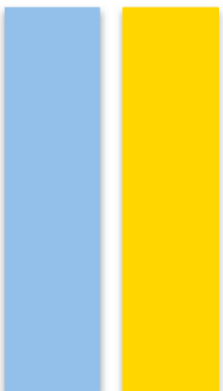
U.PORTO

O2Match: Development and Usability of a Decision Support System for Home Oxygen Therapy

Master´s Degree in Medical Informatics

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O2Match: Development and Usability of a Decision Support System for Home Oxygen Therapy

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Acknowledgments

This dissertation is the result of a journey that pushed me far outside my comfort zone—a journey that was only possible because I did not have to go though it alone. To everyone who accompanied me along this path, I offer my most sincere appreciation.

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To my children, I hope this journey serves as an enduring example: to never hesitate to step outside your comfort zone and to always seek knowledge beyond the walls of a degree.

Completing this dissertation while balancing my professional and family life, and studies was far from easy. However, I have come to realize that we do not always need to 'reinvent the wheel'—sometimes, it is enough to use it in a different way, for a purpose other than that for which it was originally intended. That is precisely what I sought to do: to draw upon other fields of knowledge to serve my own, letting computer science offer medicine new ways to solve its challenges. That is what gave this adventure its true meaning.

Declaration on the Use of Artificial Intelligence (AI)

During the development of this project, the author used generative artificial intelligence technologies (large language models) strictly as technical, design, and software engineering support tools. Specifically, AI assistance was used for the following tasks: to support the creation and design of the high-fidelity visual mockups; to assist in the programming and interaction of these mockups; to provide support in writing the Python code; and to help execute the testing of the clinical decision algorithm. Generative AI was **not** used in any capacity to write, structure, or generate the text of this dissertation manuscript. All clinical rules, software code, interface designs, and test results generated with AI assistance were exhaustively reviewed, clinically validated, and refined by the author, who assumes full and sole responsibility for the scientific, technical, and intellectual integrity of this work.

Abstract

Introduction: Home Oxygen Therapy (HOT) requires selecting an oxygen delivery device that is clinically appropriate, functionally manageable and logistically feasible. In routine practice, this decision is complex because the relevant knowledge is dispersed across clinical guidelines, Portuguese regulatory standards, Home Respiratory Care (CRD) contractual rules and manufacturer specifications. Although existing guidance defines the main indications for oxygen therapy, it does not provide an operational mechanism to match individual patients to appropriate device categories. This dissertation aimed to develop and evaluate O_2Match, an explainable rule-based Clinical Decision Support System (CDSS) for selecting home oxygen device.

Methods: The project followed a design science approach, beginning with a needs assessment based on three purpose-built questionnaires administered to prescribing physicians, non-prescribing health professionals and oxygen-therapy users. This quantitative component was complemented by three semi-structured interviews with CRD professionals, providing operational insight into home installation, patient training and device-related difficulties. These findings informed the construction of a normalised catalogue of 41 oxygen devices described across 44 technical and operational variables. The decision engine was built from 23 deterministic exclusion rules, 18 clinical preference rules and 36 alerts, organised according to a trilateral model that integrates clinical requirements, functional capacity and logistical context. The engine was verified against an independent Python oracle across 38 clinical scenarios and reviewed by two pulmonologists. A functional React single-page application prototype was then evaluated with six prescribing physicians through a combined cognitive walkthrough and think-aloud protocol, complemented by a SUS-informed questionnaire.

Results: The needs assessment included 72 participants and identified a clear gap between clinical prescription and real-world device suitability. Most physicians rated the tool as useful or very useful (94%), while non-prescribing professionals reported high perceived usefulness (mean 4.38/5). Weight and portability represented the largest unmet need in the comparison between professional priorities and patient experience, followed by autonomy. The decision engine achieved full concordance with the Python oracle across all 38 scenarios and four output dimensions: primary recommendation, acceptable alternatives, deterministic exclusions and alerts. It also passed 101 unit tests and 768 boundary permutations, including safety invariants such as the hollow-recommendation check. In usability testing, all 64 attempted tasks were completed successfully, 97.0% autonomously, with a mean subjective satisfaction score of 4.5/5.

Conclusions: O_2Match demonstrates that home oxygen device selection can be reformulated as a structured, transparent and auditable decision-support workflow. The prototype integrates clinical, functional, technical and logistical criteria into an explainable recommendation process that clinicians found usable and aligned with their reasoning. The findings establish feasibility, internal consistency and formative usability, but not clinical effectiveness. Prospective evaluation in real-world prescribing is required before conclusions can be drawn about patient outcomes, device mismatch, adherence or cost-effectiveness.

Keywords: clinical decision support system; home oxygen therapy; COPD; oxygen device selection; usability evaluation; rule-based system medical informatics.

Resumo

Introdução: A Oxigenoterapia Domiciliária exige a seleção de um dispositivo de administração de oxigénio que seja clinicamente adequado, funcionalmente manejável e logisticamente viável. Na prática clínica, esta decisão é complexa porque o conhecimento relevante encontra-se disperso em guidelines clínicas, normas regulamentares portuguesas, regras contratuais dos Cuidados Respiratórios Domiciliares (CRD) e especificações dos fabricantes. Embora as orientações existentes definam as principais indicações para oxigenoterapia, não fornecem um mecanismo operacional para corresponder cada doente a categorias de equipamento adequadas. Esta dissertação teve como objetivo desenvolver e avaliar o O_2Match, um Sistema de Apoio à Decisão Clínica baseado em regras e explicável para a seleção de equipamentos de oxigenoterapia domiciliária.

Métodos: O projeto seguiu uma abordagem de design science, iniciando-se com uma avaliação de necessidades baseada em três questionários construídos especificamente para o efeito, aplicados a médicos prescritores, profissionais de saúde não prescritores e utilizadores de oxigenoterapia. Esta componente quantitativa foi complementada por três entrevistas semiestruturadas com profissionais de CRD, que forneceram conhecimento operacional sobre a instalação domiciliária, o ensino ao doente e as dificuldades relacionadas com os equipamentos. Estes resultados informaram a construção de um catálogo normalizado de 41 dispositivos de oxigénio, descritos por 44 variáveis técnicas e operacionais. O motor de decisão foi construído a partir de 23 regras determinísticas de exclusão, 18 regras de preferência clínica e 36 alertas, organizados segundo um modelo trilateral que integra requisitos clínicos, capacidade funcional e contexto logístico. O motor foi verificado contra um oráculo independente em Python em 38 cenários clínicos e revisto por dois pneumologistas. Um protótipo funcional em React, sob a forma de single-page application, foi posteriormente avaliado por seis médicos prescritores por meio de um protocolo combinado de cognitive walkthrough e think-aloud, complementado por um questionário inspirado na System Usability Scale.

Resultados: A avaliação de necessidades incluiu 72 participantes e identificou uma clara lacuna entre a prescrição clínica e a adequação efetiva dos equipamentos. A maioria dos médicos classificou a ferramenta como útil ou muito útil (94%), enquanto os profissionais de saúde não prescritores atribuíram uma utilidade percebida elevada (média de 4,38/5). O peso e a portabilidade representaram as maiores necessidades não satisfeitas na comparação entre as prioridades dos profissionais e a experiência reportada pelos doentes, seguidas pela autonomia. O motor de decisão alcançou concordância total com o oráculo em Python em 38 cenários e nas quatro dimensões de output avaliadas: recomendação principal, alternativas aceitáveis, exclusões determinísticas e alertas. O sistema passou ainda por 101 testes unitários e 768 permutações-limite, incluindo invariantes de segurança como a verificação de recomendação oca. Na avaliação de usabilidade, todas as 64 tarefas tentadas foram concluídas com sucesso, 97% de forma autónoma, com uma pontuação média de satisfação subjetiva de 4,50/5.

Conclusões: O O_2Match demonstra que a seleção de equipamentos de oxigenoterapia domiciliária pode ser reformulada como um fluxo de apoio à decisão estruturado, transparente e auditável. O protótipo integra critérios clínicos, funcionais, técnicos e logísticos num processo de recomendação explicável, que os clínicos consideraram utilizável e alinhado ao seu raciocínio. Os resultados estabelecem a viabilidade, a consistência interna e a

usabilidade formativa do sistema, mas não a sua eficácia clínica. Será necessária uma avaliação prospetiva em contexto real de prescrição antes de tirar conclusões sobre resultados clínicos, desajuste de equipamento, adesão ou custo-efetividade.

Palavras-chave: sistema de apoio à decisão clínica; oxigenoterapia domiciliária; seleção de equipamento de oxigénio; DPOC; avaliação de usabilidade; sistema baseado em regras; informática médica

Preamble

This dissertation was developed within the Master's Degree in Medical Informatics of the Faculty of Medicine (FMUP) and the Faculty of Sciences (FCUP) of the University of Porto. It documents the design, construction and evaluation of O_2Match, a Clinical Decision Support System for selecting home oxygen therapy equipment, conducted in the clinical context of the Unidade Local de Saúde de Gaia e Espinho (ULSGE).

The work was carried out under the supervision of Daniela Filipa Ferreira dos Santos and the co-supervision of Helder Filipe Pinto de Oliveira. It was organised into two phases — the construction of the decision algorithm and the development of the desktop application — resting on a common groundwork of stakeholder engagement, needs assessment and equipment characterisation. The needs assessment, the clinical validation of the rule base and the usability evaluation were conducted with health professionals and patients at the ULSGE, following approval from the institution's Ethics Committee.

The document follows the structure recommended for the Master's dissertation. After the introduction, the objectives and the justification, the materials and methods describe the development and evaluation process; the results present the empirical findings, the decision engine and the prototype; and the discussion, conclusion and future work reflect on the contribution, its limitations and the paths for its evolution. The supporting materials — questionnaires, the equipment database, the rule specification, the clinical scenarios, the audit reports, the interface mockups and the usability instruments — are provided as annexes.

Scientific and Financial Results

Scientific Results

At the time of submission, the work described in this dissertation had not yet resulted in peer-reviewed publications. Scientific communications and publications derived from it will be reported as they arise.

Financial Results

This dissertation did not receive external funding, grants or financial support. No income, commercial revenue or financial gain was obtained from the development, implementation or results of the work presented.

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Acronyms

ADSE	Assistência na Doença aos Servidores do Estado
AI	Artificial Intelligence
API	Application Programming Interface
APCSD	Associação Portuguesa de Cuidados de Saúde ao Domicílio
ATS	American Thoracic Society
BTS	British Thoracic Society
CDSS	Clinical Decision Support System
COPD	Chronic Obstructive Pulmonary Disease
CPAP	Continuous Positive Airway Pressure
CRD	Home Respiratory Care (Cuidados Respiratórios Domiciliários)
CSS	Cascading Style Sheets
DCC	Department of Computer Science
DGS	Direção-Geral da Saúde
DOM	Document Object Model
DPCO	Doença Pulmonar Obstrutiva Crónica
DSR	Design Science Research
ERPI	Estrutura Residencial para Pessoas Idosas
EU	European Union
FAA	Federal Aviation Administration
FCUP	Faculdade de Ciências da Universidade do Porto
FMUP	Faculdade de Medicina da Universidade do Porto
GDPR	General Data Protection Regulation
HCI	Human–Computer Interaction
HIS-EVAL	Health Information Systems Evaluation (workshop)
HOT	Home Oxygen Therapy
HTML	HyperText Markup Language
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
LOTT	Long-Term Oxygen Treatment Trial

LOX	Liquid Oxygen
LTOT	Long-Term Oxygen Therapy
MCDA	Multi-Criteria Decision Analysis
MEDCIDS	Department of Health Information and Decision Sciences
ML	Machine Learning
NIV	Non-Invasive Ventilation
NOC	Norma de Orientação Clínica
OLD	Oxigenoterapia de Longa Duração (Portuguese for LTOT)
ONDR	Observatório Nacional das Doenças Respiratórias
PaO_2	Arterial oxygen partial pressure
PDF	Portable Document Format
PEM	Prescrição Eletrónica de Medicamentos
PEM-CRD	Prescrição Eletrónica de Medicamentos e Cuidados Respiratórios Domiciliários
PM6M	Prova de Marcha de 6 Minutos (six-minute walk test)
POC	Portable Oxygen Concentrator
PSAP	Pressão Sistólica da Artéria Pulmonar
QR	Quick Response (code)
REST	Representational State Transfer
RQ	Research Question
SNS	National Health Service (Serviço Nacional de Saúde)
SPA	Single-Page Application
SpO_2	Peripheral oxygen saturation
SPMS	Serviços Partilhados do Ministério da Saúde
STARE-HI	Statement on Reporting of Evaluation Studies in Health Informatics
SUS	System Usability Scale
UCD	User-Centred Design
UI	User Interface
ULSGE	Unidade Local de Saúde de Gaia e Espinho
UX	User Experience
VNI	Ventilação Não Invasiva
WHO	World Health Organization
WMA	World Medical Association



1. Introduction

Introduction

Home Oxygen Therapy is one of the longest-established interventions in the management of chronic respiratory disease. Its main therapeutic purpose is to correct clinically relevant arterial hypoxaemia, commonly defined by an arterial oxygen partial pressure (PaO_2) below 60 mmHg or a peripheral oxygen saturation (SpO_2) below 90%, thereby improving systemic oxygen availability in patients with chronic respiratory failure [1, 2]. In selected patients with severe chronic resting hypoxaemia, Long-Term Oxygen Therapy (LTOT), when prescribed for prolonged daily use, remains one of the few respiratory interventions with a demonstrated survival benefit [3, 4].

The evidence supporting LTOT is particularly relevant in Chronic Obstructive Pulmonary Disease (COPD), which remains one of the most frequent underlying diagnoses among patients receiving long-term oxygen. COPD represents a major epidemiological and clinical burden worldwide, affecting hundreds of millions of people and ranking among the leading causes of death globally [5]. In advanced disease, acute exacerbations, recurrent hospital admissions, progressive exercise limitation, dyspnoea and loss of autonomy contribute to impaired quality of life and increased healthcare utilisation. In Portugal, COPD is also clinically relevant within the Serviço Nacional de Saúde (SNS), although its true burden is likely underestimated because the disease remains frequently underdiagnosed and administrative records may not fully reflect spirometrically confirmed disease [6].

The survival benefit of LTOT in severe hypoxaemic COPD was established by two landmark randomised controlled trials in the early 1980s. The Medical Research Council Working Party [4] showed that oxygen prescribed for at least 15 hours per day was associated with lower five-year mortality compared with no oxygen therapy. The Nocturnal Oxygen Therapy Trial Group [3] compared continuous oxygen therapy with nocturnal-only oxygen therapy and found that more prolonged daily exposure was associated with lower mortality. Together, these trials remain the principal evidence base for LTOT in severe chronic resting hypoxaemia and support the clinical principle that benefit depends not only on prescribing oxygen, but also on ensuring sufficient daily exposure.

Subsequent trials have clarified the limits of this therapeutic benefit. In patients with stable COPD and moderate resting or exertional desaturation, the Long-Term Oxygen Treatment Trial Research Group [7] found no significant effect of long-term supplemental oxygen on time to death or first hospitalisation, nor sustained benefit in quality of life, anxiety, depression or functional status. Similarly, Lacasse et al. [8] reported that nocturnal oxygen in COPD patients with isolated sleep-related desaturation who did not meet daytime LTOT criteria did not reduce mortality or delay progression to standard daytime LTOT. These findings reinforce that oxygen therapy should not be treated as a uniform intervention. Its expected benefit depends on indication, severity and persistence of hypoxaemia, prescribed duration, oxygen flow requirement and delivery modality.

This distinction is central to the present dissertation. A correct oxygen prescription does not end with confirming the indication. It also requires translating the patient's physiological needs into a delivery system that can be used safely, consistently, and acceptably in the home environment. The clinical benefit demonstrated in historical trials, therefore, depends on a second, less visible but clinically decisive step: the selection of an appropriate domiciliary oxygen device.

1.1 Therapeutic Modalities and the Portuguese CRD Framework

Within the Portuguese healthcare system, the clinical and administrative application of Home Oxygen Therapy is regulated by the Direção-Geral da Saúde (DGS) through Norma n.º 018/2011, updated in 2015 [2]. This guidance forms part of the wider Cuidados Respiratórios Domiciliários (CRD), or Home Respiratory Care, ecosystem and recognises several modalities of domiciliary oxygen use: LTOT, Ambulatory Oxygen Therapy, short-term oxygen therapy, palliative oxygen therapy and oxygen used as an adjunct to positive airway pressure or non-invasive ventilation [2]. This classification is clinically relevant because each modality has a different therapeutic objective, expected duration, functional requirement and logistical implication.

LTOT is reserved for patients with severe chronic resting hypoxaemia in a stable clinical phase. The Portuguese guideline recommends assessment after clinical stabilisation, usually at least three months after an acute exacerbation, and requires objective confirmation by arterial blood gas analysis [2]. Eligibility criteria include resting PaO_2 at or below 55 mmHg, or PaO_2 between 55 and 60 mmHg when hypoxaemia-related organ involvement is present, such as chronic cor pulmonale, pulmonary hypertension or secondary polycythaemia, commonly defined by a haematocrit above 55% [1, 2]. These criteria are intended to distinguish severe persistent hypoxaemia, for which LTOT has demonstrated benefit, from moderate, transient or insufficiently characterised desaturation states.

Ambulatory Oxygen Therapy addresses a different clinical problem. It is intended for patients who desaturate during exertion and may benefit from supplemental oxygen during physical activity, rather than for those who require oxygen throughout the day. In the Portuguese DGS framework, Ambulatory Oxygen Therapy applies to patients with documented daily ambulation who either meet LTOT criteria or are normoxaemic at rest but desaturate during exercise. In the latter group, exertional desaturation is defined as SpO_2 below 88%, or a fall of at least 4% from baseline to a value below 90% during the six-minute walk test, provided that desaturation is corrected with supplemental oxygen [2]. This indication should therefore be supported not only by a numerical desaturation threshold, but also by evidence of daily ambulation, correction of desaturation and improvement in exercise capacity or dyspnoea.

International guidelines broadly support this distinction, although they differ in emphasis. The American Thoracic Society guideline recommends ambulatory oxygen for adults with COPD or interstitial lung disease who have severe exertional hypoxaemia, but the recommendation is conditional and depends on the expected benefit to mobility, symptoms, and daily functioning [1]. The British Thoracic Society guideline also distinguishes between LTOT, Ambulatory Oxygen Therapy, palliative oxygen, and other forms of oxygen use, while placing particular emphasis on formal assessment, patient education, domestic safety, and reassessment after prescription [9]. The Portuguese DGS framework adds an important national condition: liquid oxygen and portable oxygen concentrators are restricted to patients followed in respiratory rehabilitation programmes [2]. This condition is directly relevant to device selection because respiratory rehabilitation status becomes an eligibility variable, not merely a contextual detail.

Short-term oxygen therapy is a temporary intervention for transient or potentially reversible hypoxaemia. It is generally used during recovery from acute clinical deterioration, such as an exacerbation of COPD, severe pneumonia or decompensated heart failure, when the patient has persistent hypoxaemia but has not yet reached clinical stability. It should therefore be understood as a bridge to reassessment, rather than as an indirect route to chronic oxygen prescription. Under the Portuguese CRD framework, short-term oxygen prescriptions are limited to 90 days and are non-renewable [2]. Reassessment is essential because a meaningful proportion of patients discharged with temporary oxygen no longer meet criteria after systemic recovery [34, 35].

Oxygen used as an adjunct to positive airway pressure or non-invasive ventilation follows a different therapeutic logic. In this setting, oxygen is not the primary treatment for ventilatory failure. It is added only when ventilatory support has been optimized, but clinically significant residual desaturation persists, particularly during sleep. This may occur in patients with chronic type 2 respiratory failure related to obesity hypoventilation syndrome, chest wall disease, advanced COPD or progressive neuromuscular disease. Supplemental oxygen must be prescribed cautiously in patients at risk of hypercapnic respiratory failure, because oxygen without adequate ventilatory monitoring may worsen carbon dioxide retention.

Palliative oxygen therapy differs from the other modalities because its primary objective is comfort and symptom relief rather than survival benefit or long-term physiological correction. In terminal or advanced disease, the decision should be guided by symptoms, oxygenation status, treatment burden, patient preference and goals of care. The evidence base is more limited than for LTOT in severe chronic resting hypoxaemia. In patients with refractory dyspnoea and life-limiting illness who are not severely hypoxaemic, Abernethy et al. [10] found no significant symptomatic advantage of oxygen over room air delivered by nasal cannula. Campbell et al. [11] also questioned the routine use of oxygen near the end of life, supporting individualised assessment rather than automatic prescription. These findings do not imply that palliative oxygen is never appropriate; rather, they indicate that benefit should not be assumed in non-hypoxaemic patients.

Taken together, these modalities show that Home Oxygen Therapy is not a single intervention. The clinical indication, therapeutic objective, expected duration of use, flow requirement,

delivery mode and monitoring needs vary substantially across patients. A decision-support system for oxygen equipment selection must therefore distinguish between these modalities and translate them into device-relevant constraints.

1.2 Epidemiology, Economic Impact and Operational Mechanics within the SNS

Beyond its clinical dimension, Home Oxygen Therapy represents a relevant public health expenditure and an important operational responsibility for the Portuguese Serviço Nacional de Saúde (SNS). National reports from the Associação Portuguesa de Cuidados de Saúde ao Domicílio and the Observatório Nacional das Doenças Respiratórias estimate that approximately 200,000 patients in Portugal receive Home Respiratory Care (Cuidados Respiratórios Domiciliários — CRD), a broad framework that includes domiciliary oxygen therapy, home non-invasive ventilation and aerosol therapy [36, 37]. Within this population, domiciliary oxygen therapy — delivered through stationary concentrators, portable concentrators, liquid oxygen systems or compressed-gas cylinders — constitutes one of the major therapeutic subgroups. This scale is relevant for the present dissertation because it quantifies the patient stakeholder group affected by CRD prescribing decisions and reinforces the clinical, organisational and economic importance of improving the initial match between patient needs and oxygen equipment.

From an economic perspective, the provision of CRD represents a continuous and substantial expenditure for the Portuguese SNS. National reports estimate that the comprehensive CRD sector, including domiciliary oxygen therapy, home non-invasive ventilation, and aerosol therapy, accounts for approximately 50-60 million euros in direct annual expenditure [36, 37, 38]. Within this framework, prescribed oxygen therapy is fully reimbursed by the SNS when issued through the electronic Prescrição Eletrónica de Medicamentos e CRD (PEM-CRD) platform, operated within the SPMS ecosystem. This reimbursement covers equipment rental, routine maintenance, oxygen replenishment and continuous technical support in the patient's home. For electrically powered stationary concentrators, the Portuguese framework also

includes an electricity cost compensation mechanism intended to offset part of the energy burden associated with the equipment´s continuous operation [2, 38].

To preserve fiscal sustainability and limit unnecessary healthcare expenditure, the operational delivery of CRD is organised through centralised framework agreements (Acordos-Quadro) established by SPMS with contracted homecare providers. These agreements define standardised pricing structures, service-level requirements and provider responsibilities, creating an administrative framework intended to ensure equitable access, cost control and minimum quality standards [38]. Regulatory compliance is further supported by defined prescription validity periods, mandatory medical reassessment and periodic renewal, usually every 180 days, with the exception of short-term oxygen therapy prescriptions, which are limited to 90 days and are non-renewable [2, 38].

This administrative and financial structure underscores the importance of selecting appropriate initial equipment. If the prescribed device is poorly matched to the patient's clinical needs, functional capacity or home environment, the system may incur avoidable downstream costs through repeated technical visits, device substitutions, reassessments, inefficient use of contracted resources and persistent therapeutic failure. Therefore, improving the transparency and consistency in oxygen-device selection is relevant not only to patient safety and usability but also to regulatory compliance and the responsible management of SNS resources.

The present dissertation does not conduct a cost-effectiveness analysis or demonstrate financial savings. However, the population scale, reimbursement structure and annual expenditure associated with CRD provide a strong organisational rationale for developing tools that support more consistent, context-sensitive and auditable prescription decisions.

1.3 From Clinical Indication to Device Suitability

The clinical indication for oxygen defines why oxygen is required; the selected device determines whether it can be delivered effectively in daily life. This distinction is often underestimated. A patient may meet criteria for LTOT or Ambulatory Oxygen Therapy, but still

receive a device that is poorly adapted to the prescribed flow, mobility needs, manual capacity, domestic environment or safety context.

Domiciliary oxygen equipment is heterogeneous. Stationary concentrators, portable oxygen concentrators, compressed-gas cylinders and liquid oxygen systems differ substantially in oxygen flow capacity, delivery mode, weight, portability, autonomy, maintenance requirements, power dependence, noise level, suitability for sleep, and compatibility with non-invasive ventilation or positive airway pressure [12, 13]. Portable oxygen concentrators also vary in battery duration, maximum pulse-dose setting, bolus volume, trigger sensitivity, and ability to support higher oxygen needs during exertion [14]. These technical differences are clinically significant, but they are rarely presented to the prescriber in a standardised format that can be directly reconciled with guideline-based indications.

The six-minute walk test illustrates the complexity of translating clinical assessment into device selection. The test provides an objective measure of functional capacity and exertional desaturation and is commonly used to assess the need for Ambulatory Oxygen Therapy. Standardisation is essential because performance is influenced by corridor length, instructions, encouragement, monitoring procedures and patient familiarity with the protocol. Portuguese reference equations for healthy adults aged 18 to 70 years show that the six-minute walk distance is influenced by age, sex, body mass index, and heart rate variation [39]. These reference values help contextualise functional limitation but do not replace clinical judgement.

The six-minute walk test also illustrates the distinction between functional assessment and oxygen titration. When walking distance is the main outcome, oxygen flow should not be modified during the test because titration during walking would compromise the interpretation of distance and exertional response. Oxygen titration should instead be performed through a structured protocol in which flow is adjusted to correct exertional desaturation and avoid clinically relevant hypoxaemia, commonly defined as SpO_2 below 88% [2, 9]. Device selection then depends not only on the final prescribed flow, but also on the conditions under which that requirement was established.

One of the most relevant safety issues concerns pulse-dose oxygen delivery. Unlike continuous-flow systems, pulse-dose devices deliver oxygen as a bolus upon detecting the onset of

inhalation [12]. This mechanism can improve autonomy and portability, but it depends on the patient's ability to reliably trigger the device. Frail, elderly, tachypnoeic or severely dyspnoeic patients, particularly those who breathe predominantly through the mouth or have weak inspiratory effort, may fail to generate the negative pressure required to activate the demand valve during exertion [13, 15]. A patient may therefore correct desaturation during a hospital test performed with continuous-flow oxygen, yet desaturate at home when using a pulse-dose portable concentrator.

A related misconception is that pulse-dose numeric settings correspond directly to continuous-flow rates in L/min. A setting of "2" on a portable oxygen concentrator should not be interpreted as equivalent to 2 L/min of continuous oxygen. Pulse-dose settings are manufacturer-specific scales, and bolus volume can vary substantially between devices at the same nominal setting [13, 14]. During exertion, the problem may become more pronounced because the respiratory rate increases and the device's oxygen-production capacity may constrain the volume delivered per breath [12, 14]. The patient may therefore receive less oxygen at the moment of greatest physiological demand.

High-flow ambulatory oxygen introduces a different set of constraints. Liquid oxygen systems may provide higher flow rates and longer ambulatory autonomy than many portable oxygen concentrators, making them relevant for patients with substantial exertional oxygen requirements [1, 2]. However, technical capacity does not automatically imply usability. Liquid oxygen requires transfer from a stationary reservoir to a portable unit at cryogenic temperatures, typically around −180°C [12]. Filling the portable unit requires manual dexterity, strength, visual control and confidence. It may also cause anxiety due to visible cold vapour released during filling. CRD technical experience further indicates that premature use after filling may cause valve freezing, pressure loss and temporary inoperability. These operational details can determine whether liquid oxygen is feasible for a given patient.

Device suitability is therefore a multidimensional judgement. It depends on physiological need, flow requirement, delivery mode, portability, autonomy, handling ability, patient confidence, domestic environment and safety risks. A device can be clinically attractive in one dimension and unsuitable in another. This is the decision space in which O_2Match was developed.

1.4 The Prescription Paradox in Home Oxygen Equipment Selection

The transition from clinical indication to device selection can create what is sometimes described as a prescription paradox. Oxygen is prescribed according to physiological and clinical criteria, but its success depends on a delivery system that must operate within the patient's physical, domestic and social reality. The clinician is responsible for the prescription, yet may not have full visibility of the technical, environmental and logistical conditions that determine whether the prescription can be implemented.

This paradox is particularly evident in hospital-based prescribing. During a consultation, the physician can assess symptoms, arterial blood gases, resting oxygen saturation, comorbidities and broad functional limitations [1, 2]. However, the clinical encounter rarely captures the patient's housing conditions, stair access, caregiver availability, manual dexterity, storage capacity, electrical reliability, mobility pattern, transportation needs or ability to manage alarms, filters, batteries, cylinders or liquid oxygen refilling procedures. These contextual factors may determine whether a clinically appropriate prescription is usable in practice.

In the Portuguese CRD ecosystem, this information asymmetry is clinically and operationally relevant. The physician masters the clinical indication, while CRD providers and technical teams often have more detailed knowledge of device specifications, installation constraints, patient-handling difficulties, provider stock, and contractual rules. This can shift part of the practical device-selection process away from the prescribing act and towards downstream correction after home installation. The result may be early device substitution, poor adherence, unresolved desaturation, patient frustration or dependence on provider-led adjustments.

Examples are common. A stationary concentrator may be clinically appropriate, but its installation may require a backup cylinder that is difficult to store safely in a small home. A portable oxygen concentrator may improve mobility, but may not deliver sufficient oxygen during exertion or may fail to trigger in a frail patient. Liquid oxygen may be technically advantageous for high-flow ambulatory needs, but may be impractical for a patient with poor manual dexterity, fear of refilling or no caregiver support. Architectural barriers, such as multi-

storey buildings without lifts, may prevent patients from transporting equipment outside the home, thereby reducing the intended benefit of Ambulatory Oxygen Therapy.

