into a comprehensive chronic condition management approach, patient outcomes are likely to remain suboptimal [20].

The aim of this study is to propose, coherently with a disease management approach, a combination of healthcare process modelling and population analysis. The proposed method could be adopted in several geographical contexts and chronic diseases to identify critical issues and explore shared solutions based on scientific evidence and empirical data. We piloted this approach for the management of OSA.

2 Methods

We analysed healthcare processes to identify areas of possible improvement and to understand which characteristics of the assisted population are relevant for discriminating OSA subjects.

A multidisciplinary working group was created, composed of researchers from the National Research Council of Italy (CNR) with skills in process analysis, respiratory diseases, and statistical methods, and health professionals from a Community Pulmonary Service and a Pulmonary Hospital Department.

2.1 Healthcare process representation

The experts in process analysis collected information by examining the guidelines for the Management of OSA in Adults [3,17–19] and conducting semi-structured interviews and on-site meetings with the experts in the management of OSA.

The healthcare processes were represented through the standard graphical language *Unified Modeling Language*™ (UML®), which was chosen based on the result of a systematic review of graphical languages/notations adopted in the healthcare setting. UML® allows inter-professional analyses and is easy to understand also by non-experts [21].

Model accuracy was assessed through joint revisions of each iteration – involving both the analysts and the experts of the domain – until the final version was agreed.

2.2 Retrospective study of the assisted population

We retrospectively selected consecutive subjects aged ≥18 years, registered in the Local Health Unit of Brindisi, Italy (ASL-BR) Community Pulmonary Service records who underwent an overnight home cardiorespiratory polygraphy examination in a 5-year period (1/2010-12/2014). The overnight home polygraphy was performed using a portable ambulatory device (Somnoscreen Plus, Somnomedics GmbH di Randersacker, Germany) with monitoring of nasal airflow (nasal cannula), chest and abdominal respiratory movements (thoracic and abdominal belts), Sa,O2 (digital pulse oximeter with a sampling frequency of 5 s), body position (mercury sensor), and wristband actigraphy. Analysis was carried out manually. We collected data from their first visit for a suspicion of OSA and from their first polygraphy assessment and excluded patients with a time in bed during polygraphy of ≤ 5 hours. In total, 736 subjects were considered.

Anthropometric data, medical history, habits (smoking and alcohol consumption), and results from the Berlin Questionnaire (BQ) [22] were collected as part of a standard clinical assessment, and sleep data was measured by home polygraphy. Anthropometric data, include age at diagnosis, gender, circumference of the neck, and Body Mass Index (BMI) were classified according to the World Health Organization [23]. Medical history includes: heart diseases (patients with atrial fibrillation and/or coronary artery disease in drug therapy); hypertension (patients in pharmacological treatment); metabolic (only diabetes mellitus, patients in pharmacological treatment); pulmonary diseases (only Chronic Obstructive Pulmonary Disease - COPD); and patients in pharmacological treatment without any distinction for the disease severity and hypersomnia (Epworth Sleepiness Scale – ESS [24,25] – score ≥10).

Statistical analyses were performed using the free software R [26]. Unless otherwise specified, data are presented as mean ± standard deviation and percentages. All tests referring to location parameters (*t*-test and Mann-Whitney test) were two-tailed. Published data from the European Sleep Apnoea Database (ESADA), the pan-European sleep laboratory repository, which was created to facilitate cross-sectional and outcome research in sleep apnoea, were taken as a benchmark when describing the population with a suspicion of OSA [27], and differences were evaluated with chi-squared tests and independent *t*-tests. A significance level of 0.05 was considered, and the *p*–values are directly reported. Logistic regression analysis, with the occurrence of AHI ≥ 5 events/h as the dependent variable, was performed. The clinical relevance of the covariates has been carefully taken into account in the predictor selection. Linearity of continuous covariates has been checked, and design variables have been introduced to handle lack of linearity. The model fit and the presence of influencing data were assessed by the usual techniques.[28]

This study was approved by the Ethics Committee of ASL-BR (protocol 85545/2014).

3 Results

After a short learning phase, the adopted UML® symbols were easily understood by members of the research team who were not familiar with the language. A high-level model of current healthcare processes for OSA was then designed and collectively approved, after several iterations and revisions. The final graphic presentation, judged to be appealing and clearly structured by all the members of the research team, was the starting point for sharing reflections (Figure 1).

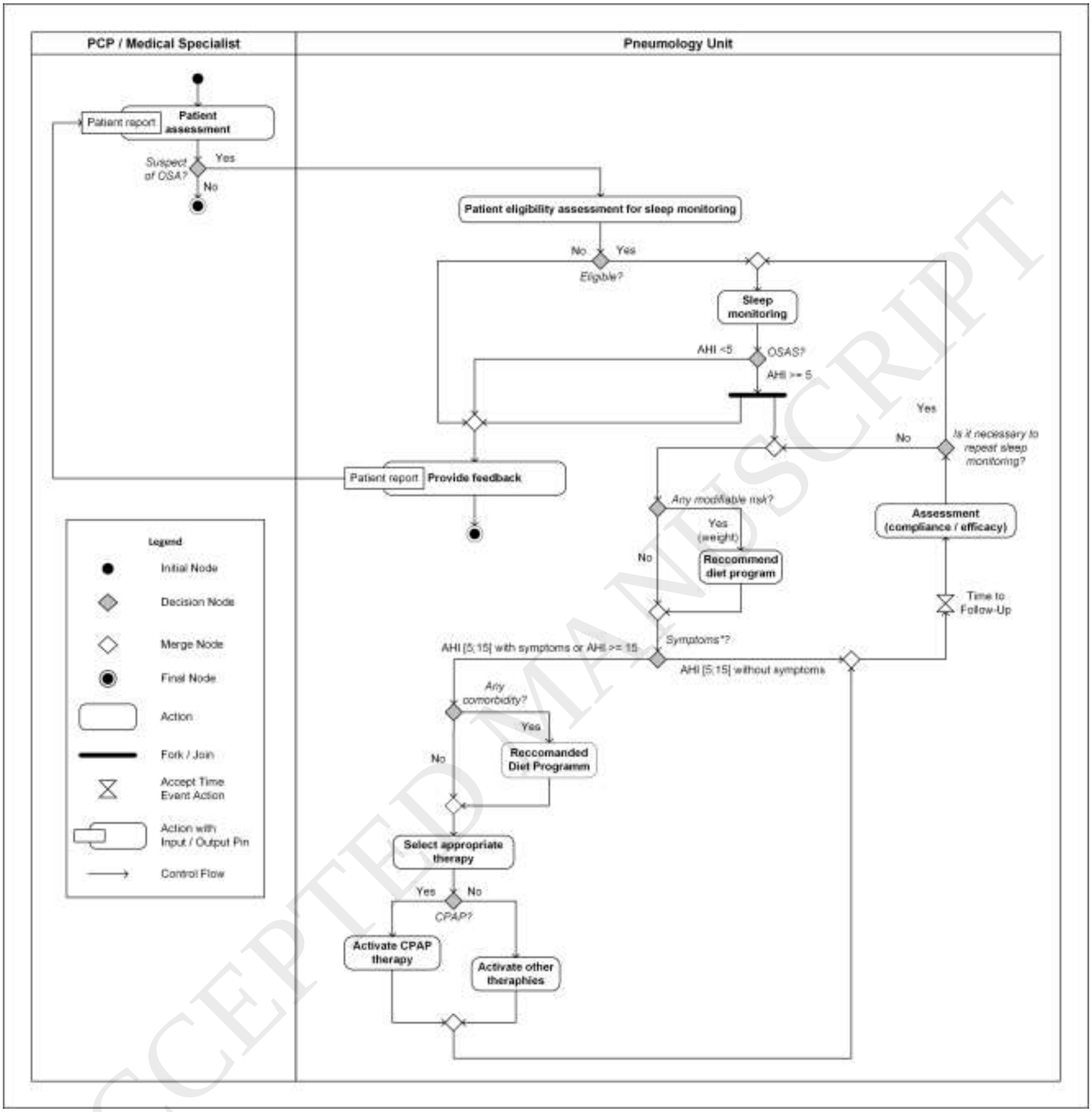

Figure 1 - Healthcare process for managing OSA subjects (current organization)

CPAP = Continuous positive airway pressure. OSA = Obstructive Sleep Apnoea. PCP = Primary Care Provider.