These factors are not secondary details. They determine whether oxygen therapy can be used safely, consistently, and in accordance with the prescribed regimen. The current guideline framework establishes the clinical indications for oxygen, but it does not provide a unified mechanism to integrate physiological thresholds, equipment specifications, functional capacity, domestic constraints, and CRD eligibility rules into a single, transparent recommendation process.

This gap provides the rationale for O_2Match. The system is based on the premise that oxygen device selection should not depend only on memory, individual familiarity with equipment or informal negotiation between clinicians and providers. It should be supported by a structured process that makes clinical requirements, technical constraints and contextual risks visible at the point of prescription.

The conceptual model underlying O_2Match therefore integrates three domains: what the patient requires, what the patient can manage and what the environment allows. The intersection of these domains defines device suitability. Within this framework, the system is designed to support more consistent, explainable and context-sensitive prescribing, while reducing the risk of technical mismatch and early therapeutic failure.

1.5 Clinical Decision Support Systems and the Gap Addressed by O_2Match

A Clinical Decision Support System (CDSS) may be defined as an interactive digital system that supports clinical decision-making by combining patient-specific information with a structured knowledge base and presenting recommendations, alerts or assessments to the clinician [16]. Its role is not to replace professional judgement, but to deliver targeted, context-sensitive information at the point of care, thereby reducing the cognitive and informational burden associated with complex, multivariable clinical tasks.

This function is particularly relevant in Home Oxygen Therapy. Oxygen device selection requires the prescriber to reconcile clinical indication, oxygen flow requirements, delivery mode, functional capacity, domestic feasibility, equipment characteristics, safety risks and Portuguese CRD rules. These variables interact in ways that are difficult to manage through unstructured reasoning alone, especially in time-constrained clinical settings and when the prescriber does not frequently prescribe oxygen therapy.

The choice of knowledge representation is therefore central. Machine-learning and deep-learning approaches can be valuable for prediction and pattern recognition, but their outputs may be difficult to interpret when the reasoning pathway is opaque, and their generalisability may be limited when trained on narrow or non-representative datasets [17]. O_2Match addresses a different type of decision problem. Oxygen device selection is governed by identifiable thresholds, mandatory exclusions, device specifications, safety rules and regulatory constraints. A rule-based architecture is therefore appropriate because it allows each recommendation or exclusion to be traced back to an explicit condition, supporting transparency, reproducibility and clinical accountability [16].

The potential value of such a system can be interpreted through the Information Value Chain proposed by Kim, Coiera and Magrabi [18]. Health information technology changes the information the user receives, which may alter a decision, influence a care process, and eventually affect outcomes or prevent harm. O_2Match intervenes in information structuring and decision support. By requiring the systematic entry of clinical, functional, and logistical variables, and by displaying recommendations, alternatives, exclusions, and alerts with explicit justifications, the system aims to make relevant constraints visible before the prescription is finalised.

Existing respiratory digital tools address related but distinct problems. CDSS for COPD have mainly focused on disease management, exacerbation assessment, guideline adherence, discharge planning, monitoring or care coordination [19, 20]. Other systems address oxygen titration, automated oxygen delivery or physiological monitoring after equipment has already been prescribed and installed [40, 41, 42]. Remote monitoring applications may support follow-up and communication between patients and healthcare professionals, but they do not primarily

determine whether a patient should receive a stationary concentrator, a portable concentrator, a compressed-gas cylinder, a liquid oxygen system, or a combined configuration [43].

This distinction defines the specific gap addressed by O_2Match. The available literature does not appear to describe a widely adopted, peer-reviewed CDSS specifically designed to match domiciliary oxygen devices to individual patients by integrating clinical oxygen requirements, functional capacity, environmental constraints, equipment specifications and Portuguese CRD eligibility rules. O_2Match is positioned within this gap as an explainable, rule-based CDSS for oxygen device selection.

Its expected contribution at this stage is not to demonstrate improved patient outcomes, but to determine whether this decision problem can be formalised, internally verified and presented through a usable interface. The system is intended to generate a primary recommended device category, acceptable alternatives, safety alerts, excluded options and explicit justifications. In doing so, it supports the prescribing physician without replacing medical judgment, preserving clinical responsibility while making the reasoning behind device selection more transparent and auditable.



2. Objectives

Objectives

This dissertation addresses a central problem in respiratory care: the limited integration between clinical prescription criteria for Home Oxygen Therapy and the functional, technical and logistical realities that determine whether a device can be used safely and consistently at home. Existing guidelines define indications for LTOT, Ambulatory Oxygen Therapy and related modalities, but they do not provide an operational mechanism for matching individual patients to specific oxygen devices while accounting for domestic constraints, functional capacity, equipment specifications and CRD contractual rules. O_2Match was conceived to address this gap through an explicit, rule-based CDSS for oxygen device selection.

The study is guided by three research questions:

RQ1. Can the clinical, logistical, and technical knowledge governing home oxygen device selection, currently dispersed across DGS Norma 018/2011 [2], international guidance, and the Portuguese CRD contractual framework, be formalised into a deterministic, auditable, and clinically interpretable rule base?

RQ2. Can a rule-based inference engine apply this knowledge to generate appropriate device recommendations, alternatives, exclusions and transparent justifications across a representative set of clinically relevant patient scenarios?

RQ3. Do health professionals perceive the resulting prototype as usable, understandable, and clinically trustworthy as a decision-support tool for selecting oxygen devices?

To address these questions, the project pursues six specific objectives:

O1. To formalise fragmented clinical, technical and contractual knowledge into a structured rule base, comprising deterministic exclusion rules for mandatory constraints, alert rules for safety-relevant conditions and preference rules for clinically acceptable alternatives.

O2. To define a representative catalogue of clinical, functional and socio-demographic patient scenarios covering the main decision pathways in Home Oxygen Therapy, thereby supporting systematic algorithmic testing.

O3. To model the oxygen equipment domain by constructing a normalised device database containing the technical variables relevant to clinical and domestic compatibility.

O4. To design and implement the O_2Match rule-based inference engine and its clinical user interface using web technologies suitable for prototype development and iterative evaluation.

O5. To verify the internal consistency of the decision engine through systematic regression testing against the source rules across the defined validation scenarios.

O6. To evaluate the prototype's usability, cognitive burden and perceived clinical acceptability through an empirical laboratory study with health professionals, using a combined cognitive walkthrough and think-aloud protocol complemented by a SUS-informed questionnaire.

Through these objectives, the dissertation aims to move oxygen device selection from an information-asymmetric and largely provider-dependent process towards a more structured, transparent and auditable decision-support workflow.



3. Justification

Justification

The rationale for O_2Match rests on a specific and clinically consequential gap. Clinical guidelines establish when oxygen is indicated and, broadly, which therapeutic modality should be considered. However, they stop short of the operational question faced by the prescriber at the point of care: given this patient's oxygen flow requirement, functional capacity and home environment, which device is appropriate, which alternatives are acceptable and which options must be excluded?

The knowledge required to answer this question exists, but it is fragmented across national standards, international guidelines, manufacturer specifications and the Portuguese CRD contractual framework. In practice, it is often concentrated in the tacit experience of specialised teams. The needs assessment underlying this work confirmed that device mismatch is a recurrent cause of early substitution and therapeutic failure, particularly when prescriptions are made under time pressure and without sufficient visibility of the domestic setting. Structuring this decision is therefore not merely a matter of convenience, but a safety-relevant clinical requirement.

A rule-based, explainable architecture is an appropriate response to this problem. Oxygen device selection is governed by identifiable clinical thresholds, regulatory criteria and technical compatibility rules, which can be represented deterministically and audited. Every recommendation and exclusion can be traced to a defined rule. In a safety-sensitive domain, where professional accountability and transparency are essential, this traceability is preferable to opaque data-driven models, particularly given the limited volume of routine data available for training a robust predictive model in this specialised area. Explainability also has clinical value in its own right, because the prescriber must be able to understand and, where necessary, challenge or override the reasoning behind a recommendation.

The Portuguese context further reinforces the need for such a tool. Access to certain oxygen technologies is determined not only by physiological indication, but also by prescriber profile, clinical modality, respiratory rehabilitation status and CRD contractual rules. A patient may meet physiological criteria for Ambulatory Oxygen Therapy yet be ineligible for a specific

portable technology under the national framework. A CDSS that encodes these constraints explicitly can help reconcile clinical need with regulatory eligibility at the moment of prescription, a reconciliation that guidelines alone do not provide.

The expected contribution is therefore deliberately defined. O_2Match does not automate prescription or replace clinical judgement. It supports the prescribing physician by integrating clinical requirements, functional capacity, environmental constraints into a coherent and transparent recommendation process. At the stage described in this dissertation, the contribution concerns the feasibility of formalising this decision logic, the internal consistency of the resulting engine and the usability of the interface through which clinicians interact with it. These are necessary foundations for any subsequent investigation of clinical effectiveness, organisational adoption or integration within the SNS.



4. Materials and Methods

Materials and Methods

This chapter describes the methodological framework, supporting materials and development stages of O_2Match, a Clinical Decision Support System (CDSS) designed to support the personalised prescription of Home Oxygen Therapy. The work follows a structured approach that combines requirements engineering logical modelling, medical software engineering and user-centred usability evaluation.

The research and development of O_2Match were guided by the principles of Design Science Research (DSR) and User-Centred Design (UCD), as applied to medical informatics [23, 30]. Because the usefulness and safety of a health information resource depend on systematic evaluation across its lifecycle, the study adopted a pragmatic, ethical and medico-legal perspective throughout the development process [31, 32].

The study was organised into four sequential and iterative phases, which together constituted the system engineering cycle. The first phase, diagnosis and requirements analysis, triangulated empirical needs through questionnaire surveys involving several stakeholder groups and semi-structured interviews with CRD professionals. This phase was conducted in parallel with an exhaustive mapping of oxygen equipment available in Portugal. The second phase, logical modelling, translated national and international clinical guidance into deterministic rules and safety alerts, structured around a conceptual model composed of three input domains. The third phase, software engineering, produced high-fidelity interfaces and a functional, interactive prototype implemented as a single-page application (SPA) in React with the support from the Claude Code development tool. The fourth phase, ergonomic evaluation, consisted of laboratory sessions based on Nielsen's discount usability engineering and the Cognitive Walkthrough protocol, with practising physicians as representative users, to examine the effectiveness, efficiency and satisfaction associated with the system.

Although presented sequentially, the phases were interdependent and iterative. The diagnostic findings shaped the rules and interface, the algorithm defined the variables collected by the application, and the evaluation of each phase informed corrections to the preceding work.

4.1 Phase I — Initial survey: stakeholders and available equipment

Before prototype construction, a diagnostic survey of the field was conducted to characterise who prescribes and uses home oxygen, the difficulties encountered during prescription and use, and the equipment available in the Portuguese CRD ecosystem. This survey provided the empirical foundation for the subsequent construction phases.

4.1.1 Stakeholder identification and ethical framework

To clarify the information problem addressed by O_2Match [23], the direct and indirect stakeholders in the home oxygen ecosystem were mapped. These included prescribing physicians from Pulmonology, General and Family Medicine, Internal Medicine and Palliative Care; supporting health professionals, including rehabilitation nurses and physiotherapists; technical teams from CRD provider companies; and patients using oxygen devices at home [30].

The protocol for the diagnostic and usability study was formally submitted to and approved by the Ethics Committee of the Unidade Local de Saúde de Gaia e Espinho (ULSGE). All stages were conducted in accordance with the principles of the Declaration of Helsinki [33]. Confidentiality and anonymity were preserved during data collection and statistical analysis, in accordance with the General Data Protection Regulation (GDPR; Regulation (EU) 2016/679) and Portuguese Law No. 58/2019. All participants signed a written informed consent form. The institutional consent model and ethical approvals are provided in Annex 10.1 (Ethics Committee Opinions) and Annex 10.2 (Informed Consent).

4.1.2 Needs assessment

To characterise the attitudes, procedural difficulties and behaviours of intended users [23], the empirical diagnostic study combined two complementary methods.

Three purpose-built questionnaires were designed and administered. The first, directed at prescribing physicians, examined familiarity with available equipment, the information sources habitually consulted, uncertainty about oxygen prescriptions, and perceived usefulness of a CDSS (Annex 10.3). The second, directed at non-prescribing health professionals, including nurses and cardiopulmonary technicians, characterised the frequency of mismatch between the

medical prescription and the patient's functional capacity, practical usability difficulties observed, adequacy of time available for equipment teaching and training in the hospital, and logistical reasons for early device substitution (Annex 10.3). The third, directed at oxygen users, recorded patients' experience with their equipment, the limitations encountered and their overall ergonomic satisfaction in daily life (Annex 10.3).

The two professional questionnaires were administered digitally through Microsoft Forms after informed consent and participants were selected from a convenience sample invited via the ULSGE institutional email system. The patient questionnaire was administered in person, on paper, during pulmonology subspecialty consultations at ULSGE, namely COPD, non-invasive ventilation (NIV) and respiratory rehabilitation clinics. Current use of home oxygen use was the inclusion criterion.

To capture operational realities and constraints that may remain invisible during clinical consultation, audio-recorded semi-structured interviews were conducted with three CRD professionals. These included one technician responsible for home installation and maintenance of oxygen equipment, and two health professionals specialising in oxygen teaching and home-adaptation follow-up. Interviews lasted approximately 15 to 20 minutes. The thematic interview guide and anonymised statements are provided in Annex 10.3, CRD Interview Guide and Thematic Analysis.

4.1.3 Equipment inventory and characterisation

In parallel with the user study, all home oxygen medical devices marketed and funded by the Portuguese National Health Service (SNS) under the CRD framework agreement, managed by the Shared Services of the Ministry of Health (SPMS), were systematically mapped and normalised. Original user manuals and technical specification sheets from provider companies accredited under the national framework agreement were collected.

Data collection produced a structured spreadsheet database describing 41 oxygen devices across 44 discrete technical and operational attributes. The variables recorded included device identification, namely manufacturer, commercial model and category, including fixed concentrator, portable concentrator, stationary liquid oxygen, portable liquid oxygen and gaseous oxygen; flow capacity, including maximum continuous-flow output in liter/minute and pulse-dose bolus settings from 1 to 6; physical specifications, including net weight in kg with

and without battery, physical dimensions and mechanical noise emission in decibel energy and logistics, including battery autonomy in pulse-dose and continuous-flow modes, recharge time, electrical compatibility for AC/DC and vehicle use, and Federal Aviation Administration (FAA) approval for commercial air travel; and interfaces and safety, including nasal cannula or mask circuit diameter, maximum circuit length and physical coupling compatibility with continuous positive airway pressure or non-invasive ventilation, CPAP/NIV. The normalised database constitutes the static relational core of the CDSS and is documented in Annex 10.4, Complete Table of the Physical and Technical Characteristics of the Equipment.

4.2 Phase II — Construction of the decision algorithm

The rule base was derived from the guideline framework and the ideal prescription model presented in the Introduction. The relevant sources included DGS Norma 018/2011 [2], BTS [9], ATS [1], and the CRD *Caderno de Encargos*. This clinical, technical and contractual knowledge was translated into deterministic, auditable decision logic.

4.2.1 The trilateral conceptual model

To reduce cognitive load and standardise data entry by the health professional, a patient-centred conceptual model was designed around an input screen divided into three axes, or strict blocks of input variables. The clinical axis, corresponding to what the patient physiologically requires, is defined by the oxygen therapy context, namely long-term, short-term, ambulatory only, palliative or adjunctive to NIV; the oxygen flow rate prescribed at rest, during sleep and during exertion; the need for continuous-flow or pulse-dose oxygen delivery; and the coexistence of mechanical ventilation interfaces. The functional axis, corresponding to what the patient is physically able to do, captures habitual mobility outside the home, physical autonomy, manual dexterity, cognitive capacity to operate electronic panels and the tolerable limit for carrying physical load. The logistical and social axis, corresponding to what the home environment allows, captures the presence and active support of a reference caregiver, architectural barriers such as dwellings with stairs and no lift, stability of the local power supply, and any history of risk behaviour such as active smoking. The general flowchart and Venn diagram of this trilateral model are presented in Figure 1, Visual Models of Clinical Reasoning.

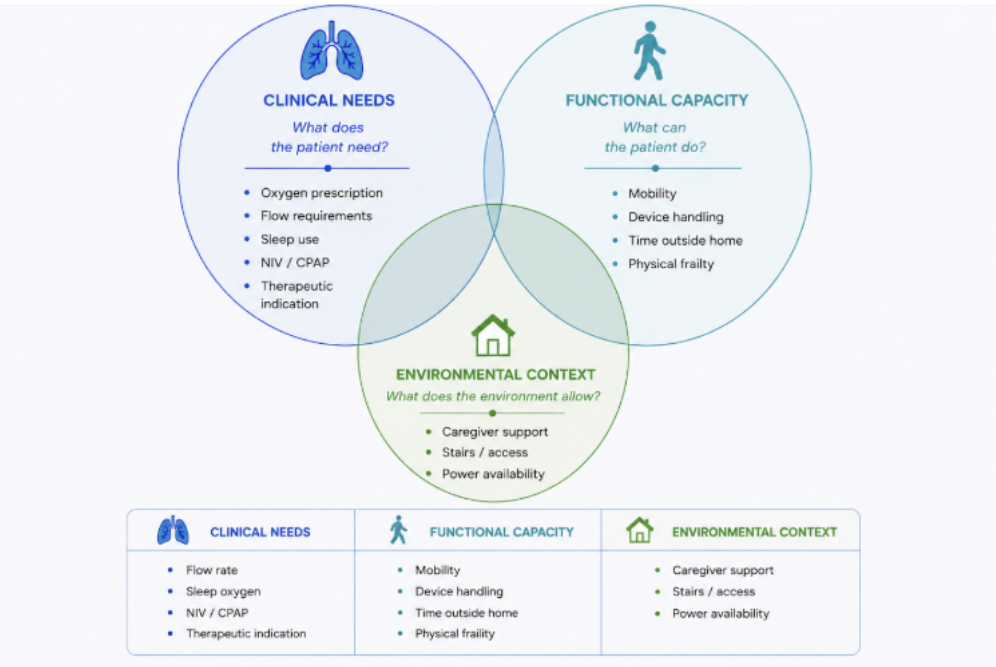


Figure 1- The trilateral conceptual model: device suitability as the intersection of clinical needs, functional capacity and environmental context. Source: Developed by the author. The graphical representation was created with the assistance of generative AI.

4.2.2 Architecture of the decision engine

The O_2Match inference engine processes patient information through a structured decision pipeline designed to prioritise clinical safety, transparency of rules and compatibility with the Portuguese CRD prescribing context. This choice reflects the need for explainability in clinical decision support, particularly where recommendations depend on guideline thresholds, regulatory constraints and device-specific technical properties [16, 31]. The pipeline is organised into three layers that serve different purposes and should not be interpreted as equivalent forms of evidence: deterministic exclusion rules, clinical preference rules and clinical alert rules (Figure 2).

The first layer applies deterministic exclusion rules: 23 deterministic exclusion rules that function as gatekeepers (Annex 10.5). If a device category violates an active deterministic exclusion rule, it is excluded from the set of viable recommendations, and the constraint cannot be offset by convenience, portability or preference. These rules, expressed as IF–THEN logic,

are derived from national guidance, including DGS Norma 018/2011, updated on 11 September 2015, and international guidelines [1, 9]. They exclude equipment that is incompatible with patient safety or with mandatory prescribing criteria.

The 23 deterministic exclusion rules are not applied simultaneously or indiscriminately to every patient profile. Instead, the engine follows contextual, role-specific logic to determine which rules are activated in each clinical scenario.

First, O_2Match applies a dynamic funnel principle. A Deterministic Exclusion Rule is activated only when the corresponding clinical or contextual input is relevant to the patient profile entered by the physician. Second, the algorithm applies strict scoping based on each device's functional role. The engine distinguishes between the primary domiciliary or nocturnal oxygen source and the ambulatory component used outside the home. This prevents safety restrictions intended for one device role from being incorrectly transferred to another. For instance, the sleep-safety rule that excludes battery-powered portable concentrators as nocturnal oxygen sources (R03) does not automatically preclude those devices from consideration for daytime outdoor use, where portability and autonomy may be clinically relevant. Therefore, the Deterministic Exclusion Rules displayed for each scenario correspond only to the active rules associated with the specific device role being evaluated at that point in the decision process.

Third, O_2Match incorporates a logistical safeguard against algorithmic paternalism. During rule modelling, contextual barriers such as stairs without a lift, moderate frailty or absence of an informal caregiver were deliberately not implemented as Deterministic Exclusion Rules. Automatically excluding a clinically appropriate option, such as liquid oxygen, solely because of these barriers could inappropriately replace clinical judgment with rigid computational logic. It would also ignore possible adaptations that the system cannot fully represent, such as rehabilitation, community support, family assistance or changes in the home environment. For this reason, these variables were assigned to the logistical-empathy alert layer, specifically A09, A10 and A11 (Annex 10.5). These alerts generate prominent call-to-action warnings for the physician, but do not remove the option from the interface. This preserves clinical responsibility and allows the prescriber to make the final ethical and practical judgement regarding the prescription's social feasibility.

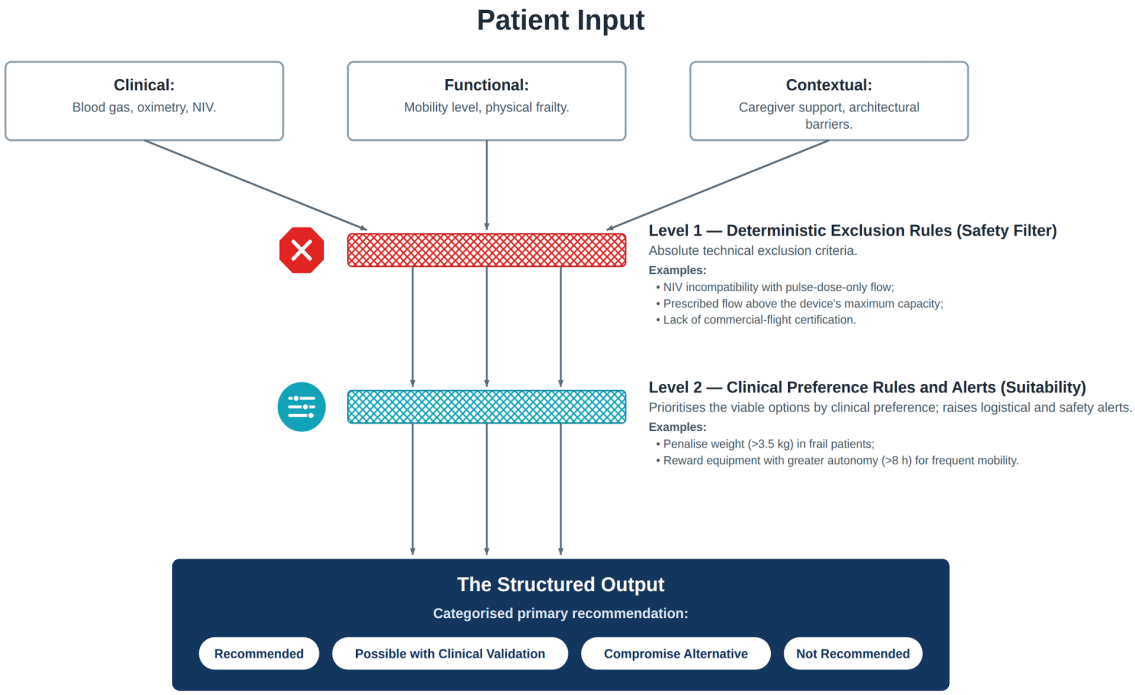


Figure 2- Architecture of the O_2Match decision engine. Source: Developed by the author. The graphical representation was created with the assistance of generative AI.

Representative deterministic exclusion rules include nocturnal CPAP/NIV incompatibility (R01) which excludes pulse-dose-only concentrators or ambulatory devices that cannot couple in continuous-flow mode to the ventilation circuit, thereby reducing the risk of severe nocturnal desaturation and ventilator asynchrony; sleep incompatibility (R03) which excludes pulse-dose-only devices when nocturnal oxygen is indicated, since shallow or apnoeic breathing may fail to trigger delivery; the exertional flow ceiling (R04) which excludes electrical portable concentrators when the exertional oxygen flow rate is ≥4 L/min, since these devices do not deliver true continuous-flow oxygen at that level and ambulation should instead be directed towards liquid oxygen or gaseous cylinders; continuous 24-hour life protection, R06, which excludes stationary equipment not certified for uninterrupted 24-hour operation in severely dependent continuous-use patients; and the smoking safety filter, R15, which excludes liquid oxygen and high-pressure gaseous cylinders in the homes of patients with persistent active smoking, restricting choice to a conventional electrical concentrator and generating a high-priority fire-risk alert.

The second layer applies clinical preference rules: 18 rules that rank the device categories remaining after deterministic exclusion. These rules do not determine clinical permissibility.

Instead, they prioritise clinically acceptable options based on clinical suitability, functional usability, logistical feasibility, and, where relevant, resource considerations [13, 14]. The status of this layer must be stated precisely. These preferences were organised as clinical preference rules and were not implemented as a formal multi-criteria decision analysis (MCDA) model with weights calibrated from the needs-assessment data, because the patient questionnaire responses did not achieve sufficient numerical and class representativeness to calibrate robust weights. One example of clinical preference rules is the resource-consolidation preference, P14. To avoid SNS funding of two electrical devices simultaneously, namely a fixed unit for home use and a portable unit for outdoor use, patients requiring both regular ambulation and long-term oxygen at rest receive, as a first-line option, an integrated liquid oxygen system composed of a stationary reservoir and a portable unit, when clinically and logistically appropriate.

The third layer generates alerts: 36 clinical and logistical messages that do not necessarily exclude a device but identify conditions requiring prescriber attention, further testing or patient education. Some risks can be managed through counselling, monitoring or additional assessment rather than automatic exclusion. Within the Information Value Chain framework, such alerts act at the point where interaction with the system changes the information available to the clinician and may alter the subsequent care process [18]. A subset of these alerts — the logistical-empathy alerts (A09, A10 and A11) — operationalises the anti-paternalism safeguard described above: rather than excluding a clinically appropriate therapy on logistical or social grounds, they make the barrier explicit to the prescriber while keeping the option available. The complete specification of deterministic rules and clinical preferences is provided in Annex 10.5, Complete Specification of the Deterministic Exclusion Rules and Clinical Preference Rules.

4.2.3 Clinical scenarios and dual clinical validation

To examine the reproducibility of the system's reasoning core, 38 simulated clinical scenarios were designed to cover eight logical entry blocks. Block A, LTOT for 16 hours per day, comprises scenarios A1−A7, crossing oxygen flow rates ≤4 L/min and >4 L/min with absent, occasional or regular ambulation at low or high exertion. Block B, LTOT for 24 hours per day, comprises B1−B6, representing severely ill patients with critical life-support constraints. Block C, ambulatory-only oxygen, comprises C1−C2, representing active patients with no resting

oxygen requirement. Block D, adjunctive oxygen to CPAP/NIV, comprises D1−D11, representing patients on chronic nocturnal or continuous 24-hour ventilation. Block E, palliative or end-of-life oxygen, comprises E1−E3, focused on physical comfort, with a palliative override pathway and suppression of the mandatory six-minute walk test (6MWT). Block F, short-term oxygen for ≤90 days, comprises F1−F4, addressing temporary solutions and the relative cost-efficiency of gaseous cylinders versus electrical device rental. Block G, isolated nocturnal hypoxaemia, comprises G1−G3 and requires prior polysomnography. Block H, isolated air travel, comprises H1−H2 and requires FAA approval and 150% spare-battery autonomy.

The decision matrices and logical transition flowcharts for these 38 simulated use cases were submitted for independent review by two senior specialist pulmonologists, who assessed, by clinical consensus, the safety and adequacy of the recommendations and exclusions generated by the engine. The complete set of the 38 scenarios is summarised in Annex 10.6.

4.2.4 Algorithm verification

Before the prototype was presented to any user, the decision engine was verified to ensure it applied the clinical rules exactly as specified. This step is a software verification, not a clinical validation: it does not test whether O_2Match improves patient outcomes, but whether the implemented logic reproduces the intended rules without programming error. In the terms of Wyatt and Brender, it corresponds to a laboratory function-demonstration study, and it aims to remove implementation error as a source of discrepancy before any user interacts with the system.

Verification was performed by independent cross-checking against a reference implementation (the oracle). A second, separate program was written in Python 3.12 (using the pandas and openpyxl libraries) that encoded the same clinical rules as the React prototype but shared no code with it. Because the two implementations were built independently, agreement between them provides strong evidence that the logic is correct, whereas any disagreement points directly to an error to be investigated.

It is important to distinguish this verification tooling from the deployed application. The clinician-facing CDSS runs entirely in the web browser (HTML, CSS and TypeScript/React) and requires no server or Python runtime. Python was used only offline, in two supporting roles:

first, to build the knowledge base, with scripts (xlsx_read.py, build_data.py) that read the master equipment spreadsheet and converted its technical specifications — flow ceilings, battery weights, flight-certification status — into the structured JSON files consumed by the application; and second, to run the verification oracle. The deployed tool, therefore, remains lightweight and serverless, with no dependency on Python.

The oracle processed the inputs for the 38 clinical scenarios in batches, cross-referenced them against the equipment table, applied the logical constraints, and generated an audit report comparing its output with that of the prototype. For each scenario, four output dimensions were compared: the primary recommended device category, acceptable alternatives, devices excluded by the deterministic exclusion rules, and safety or contextual alerts shown to the prescriber. Comparing all four matters because the system must justify not only what it recommends but also what it excludes — and, in some scenarios, the correct output is a warning that no device can be safely recommended without further clinical assessment. The same oracle was also used to stress-test the rules across 768 input permutations, well beyond the 38 scenarios, to expose edge cases.

This process uncovered subtle, data-level errors that would otherwise have been hard to detect. The clearest example was the "NaN trap". Pulse-dose-only portable concentrators (POC_p) do not deliver continuous flow, so this field was empty ("Not Applicable") in the equipment database. When a numerical comparison is applied to an empty value in Python — for instance, checking a prescribed 4 L/min against a missing value — the test returns False, which could have allowed an unsuitable pulse-dose device to slip past the continuous-flow safety check during air-travel triage. The problem was resolved by adding a categorical safeguard that explicitly excludes POC_p devices whenever a continuous flow $\geq$ 4 L/min is prescribed, before any numerical comparison is made.

4.3 Phase III — Construction of the application

4.3.1 Interface and interaction design

To support usability and address the practical constraint of limited consultation time, the O_2Match interface was designed in accordance with Nielsen's usability heuristics [26] and Norman's stages of action. Data entry was structured as a step-by-step wizard, moving from clinical to functional to contextual data to reduce the physician's working memory load. A

persistent summary panel, positioned in the upper-right corner of the entry screen, reflected in real time the clinical and logistical variables selected in previous steps, allowing the physician to verify coherence of the patient profile without navigating backwards.

The output screen presents the result through an ergonomic tricolour scheme. Green marks the primary recommendation, displaying the preferred generic device category, such as an integrated liquid oxygen system, with supporting clinical justification. Yellow marks viable alternatives, corresponding to devices that survive the deterministic exclusion rules but raise usability or comfort alerts, such as a portable concentrator flagged because its weight may be incompatible with frailty or domestic stairs. Red marks clinically excluded options, listing the devices removed by deterministic exclusion rules together with the code of the triggered safety rule, for example, exclusion by R03 when a pulse-dose device is incompatible with sleep. The detailed output and structured-entry layouts are provided in Annex 10.8, Low- and Medium-Fidelity Interface Mockups.

The interface was also designed to minimise cognitive load and reduce unnecessary clicks by linking clinically dependent variables. When one variable is selected, related fields are pre-populated where this is clinically appropriate. For example, selecting Long-Term Oxygen Therapy (LTOT), which presupposes nocturnal oxygen use, automatically activates the nocturnal oxygen field. Setting habitual mobility to “bedridden” pre-selects the corresponding functional attributes, while choosing an institutional care setting pre-sets housing conditions as having “no relevant barriers”. These conditional pre-selections remain visible and fully editable, ensuring that the clinician retains control while avoiding repetitive data entry.

Two further safeguards were built into the input form. First, mandatory-field validation prevented incomplete submissions: when the user attempted to proceed without completing the required fields, the missing fields were highlighted with a red outline, and progression was blocked until they were filled in. Second, in line with the DGS framework, the form constrained the prescription scenarios available to the user by prescriber type — hospital care or primary care — and by the prescribed duration, so that only combinations authorised by the national norm could be selected.

4.3.2 Input pathways and security-by-design

To protect highly sensitive patient health data under the GDPR, O2Match was designed using a security-by-design approach. Access is authenticated through the institutional email account and linked, in read-only form, to the physician's Ordem dos Médicos registration number and health unit. The system implements immediate lockout after three consecutive incorrect password attempts, an access-audit screen displaying the date, time, and IP address of the last access, and remote session management that allows the physician to terminate active sessions on all connected devices. These mechanisms are intended to reduce the risk of unauthorised access, particularly after a workstation is left unattended. The login is also designed to authenticate through SNS access credentials or, subject to credential validation, through those of another health institution, since the application is prepared to operate both within the SNS and outside it, including private-practice settings. A password-recovery function is also provided.

The specification also provides alternative ways to enter patient data into the same rule-based engine. When the application is integrated with the national unified patient registry, the patient can be retrieved in two ways: by SNS user number or by demographic identifiers such as name, date of birth, and sex, with the corresponding data populated automatically. A separate, non-integrated mode allows the required variables to be entered manually, with no connection to the patient registry or PEM integration, so the tool can also be used outside integrated environments. All input modes converge on the same inference engine. At the prototype stage described in this dissertation, O2Match is a research prototype and decision-support artefact; it is not claimed to be a certified medical device, and the final prescription decision remains with the prescribing physician.

4.3.3 Prototype Architecture: A Two-Layer Design

To support the subsequent usability evaluation, the O2Match prototype was implemented using a hybrid two-layer software architecture. This design separates the visual presentation of each clinical screen from the application logic governing user interaction and clinical data flow, enabling reuse of high-fidelity visual mockups while introducing the statefulness required for a functional clinical decision support tool (Figure 3).

- **Layer 1 — Standalone HTML Mockups:** Located in the application's public/mockups directory, this layer consists of self-contained HTML/CSS documents organised by screen (including patient demographics, functional assessment, environmental/logistical barriers, recommendation output, and PDF report). Each mockup operates independently and defines the static layout and visual design. Because these mockups were conceived in isolation during the UI/UX design phase, they embed static placeholder values (such as a default prescription duration of 30 days) that are intrinsic to the visual layer.

- Layer 2 — React Application: Contained in the src directory with App.tsx as its central hub, this layer is built on the React JavaScript library. It captures user inputs in real time, manages the global clinical state of the patient profile, and executes the local rule-based inference engine within the browser.

- **Integration via iframe and DOM-based Communication:** The two layers are integrated using the browser's native iframe mechanism, where the React application embeds each static mockup. Communication between the React orchestrator and the embedded mockups does not rely on external communication protocols or backend languages; instead, it is handled entirely within the browser via JavaScript. Using the Document Object Model (DOM) API, the React parent layer programmatically accesses the iframe's internal structure (using methods such as querySelector). This allows JavaScript to read user selections, intercept navigation actions, and overwrite static HTML placeholders with the active, canonical clinical state managed by React.

The state specification and variable mapping in the React code are documented in Annex 10.9, State Mapping and SPA Code Architecture.

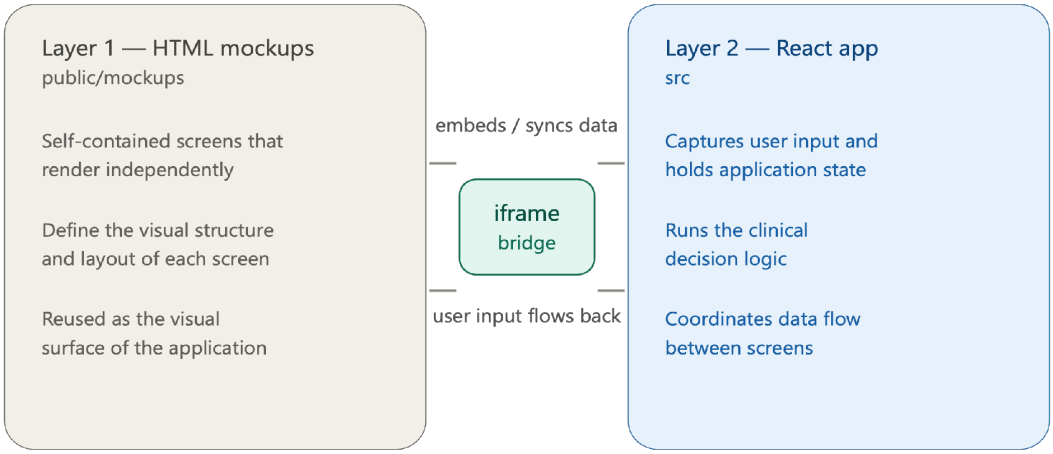


Figure 3 - Two-layer architecture of the O₂Match prototype: standalone HTML mockups (Layer 1) and React application (Layer 2).

4.3.4 Supporting modules and interoperability

Beyond the decision wizard, the prototype was designed with a set of supporting modules that reproduce the workflow of a real prescribing environment.

A configuration area allows the tool to be adapted to each institution, including the integration of the institution's logo and the prescribing physician's identifying details.

A patient-record module stores patients' previous prescriptions and allows earlier prescriptions to be imported, so the clinician can either consult an existing prescription or start a new one based on the patient's history. Patients can be retrieved by SNS number through the SNS integration pathway (Section 4.3.2), populating identifying and demographic data from the national patient registry rather than requiring manual re-entry.

For output and interoperability, the system generates a PDF report that can be filed in the clinical process or handed to the patient, and it supports a simulated export of the prescription data to the electronic medical prescription platform (PEM).

4.4 Phase IV — Usability evaluation

4.4.1 Study design and evaluation protocol (cognitive walkthrough)

To assess the extent to which users could navigate the CDSS and complete the intended clinical tasks [23], a formal laboratory study was designed using the Cognitive Walkthrough method adapted to medical information systems [26], complemented by a Think-Aloud protocol. The evaluation was designed to assess the prototype against the three dimensions of usability defined in ISO 9241-11: effectiveness, efficiency and satisfaction. Effectiveness was assessed through task completion. Efficiency was explored through observed interaction fluency, hesitation and need for assistance. Satisfaction was assessed through post-test Likert-scale ratings and qualitative comments on perceived usability, cognitive burden and clinical acceptability [24].

4.4.2 Participants and setting

A cohort of six practising prescribing physicians from ULSGE was recruited as representative users. Participants included clinicians with varying levels of hospital experience, different attitudes towards technology, and varying lengths of clinical practice, including residents and specialists in Pulmonology. Sessions were conducted individually and in person. Each physician completed a suite of 11 critical clinical tasks in the functional React prototype, covering data entry, interpretation of outputs, export of the clinical justification report as a PDF, and simulated interoperability with the Electronic Medical Prescription system, Prescrição Eletrónica Médica (PEM). Task completion was recorded by the investigator on a colour-coded grid: green for autonomous and intuitive completion; amber for completion with difficulty, including hesitation, entry errors, or the need for support; and red for failure to complete the task, indicating a critical failure or workflow block.

4.4.3 Ergonomic-satisfaction metrics (SUS-informed)

After the tasks, a structured ergonomic satisfaction questionnaire was administered using a five-point Likert scale adapted from the System Usability Scale (SUS). The questionnaire assessed layout, the summary panel, option selection, navigation and export to PEM. Because the full SUS instrument was not administered, the results are reported as SUS-informed subjective

ratings rather than as a formal SUS score. The sessions were accompanied by the Think-Aloud technique, with written free-form field notes of qualitative observations for subsequent content analysis and categorisation against Nielsen's ten usability heuristics. The methodological manual and usability instruments are provided in Annex 10.10: Usability Testing Protocol and Recording Grid, and in Annex 10.10: Ergonomic Questionnaire and Satisfaction Metrics.



5. Results

Results

This chapter presents the consolidation and empirical analysis of the results obtained during the development of the O₂Match ecosystem, following the methodological structure described in Chapter 4. Mirroring that structure, the analysis is organised into three parts: first, the initial survey of stakeholder needs and the oxygen equipment landscape (Phase I); second, the construction and logical verification of the decision model (Phase II); and third, the O₂Match application — its interface and the experimental usability evaluation with real users (Phases III and IV).

5.1 Phase I — Initial survey: stakeholder needs and equipment landscape

5.1.1 Needs assessment

The needs assessment combined quantitative evidence from three structured hospital-based questionnaires, comprising a total integrated sample of 72 participants, with qualitative evidence from three semi-structured interviews conducted with professionals involved in CRD. This mixed evidence base was used to characterise the prescribing context, identify recurrent sources of uncertainty, and inform the design requirements of the O₂Match decision-support logic.

Prescribing physicians

The questionnaire yielded 31 valid responses (Annex 10.3). The sample consisted predominantly of pulmonologists (90%), with smaller proportions of respondents from General and Family Medicine (6%) and Infectious Diseases (3%). Most participants were based in northern Portugal (81%), indicating a marked geographical concentration.

Levels of clinical experience varied considerably. Approximately 35% of respondents reported 10–19 years of clinical practice, while 32% had fewer than five years of experience. A further 10% were still undergoing specialist training. The median level of experience fell within the 5–9-year category. Most respondents worked in outpatient clinics (94%), and a substantial proportion also practised in emergency departments (71%).

For most participants, prescribing HOT was a relatively infrequent activity. Only 19% reported prescribing HOT several times per week. The remaining respondents prescribed it approximately once per week (26%), once per month (26%), or only a few times per year (29%) (Figure 4).

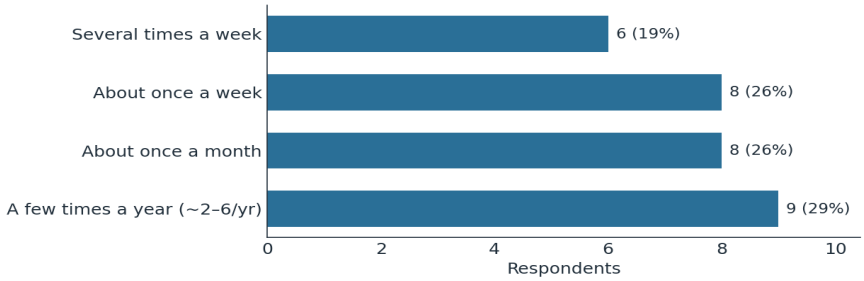


Figure 4- Frequency of home oxygen prescription (n = 31).

Physicians reported a high level of knowledge regarding the formal indications for HOT, with a mean score of 4.32 out of 5. Confidence in applying the relevant guidelines in routine clinical practice was similarly high, with a mean score of 4.23. However, this confidence did not extend to the selection of oxygen devices. When asked whether existing clinical guidelines provide sufficient support for choosing the appropriate device type, 48% of respondents disagreed, and a further 10% strongly disagreed, whereas only 26% agreed.

By comparison, self-rated knowledge of the oxygen devices available on the market was moderate, with a mean score of 3.52 out of 5 (Figure 5).

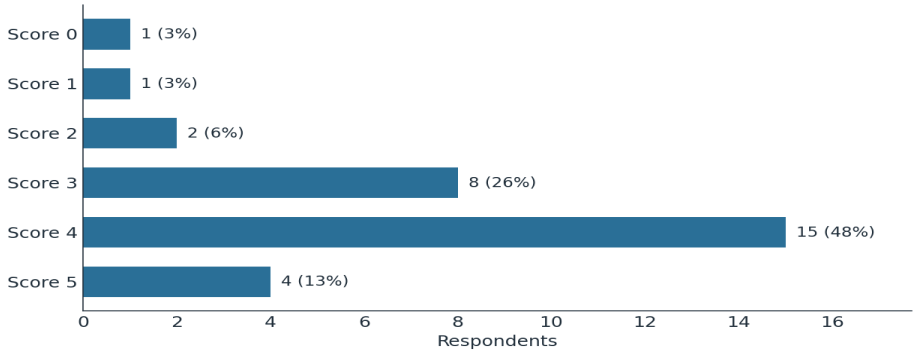


Figure 5- Self-rated overall knowledge of the oxygen devices available on the market (0–5; n = 31).

When analysed by device type, self-rated knowledge was highest for stationary oxygen concentrators (mean score 4.06) and lowest for portable oxygen concentrators (mean score 3.65).

The main source through which physicians learned about new oxygen devices was direct contact with company sales representatives, which 77% of respondents reported. Other sources were congresses or scientific training activities (45%), professional colleagues (29%), and the scientific literature (13%).

Respondents nevertheless rated the dissemination of information about new devices to prescribers poorly, with a mean score of 2.29 out of 5. The availability of technical information to support clinical decision-making received a similarly low rating, with a mean score of 2.39 out of 5.

LTOT was the most frequently prescribed modality, reported by 77% of respondents, followed by ambulatory oxygen therapy (55%). Nocturnal oxygen therapy, or oxygen prescribed as an adjunct to ventilatory support, was reported in 26%, while palliative oxygen therapy (13%) and short-term oxygen therapy (6%) were less frequently prescribed.

Oxygen device selection was reported to depend primarily on the equipment's technical characteristics (74%). Other relevant factors included patient preference (58%), information provided by CRD companies (55%), and the prescriber's own clinical experience (52%).

The order in which prescription-related factors were considered was broadly consistent across respondents. Clinical indication was ranked first almost unanimously, with a mean rank of 1.00, followed by the required oxygen flow rate (2.58). Logistical factors were assigned the lowest priority, with a mean rank of 6.58 (Table 1).

Table 1- Sequence of factors considered when prescribing (mean rank; 1 = considered first; n = 31).

Item	Average rank
Clinical indication	1.00
Required oxygen flow rate (L/min)	2.58
Needs at rest / sleep / exertion	3.23
Patient mobility	3.94
Patient's ability to handle the device	5.32
Device type	5.35
Logistical issues	6.58

Lower = considered earlier

The stage most frequently identified as difficult was matching the oxygen device to the patient's lifestyle, which 61% of respondents reported. This was followed by selecting the device itself (45%), while only 10% reported no relevant difficulties in the prescription process (Figure 6).

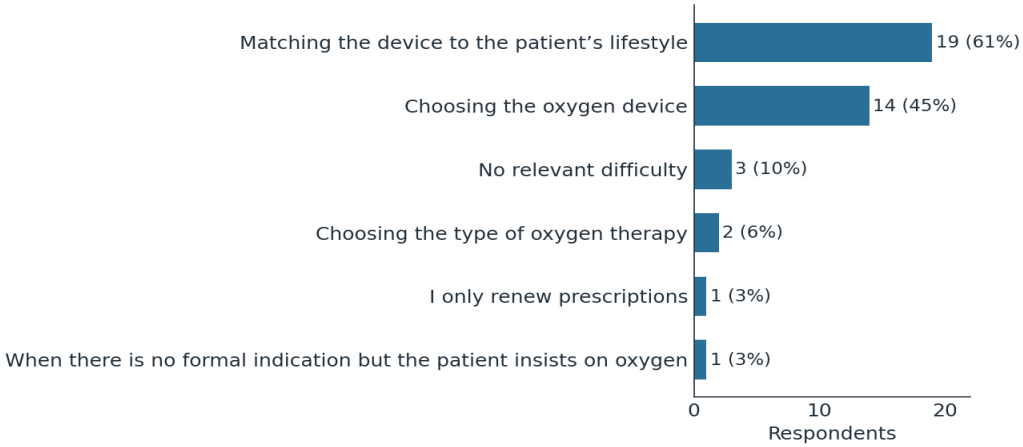


Figure 6- Stage of prescription perceived as most difficult (n = 31; multiple answers allowed).

Physicians' assessments of the suitability of different oxygen devices for each therapy modality are presented in the cross-tabulation between therapy type and device (Figure 7). Stationary oxygen concentrators were considered suitable primarily for LTOT and nocturnal oxygen therapy. Liquid oxygen systems and portable oxygen concentrators were more frequently considered appropriate for ambulatory oxygen therapy, whereas compressed gaseous oxygen cylinders were primarily associated with short-term and palliative oxygen therapy.

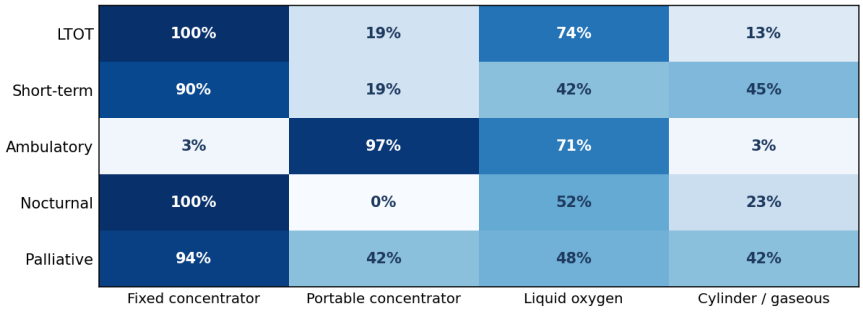


Figure 7- Devices considered adequate by therapy type (% of physicians, n = 31).

A separate set of three statements evaluated agreement with specific clinical safety principles on a 0–5 scale. Respondents showed strong agreement that patients with high oxygen flow-rate

requirements during exertion should receive continuous-flow rather than pulse-dose oxygen delivery, with a mean score of 4.34. Agreement was also high that portable oxygen concentrators providing pulse-dose delivery only should not be used as the primary oxygen source during sleep, with a mean score of 4.55. Physicians also agreed, albeit less strongly, that the effectiveness of pulse-dose-only devices should be validated in individual patients before prescribing, with a mean score of 3.87 (Annex 10.3).

When asked to rate the importance of eight equipment characteristics on a 0–5 scale, physicians assigned the highest scores to oxygen source autonomy (4.65), impact on quality of life (4.48), and maintenance requirements (3.77), which received comparatively lower ratings (Figure 8).

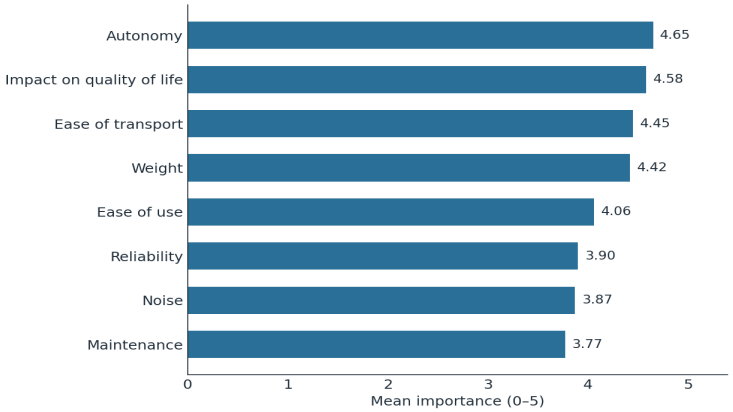


Figure 8- Importance of equipment characteristics (mean, 0–5; n = 31).

Receptiveness to a digital decision-support tool for oxygen device selection was high. Overall, 94% of physicians rated such a tool as useful or very useful, with 55% considering it very useful. Two respondents rated it as only slightly useful, and none considered it not useful (Figure 9).

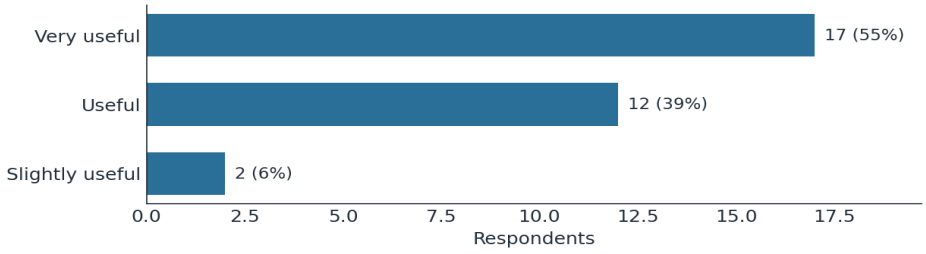


Figure 9- Physicians' perceived usefulness of a digital decision-support tool for oxygen device selection (n = 31).

The features they considered most important were a structured comparison of available devices (84%), integration of the patient profile to support equipment selection (77%), and a clinical decision tree (65%). Fewer respondents prioritised an explanation of the rationale underlying each recommendation (42%) or structured support for the prescribing process (42%) (Figure 10). In the free-text responses, the main factors that could discourage use were limited consultation time, excessive data-entry requirements, and concerns that the information provided might be confusing or unreliable.

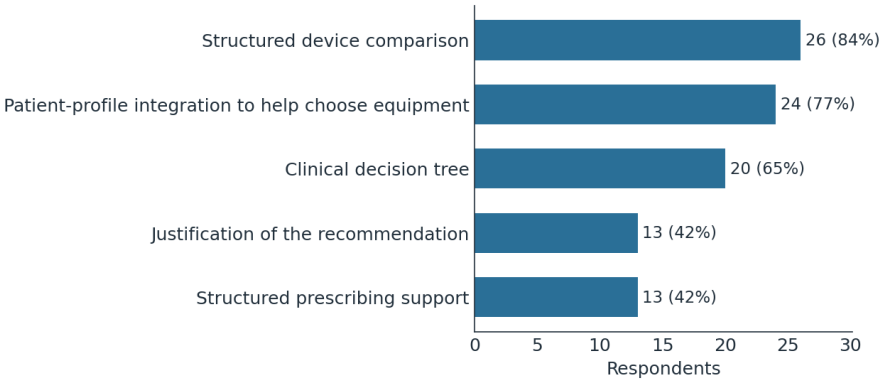


Figure 10- Features rated most important in a digital decision-support tool (n = 31).

Non-prescribing health professionals

A total of 8 non-prescribing health professionals completed the questionnaire. The sample was composed of nurses (6 of 8; 75%) and cardiopulmonary technicians (2 of 8; 25%), a highly experienced group — 7 of 8 (88%) with more than 20 years of clinical practice — working almost entirely in outpatient clinics.

When asked about the most frequent difficulties they observe in patients, weight and portability of the equipment were reported by all respondents (100%), followed by stigma or embarrassment in public (88%), non-adherence to the prescribed use (75%) and management of autonomy/batteries (62%) (Figure 11)

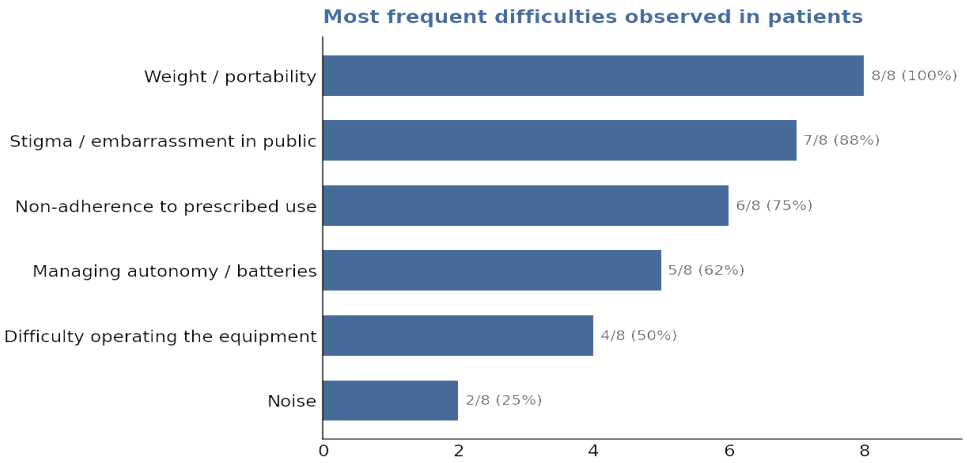


Figure 11- Most frequent difficulties observed in patients (n = 8; multiple choice).

Incorrect use of the equipment was commonly seen: seven of the eight professionals (88%) reported observing it at least occasionally. Views on the adequacy of the initially prescribed device were evenly divided — half considered it adequate most of the time (four of eight), and half considered that it frequently required adjustment (four of eight).

When the equipment proved unsuitable, the most frequently cited factor was low adherence or difficulty of use by the patient (75%). Change in clinical condition after prescription and insufficient technical information at the moment of choice, followed, each reported by half of the professionals (50%). Home-setting barriers, functional or cognitive limitations, and a required oxygen flow incompatible with the device were each noted by three of the eight (38%) (*Figure 12*).

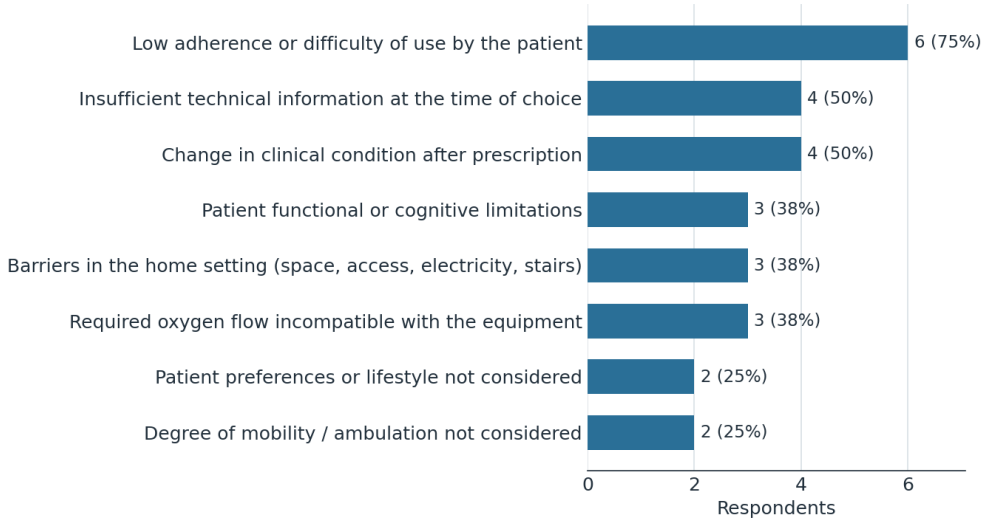


Figure 12- Factors associated with inadequacy of the prescribed equipment (n = 8; multiple answers allowed).

Asked to rate, from the patient's standpoint, the importance of six equipment characteristics (0–5), the professionals placed autonomy of the oxygen source at the ceiling of the scale (mean 5.00), followed by speed and quality of technical support (4.88) and weight and portability (4.75); ease of use (4.38), noise (4.25) and reliability and safety (4.12) followed (*Table 2*).

Table 2- Importance of equipment characteristics, professionals' perception of patients' priorities (mean, 0–5; n = 8).

Characteristic	Mean (0–5)
Autonomy of the oxygen source	5.00
Speed and quality of technical support	4.88
Weight and portability	4.75
Ease of use	4.38
Noise level	4.25
Reliability and safety	4.12

Receptiveness to a digital tool to support device selection was high: the mean rating was 4.38 out of 5 (median 4.5; range 3–5). In free-text suggestions, they described features such as a decision algorithm that selects a suitable device based on the patient's characteristics, a structured comparison of devices by autonomy, weight, and noise, sharing the record across the multidisciplinary team, and monitoring usage time against oximetry.

Oxygen therapy users

The questionnaire obtained 33 valid patient responses. Most respondents were older adults, with 64% aged between 61 and 80 years, although a smaller proportion were younger than 50 years. Chronic obstructive pulmonary disease (COPD) or chronic bronchitis was the most frequently reported underlying condition, affecting 70% of the sample. Most participants had been receiving oxygen therapy for more than one year, and 42% reported using oxygen for more than 16 hours per day. Among the 30 respondents who answered the relevant question, 77% managed the equipment independently, while the remainder relied to some extent on a caregiver.