(*) Symptoms are considered any of the following: unintentional sleep episodes during wakefulness; unrefreshing sleep, daytime sleepiness, fatigue or insomnia, awakening with breath holding, gasping or choking, loud snoring, breathing interruptions, or witnessed apnoeas.[4]

Primary Care Providers (PCP) and medical specialists from other units are a key node for reducing the burden of undiagnosed cases. As there is no guideline for OSA screening in primary care [29], informing PCPs and medical specialists on OSA risk factors, symptoms, and associated comorbidities becomes a critical factor.

For subjects with confirmed OSA, continuous positive airway pressure (CPAP) is the first-line treatment [17,18], the efficacy of which is notoriously limited, usually by poor patient adherence [30,31]. Several strategies increasing compliance exist, mostly based on patient empowerment for self-management [32], whose identification and correct application require a counselling phase to identify case-by-case interventions. As there is no operational guideline for physicians to address this issue, which could also require social and psychological skills, two actions are suggested: a) preparing an operational tool, based on the current body of evidence of known risk factors for low compliance and how to assess them, and coupled with strategies to support adherence; and b) modifying the local patient database to start collecting data on risk factors for poor adherence and measurements of the actual use of CPAP in the assisted population.

By comparing the current process with recent evidence, the absence of a formalised specific emphasis on physical exercise was highlighted. This is a recognised emerging cornerstone of OSA therapy with proven beneficial effects on AHI reduction, regardless of the effect on BMI [33–35]. To overcome this limit, a dedicated task is proposed for inclusion in the revised healthcare process.

The availability of an agreed model of the healthcare processes allows defining process indicators on critical nodes for measuring the service quality: e.g., sensitivity and specificity of the screening phase and the rate of compliance in the therapy phase.

In the study period, 736 adult subjects were enrolled as compliant with the inclusion criteria: their characteristics are reported in Table 1.

	Female			Male			Total
	ASL-BR	**ESADA**	***p*[1]**	**ASL-BR**	**ESADA**	***p*[1]**	**ASL-BR**
Recruited[2]	246 (33.4)	1426 (27.9)		490 (66.6)	3677 (72.1)		736
Age [years]	60.4 ± 12.0	53.6 ± 12.6	0	59.2 ± 13.6	51.2 ± 12.6	0	59.6 ± 13.1
BMI [kg/m^2]	35.9 ± 8.5	31.5 ± 7.6 (1420)	0	31.9 ± 7.2	31.0 ± 6.1 (3658)	0.004	33.2 ± 7.9
Normal, < 25	6.1	20.1		9.6	12.4		8.4
Overweight, [25; 30[	20.7	28.1	0	35.7	37.5	0.15	30.7
Obese, [30; 35[	27.6	23.2		30.6	28.9		29.6
Morbidly obese, ≥ 35	45.6	28.6		24.1	21.2		31.3
Neck circumference [cm]	38.2 ± 3.8 (203)	37.5 ± 5.0 (1404)	0.06	42.5 ± 3.9 (416)	42.5 ± 4.1 (3520)	0.92	41.1 ± 4.3 (619)
% with large neck[3]	24.1	N.R.	-	37.0	N.R.	-	32.8
Current Smoker	14.3 (245)	21.3 (1388)	0.012	19.4 (485)	26.0 (3596)	0.002	17.7 (730)
Previous Smoker	11.4 (245)	N.R.	-	41.0 (485)	N.R.	-	31.1 (730)
Heart diseases	35.9 (245)	N.C.	-	32.6	N.C.	-	33.7 (735)
Hypertension	67.1	N.C.	-	58.2	N.C.	-	61.1
Diabetes mellitus	26.8	N.C.	-	16.9	N.C.	-	20.2
COPD	28.4	N.R.	-	31.1 (489)	N.R.	-	30.2 (735)
Hypersomnia[4]	32.9 (243)	N.R.	-	33.9 (483)	N.R.	-	33.6 (726)

TABLE 1 - Anthropometric data, modifiable risk factors and comorbid conditions of the subjects eli

study Data are presented either as mean ± SD (n) or as %.