Continuous oxygen use throughout the day was reported by 52% of patients, whereas 30% used oxygen only at night. Most respondents left their homes at least occasionally, and some reported maintaining an active social life or taking regular walks. The most commonly used device was the stationary oxygen concentrator, reported by 70% of respondents, followed by the portable oxygen concentrator (39%) and liquid oxygen systems (18%).

Patients generally agreed that their equipment was easy to use in daily life and expressed moderately positive views regarding oxygen source autonomy and noise levels. Ratings were lower for characteristics related to portability, including ease of transport, device weight, and comfort when using oxygen in public. The negatively worded statement that the equipment limited daily activities received a mean score of 2.73 out of 5, which appears consistent with the reported limitations in mobility and public use. (Figure 13)

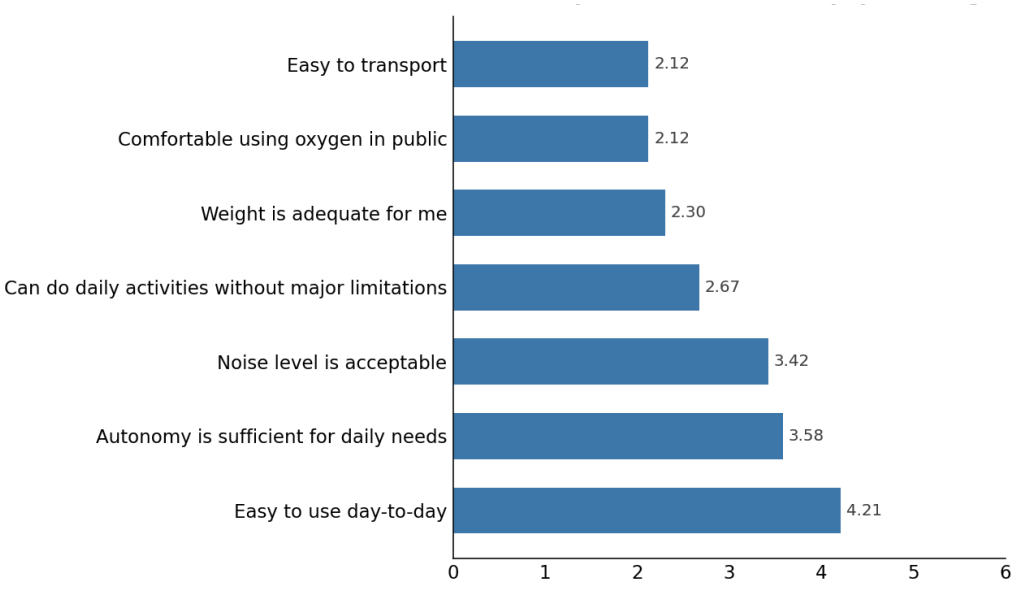


Figure 13- Patient agreement with statements about their equipment (0–5; n = 33).

Overall satisfaction with the oxygen equipment was moderate, with a mean score of 3.48.

When asked to identify the main difficulties associated with their equipment, patients most frequently reported its weight and the difficulty of transporting it. Other commonly reported problems included limited oxygen source autonomy, noise or discomfort, and restrictions on mobility (Figure 14).

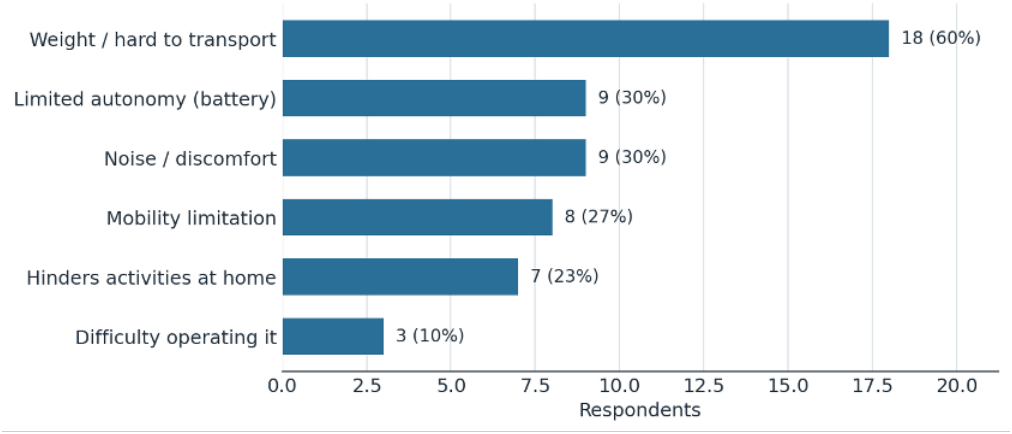


Figure 14- Main difficulties reported by patients (n = 30).

Professionals versus patients: comparing perceived priorities with reported experience

The comparison between healthcare professionals' importance ratings and patients' reported experiences revealed a mismatch between professional priorities and the aspects of the equipment that most affected patients in daily life.

Healthcare professionals assigned high importance to most equipment characteristics, particularly oxygen source autonomy, impact on quality of life, ease of transport, and device weight. Patient-reported experience did not follow the same pattern. Ease of use was rated positively, while autonomy and noise received intermediate ratings. The lowest ratings concerned device weight, ease of transport, and comfort when using oxygen in public, indicating that portability-related limitations were more prominent in patients' daily experience than the professional importance ratings alone might suggest. Figure 15 presents the professional importance ratings alongside the corresponding patient-reported experience scores, highlighting the areas of greatest divergence between the two groups.

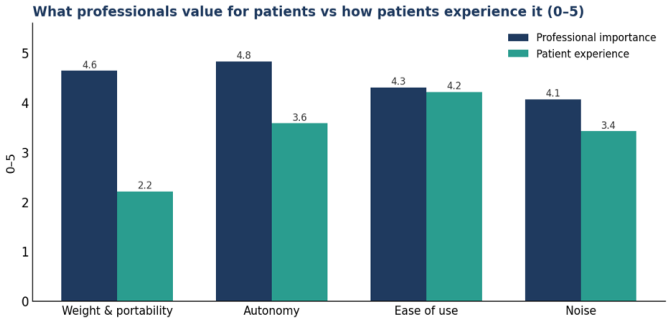


Figure 15- Professional importance vs patient experience, by criterion (0–5).

Ranking the criteria by the gap between professional importance and patient experience yields a clear priority list for improving the patient experience (Figure 16). Weight and portability are by far the largest unmet need (a gap of about +2.4 points): professionals rate them among the most important attributes, yet they are the ones patients experience most poorly. Autonomy is the second priority (+1.3) and noise a smaller third (+0.6). Ease of use, by contrast, is essentially already met (+0.1) — patients find the equipment easy to operate, so it is not an improvement priority.

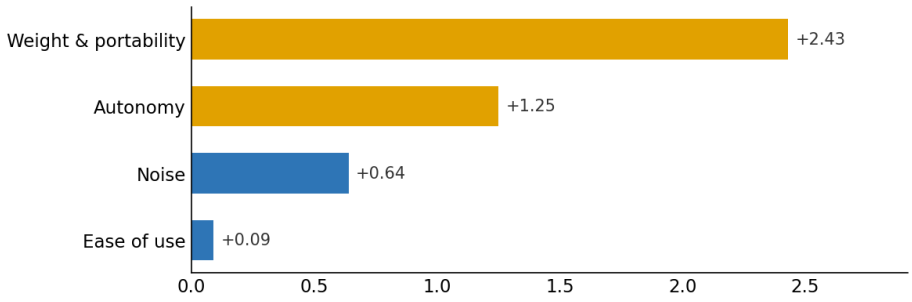


Figure 16- Improvement priority (professional importance − patient experience).

Qualitative interviews with CRD professional

The semi-structured interviews conducted with CRD professionals (n = 3) added operational depth to the quantitative findings by revealing practical dynamics that occur during the transition from hospital prescription to domiciliary installation.

First, the interviews highlighted the context in which prescription–device mismatch most frequently occurs. According to the participants, mismatches between the prescribed equipment and the patient's functional capacity are particularly common after hospital discharge or in urgent-care contexts, where functional assessment and domestic evaluation are often limited. This contrasts with scheduled specialist consultations, where there is usually more time to assess mobility, oxygen requirements and contextual constraints. The interviews also suggested that when the electronic prescription contains insufficient clinical or functional information, the final choice of delivery mode or portable device is often left to the CRD technician at the time of home installation.

Second, the interviews identified a recurrent safety problem related to pulse-dose oxygen delivery. Frail, tachypnoeic, or predominantly mouth-breathing patients may lack the inspiratory strength required to activate the demand valve (trigger) of portable oxygen concentrators. When this occurs, the device may fail to release the oxygen bolus during ambulation, leading to desaturation outside the home. This problem may be underestimated in hospital workflows because walk tests are frequently performed using stable continuous-flow oxygen, which can mask the patient's inability to trigger a commercial pulse-dose device. The risk is further increased by the common misconception that numeric pulse-dose settings are equivalent to continuous-flow values in L/min.

Third, the interviews described relevant physical and social barriers to effective device use. Multi-storey apartments without lifts may make it impractical for frail patients to transport shoulder-carried or trolley-based equipment. Battery autonomy also emerged as a behavioural constraint: fear of running out of battery may limit outdoor activity even when the device is technically portable. In addition, the visible stigma associated with wheeled oxygen trolleys can lead to strong social rejection, prompting some patients to prefer backpack-based solutions, even when this requires carrying a heavier load.

Finally, the interviews identified critical use errors related to limited health literacy, inadequate training or insufficient follow-up. Reported examples included obstruction of air filters due to poor cleaning, degradation of lithium batteries after repeated deep discharges to 0%, and cryogenic freezing of liquid oxygen portable unit valves due to incorrect filling procedures.

The suitability preference layer prioritises, in a non-arbitrary manner, device lightness, energy autonomy and visual discretion.

5.1.2 Equipment inventory and market characterisation

The systematic mapping and normalisation of medical devices funded by the Portuguese SNS under the *Caderno de Encargos do Acordo-Quadro de Cuidados Técnicos Respiratórios Domiciliários*, managed by the Shared Services of the Ministry of Health (SPMS) / DGS [38], resulted in the comprehensive identification of 41 oxygen therapy devices commercialised in Portugal by CRD providers.

For each device, the relevant technical and physical hardware characteristics were standardised across 44 unified attributes. These included maximum continuous-flow and pulse-dose

delivery capacities, device weight, noise emissions, energy consumption, Federal Aviation Administration (FAA) approval for commercial air travel, compatibility with CPAP or non-invasive ventilation (NIV) systems, and supported interfaces. To preserve the readability of the main text, the complete raw dataset and normalised technical specification sheets are provided in Annex 10.4.

Table 3 presents the distribution of devices by category. Concentrators, including fixed and portable models, constituted the largest group with 23 devices. Liquid oxygen systems accounted for 13 devices, including stationary reservoirs and portable units, while gaseous oxygen was represented by 5 cylinder-based options.

Table 3- Distribution of the 41 home oxygen devices by category.

CONCENTRATORS	**Fixed concentrators (n= 11)**	
	Drive DeVilbiss: **Série 525**, **1025 KS;** Philips Respironics: **EverFlo**, **EverFlo Q**; Nidek / Konsung: **Oxygenate 5**; BMC: **SO1 5A**, **SO1 5B;** CAIRE / AirSep: **VisionAire 5**, **NewLife Elite**, **NewLife Intensity 10**; Yuwell: **Yuwell 8F-5A**	
	Portable concentrators (n=12)	
	Pulse- dose only concentrator (n=9)	Inogen: **Rove 6, Rove 4, Inogen One G2, Inogen One G3, Inogen One G5;** CAIRE: **FreeStyle Comfort;** Philips Respironics: **SimplyGo Mini;** GCE**: Zen-O lite;** Invacare: **Platinum Mobile**
	Mixed delivery mode concentrator (continuos-flow + pulse-dose) (n=3)	GCE: **Zen-O;** Philips Respironics: **SimplyGo**; CAIRE / SeQual: **Eclipse 5**
LIQUID OXYGEN	**Stationary Liquid Oxygen (n=2)**	
	Stationary reservoir	CAIRE - Chart: **Helios U46, Liberator 45**
	Portable Liquid Oxygen (n=11)	
	Continuous-flow only portable liquid oxygen (n=7)	CAIRE - Chart: **Companion 1000, Companion 1000 T, Stroller, Hi Flow Stroller;** Dehas: **EasyMate 6, EasyMate 12**; CryopAL: **Freelox 0,5L e 1,2L**
	Mixed delivery mode Continuous-flow + pulse-dose portable liquid oxygen (n= 4)	CAIRE - Chart: **Helios Marathon H850, Helios Plus 300, Spirit 1200, Spirit 300;**
GASEOUS OXYGEN	Gaseous oxygen	
	Gaseous oxygen cylinders (n=5)	3 L cylinder, 5 L cylinder, 7 L cylinder, 14 L cylinder, 20 L cylinder.

5.2 Phase II — The decision model

5.2.1 Logical specification of clinical decision rules and alerts

To enable the translation of theoretical clinical guidelines, including DGS Norma 018/2011 [2], BTS and ATS [1, 9], into the deterministic architecture of the inference engine, the algorithm was designed as a logical funnel structured into three operational levels: 23 deterministic exclusion rules, corresponding to deterministic safety exclusions; 18 clinical preferences, used to rank viable options; and 36 alerts, which generate warnings requiring prescriber review without excluding the device.

Logical activation dynamics and explainability of the deterministic exclusion rules

As detailed in Section 4.3 of the architectural specification of the decision engine, the O_2Match exclusion rules operate via contextual activation and scoping based on functional device role, thereby avoiding the indiscriminate application of safety restrictions. To facilitate the interpretation of the dynamic simulations presented in the following sections, Table 4 summarises the most prevalent deterministic exclusion rules in the algorithm. For a complete description of all developed logical rules, their corresponding system input variables, exact mathematical syntax conditions, and specific effects on mixed portable oxygen concentrators (POC_cp), the reader is referred to Annex 10.5 - Integral Logical Matrix of the O_2Match Algorithm.

Table 4- Summary of deterministic exclusion rules in the O₂Match Decision Engine

Rule ID	Clinical / Technical Concept	Simplified Decision Logic	Supporting Guideline / Framework
R01	NIV compatibility	Excludes portable oxygen concentrators (POCs) and devices without technical coupling compatibility when the patient uses domiciliary NIV	Pressurised circuit requirements (DGS clinical guidance / ATS)
R02	Tracheostomised patient	Excludes dry gaseous oxygen and purely nasal-interface devices	Requirement for active humidification (BTS)
R03	Sleep safety	Excludes battery-powered portable oxygen concentrators and cryogenic ambulatory units as the primary nocturnal oxygen source	Mechanical compressor protection and autonomy requirements (BTS)
R04	Technical flow ceiling	Excludes any device whose maximum continuous-flow hardware capacity is lower than the prescribed oxygen flow rate	Physical hardware limitation
R06	Suitability for 24-hour use	Excludes devices that are not technically validated for uninterrupted 24-hour operation	Manufacturer engineering specifications
R09	Grey-zone gatekeeper	Blocks automatic recommendation and requires a sleep study in pure isolated nocturnal hypoxaemia	*Primum non nocere* principle; ATS guidance.
R14	Hospital referral requirement	Blocks initial LTOT prescription from Primary Health Care / General and Family Medicine when specialist hospital assessment is required	Portuguese legal and regulatory framework; DGS Norma 018/2011[2]
R15	Active-smoker fallback	Blocks combustible portable oxygen sources, including liquid oxygen and gaseous oxygen, in active smokers when no safer electrical alternative exists	Prevention of serious fire and burn risk
R16	LOX financial constraint	Excludes liquid oxygen (LOX) at low oxygen flow rates, ≤4 L/min, when the patient does not have regular ambulation.	SNS sustainability and cost–benefit rationale (DGS)
R19	Exclusion of gaseous oxygen in LTOT	Excludes gaseous oxygen cylinders as the main domiciliary source for long-term use	Fixed concentrator as the standard domiciliary source in LTOT; DGS Norma 018/2011
R30	Palliative humanisation	Excludes, by default, cryogenic LOX and battery-powered POCs in end-of-life contexts to reduce caregiver burden	Minimisation of logistical burden for the informal caregiver

Modulation by clinical preferences and the alert layer

Beyond the physical and safety exclusions imposed in the first phase by the deterministic exclusion-rules filter, the O₂Match inference engine introduces two subsequent decision-support layers designed to refine and contextualise the recommendation: Clinical Preferences (n=18) and the Clinical and Logistical Alert Layer (n=36).

The first of these layers, summarised in Table 5 and described in full in Annex 10.5, ranks and prioritises the equipment categories that remain viable after applying the deterministic exclusion rules. These preferences translate clinical and contractual criteria into decision logic that guides the physician towards options that may be more cost-effective for the Portuguese SNS or mechanically safer for the patient.

One example is the economic and logistical consolidation rule (P14), which prevents unnecessary duplication of fixed home oxygen sources when the patient already benefits from regular ambulation supported by liquid oxygen. Another example is P13, which prioritises 10 L/min concentrators when appropriate, to avoid excessive mechanical strain and purity reduction, or derating in standard 5 L/min concentrator motors operated close to their technical limit.

Table 5- Summary of clinical preferences rules in the O_2Match Decision Engine

Preference ID	Clinical / Technical Concept	Simplified Decision Logic	Clinical Rationale and Support
P01	LOX preference in LTOT with regular ambulation	If LTOT is indicated and ambulation is regular, prioritise an integrated liquid oxygen system.	Economic and clinical suitability: liquid oxygen may be the most appropriate and sustainable option for high-volume ambulatory needs within the SNS framework
P02	High-flow ambulatory preference	If the prescribed ambulatory oxygen flow rate is >3 L/min, prioritise LOX and deprioritise standard pulse-dose portable oxygen concentrators	Mitigation of technical limitations: high oxygen flow requirements during exertion may rapidly deplete portable batteries and exceed the bolus delivery capacity of pulse-dose POCs
P03	Continuous flow during ventilatory support	If ventilatory support with NIV or CPAP is present, prioritise stable continuous-flow oxygen sources	Circuit pressurisation: non-invasive ventilation circuits require stable oxygen delivery to maintain FiO_2 and compensate for mask leak .
P04	Continuous flow during sleep	If nocturnal oxygen is indicated, exclude or deprioritise pulse-dose delivery in favour of continuous-flow oxygen	Sleep safety: continuous-flow delivery reduces the risk of hypoxaemia caused by weak nocturnal inspiratory efforts failing to trigger pulse-dose demand valves
P09 / P10	Dual-mode portability using mixed POCs	If the patient requires ambulation and has variable daily oxygen needs, assign preference to mixed-mode portable oxygen concentrators (POC_cp)	Recommendation screen logic: mixed POCs allow pulse-dose use to preserve battery autonomy and continuous-flow use during recovery from severe dyspnoea, when clinically appropriate
P13	Safety margin in high-flow prescription	If the prescribed oxygen flow rate is 5 L/min, prioritise 10 L/min concentrators over standard 5 L/min units	Engineering derating principle: avoids operating standard compressor motors at maximum capacity, reducing the risk of oxygen purity decline
P14	Economic and logistical consolidation	If portable LOX is selected for ambulation, avoid recommending a redundant stationary concentrator	Avoidance of device duplication: a stationary LOX reservoir can already serve as the domiciliary source, reducing unnecessary duplication and associated costs

The Alert Layer, summarised in Table 6 and fully mapped in Annex 10.5, consists of 36 dynamic safety warnings. These alerts do not exclude devices. Instead, they notify the prescriber of mandatory functional validations, such as oximetry assessments and walk tests

(A02, A03 and A33); life-support redundancy requirements (A29 and A31); and electrical contingency issues (A21).

Consistent with the anti-paternalism principle defined in the methods, these logistical-empathy alerts (A09, A10 and A11) flag constraints such as stairs, frailty or social isolation without automatically rejecting reference therapies such as liquid oxygen.

Table 6- Summary of clinical alerts in the O_2Match Decision Engine

Alert ID	Category / Context	Trigger Condition	Displayed Message / Clinical Action Item	Guideline / Technical Reference
A01	Safety red flag	Active smoking = Yes	**Active smoking alert:** extreme fire and burn risk. Restrict prescription to electric concentrators and strictly avoid liquid oxygen and gaseous oxygen cylinders	BTS Quality Standards for Home Oxygen
A02 / A03	Functional validation	Pulse-dose POC prescribed or Ambulatory Oxygen Therapy selected	**Pulse-dose titration required:** numeric POC settings do not correspond to L/min. A 6MWT must be performed using the selected device to confirm correction of exertional desaturation	ATS Home Oxygen Guidelines and BTS Ambulatory Oxygen guidance
A09 / A10 / A11	Logistical empathy	Presence of stairs, patient frailty or absence of caregiver	**Logistical and social warning:** do not automatically exclude reference therapies, such as liquid oxygen, solely on the basis of contextual barriers. Flag the risks and prompt clinician review of the patient's real domestic and social context	Ethical-by-design framework in Design Science Research
A16 / A17 / A18	Commercial flight safety	Planned air travel = Yes	**Aviation clearance required:** suppress liquid oxygen and gaseous oxygen cylinders. Require an FAA-approved portable oxygen concentrator, verification of 150% battery autonomy and pre-flight hypoxia simulation testing when clinically indicated	FAA cabin regulations and BTS travel recommendations
A21	Electrical contingency	Stationary concentrator recommended	**Power outage backup:** require an emergency backup oxygen cylinder, with humidification if the patient is tracheostomised. Backup cylinders are contraindicated in active smokers because of fire risk	BTS guidance on home oxygen backup requirements
A31	Life-support critical alert	24-hour non-invasive ventilation + oxygen	**Critical shared-failure risk:** power failure may interrupt both ventilation and oxygen delivery. Require an uninterruptible power supply or equivalent battery backup. Consider liquid oxygen when electric-independent oxygen delivery is clinically and logistically appropriate	Clinical engineering redundancy standards in life-support contexts.
A34	Sleep apnoea gatekeeper	Isolated nocturnal hypoxaemia without resting LTOT criteria	**Hypercapnia / hypoventilation risk:** oxygen may mask nocturnal hypoventilation, including obstructive sleep apnoea or neuromuscular-related hypoventilation. Block automatic oxygen recommendation and require formal sleep assessment.	BTS/ATS guidance on sleep-disordered breathing and nocturnal oxygen use
A35	Airway accessories	Tracheostomised patient = Yes	**Active humidification required:** avoid dry gas delivery and require appropriate heated humidification coupled to the stationary source to reduce the risk of secretion thickening and mucous plugging.	BTS guidance on humidification in airway bypass

5.2.2 Verification of the decision engine (Python oracle)

The O_2Match decision engine underwent rigorous logical verification and stress testing using a suite of 38 simulated real-world clinical scenarios. These scenarios were organised into eight blocks, A to H, covering common prescription pathways as well as boundary conditions: Block A- LTOT for 16 hours per day; Block B- LTOT for 24 hours per day; Block C- isolated Ambulatory Oxygen Therapy; Block D- oxygen as an adjunct to CPAP/NIV; Block E- palliative oxygen; Block F- short-term oxygen; Block G- isolated nocturnal hypoxaemia; Block H- isolated air travel (Table 7) .

Table 7- Complete Decision-Engine Verification Matrix (38 Stress Scenarios)

Block	Scenario ID	Clinical Context / Objective	Key Inputs (Flow, Sleep, Exertion, NIV, Smoking)	Activated Hard Rules & Overrides	Verified Technical Output & Device Class Recommendations [Grounding Passages]
A	**A1**	LTOT (16h) — Low Flow	≤ 4 L/min, Rest/Sleep only, No Exertion	R03, R16, R19	**Stationary standard 5 L/min Concentrators** (e.g., EverFlo, VisionAire 5, 525 DeVilbiss)
A	**A2**	LTOT (16h) — Low Flow	≤ 4 L/min, Rest/Sleep, Pontual Exertion	R03, R19	**Stationary standard Concentrator + Gaseous Cylinder** (for pontual/emergency clinical outings) [
A	**A3**	LTOT (16h) — Low Flow	≤ 4 L/min, Rest/Sleep, Regular Exertion	R03, R17, R19, R16 (inactive)	**LOX Integral System** (Base + Portable deambulator). P14 consolidation eliminates redundant stationary concentrator
A	**A4**	LTOT (16h) — High Exertion	Rest ≤ 4, Effort ≥ 4 L/min, Regular	R03, R04 (exertion), R17, R19	**LOX Integral System Unique Recommendation**. Portable electric concentrators (POCs) and gas cylinders excluded due to high flow exertion (R04).
A	**A5**	LTOT (16h) — High Flow	Rest > 4 L/min, No Exertion	R03, R04 (rest), R05, R16, R19	**Stationary High-Flow 10 L/min Concentrators** (e.g., DeVilbiss 1025 KS, Intensity 10). Standard 5L/min excluded (R04).
A	**A6**	LTOT (16h) — High Flow	Rest > 4 L/min, Pontual Exertion	R03, R04 (rest), R19 (modulated)	**High-Flow 10 L/min Concentrator + Gaseous Cylinder**. Gaseous cylinder allowed strictly for pontual exertion.
A	**A7**	LTOT (16h) — High Flow	Rest > 4 L/min, Regular Exertion ≥ 4	R03, R04, R17	**LOX Integral System**. High continuous flows at rest and exertion collapse both standard electrics and gaseous systems.
B	**B1-B6**	LTOT (24h/dia)	*Identical profile to A1-A7 but continuous usage*	R06 (24h lock), R03, R05, R17	Same technical allocations as Bloco A. **R06 prevents POC-only prescriptions**, ensuring robust stationary supply.
C	**C1**	Ambulatory O_2 Only	No LTOT, Effort < 4 L/min, Sleep: No	R03 (inactive), R05 (inactive)	**Pulsed Portable Oxygen Concentrators (POC_p)** or **LOX Portátil**. Active alerts A02/A03 mandate PM6M titration.
C	**C2**	Ambulatory O_2 Only	No LTOT, Effort ≥ 4 L/min, Sleep: No	R04 (effort), R05 (inactive)	**LOX Portátil only**. High flow requirement excludes all lightweight pulsed and continuous POCs (R04).

D	**D1-D6**	Nocturnal CPAP/NIV Adjuvant	CPAP/VNI nocturnal, Flow ≤ 4 vs. > 4	R01 (NIV compatibility), R03	**NIV-compatible Stationary standard or High-Flow Concentrators** coupled to circuit [tabelas_Algoritmo_v2, Auditoria_APP-O2_BlocoD.docx]. POCs excluded (R01/R03)
D	**D7-D11**	24h VNI Adjuvant	Continuous VNI, Rest ≤ 4 vs. > 4 L/min	R01, R03, R06 (continuous lock)	**Stationary Concentrator coupled to VNI**. D8/D9/D11 allow LOX Portátil or continuous POC (Eclipse 5) for deambulation
E	**E1-E3**	Palliative Care	Late-stage palliation, comfort outings	R28 (override), R16/R19 (inactive)	**Palliative "Via Verde" Override (R27)** allows lightweight POC/Gas for pontual comfort outings, suppressing PM6M requirement
F	**F1-F3**	Short-Term Therapy (<3mo)	Acute transient recovery, No Exertion	R29 (cost-guillotine), P06	**Stationary standard Concentrator**. LOX and POCs strictly excluded (R29) to optimize SNS public resources
F	**F4**	Short-Term — Active Rehab	Transient recovery, Regular Exertion	R26 (override active), R29 (partial)	**Stationary Concentrator + Pulsed POC**. R26 override suspends R29 cost-guillotine for electrics to support active rehab
G	**G1**	Isolated Nocturnal Hypoxemia	Sleep desaturation without prior diagnostics	R09 GATEKEEPER	**Dead-End Intentional**. No equipment prescribed. Visual block demanding specialized sleep study (A34)
G	**G2**	Isolated Nocturnal Hypoxemia	Sleep desaturation + Exertion hypoxemia	R09 Modulated	**Recomendação Parcial diurna only** (POC/LOX for exertion). Nocturnal O_2 remains strictly blocked pending sleep study
G	**G3**	Isolated Nocturnal + VNI	Cheyne-Stokes sleep hypoxemia, active VNI	Bypass R09 + Transition to Bloco D	**Automatic re-routing to CPAP/VNI Adjuvant (D1/D4)**. Active VNI protects airway, allowing safe nocturnal oxygen enrichment
H	**H1**	Commercial Air Travel	Flow required for flight cabin < 4 L/min	R07 (FAA certification gate)	**FAA-Approved Pulsed POC** (e.g., FreeStyle Comfort, Inogen Rove) [tabelas_Algoritmo_v2, Auditoria_APP-O2_BlocoH_1.docx]. Base LOX, cylinders, and fixos excluded (R07)
H	**H2**	Commercial Air Travel	Flow required for flight cabin ≥ 4 L/min	R07 (FAA active), R04 (teto collapse)	**Dead-End Intentional (Inviabilidade Comercial)**. Safety block; flight cabin is unsafe without continuous flow exceeding POC battery limits

The 38 scenarios underwent two complementary, sequential verification procedures: an independent clinical audit by two pulmonologists, followed by an automated cross-check against a Python reference implementation (the oracle). The clinical audit came first, and the feedback it produced was used to correct the engine before the automated procedure confirmed the revised logic.

The decision matrices and final outputs of the 38 scenarios were first submitted to an independent clinical audit. Two pulmonologists, who had not taken part in building the rule base, reviewed each scenario together with its primary recommendation, alternative options, exclusions, and alerts, and, by consensus, judged the safety and clinical adequacy of the engine's behaviour. When they identified inadequate or ambiguous output, their feedback was used to correct and refine the corresponding rules before any automated testing was conducted. The reviewers concluded that, within the tested scenario set, the engine reproduces expert reasoning considers both its recommendations and its exclusions, and correctly identifies the case in which the appropriate output is to recommend no device.