[1] Comparisons with ESADA study[27] are performed with two-tailed *t*-test for means, *z*-test or chi-squared test for proportions. N

not comparable

[2] Smaller group sizes due to missing data are indicated (m) close to the corresponding means/percentages.

[3] Large Neck Circumference (> 43.2 cm for males and > 40.6 cm for females).[3]

ASL-BR - Local Health Unit of Brindisi (Italy); BMI - Body Mass Index; COPD - Chronic obstructive pulmonary disease; ESAI

Apnoea Database;

[4] Hypersomnia defined by Epworth Sleepiness Scale (ESS) score ≥ 10

On average, the ASL-BR cohort is older and heavier than the ESADA cohort. Unlike the latter, the ASL-BR cohort does not consider 80 years as a cut-off age for inclusion. Even excluding octogenarians (27 subjects, 3.7%), the ASL-BR cohort remains older. The frequency distribution of BMI also differs between the two cohorts, with a remarkable 45.6% of females in the ASL-BR group being obese vs. 28.6% in the ESADA cohort. Another difference exists in regards to smoking habits, with fewer smokers present in the ASL-BR cohort.

Hypertension and heart diseases are the most frequent conditions, followed by hypersomnia, COPD, and diabetes mellitus. In these cases, comparisons with the ESADA cohort are not possible due to different criteria of classification or unavailable data.

In order to identify the relevant critical variables with respect to OSA, a logistic regression has been carried out.

As previously reported, anthropometric data, medical history, habits, and BQ are usually used to identify subjects at a high risk for OSA (i.e. subjects with AHI ≥ 5 episodes/h). A preliminary univariate analysis had been performed to identify the associated covariates.

Only alcohol consumption and the BQ had been excluded by the preliminary univariable analysis because of a lack of association with OSA (p-value > 0.80). Data on alcohol consumption is based on a single, non-validated question that is prone to misunderstandings and does not allow us to assess unit consumption. Worldwide, BQ is applied in the discrimination of OSA subjects, but with poor performance: a recent meta-analysis reports a pooled sensitivity of 76% (95% CI, 71%-81%), specificity of 59% (95% CI, 48%-66%), and Odds Ratio (OR) of 4.3 (95% CI, 2.96-6.24) [36]. BQ lower discrimination capability in the ASL-BR population may be due also to the fact that although it is extensively adopted in Italian sleep centres, it is still a not validated tool for the Italian context.

The analysis of the relationship between age and the (univariable) logit showed a clear non-linearity (Supplementary Figure 1). A design variable based on two age thresholds (40 and 70 years) was consequently considered (AgeCL).

BMI classes, age classes, gender, large neck circumference, number of comorbidities, and smoking habit showed a significant association with OSA.

The model that best predicted OSA occurrence according to the final logistic regression analysis included BMI classes of obesity, age classes, gender, and large neck circumference classes and did not include interactions. The model showed a satisfactory fit to the data (Hosmer-Lemeshow test, *p*-value = 0.35).

A few influential covariate patterns have been identified which were not excluded upon evaluation of the clinicians in the working group. Smoking habits were eventually excluded from the fitted multivariate model. Again, similarly to what was already noted for alcohol consumption, for smoking habits, a lack of standardised and validated assessing tools was registered in the current local database. The number of comorbidities has also been excluded from the final logistic model, reasonably due to its strong association with both BMI classes and age classes (chi-square test, *p*-value = 0). It should be noted that the database adopted at the local service considered some of the comorbidities as binary variables. A refinement of data collection is recommended to address also this issue. The estimated odds ratios of the fitted model are reported in Table 2.

Variable	**Value**	**Odds Ratio**	**95% CI**
Gender	1: if male 0: if female	1.75	(1.09, 2.81)

Large neck	1: if neck circumference over threshold[1]	2.10	(1.15, 3.98)
	0: otherwise		
BMI	3 : BMI > 35 kg/m^2	5.67	(2.45, 13.34)
	2 : BMI 30-35 kg/m^2	3.91	(1.85, 8.34)
	1 : BMI 25-30 kg/m^2	1.90	(0.95, 3.78)
	0 : BMI < 25 kg/m^2		
Age	2 : age ≥ 70 years	4.81	(2.24, 10.49)
	1 : age 40-69 years	3.77	(1.91, 7.46)
	0 : age ≤ 40 years		

ASL-BR – Local Health Unit of Brindisi (Italy); BMI - Body Mass Index; OSA - Obstructive sleep apnoea.

[1] neck circumference threshold: 43.2 cm for males and 40.6 cm for females[3]

TABLE 2 - Estimated odds ratios and 95% confidence intervals for the ASL BR cohort

The area under the Receiver Operating Characteristics (ROC) Curve is 0.72, indicating an acceptable discrimination capability. Sensitivity and specificity are optimized at the cut-off point of about 0.77, yielding these values equal to 0.66 and 0.63, respectively.

The model allowed us to highlight several critical elements. First of all, body weight and fat distribution were a confirmed burden for OSA subjects [16]. As reported in the literature, in fact, weight loss trials including both diet and exercise in their program have the potential to deliver significant health benefits in terms of treating OSA in the majority of patients with mild [37] and mild-to-moderate [38] OSA. This kind of interventions is of significant impact if we consider, with a broader view, their effects not only on OSA management, but also on public health issues. By encouraging physical activity and healthy nutrition among all individuals, everyone, regardless of weight status, may benefit with respect to health and well-being. In fact, evidence suggests that weight-neutral physical activity and nutrition-based approaches may be a promising new direction for encouraging lasting wellness in all individuals [39].

Other critical risk factors were age and gender, but these did not determine any practical change in the current clinical pathway.

As reported above, the number of comorbidities is strongly associated with both BMI classes and age classes. This led us to suggest that an increased attention be placed on the management of any possible co-occurring disease through interdisciplinary cooperation.

Table 3 reports the critical issues identified as well as the corresponding proposed solutions with respect to the DM components, as described by the Care Continuum Alliance (CCA) [2], whilst Figure 2 depicts suggested changes in the healthcare process (additional elements in green).

DM components						**Issue**	**Solution**
Population identification processes	**Evidence-based practice guidelines**	**Collaborative practice models**	**Patient self-management education**	**Process and outcomes measurement**	**Routine reporting**		
X						Some of the data collected in the local patient database did not result in links to OSA, and other are collected only in general terms. This limitation could also compromise the discriminating power of the developed predictive model.	Update the local patient database with a refined data collection also using validated tools and further improving the predictive model.
X	X	X			X	Though PCPs and other medical specialists (the gate-keepers) have a primary role in the identification of subjects at risk for OSA, there is no guideline for OSA screening in primary care.	*Inform PCPs and medical specialists on OSA risk factors, symptoms and comorbidities.*

DM components						Issue	Solution
Population identification processes	**Evidence-based practice guidelines**	**Collaborative practice models**	**Patient self-management education**	**Process and outcomes measurement**	**Routine reporting**		
X		X	X		X	Poor patient adherence to CPAP therapy is a common problem.	• Develop and adopt an operational tool, based on the current body of evidence, of: a) known risk factors for low compliance - and how to assess them; and b) coupled with strategies to support adherence. Include a dedicated task on the *management of CPAP compliance;* • Collect data on: a) risk factors for poor adherence; and b) measurements of actual use of CPAP.
	X	X				Absence of formalised specific attention on physical exercise as a complementary therapeutic strategy for OSA subjects.	Include *recommendations for physical exercise* in the healthcare process.
		X				The presence of comorbidities in OSA subjects requires a stronger cooperation between different specialties to manage the increasing complexity of knowledge required for a comprehensive care.	Include *interdisciplinary cooperation with external teams.*
				X		Process and outcome quality indicators are not defined.	Define process indicators on critical nodes for measuring the quality of the service: e.g., *sensitivity* and *specificity* of the screening phase; *rate of compliance* in the therapy phase.