With the rule base revised in line with the clinical audit, its logical integrity was then confirmed through dual independent implementation. A Python reference implementation (oracle), developed separately from the prototype, processed the inputs for the 38 scenarios in batch and compared its outputs with the engine's on a scenario-by-scenario basis. Full concordance was observed across all 38 scenarios and across the four output dimensions evaluated: the primary recommendation, the alternative options, the exclusions with the rule responsible for each, and the alerts. This scenario-by-scenario comparison was recorded as a set of per-block audit reports (Blocks A–H) [Annex 10.7].

The engine was further exercised through regression testing — 101 unit tests, all of which passed — and through a broader stress test of 768 clinical permutations, which showed full compliance and no logical violations. This confirmed a set of safety invariants, including the hollow-recommendation check, which ensures that every recommended category corresponds to a real device in the mapped equipment database.

The automated verification also exposed, and allowed the correction of, hidden data anomalies. The most relevant was the "NaN trap", in which missing values in pulse-dose-only devices could, if left unhandled, bypass a safety filter in the air-travel context. The algorithm was

corrected in the oracle, and the correction propagated to the React single-page application, so that the device category is explicitly isolated and evaluated before any numerical comparison:

```
if categoria == "POC_p" and debito_prescrito >= 4:
    excluir_equipamento("R04 - pulsed POC unable to deliver continuous
flow")
```

This eliminated a clinically significant failure mode: the potential recommendation of a device that could not meet the patient's physiological oxygen requirement during exertion.

5.3 Phase III — The O_2Match React SPA interface

The verification established that the decision logic is internally consistent, clinically defensible and safe within the tested scenarios. A verified engine, however, is not yet a usable tool: for the logic to support real prescribing, it must reach the clinician through an interface that preserves the transparency of the reasoning while keeping the effort of using it low. Phase III addresses this translation from logic to tool. The O_2Match prototype — a React single-page application (SPA) — turns the three dimensions of the trilateral model (what the patient requires, what the patient can manage, and what the environment allows) into a guided pathway, and returns an explained recommendation ready to be issued as an electronic prescription (PEM) (Figure 17).

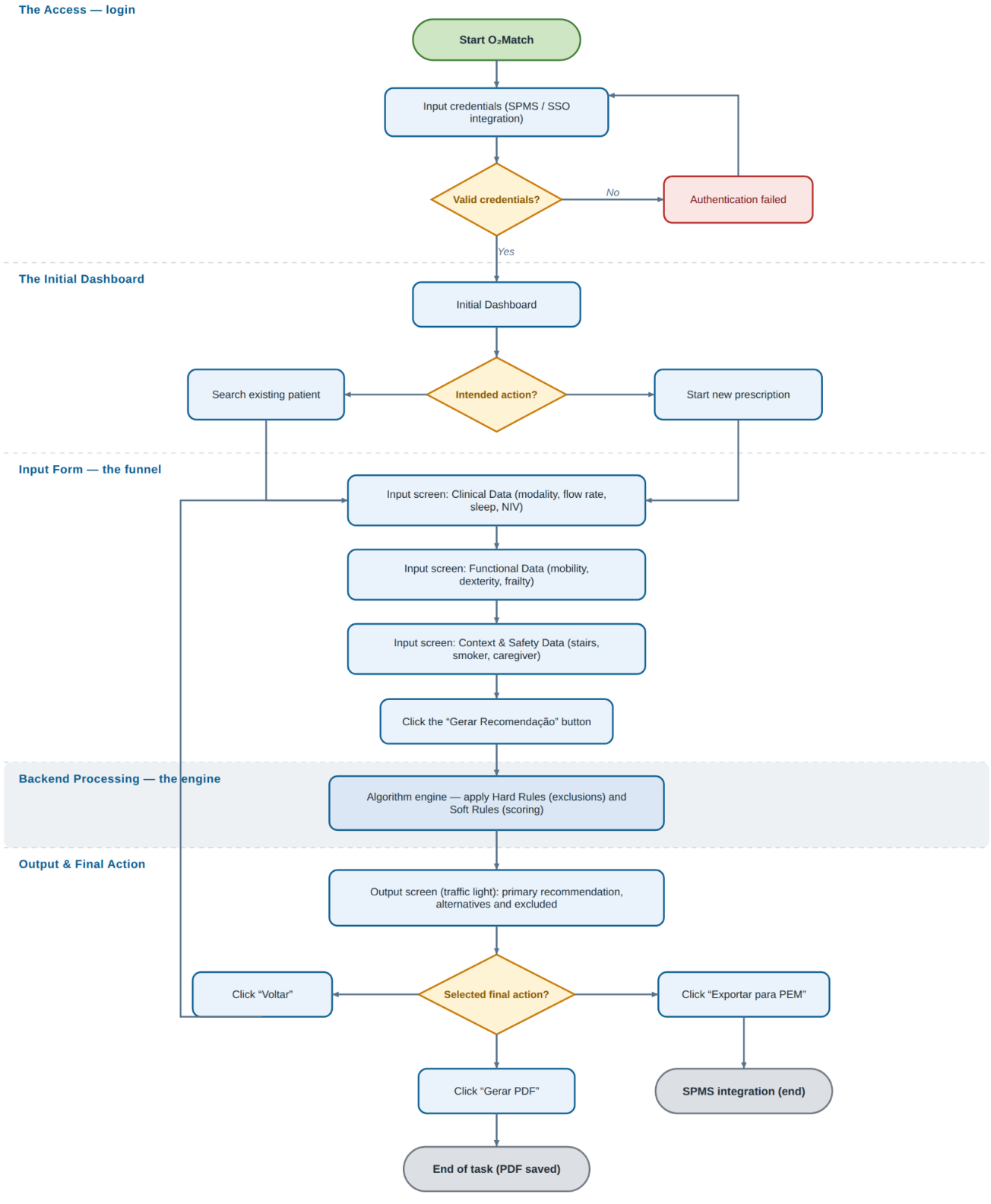


Figure 17- O_2 Match user journey: from authentication to prescription export (PEM) or PDF report, across five stages (login, dashboard, input funnel, decision engine, output).

5.3.1 Adaptive input pathways: from login to PEM prescription

Within the prototype, data entry follows an adaptive pathway that mirrors the clinician's own reasoning. Built as a React single-page application (SPA) and refined iteratively — using Claude Code to reduce working memory load at each step — it guides the user from professional authentication through to the generated PEM prescription, structuring the input around the three dimensions of the trilateral model. This section presents the prototype through the screens of the functional application, following the complete user pathway; the full set of mockups, from login to PEM, is compiled in Annex 10.8.

To make the pathway concrete, the screens are described against a single demonstration scenario built on simulated data — the same case used during usability testing. The demonstration follows a single prescriber and a single patient.

The prescriber is Dr Inês Sanches, a hospital pulmonologist registered with the Ordem dos Médicos (no. 47762), who authenticates with her institutional professional e-mail. Because she prescribes at hospital level, the system makes the full range of prescribing contexts available to her, including long-term oxygen therapy — a constraint that a primary-care login would not satisfy.

The patient is João Manuel Silva (SNS user number 123456789; subsystem ADSE 23344555OA), a non-smoker with respiratory failure (room-air PaO_2 of 45 mmHg on arterial blood gas; PSAP and haematocrit unknown; no apparent cor pulmonale). The prescribing context is long-term oxygen therapy (LTOT) for 16 hours a day, with a resting flow requirement of 2 L/min, a confirmed need for oxygen during sleep, and a need during exertion at a predicted 3 L/min; he does not use CPAP or NIV and is not tracheostomised. Functionally, he leaves home almost daily, is socially active and is typically away for more than six hours a day, with no physical frailty and with cognitive and physical capacity to manage the equipment. Socially, he lives alone and needs no carer, in a single-storey dwelling free of relevant barriers and with a stable electricity supply.

Authentication and configuration

The pathway begins at the entry and authentication screen, which validates professional credentials and applies a security lockout after three invalid login attempts, supporting the protection of personal health data under the General Data Protection Regulation (GDPR) (Figure 18) and also presents information about the O_2Match application.

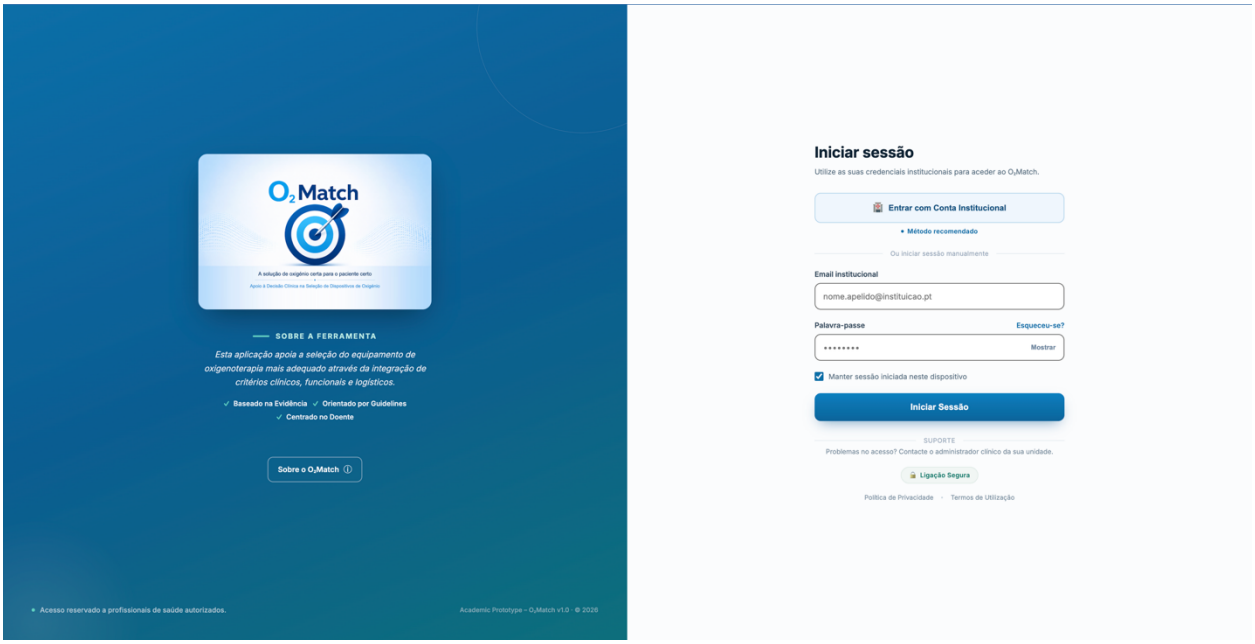


Figure 18- Login screen with institutional authentication.

Once the professional credentials are validated, the prescriber is taken to the application's home screen (Figure 19). This screen confirms the identity of the logged-in clinician — in the demonstration, Dr Inês Sanches — and lets the institution's logo be uploaded, so that the reports generated later carry the correct institutional identity. It also presents the patient-prescription flowchart and provides access to the system's alerts and preferences, as well as relevant clinical information. From this screen, and before any patient is selected, the prescriber can review or adjust these settings, which then apply throughout the prescription pathway. Configuration panels let the user manage the professional profile, security options, help resources, PEM interoperability preferences and language selection.

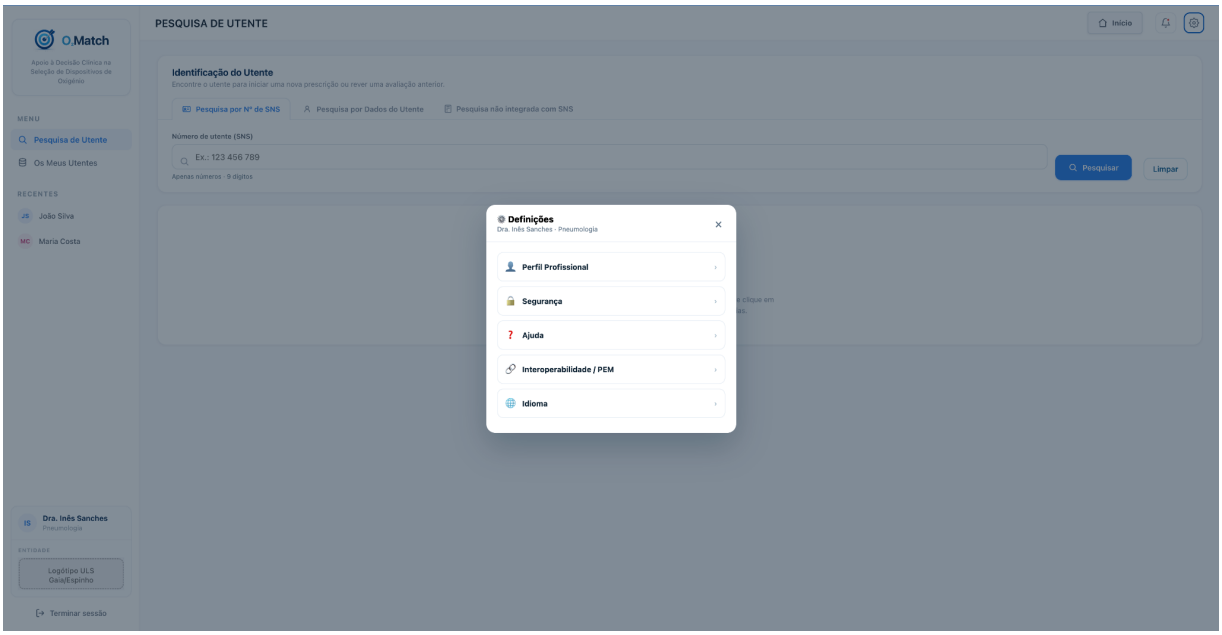


Figure 19- Application information and configuration panels: professional profile, security, help, PEM interoperability and language selection.

Patient selection and input modes

From the dashboard, the clinician can search for a new patient, open one of their own patients, or consult the most recent prescriptions (Figure 20). Patient lookup and clinical history retrieval are central here, including the ability to import a previous prescription, which shortens the time required during the consultation. To accommodate different clinical and privacy contexts, the system offers multiple ways to supply patient data to the same rule-based inference engine.

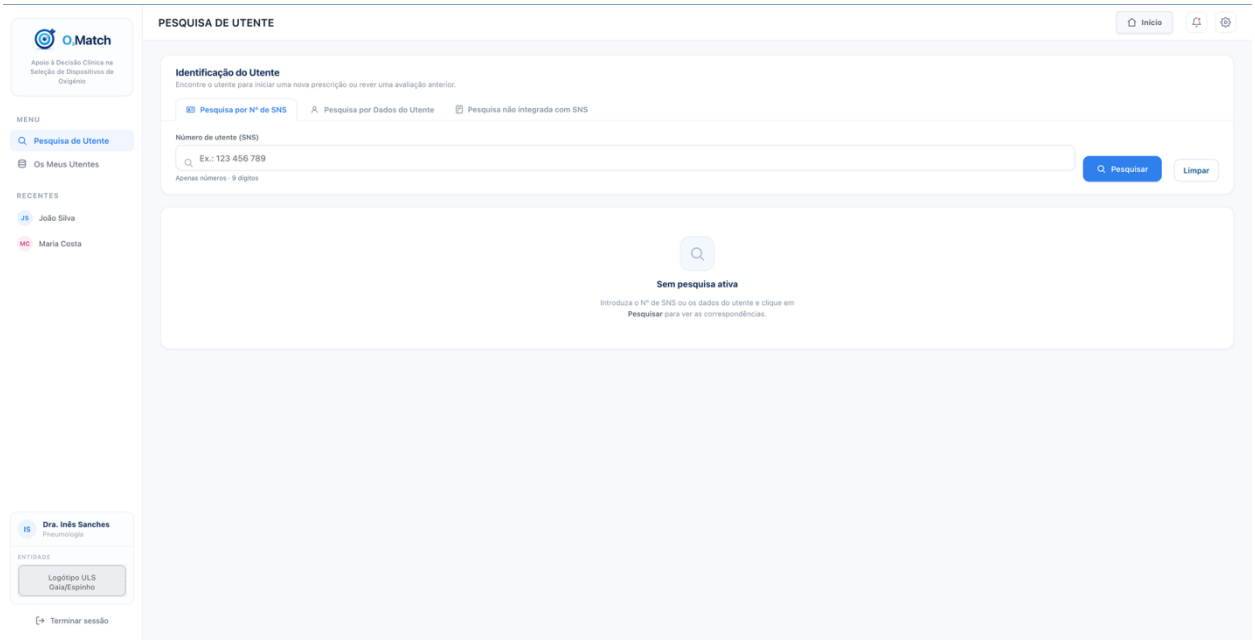


Figure 20- Dashboard and patient-selection screen (search by SNS number, clinical history, new patient entry).

In the integrated mode, when the application is connected to the national unified patient registry, the patient's data can be retrieved automatically in two ways: through the SNS user number, or through demographic identifiers such as name, date of birth and sex, for cases in which the user does not know the SNS number. In an authorised production environment, this integration — based on automated REST communication — would populate the selected demographic data and the information on prior prescriptions from the central clinical record; a previous prescription could then be imported, or a new one started, reducing manual transcription and the associated data-entry errors (Figure 21).

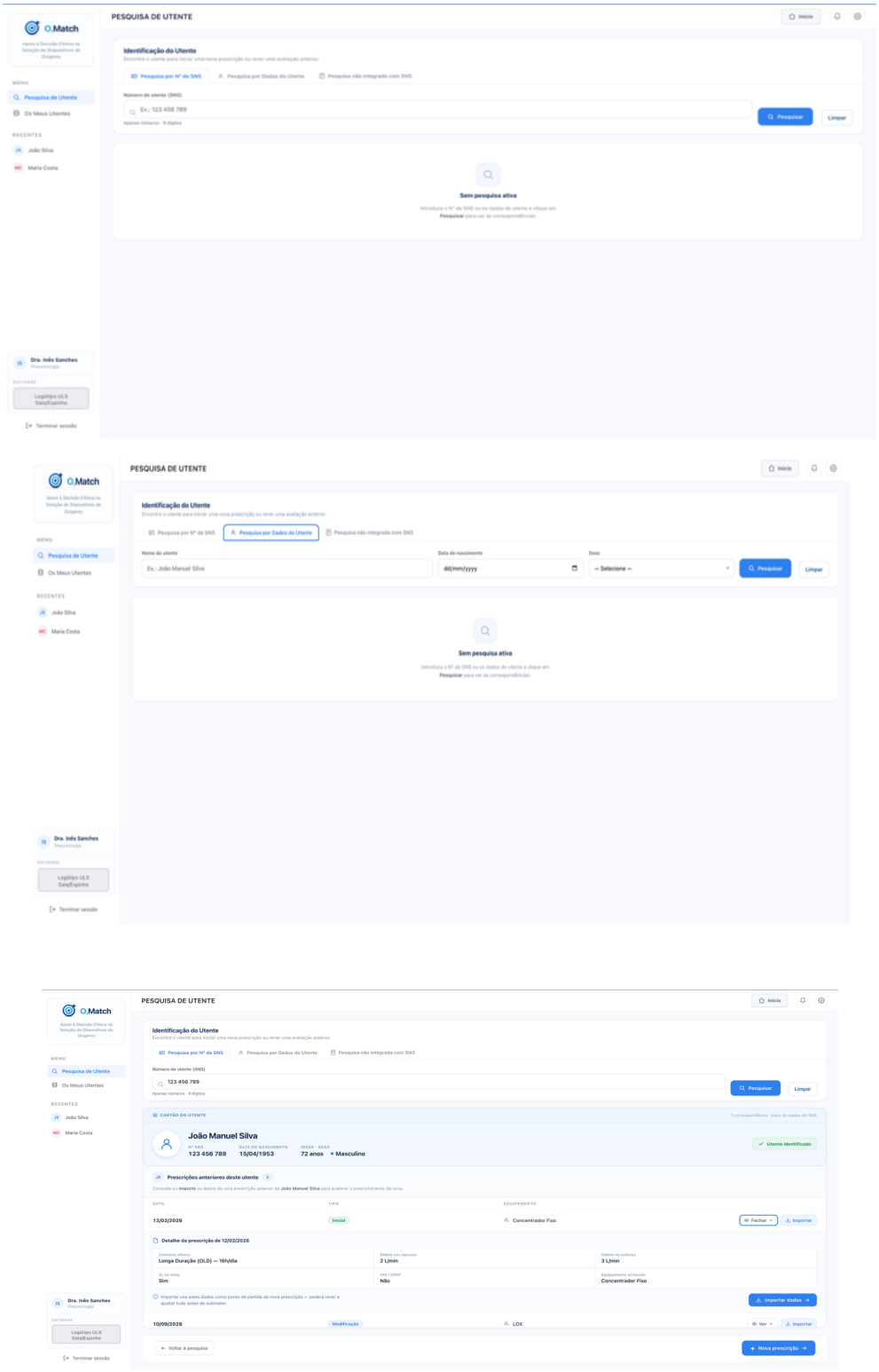


Figure 21- Patient search, integrated pathway: retrieval by SNS user number or by demographic identifiers (name, date of birth and sex), showing the patient card, demographics and a list of prior prescriptions available to view or import.

In the non-integrated mode, the required variables are collected directly from the clinician through the clinical wizard, with real-time validation of clinical thresholds. This mode does not connect to the patient registry or to the PEM and can therefore be used outside integrated environments, including private practice; because it does not require directly identifiable data to be linked to external systems, it also supports teaching, demonstration and preliminary decision-support use, in line with a privacy-by-design approach consistent with the GDPR. This was the mode implemented in the prototype and used during usability testing (Figure 22).

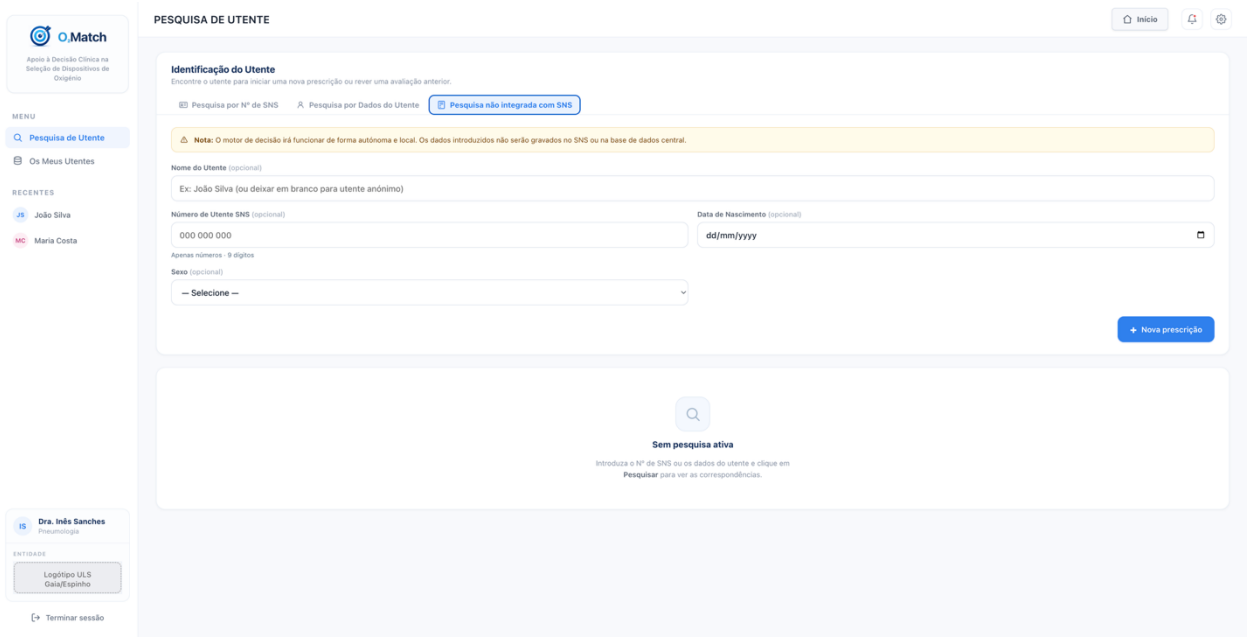


Figure 22- Patient search in non-integrated mode, with optional name, SNS number, date of birth and sex fields and an empty results panel.

Regardless of the input mode, all pathways converge on the same decision engine, so that the recommendation remains logically consistent (Figure 23).

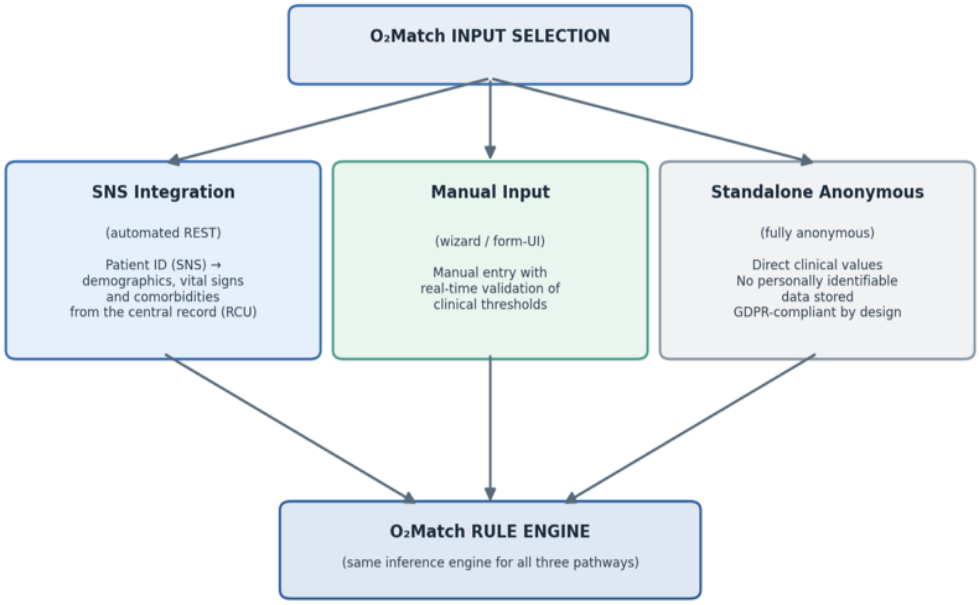


Figure 23- The three input pathways converging on a single decision engine.

The tripartite clinical wizard

Patient data are then entered via a tripartite clinical wizard, structured into three sequential steps that correspond to the three dimensions of the trilateral model, before the recommendation screen. In the demonstration scenario, a new prescription was started for the patient described above.

Step 1 — Clinical Data

Step 1 collects the oxygen flow rates, the pattern of use, arterial blood gas information, and any respiratory support requirements, including CPAP or NIV (Figure 24).

In this scenario, the clinical context is LTOT at 16 h/day, with 2 L/min at rest, oxygen required during sleep, and 3 L/min during exertion.

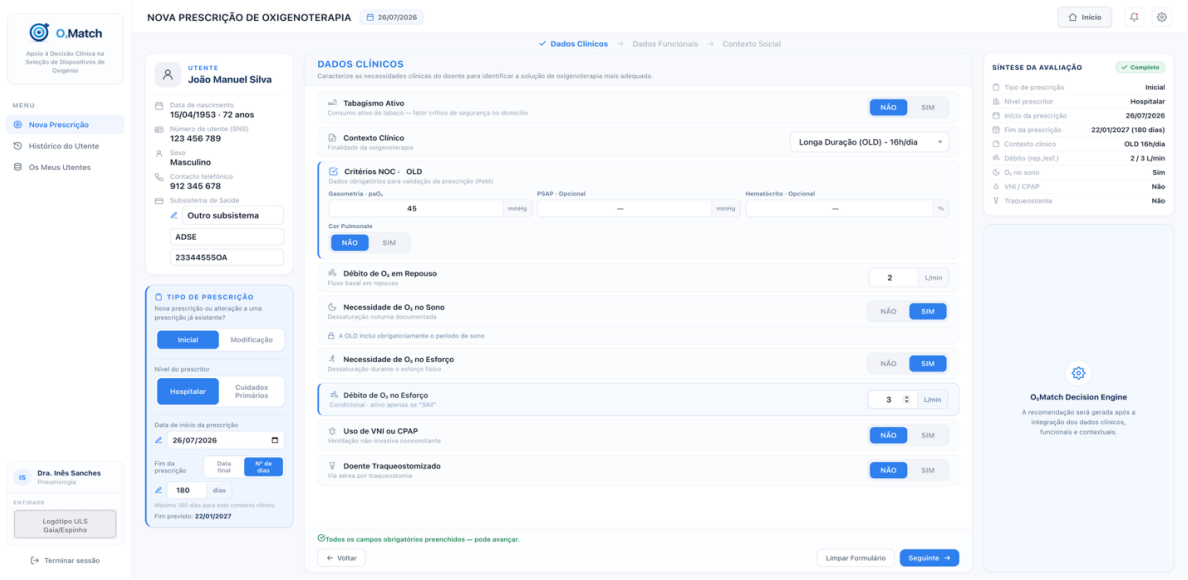


Figure 24- Prescription wizard, Step 1: Clinical Data (full interface view; demonstration case).

The step embeds several safety and ergonomic features. A role-based constraint restricts prescription options to the prescriber's level of care: LTOT, for example, can only be prescribed at the hospital level, and a primary-care prescriber may only renew an already active prescription (Figure 25).

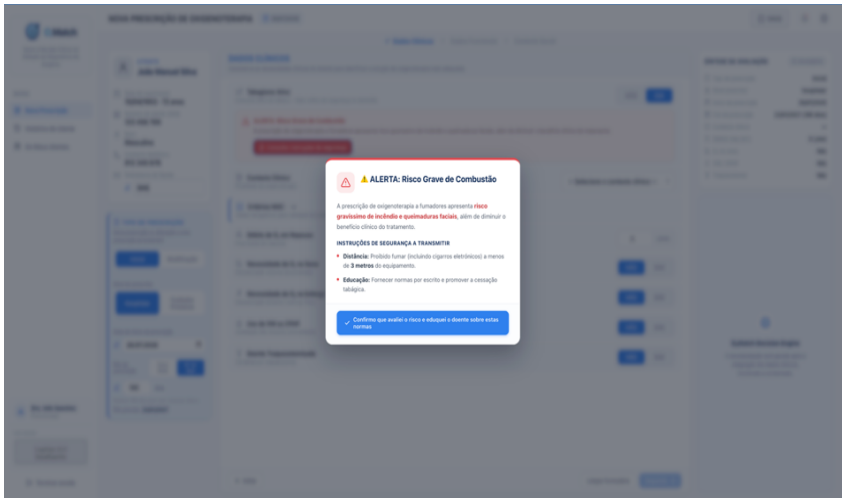


Figure 25- Clinical Data step with the Clinical Context dropdown open (LTOT 16h/24h, ambulatory, short-term, ventilation adjunct, palliative care, air travel).