TABLE 3 – Issues and proposed solutions for ameliorating healthcare services for OSA

DM components = Disease Management components as defined by the Care Continuum Alliance (CCA)[2]

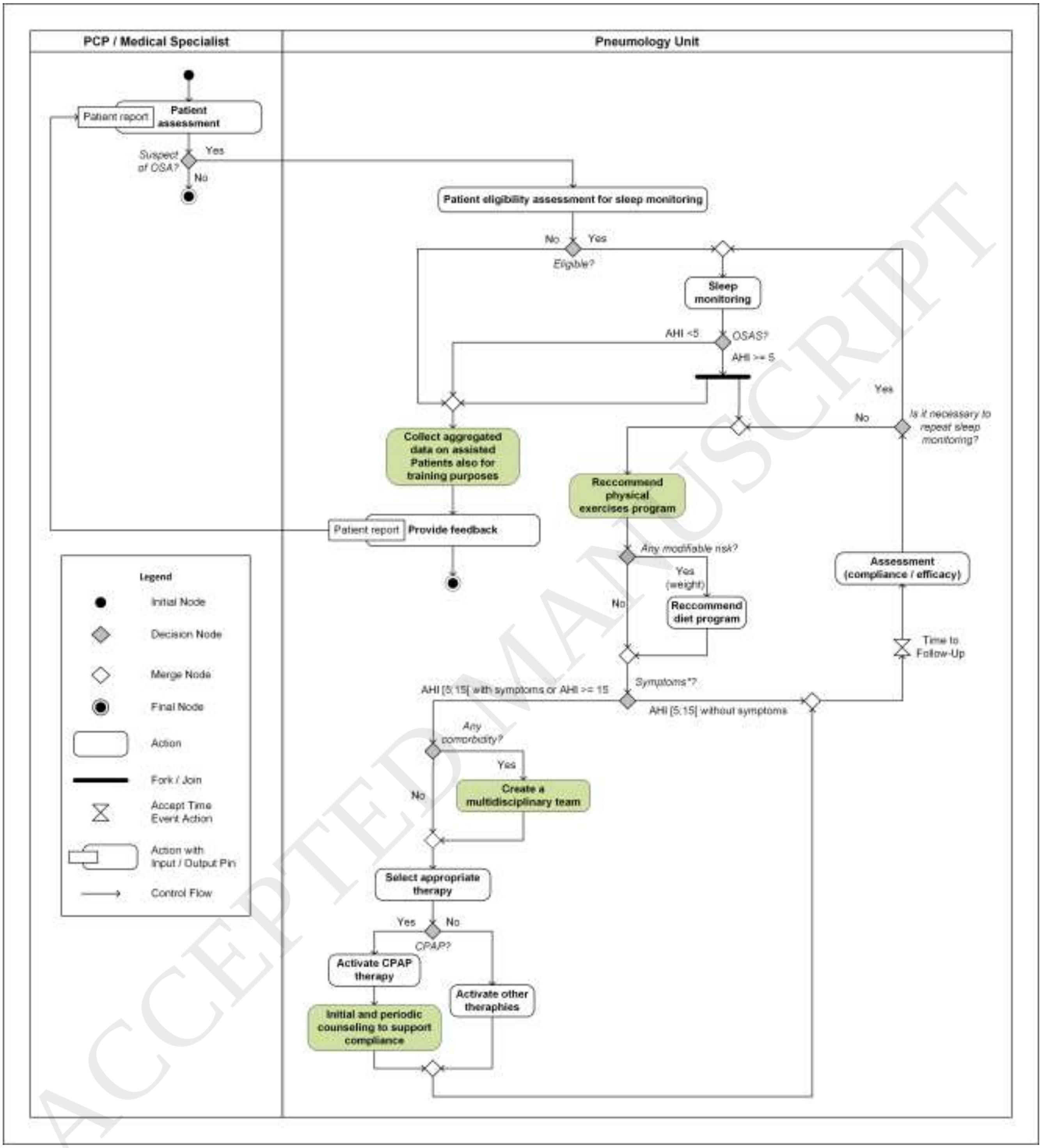

Figure 2 - Healthcare process for managing OSA subjects (proposed solutions for improving healthcare services)