When active smoking is recorded, the system issues an information alert to the prescriber, flagging the severe combustion risk and linking to safety instructions (Figure 26).

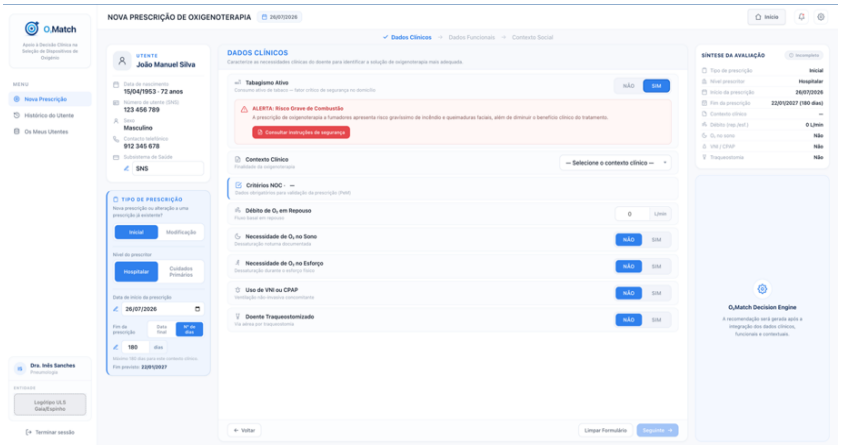


Figure 26- Clinical Data step with Active Smoking set to 'Yes', triggering a severe-combustion-risk alert and a link to safety instructions.

The Clinical Context selector offers the full set of prescribing contexts — LTOT 16h/24h, ambulatory, short-term, ventilation adjunct, palliative care and air travel (Annex 10.6) — and pre-selects dependent options to reduce the number of clicks: choosing an LTOT context, which necessarily implies a need for oxygen during sleep, sets that field to 'yes' automatically, and the exertion-flow field is revealed only when a need during exertion is indicated.

A dynamic summary bar in the upper-right corner updates in real time as variables are entered, acting as a running synthesis of the selected data and reducing the physician's short-term memory burden by allowing continuous verification of the patient profile. Mandatory fields still missing are highlighted in red (Figure 27); once all required fields are complete, the interface displays the message 'all mandatory fields completed — you may proceed'.

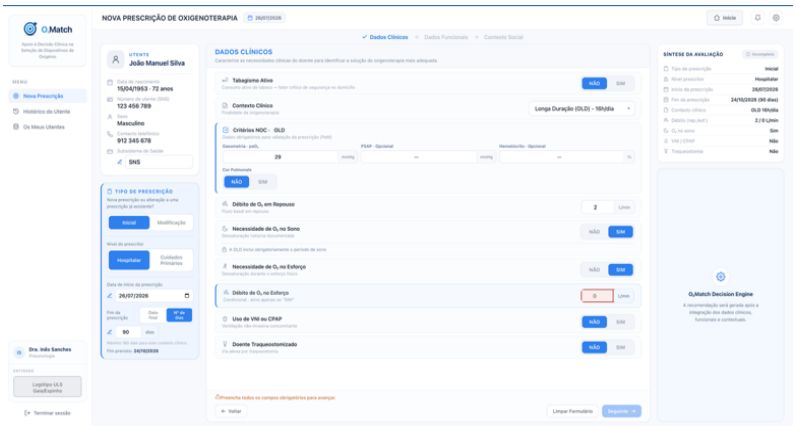


Figure 27- Clinical Data step with Mandatory fields still missing are highlighted in red

Step 2 — Functional Data

Step 2 records mobility, manual dexterity and tolerance to physical weight-bearing (Figure 28). In the scenario, the patient leaves home almost daily, is socially active and is usually away for more than six hours a day; he shows no physical frailty and is able to manage the equipment. Here too the interface adapts: a bedridden patient, for instance, would have physical frailty set automatically to ‘yes’, with dependence for equipment handling recorded accordingly. The selected data are added to the running summary bar, on top of the information already entered.

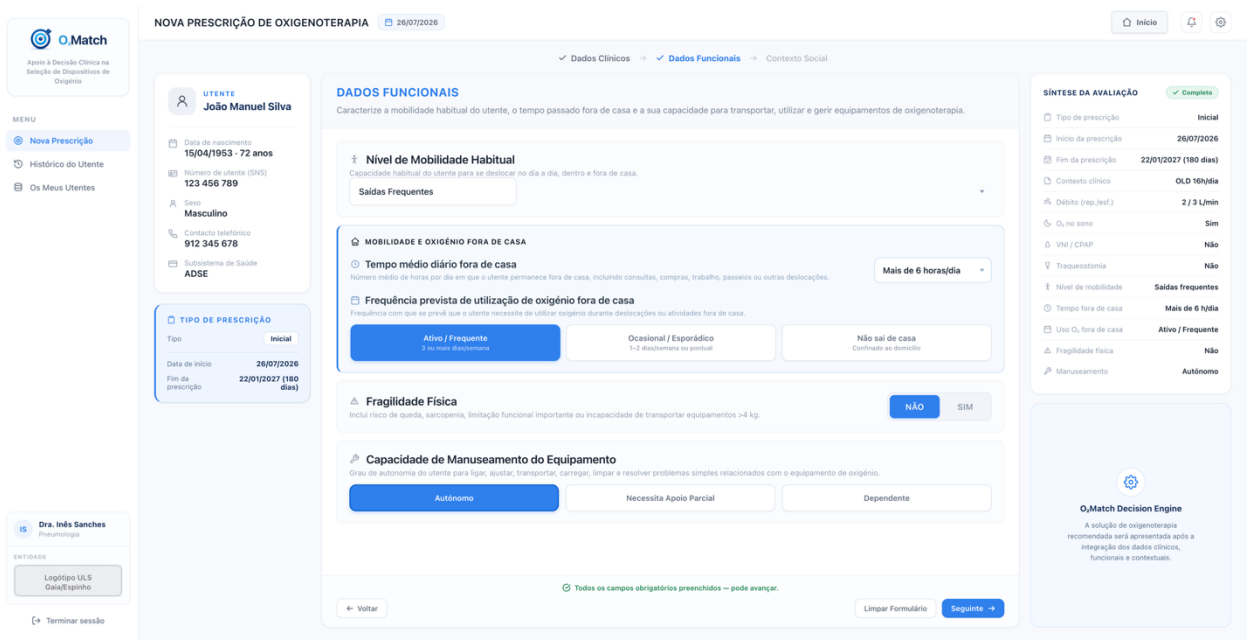


Figure 28- Prescription wizard, Step 2: Functional Data (full interface view).

Step 3 — Social and Logistical Context

Step 3 captures caregiver availability, the presence of stairs without a lift and the stability of the electrical supply (Figure 29). In the scenario, the patient lives alone and needs no carer, in a single-storey dwelling free of relevant barriers and with a stable electricity supply. For an institutionalised patient (a care home or ERPI), the housing conditions are set automatically to ‘no relevant barriers’, since certification of these facilities requires this — again reducing the number of clicks.

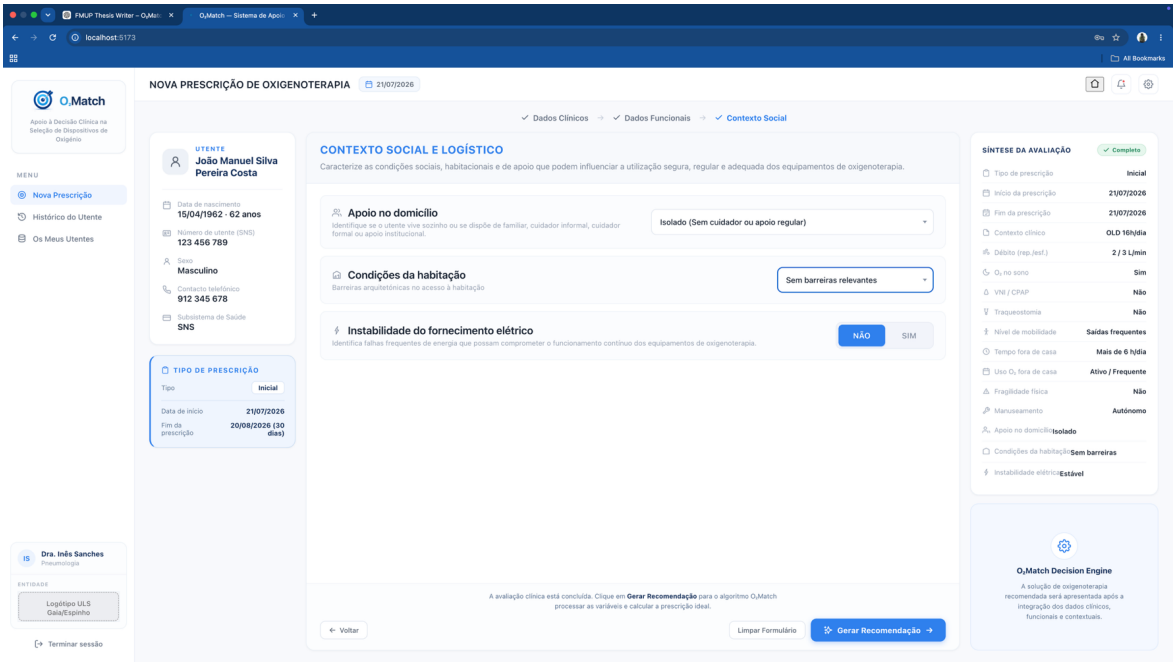


Figure 29- Prescription wizard, Step 3: Social and Logistical Context.

Step 4 — Clinical output and recommendation

Step 4 presents the engine's result, structured into three colour-coded priority bands (Figure 30). Green identifies the primary recommendation, expressed as a generic device category to preserve flexibility with respect to local hardware stock. Amber identifies acceptable alternatives, with explicit alerts on ergonomic suitability and ambulatory-device limitations. Red identifies clinical exclusions, transparently listing the excluded devices and the safety-rule code activated by the engine.

A)

B)

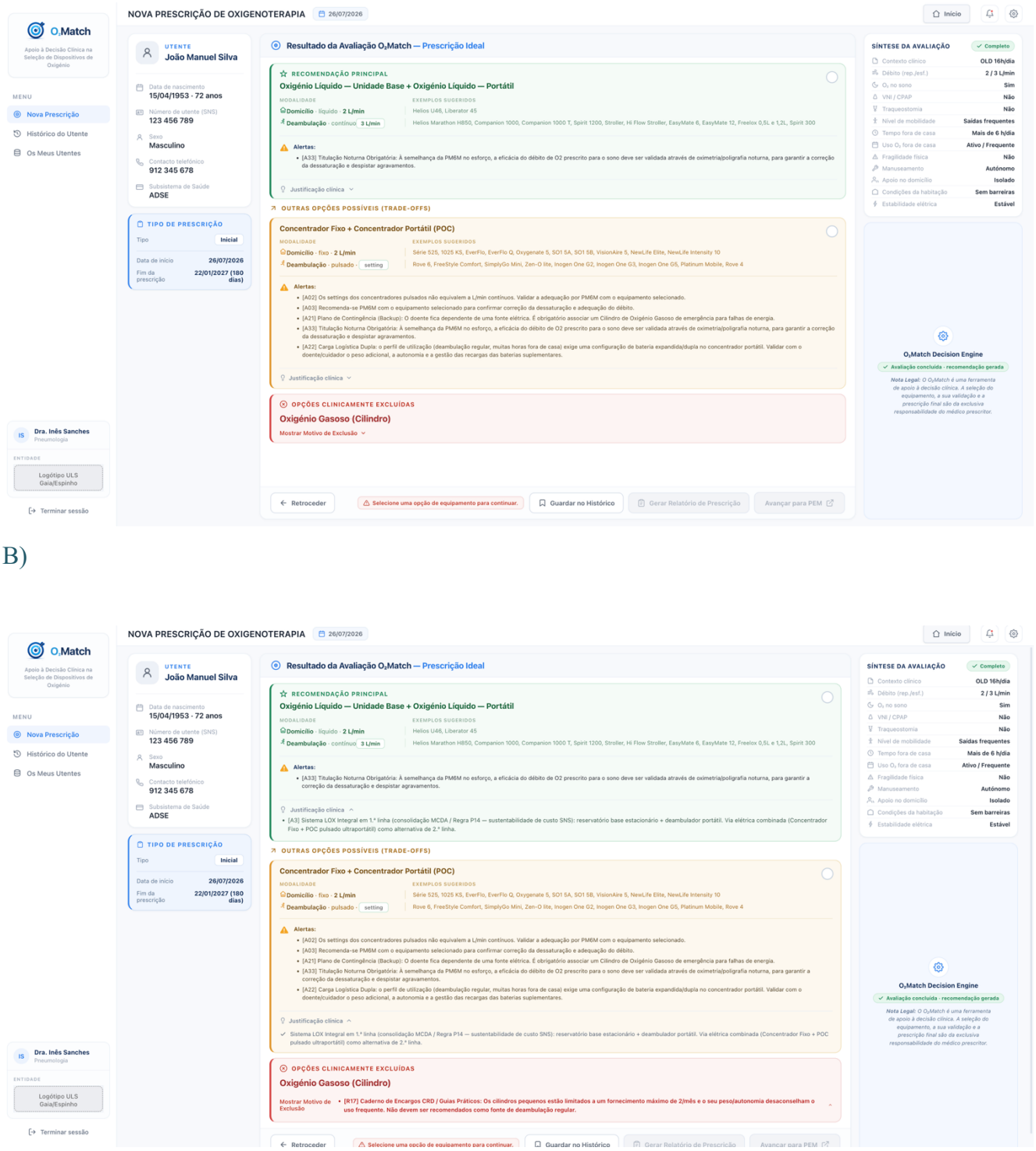


Figure 30- Output screen: primary recommendation (green), acceptable alternatives (amber) and excluded devices (red), without (A) and with (B) the clinical-justification panels expanded.

For the demonstration scenario, the primary recommendation was a liquid-oxygen solution: a stationary device for use at home and at rest at 2 L/min, together with a portable device for ambulation at 3 L/min, the exertion flow selected by the prescriber in the Clinical Data step. Within each device type, the interface lists the models available and authorised under the SNS terms of reference (Caderno de Encargos [reference]) that CRD providers may hold in stock, so as to familiarise the prescriber with the corresponding commercial names. The engine deliberately recommends a device category rather than a specific model, both because CRD providers may not stock every model and because no MCDA scoring of individual devices based on their particular characteristics was performed. Alongside the primary recommendation, the interface shows the alerts generated during selection — in this case, alert A33, mandatory nocturnal titration: as with the six-minute walk test for exertion, the efficacy of the prescribed sleep flow must be validated through nocturnal oximetry or polygraphy, to confirm the correction of desaturation and to rule out worsening. A clinical-justification item is shown collapsed; if the prescriber wishes to see why a given device was recommended, expanding it reveals the rationale (Figure 30-b).

The acceptable alternative for this case was the combination of a fixed concentrator at rest at 2 L/min with a pulsed portable concentrator at the default flow set in the settings, to be selected by the prescriber; the alerts it activates and the clinical justification for its being a second choice rather than the primary recommendation are shown, together with the commercial names of the fixed and portable concentrators. The excluded-options band, in red, lists the device classes ruled out by the deterministic exclusion rules, each with its reason. This result follows from the analysis of all entered variables using the deterministic exclusion rules, the clinical-preference rules, and the alerts.

Although the engine issues a primary recommendation and alternatives, the prescriber may select any of the presented options; the final decision rests with the prescriber, and the chosen option is reinforced in the right-hand side panel (Figures 31 and 32).

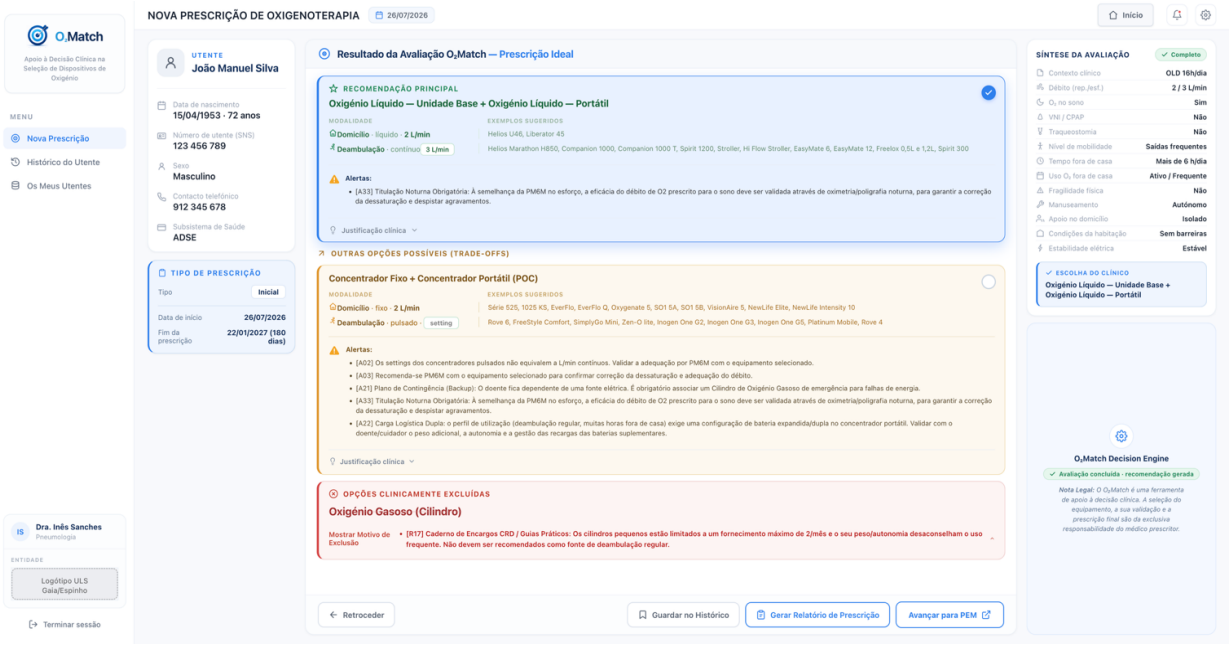


Figure 31- Assessment result with the primary recommendation selected, enabling the save, generate-report and export-to-PEM actions.

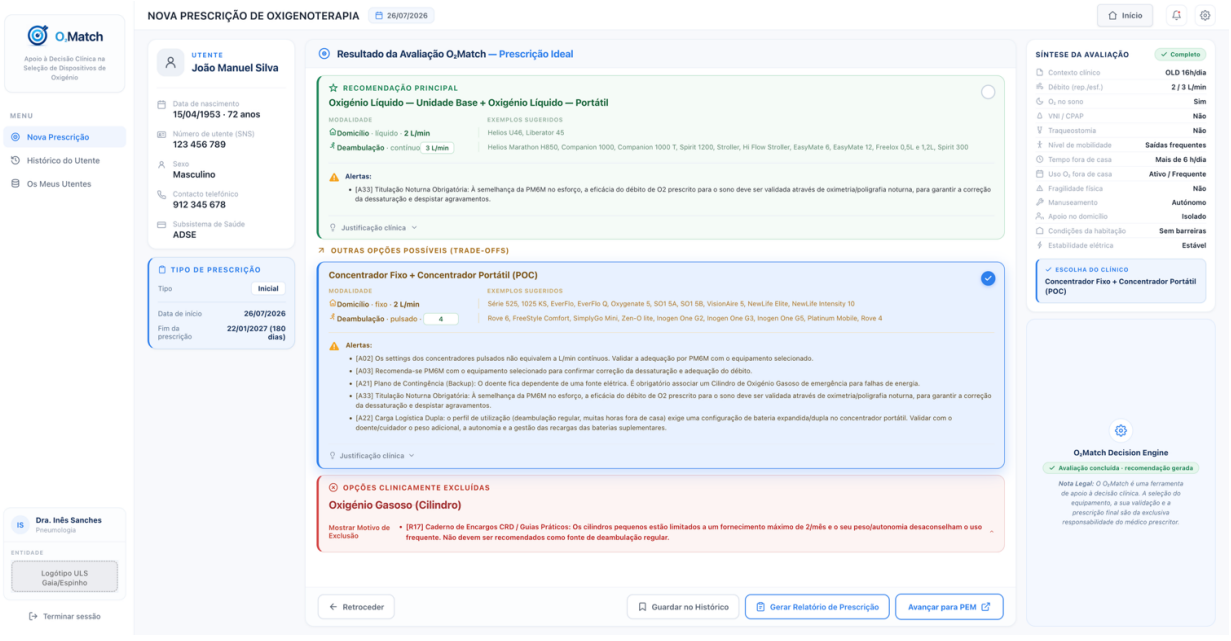


Figure 32- Assessment result with the alternative option selected, enabling the save, generate-report and export-to-PEM actions.

Report generation and PEM export

The recommendation screen also provides options to generate a PDF report, save the recommendation to the patient's history, and either export it or proceed to the Electronic Medical Prescription system (Prescrição Eletrónica Médica, PEM). The generated report is structured and contains the patient data, the prescription details, the clinical justification and any alerts issued by the decision engine (Figure 33); a technical annex sets out the decision justification, the applied rules and the non-preferred options and trade-offs (Figure 34). The report can be exported for delivery to the patient or to the CRD provider and may support future integration with the electronic prescription workflow, with the O_2Match fields mapped to the corresponding PEM fields on export (Figure 35).

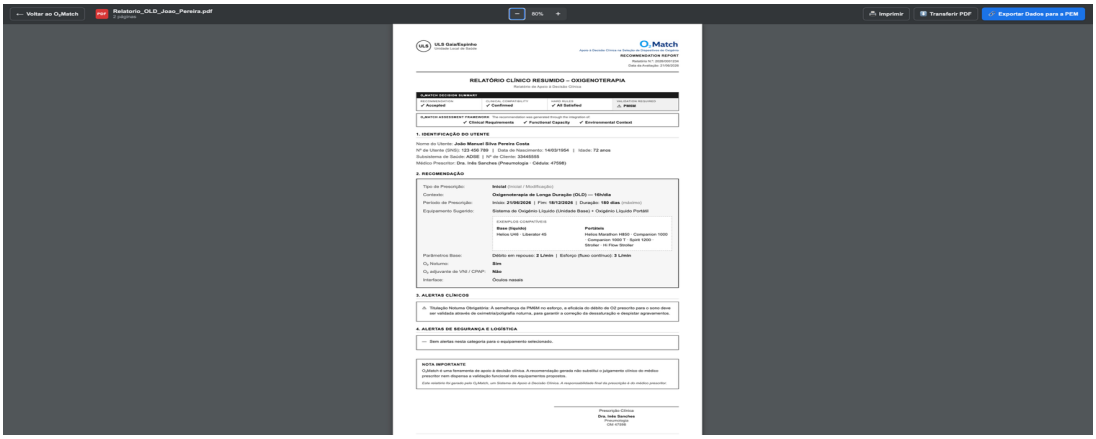


Figure 33- Exportable clinical report in PDF format (page 1): institutional header, decision summary, patient identification, recommendation and clinical alerts.

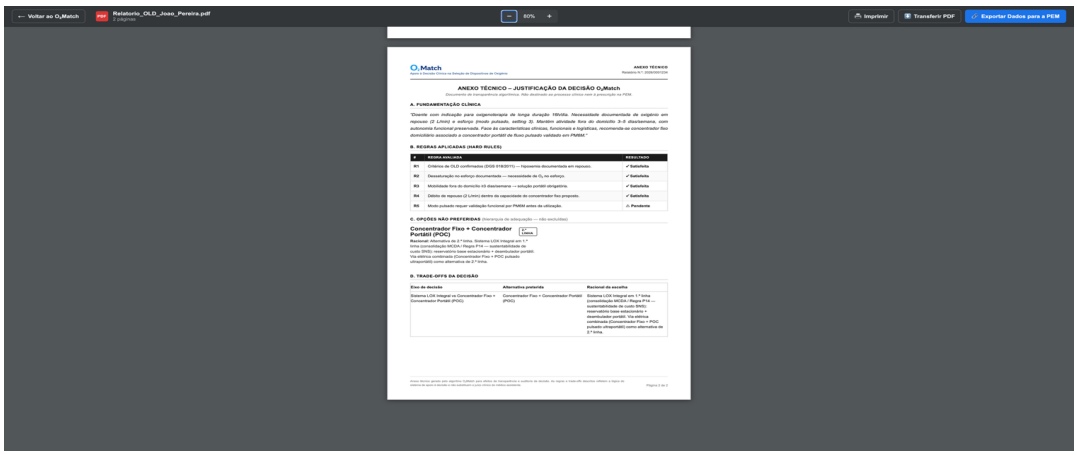


Figure 34- Generated PDF technical annex (page 2): decision justification, applied rules, non-preferred options and trade-offs.

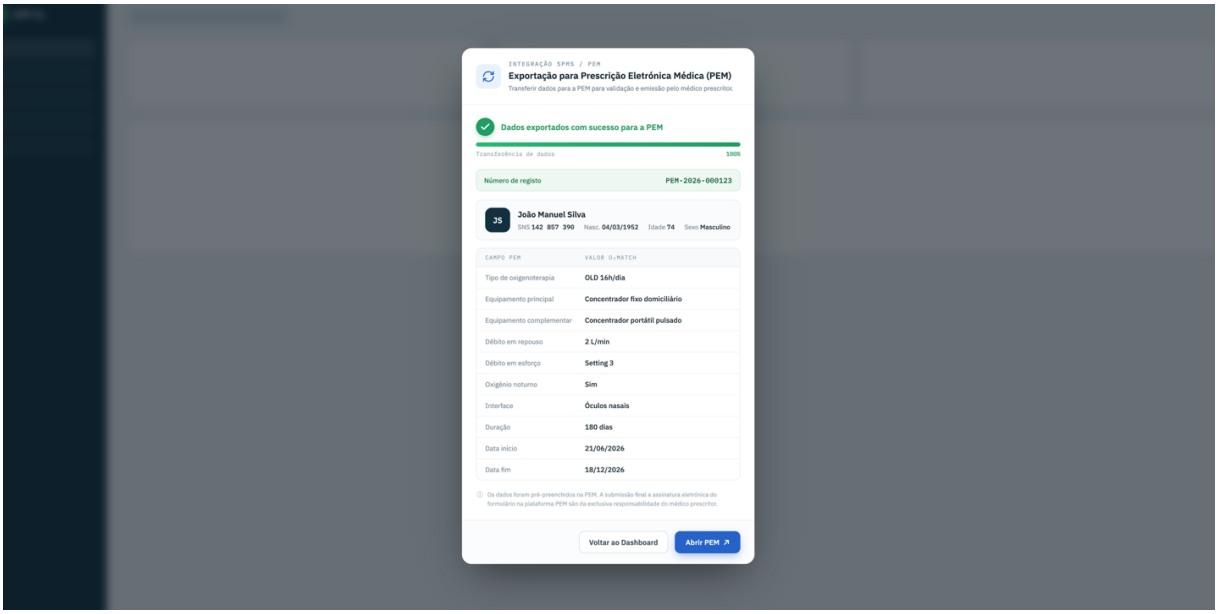


Figure 35- PEM export confirmation: O_2Match fields mapped to the electronic medical prescription (PEM).

5.3.2 Usability friction points and state-synchronisation redesign

The two-layer architecture (React embedding mockups via iframes) introduced a specific software engineering challenge regarding data consistency. While the React layer contained the clinician-entered canonical patient data, the embedded mockup retained its static placeholder values.

During technical verification and early laboratory testing, a data-consistency glitch was identified in which the output interface occasionally displayed an outdated, static placeholder (specifically, a default prescription duration of 30 days) instead of the actual value entered by the physician. This friction point was directly tied to the two-layer iframe architecture. Because the mockups retained their static placeholders, a coherent user interface depended on the React layer actively synchronising and overwriting the mockup's DOM elements. Where DOM queries failed to trigger or complete (due to asynchronous iframe rendering delays), the static placeholder survived.

This issue was corrected prior to the final usability evaluations by implementing robust React synchronisation hooks (useEffect with explicit iframe load listeners) to guarantee that all canonical state values are successfully propagated and forced into the embedded DOM elements before the screen is revealed to the clinician.

5.4 Phase IV — Usability evaluation

For the usability evaluation, the O₂Match prototype was made available as a dedicated web deployment (app-o2match.vercel.app) and through a QR code shown to participants, so that each physician could open the functional React single-page application on a desktop browser or a mobile device and interact with it under controlled conditions (Figure 36).



Figure 36- Access screen for the O₂Match usability-testing prototype.

5.4.1 Objective effectiveness (task completion)

The objective effectiveness of O₂Match was evaluated by tracking participants' ability to complete 11 predefined clinical simulation tasks that represent the core user journey for oxygen device selection. These tasks covered authentication, patient search, navigation, clinical data entry, functional and logistical assessment, recommendation generation, output interpretation, simulated export and secure logout. Each task was graded using a traffic-light taxonomy consistent with formative usability testing and task-based inspection methods [26, 27].

A Green score indicated autonomous completion, meaning that the participant completed the task independently and without relevant hesitation or investigator assistance. A Yellow score indicated assisted completion, meaning that the task was completed successfully but with visible hesitation, a temporary navigation detour or a minor verbal prompt. A Red score indicated task failure, meaning that the participant was unable to complete the task, abandoned

the attempt or followed an incorrect pathway. Tasks not attempted because of clinical time constraints were recorded as not applicable and excluded from rate calculations.

Across the evaluation cohort, all 66 attempted tasks were completed successfully, corresponding to an overall task completion rate of 100% (66/66) (Table 8). Of these, 64 tasks were completed autonomously, corresponding to 97.0% Green outcomes, while two tasks required minor assistance, corresponding to 3% Yellow outcomes. No Red outcomes were observed. The two assisted tasks occurred during the session of a single participant, specifically during the transition to the recommendation screen and during the interpretation of the relationship between alerts and justifications.

Table 8- Individual and aggregate task completion matrix

Task ID	Predefined clinical task/action	P1	P2	P3	P4	P5	P6	Task success rate
T1	Login, including security failure check	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T2	Account recovery pathway	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T3	Patient search using SNS/local data	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T4	Navigation in settings, security and help areas	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T5	Clinical input completion, Wizard Step 1	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T6	Functional input completion, Wizard Step 2	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T7	Logistical input completion, Wizard Step 3	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T8	Recommendation generation	🟡	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T9	Interpretation of recommendation output	🟡	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T10	Simulated export/interoperability pathway	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)
T11	Secure logout	🟢	🟢	🟢	🟢	🟢	🟢	100.0% (6/6)

5.4.2 Level of subjective satisfaction: SUS-informed metrics

Subjective usability and perceived cognitive burden were assessed immediately after the walkthrough sessions using a customised five-dimensional Likert-scale questionnaire. The questionnaire was informed by the ISO 9241-11 usability dimensions and by concepts commonly assessed through instruments such as the System Usability Scale (SUS), but the full SUS instrument was not administered [24, 28, 29]. For this reason, the results should be interpreted as subjective usability ratings rather than as a formal SUS score.

Each dimension was scored on a five-point Likert scale, ranging from 1, corresponding to very difficult or inadequate, to 5, corresponding to very easy or excellent. The five evaluated dimensions were: visual layout and aesthetics; dynamic summary panel utility; option-selection ergonomics; navigation between screens; and advanced functions, including recommendation review and simulated PEM-CRD export.

The overall cohort mean was 4.50 out of 5.00. Dimension C, option selection ergonomics, received the highest mean score, at 4.83 (Table 9). Participants responded positively to segmented buttons, toggles and predefined selection menus, which were perceived as easier and safer than free-text entry.

Dimension B, dynamic summary panel utility, achieved a mean score of 4.50. Participants reported that the persistent sidebar summary helped them monitor previously entered clinical, functional and logistical information without repeatedly navigating backwards.

Dimension E, advanced functions and simulated PEM-CRD export also achieved a mean score of 4.67. Participants valued the combination of device recommendations, explicit clinical justifications, and safety alerts. The simulated export pathway was perceived as relevant to the Portuguese CRD prescribing workflow.

Dimension D, navigation between screens, achieved a mean score of 4.33. Dimension A, visual layout and aesthetics, achieved the lowest mean score, at 4.17.

Table 9- Individual and average Likert usability scores

Perceived usability dimension	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Mean score**
Dimension A: Visual layout and aesthetics	3	5	5	5	3	4	4.17
Dimension B: Dynamic summary panel utility	4	5	5	5	4	4	4.50
Dimension C: Option selection ergonomics	5	5	5	5	4	5	4.83
Dimension D: Navigation between screens	5	4	4	5	4	4	4.33
Dimension E: Advanced functions and PEM-CRD export simulation	4	5	5	5	4	5	4.67
Overall participant mean	4.20	4.80	4.80	5.00	3.80	4.40	4.50

5.4.3 Detected bugs and qualitative improvement proposals

During the Think-Aloud observation, several opportunities for improvement were identified and will be incorporated into subsequent iterations of the prototype:

1. **Scroll-lock bug on the initial page:** identified by two physicians; the React landing page prevented vertical scrolling on lower-resolution monitors, hiding fields located further down the screen.
2. **Small Home button:** reported by one physician as being visually diluted on the output screen, making rapid return to the patient list less intuitive.
3. **Information density:** one physician reported that the initial clinical data screen displayed too many input fields simultaneously, suggesting the need for greater visual spacing.
4. **PEM-CRD integration:** all participating physicians emphasised that the application's full practical value would depend on future interoperability with the Ministry of Health's electronic prescription servers.
5. **Emphasis on the three input blocks:** an additional prescribing physician recommended giving greater visual prominence to the three data-entry blocks — clinical, functional and logistical — to reinforce the trilateral mental model during completion.
6. **Completion-state salience:** the same physician suggested making the complete or incomplete status shown in the dynamic summary sidebar more visible, so that the clinician can confirm at a glance whether all mandatory data have been entered.
7. **Simplified pathway for emergency prescribing:** the physician proposed a streamlined, fast-track prescription route for use in the emergency department, where consultation time is more constrained.
8. **Task-focused, progressive-disclosure interface:** the physician also recommended reducing the amount of information displayed at once and focusing the screen on the task in progress, following the progressive-disclosure model used by oncology decision-support tools such as the NCCN guidelines.

In the final qualitative interview, this physician considered that the main advantage of a tool of this type would be to improve home oxygen prescribing with respect to indications and clinical context, and reiterated that effective integration within the PEM would be essential for routine adoption.

These findings led to concrete corrections in the prototype: activation of scrolling and reorganisation of the initial screen; increased contrast in the header; reordering of the output screen to place the primary recommendation above the alerts; a more visible Home button; and stratification of alerts into separate cards, preventing irrelevant warnings, such as electrical contingency alerts, from visually contaminating the green primary recommendation when liquid oxygen was recommended. The detailed instruments and results are provided in Annex 10.10



6. Discussion

Discussion

This dissertation addressed a practical and clinically relevant problem in Home Oxygen Therapy: the selection of oxygen equipment depends not only on the indication for oxygen, but also on flow requirements, delivery mode, functional capacity, domestic constraints, safety risks, device specifications and Portuguese CRD contractual rules. Current guidelines define when oxygen should be prescribed, but they do not provide an operational mechanism for matching an individual patient to a specific device category.

O_2Match was developed to respond to this gap. Its main contribution is the formalisation of a fragmented and partly tacit decision process into a structured, explainable and auditable Clinical Decision Support System. The project produced a normalised catalogue of 41 oxygen devices across 44 technical and operational variables; a rule base comprising 23 deterministic exclusion rules, 18 clinical preference rules, and 36 alerts; a set of 38 simulated clinical scenarios; and a functional prototype submitted to clinical review, automated verification, and formative usability evaluation.

The trilateral conceptual model — what the patient requires, what the patient can manage, and what the environment allows — proved useful both for structuring the algorithm and for organising the interface. This model reflects the central argument of the dissertation: oxygen device suitability cannot be inferred from physiological indication alone. A technically inadequate, excessively heavy, unsafe, or poorly adapted device may compromise the intended benefit of oxygen therapy, even when the clinical indication is correct.

It is important to define the scope of the findings. This study demonstrates feasibility, explainability, internal consistency and formative usability. It does not demonstrate clinical effectiveness, reduction in device mismatch, improvement in adherence, cost savings or impact on patient outcomes. These remain hypotheses for future prospective evaluation.

Clinical and Organisational Interpretation

The needs assessment confirmed that the main difficulty is not simply deciding whether oxygen is indicated, but selecting the device that can deliver the prescribed therapy safely and realistically in daily life. Physicians reported high confidence in the formal indications for oxygen therapy, but lower confidence in their knowledge of available devices, particularly

portable concentrators. They also rated the availability of technical information for clinical decision-making poorly.

This finding reveals an information asymmetry in the Portuguese CRD ecosystem. The physician is clinically responsible for the prescription, but detailed knowledge about device characteristics, autonomy, portability, triggering behaviour, stock variability and contractual restrictions is often concentrated among CRD providers and technical teams. O_2Match can therefore be interpreted as a knowledge-brokering tool: it brings technical and contractual information into the clinical decision pathway, while preserving the physician's responsibility for the final prescription.

The results also showed convergence across stakeholder groups. Physicians identified device selection and lifestyle matching as difficult; non-prescribing professionals frequently observed problems with weight, portability, autonomy and incorrect use; and patients reported their poorest experience in portability-related dimensions. The importance–performance analysis reinforced this interpretation, identifying weight/portability and autonomy as the largest unmet needs.

These findings justify the inclusion of functional and logistical variables in the decision model. A purely physiological algorithm would be insufficient. A patient may meet criteria for Ambulatory Oxygen Therapy and still fail to benefit from it if the prescribed device is too heavy, has insufficient autonomy, is socially unacceptable, or cannot be handled safely.

Response to the Research Questions

The first research question asked whether dispersed clinical, technical, logistical and contractual knowledge could be formalised into a deterministic, auditable and clinically interpretable rule base. The findings support this objective. O_2Match showed that a substantial part of the oxygen-device selection process can be expressed through explicit IF–THEN logic, particularly when the decision involves safety exclusions, technical incompatibility or regulatory eligibility.

The second research question examined whether the inference engine could apply this knowledge consistently across representative clinical scenarios. This was supported by the verification process. Across the 38 simulated scenarios, the engine generated primary recommendations, acceptable alternatives, rule-tagged exclusions and alerts in full concordance

with an independent Python oracle. The ability to produce justified non-recommendations is clinically relevant. A safe CDSS should not always return a convenient device; it must also indicate when no appropriate recommendation can be made without further assessment.

The third research question concerned usability and perceived clinical acceptability. The formative evaluation showed that physicians could complete the main user pathway, interpret the output structure and use the report-generation and simulated PEM-export functions. The three-step wizard, structured inputs and persistent summary panel were aligned with clinicians' reasoning and were perceived as useful. These results support continued development and real-world testing.

Design Choices: Safety, Transparency and Cognitive Ergonomics

The rule-based architecture was appropriate for the decision problem addressed. Home oxygen equipment selection is governed by explicit clinical thresholds, hardware limitations, safety constraints and regulatory rules. In this context, transparency and auditability are more important than algorithmic adaptivity. Unlike an opaque predictive model, a rule-based system allows the clinician to understand why a device was recommended, why another remains only an alternative, and why some options were excluded.

The green–amber–red output structure was designed to support this reasoning. Green identifies the primary recommendation, amber presents acceptable alternatives, and red displays excluded options with explicit rule codes and justifications. This structure supports rapid interpretation while preserving auditability.

The system was also designed to avoid algorithmic paternalism. Social and logistical barriers, such as stairs, frailty, or the absence of an informal caregiver, were implemented as alerts rather than as deterministic exclusions. This choice is important because such factors may affect feasibility but should not automatically deny access to a clinically appropriate therapy. The alert layer makes the barrier visible while preserving clinical judgement.

From a human–computer interaction perspective, the three-step wizard and the persistent summary panel reduced cognitive load. Device selection requires the clinician to consider multiple interacting variables during a time-limited consultation. By organising inputs into clinical, functional and logistical blocks and keeping the evolving patient profile visible, the interface reduces the need for memory-dependent reasoning and supports safer data entry.

Technical and Methodological Lessons

Two technical lessons were particularly relevant. The first concerns the iframe-based architecture. Embedding high-fidelity static mockups inside a React application was useful for rapid prototyping because it preserved visual design and accelerated usability testing. However, it introduced fragility because the React state had to be synchronised manually with the embedded HTML. The "30-day" prescription-duration glitch illustrated this limitation: a static placeholder could persist visually even though a different value was stored in the application state. Although corrected before the final usability evaluation, this showed that a production version should replace the iframe bridge with native React components and unidirectional data flow. The second lesson concerns the "NaN trap". Pulse-dose-only portable concentrators do not provide continuous-flow oxygen; therefore, the corresponding field may be empty or marked as not applicable in the device database. If numerical comparisons are applied naively to missing values, a safety rule may fail silently. The solution was to introduce categorical guard conditions before numerical comparison. This episode shows that, in health informatics, the database is part of the safety system. Correct rules applied to incomplete or poorly typed data may still generate unsafe outputs.

The independent Python oracle was therefore valuable not as a clinical gold standard, but as a technical comparator. It helped detect discrepancies between intended and implemented logic and reinforced the need for regression testing whenever rules or device specifications are updated.

Limitations

This work has several limitations. First, the needs assessment relied on modest convenience samples: 31 physicians, 33 patients and 8 non-prescribing professionals. The physician sample was geographically concentrated and mainly composed of pulmonologists, limiting generalisability to other prescribing groups such as General and Family Medicine, Internal Medicine and Palliative Care.

Second, the questionnaires were purpose-built for this project. At the time of their development, there was no widely adopted, simple and validated questionnaire specifically designed to evaluate the patient experience of long-term home oxygen therapy, including usability, effectiveness, side effects and equipment-related burden. This limited the possibility of using a

standardised instrument and means that the patient-reported findings should be interpreted as exploratory.

Third, the current clinical preference layer is expert-informed but not formally calibrated. The available data did not support the development of a validated Multi-Criteria Decision Analysis model with empirically derived weights. Therefore, the preference layer should be interpreted as structured clinical prioritisation rather than a statistically validated scoring model.

Fourth, the usability evaluation was formative and small-scale. Six physicians tested the prototype in a controlled environment using simulated scenarios. The sessions did not reproduce the interruptions, time pressure, and incomplete information found in real clinical practice. In addition, the satisfaction questionnaire was SUS-informed but did not administer the full System Usability Scale, so the results should not be reported as a formal SUS score.

Finally, O_2Match has not yet undergone external clinical validation. The study does not demonstrate that the tool improves outcomes, reduces device substitution, increases adherence, lowers costs or changes prescribing behaviour. These outcomes require prospective evaluation in real-world care.

Implications

Despite these limitations, O_2Match provides a relevant contribution to medical informatics and respiratory care. It shows that a complex, context-dependent prescribing decision can be decomposed into explicit variables, translated into auditable rules and presented through a clinician-facing interface.

Clinically, the tool may be most useful for decisions that are technically detailed, infrequent or prone to mismatch. It may support occasional prescribers, improve communication with CRD providers and make the reasoning behind device selection more transparent. However, it should remain a decision-support tool. The final prescription must remain the responsibility of the physician, who should be able to accept, reject or adapt the recommendation according to the patient’s clinical and social context.



7. Conclusion

Conclusion

This dissertation aimed to design, implement and evaluate O_2Match, a CDSS for selecting Home Oxygen Therapy equipment. The project addressed the prescription paradox that characterises this field: oxygen therapy is prescribed according to clinical indication, but its success depends on whether the selected device can meet the patient's physiological needs, functional capacity, domestic context and the technical and contractual constraints of the Portuguese CRD ecosystem.

At prototype level, this objective was achieved. The study showed that fragmented clinical criteria, device specifications, patient-centred functional variables and CRD restrictions can be integrated into a unified, deterministic and explainable algorithm. The resulting rule base comprised 23 deterministic exclusion rules, 18 clinical preference rules and 36 alerts, supported by a normalised catalogue of 41 oxygen devices across 44 variables.

The three research questions were addressed. First, the work demonstrated that dispersed clinical, technical and contractual knowledge can be formalised into an auditable rule base. Second, verification across 38 simulated scenarios and comparison with an independent Python oracle showed that the engine applies this logic consistently. Third, formative usability testing suggested that prescribing physicians could understand and use the prototype in a controlled environment.

The main contribution of this dissertation is therefore methodological and translational. O_2Match shows that home oxygen device selection, currently dependent on dispersed information and varying familiarity with equipment, can be reformulated into a structured, transparent decision-support workflow. The system acts as a bridge between clinical prescription criteria and the technical-operational knowledge of the CRD ecosystem.

These conclusions must remain bounded by the study design. O_2Match is not an autonomous prescribing system and does not replace medical judgement. It is a decision-support artefact. The final therapeutic decision and legal responsibility remain with the prescribing physician.

This dissertation establishes feasibility, explainability, internal consistency and formative usability. It does not yet demonstrate clinical effectiveness, cost savings, improved adherence, reduction in hospitalisations or readiness for production deployment. O_2Match should therefore be understood as a robust research prototype and a foundation for subsequent real-world validation, technical refactoring, interoperability development and regulatory assessment.



8. Future Work

Future Work

In its current state, O₂Match provides a solid foundation for several lines of future development. Taken together, these developments could create a continuous cycle between decision support, prescription and real-world feedback. Patient-reported and device-generated data could inform the calibration of the decision engine; integration with Portuguese National Health Service systems could bring recommendations directly into the prescribing workflow; and monitoring of real-world outcomes could feed back into subsequent refinement of the system.

The future development of O₂Match should therefore follow a staged pathway: real-world clinical evaluation, structured patient feedback, calibration of the clinical preference layer, interoperability with national systems, connection with CRD provider data, telemonitoring integration, oxygen-flow titration support, technical refactoring and regulatory preparation.

8.1 Patient Module and QuOTE-Based Oxygen-Therapy Feedback

A patient-facing module could be developed to collect structured feedback on the real-world experience of Home Oxygen Therapy after device installation. This would transform evaluation from a single assessment episode into a continuous feedback process, allowing the system to learn from the patient's actual experience with the prescribed device.

This module could incorporate the Questionnaire for Oxygen Therapy Evaluation (QuOTE) [44], a simple oxygen-therapy assessment instrument designed to evaluate long-term oxygen therapy use, perceived effectiveness and side effects. Its integration into O₂Match would be particularly relevant because one limitation of the present study was the absence, at the time of questionnaire development, of a widely adopted, validated instrument specifically designed to assess the needs and experience of patients using home oxygen therapy.

A QuOTE-based module could be administered at predefined time points, for example at one, three and six months after prescription. It could assess device weight, ease of transport, autonomy, noise, perceived benefit, adherence, handling difficulties, stigma associated with public use, side effects, and problems related to pulse-dose triggering. These patient-reported data would provide a structured basis for detecting device mismatch, identifying barriers to use and refining future recommendations.

8.2 Prospective Clinical Evaluation and Broader Samples

The most important next step is prospective evaluation in real prescribing conditions. The current study used simulated scenarios and controlled usability sessions; it did not assess the effect of O_2Match during routine consultations with real patients, in the presence of incomplete information, time pressure, and competing clinical priorities.

A future study should compare usual oxygen-device prescription with O_2Match-supported prescription. Relevant outcomes could include early device substitution, unresolved desaturation after installation, patient-reported usability, adherence to prescribed use, CRD reassessment, clinician confidence and frequency of prescription correction.

Future evaluations should also include a broader and more representative sample of prescribers and patients. The current work was centred mainly on Pulmonology and on a limited local sample. Further studies should include General and Family Medicine physicians, who are often involved in renewals and long-term follow-up; Internal Medicine physicians, who manage complex multimorbid patients; and Palliative Care teams, for whom the therapeutic objective may be comfort rather than long-term physiological correction.

The patient sample should also extend beyond COPD. Future work should include patients with neuromuscular disease, thoracic restrictive disorders, interstitial lung disease, advanced cancer, palliative-care needs and patients requiring oxygen as an adjunct to NIV or CPAP. This would improve external validity and test whether the trilateral model remains appropriate across different clinical phenotypes.

8.3 Development of a Multi-Criteria Decision Analysis System

The data accumulated through patient feedback, larger-scale questionnaires and real-world follow-up could support the evolution of the current clinical preference layer into a formal Multi-Criteria Decision Analysis (MCDA) system with empirically calibrated weights. At present, the preference layer is clinically justified but static. It should therefore be interpreted as structured clinical prioritisation rather than a fully calibrated quantitative scoring model.

Future work could use structured expert elicitation, such as Delphi methodology or the Analytic Hierarchy Process, to define the relative importance of criteria such as oxygen flow capacity, portability, autonomy, noise, ease of handling, sleep suitability, compatibility with NIV or

CPAP, patient preference, caregiver burden, cost and availability.

In a more advanced stage, these weights could be adjusted using real-world performance data. Device categories or models associated with poorer observed performance, such as low autonomy, frequent pulse-dose trigger failure, early substitution or low patient satisfaction, could be penalised in the preference-ranking layer. This would transform device prioritisation into a more evidence-informed and performance-sensitive process, while maintaining transparency and clinical oversight.

Deterministic exclusion rules should remain separate from MCDA scoring. Unsafe or technically incompatible devices should not become acceptable because they perform well on convenience, cost, portability or availability.

8.4 Integration with PEM-CRD and National Health Systems

Integration with the Electronic Medical Prescription pathway for CRD, through an authorised API managed within the SPMS ecosystem, would represent a natural next step. Such integration could allow mandatory prescription fields to be automatically populated from the recommendation generated by O_2Match.

Read-level integration could allow demographic data, relevant clinical history, previous prescriptions, arterial blood gas results, oximetry data and respiratory tests to be imported from national health information systems, such as the central health record or equivalent registry structures. This would reduce redundant data entry and improve data completeness.

Write-level integration should focus on the PEM-CRD pathway. The structured recommendation generated by O_2Match could populate the corresponding electronic prescription fields, while retaining the physician's final confirmation step. This would reduce transcription errors, support conformity with DGS requirements and improve traceability between the clinical justification and the final prescription.

Any such integration would require formal governance, authentication, auditability, cybersecurity safeguards, institutional approval and GDPR-compliant data processing. O_2Match should support the prescription workflow, but not issue prescriptions autonomously.

A specific direction, raised during usability testing, is a simplified fast-track prescription pathway for emergency department use, accessible through the PEM-CRD integration and complemented by a task-focused, progressive-disclosure interface, so that time-constrained settings can still benefit from structured, auditable oxygen device selection.

8.5 Connection with CRD Provider Stock and Operational Feedback

A major real-world limitation of any device-selection system is that the clinically preferred device may not be available at the required time and location. Future development should therefore explore integration with CRD providers authorised by the SNS, allowing the system to distinguish between clinically suitable devices and locally available devices.

This could include provider-specific stock information, geographic availability by patient postcode, expected delivery time, maintenance constraints and availability of portable units. The system could identify the clinically preferred device category and then show which providers can supply an appropriate device within the required timeframe.

This development would require careful governance. Provider availability should never override deterministic safety rules or clinical suitability. Real-time stock should refine logistical feasibility, not determine clinical appropriateness.

Structured feedback from CRD professionals should also be incorporated. Installation technicians and home-follow-up teams often identify barriers not visible during consultation, including handling difficulties, domestic constraints, incorrect use, and equipment maintenance problems. Their input could improve the functional and logistical dimensions of future recommendations.

8.6 Integration with Patient Telemonitoring

Connection to telemonitoring systems could provide objective, continuous feedback on adherence, oxygen saturation profiles, and equipment performance in the home environment. These data would help close the loop between the recommendations made at the point of prescription and the actual performance of the prescribed equipment.

Telemonitoring could support early detection of mismatch, poor adherence, persistent desaturation, battery problems, inappropriate device use or failure of pulse-dose triggering during ambulation. For example, a patient prescribed a portable pulse-dose concentrator might report or demonstrate poor exertional correction despite apparently adequate hospital titration. Such information could prompt reassessment and guide device substitution.

Over time, telemonitoring data could help identify patterns associated with prescription failure and improve the calibration of future recommendations. This would allow O_2Match to evolve from a static decision-support tool into a system informed by real-world performance, while preserving transparency and clinical supervision.

8.7 Oxygen Flow Rate Prescription and Titration Algorithm

The scope of O_2Match could also be extended beyond equipment selection to include support for oxygen flow-rate prescription and titration. A future module could assist in defining oxygen flow rates at rest, during sleep and during exertion, while distinguishing between continuous-flow oxygen delivery and pulse-dose oxygen delivery.

Such a module should be closely linked to the six-minute walk test and structured exertional titration protocols. It could guide the documentation of arterial blood gas values, resting oximetry, nocturnal oximetry or polygraphy, and the correction of exertional desaturation. It should also support safer translation between delivery modes and help prevent the common error of treating pulse-dose numeric settings as equivalent to continuous-flow L/min values.

If developed and validated, this extension would allow O_2Match to support a broader decision pathway, from clinical indication to oxygen flow configuration and device selection. Because oxygen titration is a clinical act dependent on physiological testing, this module would require strict clinical governance and prospective validation.

8.8 Production Robustness and Architectural Refactoring

Alongside these functional extensions, the prototype requires further technical consolidation before any production deployment. This includes correcting rare edge-case errors, conducting systematic regression testing after each rule or database update, and implementing mechanisms to preserve the integrity of the knowledge base. The source data and applied logic must remain

synchronised when equipment specifications, clinical guidelines or CRD contractual rules change.

A technically mature version of O_2Match should also replace the current iframe-based bridge architecture with a fully declarative React single-page application. The hybrid architecture used in the prototype was useful for rapid development, but it required manual DOM manipulation and introduced state-synchronisation risks.

Future development should rebuild the interface as native reusable React components, governed by a single canonical application state and unidirectional data flow. The refactored system should separate the user interface, rule engine, device database and reporting/export layer into maintainable modules. Automated regression testing should be triggered whenever clinical rules, device specifications or interface components are updated.

8.9 Regulatory, Ethical and Cybersecurity Preparation

Future work should examine the applicable regulatory framework if O_2Match is intended to move beyond a research prototype. Depending on its intended use and degree of influence on clinical decisions, the system may fall within the scope of the European Medical Device Regulation.

This would require definition of intended use, clinical responsibility, risk classification, clinical evaluation requirements, documentation strategy, audit trails, post-deployment monitoring and cybersecurity requirements. Integration with patient registries, PEM-CRD, CRD providers or telemonitoring platforms would also require authentication, role-based access control, encryption, session management, access logging and GDPR-compliant data processing agreements.

Ethically, the system should preserve human oversight. The prescriber must remain able to inspect the activated rules, understand the recommendation and override the system when clinically justified. The logistical-empathy alert mechanism should be maintained to prevent the conversion of social disadvantage into automatic exclusion from potentially appropriate therapies.

8.10 Summary

Together, these development lines define a coherent path for O_2Match: from an explainable prototype to an integrated system calibrated by real-world data and embedded within the Portuguese National Health Service prescribing workflow.

The future development of O_2Match should therefore proceed through staged maturation: prospective clinical evaluation, broader user testing, integration of structured patient-reported assessment such as QuOTE, MCDA calibration, SPMS and PEM-CRD interoperability, connection with CRD provider data, telemonitoring linkage, oxygen titration support, React-native refactoring and regulatory preparation.

This pathway reflects the current maturity of the project. O_2Match is a coherent and usable research prototype. Its next scientific challenge is to demonstrate value in real-world prescribing. Its next technical challenge is to become robust, interoperable and maintainable. Its next regulatory challenge is to support clinical decisions safely without displacing medical responsibility.



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10. Annexes

Annexes

10.1. Ethics Committee authorization

UNIDADE LOCAL DE SAÚDE
GAIA E ESPINHO

REPÚBLICA PORTUGUESA | SAÚDE | SNS SERVIÇO NACIONAL DE SAÚDE

DECLARAÇÃO

Para os devidos efeitos, declara-se que a Comissão de Ética para a Saúde da Unidade Local de Saúde Gaia e Espinho, E.P.E., apreciou a documentação submetida relativa ao trabalho de investigação intitulado: "**Desenvolvimento e validação de uma ferramenta digital de apoio à decisão para seleção de dispositivos de oxigenoterapia domiciliária**" com o **Documento CES n.º 107/2026**, a desenvolver nos Serviços de Pneumologia, Medicina Interna e Cuidados Paliativos da Unidade Local de Saúde Gaia e Espinho, tendo como investigador/requerente a Dra. Inês Sanches.

Após análise da documentação apresentada, nomeadamente autorizações institucionais, formulário da Comissão de Ética, protocolo do estudo, consentimento informado, declaração de conflitos de interesses, instrumentos de colheita de dados e demais elementos constantes do processo, a Comissão de Ética para a Saúde considerou que o estudo reúne as condições éticas necessárias para a sua realização.

Assim, ouvido o relator e após votação pelos membros presentes, a Comissão de Ética para a Saúde da Unidade Local de Saúde Gaia e Espinho deliberou, **por unanimidade**, emitir **parecer favorável** à realização do referido estudo.

A presente declaração é emitida a pedido do interessado e destina-se aos fins considerados convenientes no âmbito da instrução, implementação e acompanhamento do trabalho de investigação acima identificado.

Vila Nova de Gaia, 22 de julho de 2026

O Presidente da Comissão de Ética para a Saúde (CES),

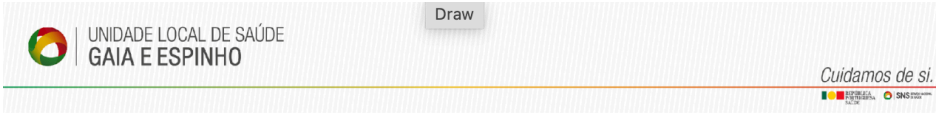
Ricardo Fernandes

(*Ricardo Fernandes*)

[comissao.etica@ulsge.min-saude.pt]

10.2. Informed consent forms

Oxygen users



CONSENTIMENTO INFORMADO

Título do estudo: Desenvolvimento e validação de uma ferramenta digital de apoio à decisão para seleção de dispositivos de oxigenoterapia domiciliária

Participação em estudo de investigação

1. Informação ao participante

Está a ser convidado(a) a participar num **estudo de investigação realizado no âmbito** de uma **tese de Mestrado em Informática Médica da Faculdade de Medicina da Universidade do Porto.** Este estudo pretende compreender melhor a experiência dos doentes que utilizam oxigénio em casa e identificar quais os fatores que devem ser considerados na escolha do equipamento de oxigenoterapia domiciliária..
A sua participação é **totalmente voluntária**.
Antes de decidir participar, é importante que compreenda porque está a ser realizado este estudo e o que lhe é pedido. Se tiver alguma dúvida, pode colocá-la agora ou em qualquer momento.

2. Objetivo do estudo
O objetivo deste estudo é compreender melhor:

- como os doentes utilizam o oxigénio no seu dia-a-dia;
- quais as principais dificuldades associadas ao uso dos dispositivos de oxigenoterapia domiciliária;
- que características dos equipamentos de oxigenoterapia são consideradas mais importantes pelos doentes.