CPAP = Continuous positive airway pressure. OSA = Obstructive Sleep Apnoea. PCP = Primary Care Provider.

(*) Symptoms are considered any of the following: unintentional sleep episodes during wakefulness; unrefreshing sleep, daytime sleepiness, fatigue or insomnia, awakening with breath holding, gasping or choking, loud snoring, breathing interruptions, or witnessed apnoeas.[4]

4 Discussion

We propose a combination of healthcare process modelling and population analysis to identify critical issues and explore shared solutions based on scientific evidence and empirical data and apply it to better manage patients with OSA in a Community Pulmonary Service.

Process modelling was formalised through a standard graphic language (UML®). This method represents an opportunity for interdisciplinary teams who can benefit from a standard and intuitive language, as well as a reduction in misunderstandings. The team worked directly on the process representation, achieving a final shared version with suggested solutions to critical issues. A personal commitment is requested by the applied methodology to find solutions, and this is a recognised condition to increase the likelihood of accepting and implementing the suggested changes [40].

Despite the presence of internationally recognized guidelines that assist practitioners and patients on appropriate management of OSA [3,17–19], local deviations from standard practice were expected given the different demands and resources available to each care provider [41]. Acquiring and incorporating such micro-level knowledge was important in order for the model to be relevant and acceptable by the stakeholders [42].

The combination of population and process analyses allows us to adopt a process-driven data management approach, where data are collected and managed according to their value in the healthcare process. More practically, among others, our approach allowed us to highlight some critical issues and propose corrections in the data management area: a) data collection should be refined to increase details on comorbidities and incorporate standards on habits assessment (these variables resulted as marginal in our prediction model, but are known decision criteria according to current scientific evidence); b) known risk factors of the studied disease should be also quantitatively used (through predictive models) to help the physician routing the patients through the healthcare process; and c) periodic statistical analyses should be performed to identify possible evolution trends in the assisted population, as well as for process assessment. Knowing the sensitivity and specificity of the screening process, as well as the key variables adopted by healthcare providers in their decisions, could be a valuable way to identify any possible deviation from the agreed clinical pathways and plan corrective actions either on the actors (e.g., training sessions, routine summary reporting to individuals participating in the process) or on the process (clinical pathways revision).

The suggested improvements on population data management require robust interventions in terms of Information and Communications Technologies (ICT) tools, as well as for enabling inter-professional cooperation [43]. Another area of convergence of healthcare process modelling and population analysis is the possibility to rely on a process-driven methodology for continuous information systems modelling. The adopted language for process modelling, UML®, is natively suited for ICT tools development and has potentialities that have not been exploited in the present work.

The UML® Activity Diagram that we adopted, shown in Figures 1 and 2, allows us to represent behavioural issues. UML® has other typologies of diagrams that allow to also represent organizational aspects and interactions within a system. Moreover, the UML® capacity to model business processes and ICT systems can be exploited in order to support healthcare providers in the execution of the processes modelled. Lastly, UML® responds to the need for flexibility that characterizes the healthcare context and allows for the building of ICT systems that easily follow the evolution of the underlining process [21,44].

A main strength of our approach is the capacity to merge different disciplines (clinicians and other health professionals; researchers with background in process analysis, statistical analysis and respiratory issues) for a systematic identification of issues and solutions.

Our study has some limitations. First, our evaluation of the approach is preliminary: we worked with one, albeit complex, case study and we did not assess the proposed solutions in clinical practice. With specific reference to the graphical representation of healthcare processes, more research is needed to systematically assess the applicability and usability of these formal representations. Another limit of our analysis is due to the fact that the database was adopted locally, namely, the lack of details for comorbidities and the use of non-validated tools for the assessment and evaluation of some risk factors. Once this limit is removed, a more detailed analysis of the weight of the comorbidities and other known risk factors in managing OSA patients could be performed.

5 Conclusions

We propose an improvement of healthcare services through a combination of healthcare process modelling and population analysis.

The graphical representation of healthcare process allowed us to build an easily understandable model for all the health professionals involved and, consequently, to maintain motivation and ease communication. Moreover, the specific adoption of UML® allows us to formalise patient care processes through a standard language, which is useful in developing an ICT system to support the execution of the processes modelled.

The population analysis allowed us to identify critical factors of the assisted population with an impact on the investigated health condition (especially in terms of modifiable risk conditions). The concomitant analysis of formalised processes and critical risk factors allowed the research team to identify critical issues and propose either solutions or additional study routes with an impact on all the Care Continuum Alliance - Disease Management components.

We tested this approach in a case study on a chronic condition, namely, OSA, and proposed a disease management view of process modelling and population analysis to systematically identify areas of improvement in healthcare processes in other domains as well.

AUTHORS' CONTRIBUTIONS

- Carlo Giacomo Leo and Pierpaolo Mincarone equally contributed to the work. They work together in conceptualizing and designing the work, collecting the data from clinical records, organizing, cleaning and interpreting the data. They represented the healthcare process. They drafted the article.
- Antonella Bodini performed the statistical analysis, contributed to model interpretation and critically revised the manuscript for important intellectual content.
- Raffaella Sedile contributed to data acquisition and critically revised the manuscript.
- Roberto Guarino contributed to data acquisition, collaborated in representing the healthcare processes and drafted the manuscript.
- Maria Rosaria Tumolo contributed to data acquisition and critically revised the manuscript.
- Roberto Malorgio contributed to data acquisition and analysis of healthcare process and critically revised the manuscript.
- Matteo Quitadamo contributed to data acquisition and analysis of healthcare process and critically revised the manuscript.
- Eugenio Sabato contributed to data acquisition and analysis of healthcare process and critically revised the manuscript.
- Giovanni Viegi and Giuseppe Insalaco contributed in conceptualizing and designing the work. They critically revised the manuscript for important intellectual content.
- Saverio Sabina contributed in conceptualizing and designing the work, he represented the healthcare process. He critically revised the manuscript for important intellectual content.

All the authors read and approved the submitted version of the manuscript and agree to be accountable for all the aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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STATEMENT OF CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

SUMMARY TABLE

What was already known on the topic

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- Internationally recognized guidelines assist practitioners and patients on appropriate management of OSA, but further efforts are required to organise healthcare processes at the local level, taking into account organisational factors and the specificity of the assisted population.
- Chronic conditions require a continuous management of treatments and problems - residual symptoms, deficits and co-morbidities, and integrated and systematic patient-centred approaches. Disease management (DM) is a strategy aimed at providing efficient and effective care especially in chronic conditions. Its key components are collaborative models, evidence-based practices, population identification processes, and healthcare process evaluation and management.
- Modeling care processes explicitly is a powerful way to understand, communicate and assess a program's healthcare delivery. Standardized graphical languages for process representation can increase the clarity of description of healthcare processes thanks to their visual properties, easily allow the management of macro and micro scenarios, and clearly and precisely represent the process logic. These languages can also increase guidelines/pathways applicability by representing complex scenarios through charts and algorithms.

What this study added to our knowledge

- The graphical representation of healthcare processes allowed us to design an easily understandable collaborative model for all the professionals involved and, consequently, to maintain the motivation and ease communication.
- The population analysis highlighted key factors for the identification and management of OSA.
- The combination of the graphical representation of the healthcare process and population analysis in a OSA management program allowed us to collaboratively identify critical issues,

and explore shared solutions based on scientific evidence and empirical data, hence realising the key components of the DM approach.

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