A informação recolhida ajudará a desenvolver uma ferramenta digital que poderá apoiar os profissionais de saúde na escolha do equipamento de oxigenoterapia mais adequado às necessidades de cada doente.

3. O que implica a sua participação

Se aceitar participar:

- será convidado(a) a responder a um **questionário curto** sobre a sua experiência com a utilização do oxigénio em casa;
- o questionário tem perguntas simples e demora aproximadamente **5 a 10 minutos** a responder;
- o questionário pode ser **respondido por si ou com ajuda da investigadora**, caso prefira.

Não será realizado **qualquer exame, intervenção ou alteração ao seu tratamento**.

4. Riscos e desconforto

A participação neste estudo apresenta risco mínimo.

O único possível desconforto é o tempo necessário para responder ao questionário. Se em algum momento se sentir cansado(a) ou desconfortável, pode interromper ou terminar a sua participação.

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GAIA E ESPINHO
Cuidamos de si.

5. Benefícios

Não existe um benefício direto para si.
No entanto, a informação recolhida poderá contribuir para melhorar a adequação dos dispositivos de oxigenoterapia às necessidades dos doentes e para melhorar a qualidade dos cuidados prestados a outros doentes no futuro.

6. Voluntariedade e direito a desistir

A sua participação é totalmente **voluntária**.
Pode recusar participar ou desistir em qualquer momento, sem qualquer prejuízo nos cuidados de saúde que lhe são prestados atualmente ou no futuro.

7. Confidencialidade e proteção dos dados

Os dados recolhidos neste estudo serão tratados de forma estritamente confidencial e segura, em conformidade com o Regulamento Geral sobre a Proteção de Dados (RGPD):

- Responsável pelo Tratamento: O responsável pelo tratamento dos seus dados pessoais é a Unidade Local de Saúde de Gaia e Espinho, E.P.E. (ULSGE), representada pela Investigadora Principal, Dra. Inês Sanches.
- Anonimização e Codificação: As suas respostas serão registadas de forma totalmente codificada através de um código numérico único. Não será recolhido nenhum dado que permita a sua identificação direta (como o seu nome completo ou número de utente).
- Destinatários dos Dados: Os dados recolhidos destinam-se exclusivamente a fins académicos e científicos no âmbito deste projeto. O acesso aos dados codificados será restrito à Investigadora Principal e aos Orientadores Científicos. Não haverá partilha de dados com terceiros nem transferência de dados para fora da União Europeia.
- Prazo de Conservação: Os dados serão conservados de forma segura pelo período de 5 anos após a conclusão do estudo, sendo permanentemente eliminados após este prazo.
- Direitos do Titular dos Dados: Como participante, tem o direito de solicitar à Investigadora Principal o acesso aos seus dados pessoais, bem como a sua retificação, apagamento ("direito a ser esquecido"), limitação do tratamento ou oposição ao tratamento. Caso pretenda exercer estes direitos ou tenha dúvidas sobre o tratamento dos seus dados, poderá contactar o Encarregado de Proteção de Dados da ULSGE através do e-mail: dpo@ulsge.min-saude.pt. Mais se informa que tem o direito de apresentar uma reclamação junto da autoridade de controlo nacional (Comissão Nacional de Proteção de Dados - CNPD)

8. Contactos

Se tiver alguma dúvida sobre o estudo, pode contactar:

UNIDADE LOCAL DE SAÚDE
GAIA E ESPINHO

Cuidamos de si.

Investigadora responsável: Inês Sanches / Instituição: ULS Gaia Espinho /email: ines.sanches@ulsge.min-saude.pt
Orientadores Científicos (FMUP / INESC TEC): Prof.ª Doutora Daniela Ferreira-Santos (daniela.santos@inesctec.pt) e Prof. Doutor Hélder Oliveira (holiveira@fc.up.pt)
Encarregado Proteção de dados: José Ribeiro / Instituição: ULS Gaia Espinho/ email: dpo@ulsge.min-saude.pt

9. Declaração de consentimento

Declaro que:

- li (ou me foi lida) a informação acima;
- compreendi o objetivo do estudo e o que me é pedido;
- tive oportunidade de colocar questões;
- aceito participar de forma livre e voluntária neste estudo.

Nome do(a) participante: _____

Assinatura: _____

Data: ____ / ____ / _____

Assinatura do investigador que prestou a informação: _____

Informed consent forms – CRD

CONSENTIMENTO INFORMADO

Título do estudo: Desenvolvimento e validação de uma ferramenta digital de apoio à decisão para seleção de dispositivos de oxigenoterapia domiciliária

Participação em estudo de investigação

1. Informação ao participante

Está a ser convidado(a) a participar num **estudo de investigação realizado no âmbito** de uma **tese de Mestrado em Informática Médica da Faculdade de Medicina da Universidade do Porto.** Este estudo pretende compreender melhor a experiência dos doentes que utilizam oxigénio em casa e identificar quais os fatores que devem ser considerados na escolha do equipamento de oxigenoterapia domiciliária..
A sua participação é **totalmente voluntária**.
Antes de decidir participar, é importante que compreenda porque está a ser realizado este estudo e o que lhe é pedido. Se tiver alguma dúvida, pode colocá-la agora ou em qualquer momento.

2. Objetivo do estudo
O objetivo deste estudo é compreender melhor:

- O grau de adequação entre a prescrição médica e a realidade/viabilidade técnica encontrada no domicílio do doente;
- Quais as principais características técnicas que falham ou que são mais valorizadas na prática diária;
- A sua opinião sobre a utilidade e os desafios da implementação de uma futura ferramenta digital de apoio à decisão médica.

A informação recolhida ajudará a desenvolver uma ferramenta digital que poderá apoiar os profissionais de saúde na escolha do equipamento de oxigenoterapia mais adequado às necessidades de cada doente

3. O que implica a sua participação

Se aceitar participar:

- Será convidado(a) a participar numa **entrevista semi-estruturada** orientada por um guião de tópicos;
- A entrevista terá uma duração aproximada de **15 a 30 minutos**;
- A entrevista será **gravada em formato áudio** (mediante a sua autorização expressa) de forma a facilitar o registo fiel das informações e a sua posterior análise pela investigadora;
- Não será realizado qualquer procedimento adicional ou avaliação do seu desempenho profissional.

4. Riscos e desconforto

A participação neste estudo apresenta risco mínimo.

O único possível desconforto é o tempo necessário para a realização da entrevista. Se em algum momento se sentir desconfortável, pode não responder a determinada questão ou terminar a sua participação de imediato.

5. Benefícios

Não existe um benefício direto para si.
No entanto, a sua experiência de terreno é fundamental e poderá contribuir para melhorar o alinhamento da prescrição médica com a realidade do doente, otimizando os cuidados prestados e a logística associada

6. Voluntariedade e direito a desistir

A sua participação é totalmente **voluntária**.
Pode recusar participar ou desistir em qualquer momento, sem necessidade de justificação e sem qualquer prejuízo profissional ou pessoal.

7. Confidencialidade e proteção dos dados

Os dados recolhidos neste estudo serão tratados de forma estritamente confidencial e segura, em conformidade com o Regulamento Geral sobre a Proteção de Dados (RGPD):

- Responsável pelo Tratamento: O responsável pelo tratamento dos seus dados pessoais é a Unidade Local de Saúde de Gaia e Espinho, E.P.E. (ULSGE), representada pela Investigadora Principal, Dra. Inês Sanches.
- Tratamento das Gravações Áudio: A entrevista será gravada em formato áudio apenas mediante a sua autorização expressa e para fins de transcrição escrita rigorosa.
- Acesso: O ficheiro áudio original será armazenado em suporte digital encriptado com acesso restrito e exclusivo à Investigadora Principal.
- Eliminação do Áudio: O ficheiro áudio original será eliminado de forma definitiva e permanente de todos os dispositivos imediatamente após a conclusão e validação da transcrição de texto e anonimização, num prazo máximo de 3 meses após a realização da entrevista.
- Anonimização da Transcrição: A transcrição escrita será totalmente desprovida de quaisquer elementos identificativos diretos ou indiretos (como o seu nome ou a empresa de CRD que representa), garantindo o seu anonimato.
- Destinatários dos Dados: Os dados destinam-se a fins científicos e de investigação. O acesso à transcrição anónima é limitado à Investigadora Principal e aos Orientadores Científicos, não existindo partilha de dados com terceiros nem transferências internacionais.
- Prazo de Conservação: A transcrição anónima será conservada em suporte digital seguro pelo período de 5 anos após a conclusão do estudo, sendo eliminada de forma irreversível após esse período.
- Direitos do Titular dos Dados: Como participante, tem o direito de solicitar à Investigadora Principal o acesso aos seus dados, bem como a sua retificação, apagamento ("direito a ser esquecido"), limitação do tratamento ou oposição ao tratamento. Para exercer estes direitos ou esclarecer dúvidas, poderá contactar o Encarregado de Proteção de Dados da ULSGE através do e-mail:

dpo@ulsge.min-saude.pt. Mais se informa que tem o direito de apresentar uma reclamação junto da autoridade de controlo nacional (Comissão Nacional de Proteção de Dados - CNPD).

8. Contactos
Se tiver alguma dúvida sobre o estudo, pode contactar:
Investigadora responsável: Inês Sanches / Instituição: ULS Gaia Espinho /email: ines.sanches@ulsge.min-saude.pt
Orientadores Científicos (FMUP / INESC TEC): Prof.ª Doutora Daniela Ferreira-Santos (daniela.sanches@inesctec.pt) e Prof. Doutor Hélder Oliveira (holiveira@fc.up.pt)
Encarregado Proteção de dados: José Ribeiro / Instituição: ULS Gaia Espinho/ email: dpo@ulsge.min-saude.pt

9. Declaração de consentimento

Declaro que:

- li (ou me foi lida) a informação acima;
- compreendi o objetivo do estudo e o que me é pedido;
- tive oportunidade de colocar questões;
- aceito participar de forma livre e voluntária neste estudo.
- Autorizo expressamente a gravação áudio desta entrevista para efeitos exclusivos de registo e investigação.

Nome do(a) participante: _____

Assinatura: _____

Data: ____ / ____ / _____

Assinatura do investigador que prestou a informação: _____

10.3. Data-collection questionnaires: prescribing physicians; non-prescribing professionals; oxygen therapy users

	Acess
Prescribing physicians	Physician_Questionnaire_Report.docx
Non-prescribing professionals	O2Match_HealthProfessionals_Questionnaire_Report.docx
Oxygen therapy users	O2Match_Patient_Questionnaire_Report.docx
CRD interview guide	Cópia de Guião de Entrevista: APP-O_2 e a Oxigenoterapia Domiciliária

10.4. Oxygen equipment database

tabelas_Algoritmo_v2

Table 10- Oxygen equipment database

Database_part 1

Categoria_eq	Fabricante	Modelo	fluxo_cont	to_max_cont_l	Fluxo_puls	Settings_max	compati_tecnica	Adequado_sono	Aprovado_voo	custo_SNS	uso_continuado	so_max_h	Dimensoes	Formato_tran	capacidade_por	autonomia_max	hpo_carreg_ma	eletric_cont	uido_max_dB
POC_p	Inogen	Rove 6	0	N/A	1	6	0	0	1	Médio	0	2,6	18,2 x 8,3 x 20,	1, 2	1	13	4	0	39
POC_p	Caire	FreeStyle Comfort	0	N/A	1	5	0	0	1	Médio	0	2,7	25,4 x 18,5 x 7,5	1, 2, 3	1	8	6	0	39,9
POC_p	Philips Respironics	SimplyGo Mini	0	N/A	1	5	0	0	1	Médio	0	2,3	23,9 x 21,1 x 9,1	1, 2	1	9	4	0	43
POC_p	GCE	Zen-O lite	0	N/A	1	5	0	0	1	Médio	0	2,5	24,9 x 9,7 x 23,1	1, 2	1	8	3	0	37
POC_cp	GCE	Zen-O	1	2	1	6	0	0	1	Médio	0	4,66	21,2 x 16,8 x 31,	1, 2, 4	1	8	3	0	38
POC_cp	Philips Respironics	SimplyGo	1	2	1	6	0	0	1	Médio	0	4,5	29,2 x 25,4 x 15	1, 2, 4	1	3,5	3	0	43
POC_p	Inogen	Inogen One G2	0	N/A	1	6	0	0	1	Médio	0	3,18	27,2 x 9,9 x 22,2	1, 2, 4	1	10	8	0	38
POC_p	Inogen	Inogen One G3	0	N/A	1	5	0	0	1	Médio	0	2,2	22,2 x 7,6 x 21 c	1, 2	1	4,5	4	0	39
POC_p	Inogen	Inogen One G5	0	N/A	1	6	0	0	1	Médio	0	2,2	18,2 x 8,3 x 20,	1, 2	1	13	4	0	38
CONC_FIXO	Drive DeVilbiss	Série 525	1	5	0	N/A	1	1	0	Baixo	1	16,3	62,2 x 34,2 x 3C	4	0	N/A		1	48
CONC_FIXO	Drive DeVilbiss	1025 KS	1	10	0	N/A	1	1	0	Baixo	1	19	62,2 x 34,2 x 3C	4	0	N/A		1	57
CONC_FIXO	Philips Respironics	EverFlo	1	5	0	N/A	1	1	0	Baixo	1	15	58 x 38 x 24 cm	4	0	N/A		1	50
CONC_FIXO	Philips Respironics	EverFlo Q	1	5	0	N/A	1	1	0	Baixo	1	15	58 x 38 x 24 cm	4	0	N/A		1	40
CONC_FIXO	Nidek / Konsung	Oxygenate 5	1	5	0	N/A	1	1	0	Baixo	1	18	41 x 26,5 x 53 c	4	0	N/A		1	40
CONC_FIXO	BMC	SO1 5A	1	5	0	N/A	1	1	0	Baixo	1	18	38,8 x 27,9 x 6C	4	0	N/A		1	50
CONC_FIXO	BMC	SO1 5B	1	5	0	N/A	1	1	0	Baixo	1	18	38,8 x 27,9 x 6C	4	0	N/A		1	58
CONC_FIXO	Caire / Airsep	VisionAire 5	1	5	0	N/A	1	1	0	Baixo	1	13,6	52,8 x 35,8 x 25	4	0	N/A		1	45
LOX_base	Caire - Chart	Helios U46	1	15	0	N/A	1	1	0	Elevado	1	77,1	95,2 x 39,1 cm	4	0	N/A	N/A	0	Silencioso
LOX_base	Caire - Chart	Liberator 45	1	15	0	N/A	1	1	0	Elevado	1	74,99	94,0 x 35,6 x 3!	4	0	N/A		0	Silencioso
LOX_port	Caire - Chart	Helios Marathon H850	1	6	1	5	0	0	0	Elevado	0	2,5	N/D	1, 2	1	29		0	Silencioso
LOX_port	Caire - Chart	Helios Plus 300	1	0,75	1	7	0	0	0	Elevado	0	1,6	N/D	1, 2	1	18		0	Silencioso
LOX_port	Caire - Chart	Companion 1000	1	6	0	N/A	0	0	0	Elevado	0	3,67	36,8 x 16,5 x 15	1, 2, 3	1	7,7		0	Silencioso
LOX_port	Caire - Chart	Companion 1000 T	1	15	0	N/A	0	0	0	Elevado	0	3,99	36,8 x 16,5 x 15	1, 2, 3	1	7,7		0	Silencioso
LOX_port	Caire - Chart	Spirit 1200	1	2	1	6	0	0	0	Elevado	0	3,63	35,5 cm (altura	1, 2	1	30		0	Silencioso
LOX_port	Caire - Chart	Stroller	1	6	0	N/A	0	0	0	Elevado	0	3,63	34,3 x 19,1 x 14,	1, 2, 3	1	8		0	Silencioso
LOX_port	Caire - Chart	Hi Flow Stroller	1	15	0	N/A	0	0	0	Elevado	0	3,86	34,3 x 19,1 x 14,	1, 2, 3	1	8		0	Silencioso
LOX_port	Dehas	EasyMate 6	1	6	0	N/A	0	0	0	Elevado	0	3,5	37,9 x 14,5 x 12,	1, 2	1	6,5		0	Silencioso
LOX_port	Dehas	EasyMate 12	1	12	0	N/A	0	0	0	Elevado	0	3,5	37,9 x 14,5 x 12,	1, 2	1	6,5		0	Silencioso
Oxigénio Gasoso	N/A	Cilindro 3L	1	15	0	N/A	1	0	0	Baixo	0		N/D	1, 2	1	2		0	Silencioso
Oxigénio Gasoso	N/A	Cilindro 5L	1	15	0	N/A	1	0	0	Baixo	0		N/D	1, 2	1	2		0	Silencioso
Oxigénio Gasoso	N/A	Cilindro 7L	1	15	0	N/A	1	0	0	Baixo	0		N/D	4	0	11.5		0	Silencioso
Oxigénio Gasoso	N/A	Cilindro 14L	1	15	0	N/A	1	0	0	Baixo	0		N/D	4	0	23		0	Silencioso
Oxigénio Gasoso	N/A	Cilindro 20L	1	15	0	N/A	1	0	0	Baixo	0		N/D	4	0	33		0	Silencioso
POC_p	Invacare	Platinum Mobile	0	N/A	1	5	0	0	1	Médio	0	2,2	N/D	1, 2	1	10	N/D	0	< 40 dBA
LOX_port	CryopAL	Freelox 0,5L e 1,2L	1	7	0	N/A	0	0	0	Elevado	0	3,6	N/D	1, 2	1	30	N/A	0	Silencioso
POC_p	Inogen	Rove 4	0	N/A	1	4	0	0	1	Médio	0	1,3	15,0 x 6,8 x 19,(	1, 2	1	5,8	4	0	39
CONC_FIXO	CAIRE / AirSep	NewLife Elite	1	5	0	N/A	1	1	0	Baixo	1	24,5	72,4 x 40,0 x 3(	4	0	N/A	N/A	1	53
CONC_FIXO	CAIRE / AirSep	NewLife Intensity 10	1	10	0	N/A	1	1	0	Baixo	1	26,3	69,9 x 41,9 x 36	4	0	N/A	N/A	1	58
CONC_FIXO	Yuwell	Yuwell 8F-5A	1	5	0	N/A	1	1	0	Baixo	1	15,5	N/D	4	0	N/A	N/A	1	48
POC_cp	CAIRE / SeQual	Eclipse 5	1	3	1	9 settings	1	0	1	Médio	0	8,34	49,0 x 31,2 x 18	3	1	5,4	~5h	0	40
LOX_port	CAIRE - Chart	Spirit 300	1	2	1	6 settings	0	0	0	Elevado	0	1,95	22,3 cm (altura	1, 2	1	15,1	N/A	0	Silencioso

Database_part 2

Tipo_tecnico	Categoria_eq	Manuseamento	Manuten_doe	Alertas_tecnicas	tipo_alertas	o_autonomia_fluxo_m	modo_trigger	interface_compativel	adequado_t	caqueos	fonte_energia	hot_swap_bateria	necessita_backup	essita_recarga_ma	sumo_oxigenio_rela	classe_portabilidad	eite_uso_durante_cl
2	POC_p	Simples (ecrã LCD)	Limpeza dos fi	Bateria fraca, sem resp	Visuais e Sonoros	~2,5h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	POC_p	Simples (ecrã a cores)	Limpeza dos fi	Alta/baixa temp, pressi	Visuais e Sonoros	~2h	Adaptativo (autoSAT)	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	POC_p	Simples (ecrã tátil)	Limpeza do ex	Sem respiração, baixa	Visuais e Sonoros	~3h	Sensível	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	POC_p	Simples (ecrã LCD)	Limpeza e sub	Bateria fraca, verificar	Visuais e Sonoros	~2h	Sensível	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	POC_cp	Simples (ecrã LCD)	Limpeza exteri	Bateria fraca, verificar	Visuais e Sonoros	~1,5h (contínuo)	Sensível	Cânula nasal e Máscara	0		Bateria/Elétrica	1	1	0	N/A	Portátil	1
2	POC_cp	Simples (ecrã)	Limpeza do ex	Bateria fraca, sem resp	Visuais e Sonoros	~0,9h (contínuo)	Sensível	Cânula nasal e Máscara	0		Bateria/Elétrica	0	1	0	N/A	Portátil	1
2	POC_p	Simples (ecrã LCD)	Limpeza e sub	Bateria fraca, sem resp	Visuais e Sonoros	~2h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Portátil	1
2	POC_p	Simples (ecrã LCD)	Limpeza e sub	Bateria fraca, sem resp	Visuais e Sonoros	~2h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	POC_p	Simples (ecrã LCD)	Limpeza e sub	Bateria fraca, sem resp	Visuais e Sonoros	~3h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
1	CONC_FIXO	Simples (botão on/off	Limpeza sema	Falha de energia, baixc	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (LEDs e fluxo	Limpeza sema	Pressão alta, fluxo alto	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (botão on/off	Limpeza sema	Falha de energia, baixc	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (botão on/off	Limpeza sema	Falha de energia, baixc	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (botões e tem	Limpeza mens	Falha de energia, baixc	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (ecrã LED e fl	Limpeza do ex	Perda de energia, auto	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (controlo remi	Limpeza do ex	Perda de energia, auto	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (botão on/off	Limpeza exteri	Falha de energia, press	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	LOX_base	Simples	Limpeza exteri	Nível baixo	Visuais	Depende do débito	N/A	Todas (incl. VNI/Traq)	1		LOX	N/A	1	0	Alto	Estacionário	0
	LOX_base	Simples (LED de nível	Limpeza exteri	Nível baixo	Visuais	Depende do débito	N/A	Todas (incl. VNI/Traq)	1		LOX	N/A	1	0	Alto	Estacionário	0
2	LOX_port	Simples (botão e fita ir	Limpar exterio	Nível baixo	Visuais (mecânicos)	~1,5h (contínuo)	Pneumático (Sensível)	Cânula nasal e Máscara	0		LOX	N/A	0	1	Moderado	Portátil	0
2	LOX_port	Simples	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~1,5h (pulsado)	Pneumático (Sensível)	Cânula nasal	0		LOX	N/A	0	1	Baixo	Ultra portátil	0
2	LOX_port	Simples (escala de mo	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~1,5h	N/A	Cânula nasal	0		LOX	N/A	0	1	Moderado	Portátil	0
2	LOX_port	Simples (escala de mo	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~0,5h (a 15L)	N/A	Cânula nasal e Máscara	0		LOX	N/A	0	1	Alto	Portátil	0
2	LOX_port	Simples (botão rotativ	Limpeza exteri	Nível baixo, bateria fra	Visuais e Sonoros	~2h (pulsado)	Pneumático (Sensível)	Cânula nasal	0		LOX	N/A	0	1	Moderado	Portátil	0
2	LOX_port	Simples (botão rotativ	Limpeza exteri	Nível baixo, bateria fra	Visuais (Mecânicos e LED)	~1,5h	N/A	Cânula nasal	0		LOX	N/A	0	1	Moderado	Portátil	0
2	LOX_port	Simples (botão rotativ	Limpeza exteri	Nível baixo, bateria fra	Visuais (Mecânicos e LED)	~0,5h (a 15L)	N/A	Cânula nasal e Máscara	0		LOX	N/A	0	1	Alto	Portátil	0
2	LOX_port	Simples (escala e fluxo	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~1h	N/A	Cânula nasal	0		LOX	N/A	0	1	Moderado	Portátil	0
2	LOX_port	Simples (escala e fluxo	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~0,5h (a 12L)	N/A	Cânula nasal	0		LOX	N/A	0	1	Alto	Portátil	0
3	Oxigénio Gasoso	Simples (redutor/manc	Limpeza exteri	Nível baixo	Visuais (mecânicos no manómetro	~0,5h (a 3L)	N/A	Todas	1		Gasoso	N/A	0	0	Alto	Portátil	0
3	Oxigénio Gasoso	Simples (redutor/manc	Limpeza exteri	Nível baixo	Visuais (mecânicos no manómetro	~1h (a 3L)	N/A	Todas	1		Gasoso	N/A	0	0	Alto	Portátil	0
3	Oxigénio Gasoso	Simples (redutor/manc	Limpeza exteri	Nível baixo	Visuais (mecânicos no manómetro	11.5 (a 2L)	N/A	Todas	1		Gasoso	N/A	0	0	Alto	Estacionário	0
3	Oxigénio Gasoso	Simples (redutor/manc	Limpeza exteri	Nível baixo	Visuais (mecânicos no manómetro	23h (a 2L)	N/A	Todas	1		Gasoso	N/A	0	0	Alto	Estacionário	0
3	Oxigénio Gasoso	Simples (redutor/manc	Limpeza exteri	Nível baixo	Visuais (mecânicos no manómetro	33h (a 2L)	N/A	Todas	1		Gasoso	N/A	0	0	Alto	Estacionário	0
2	POC_p	Simples	Limpeza exteri	Bateria fraca, respiraçi	Visuais e Sonoros	~3,5h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
2	LOX_port	Simples (escala)	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~1,5h	N/A	Cânula nasal e Máscara	0		LOX	N/A	0	1	Moderado	Portátil	0
2	POC_p	Simples (ecrã LCD)	Limpeza dos fi	Bateria fraca, sem resp	Visuais e Sonoros	~1,8h	Adaptativo	Cânula nasal	0		Bateria/Elétrica	0	1	0	N/A	Ultra portátil	1
1	CONC_FIXO	Simples (botão on/off	Limpeza sema	Falha de energia, altar	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples (botão on/off	Limpeza sema	Falha de energia, altar	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
1	CONC_FIXO	Simples	Limpeza do filt	Falha de energia, baixc	Visuais e Sonoros	Ilimitado	N/A	Todas (incl. VNI/Traq)	1		Elétrica	N/A	1	0	N/A	Estacionário	N/A
2	POC_cp	Simples (ecrã e botõe	Limpeza do filt	Bateria fraca, baixo O2	Visuais e Sonoros	~4,4h (contínuo)	Sensível (ajustável)	Cânula nasal e Máscara	0		Bateria/Elétrica	1	1	0	N/A	Portátil (Trolley)	1
2	LOX_port	Simples (botão rotativ	Limpeza exteri	Nível baixo	Visuais (mecânicos)	~2,4h (contínuo)	Pneumático (Sensível)	Cânula nasal	0		LOX	N/A	0	1	Baixo	Ultra portátil	0

Database_part 3

Tipo_tecnico	Categoria_eq	eite_uso_durante_c	fonte_ficha_tecnica	grau_confianca_dado	documento_tecnico_nome	data_validacao_dado
2	POC_p	1	manual utilizador	confirmado por manual	Rove 6.pdf	2026-06-03
2	POC_p	1	manual utilizador	confirmado por manual	FreeStyle Comfort.pdf	2026-06-03
2	POC_p	1	manual utilizador	confirmado por manual	Simply Go Mini.pdf	2026-06-03
2	POC_p	1	manual utilizador	confirmado por manual	Zen-O Lite.pdf	2026-06-03
2	POC_cp	1	manual utilizador	confirmado por manual	Zen-O.pdf	2026-06-03
2	POC_cp	1	manual utilizador	confirmado por manual	Simply Go.pdf	2026-06-03
2	POC_p	1	manual utilizador	confirmado por manual	IOGEN_OUSER_MANUAL_PT.pdf	2026-06-03
2	POC_p	1	manual utilizador	confirmado por manual	IOGEN G3_User_Manual_PT.pdf	2026-06-03
2	POC_p	1	ficha tecnica	confirmado por ficha técni	Inogen One G5 Spec Sheet.pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	525-Devilbliss.pdf	2026-06-03
1	CONC_FIXO	N/A	ficha tecnica	confirmado por ficha técni	1025 KS (DeVilbiss).pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	EverFlo.pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	EverFlo.pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	Oxygenate 5.pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	SO1 5B (BMC).pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	SO1 5B (BMC).pdf	2026-06-03
1	CONC_FIXO	N/A	manual utilizador	confirmado por manual	Manual_VisionAire_5.pdf	2026-06-03
1	LOX_base	0	ficha tecnica	confirmado por ficha tén	ML-LOX0006_G_HELIOS_Base_5	2026-06-21
	LOX_base	0	ficha tecnica	confirmado por ficha técni	liberator.pdf	2026-06-03
2	LOX_port	0	distribuidor	confirmado por ficha técni	Vit_Tabelas_O2_Deambuladores.p	2026-06-03
2	LOX_port	0	ficha tecnica	confirmado por ficha técni	Helios Pplus.pdf	2026-06-03
2	LOX_port	0	ficha tecnica	confirmado por ficha técni	companion Caire.pdf	2026-06-03
2	LOX_port	0	ficha tecnica	confirmado por ficha técni	companion Caire.pdf	2026-06-03
2	LOX_port	0	manual utilizador	confirmado por manual	spirit 1200.pdf	2026-06-03
2	LOX_port	0	manual utilizador	confirmado por manual	Sprint_Stroller_HiFlow_UM.pdf	2026-06-03
2	LOX_port	0	manual utilizador	confirmado por manual	Sprint_Stroller_HiFlow_UM.pdf	2026-06-03
2	LOX_port	0	manual utilizador	confirmado por manual	Easymate-6-66-12-en.pdf	2026-06-03
2	LOX_port	0	manual utilizador	confirmado por manual	Easymate-6-66-12-en.pdf	2026-06-03
3	Oxigénio Gasoso	0	inferido	Cálculo Matemático Padrã	Norma 018/2011 DGS	2026-06-03
3	Oxigénio Gasoso	0	inferido	Cálculo Matemático Padrã	Norma 018/2011 DGS	2026-06-03
3	Oxigénio Gasoso	0	inferido	Cálculo Matemático Padrã	Norma 018/2011 DGS	2026-06-03
3	Oxigénio Gasoso	0	inferido	Cálculo Matemático Padrã	Norma 018/2011 DGS	2026-06-03
2	POC_p	1	nfirmado por ficha técni	confirmado por ficha técni	DSAL005613_6P Platinum Mob	2026-06-11
2	LOX_port	0	confirmado por manual	confirmado por manual	Freelox-12-englisch.pdf	2026-06-11
2	POC_p	1	manual utilizador	confirmado por manual	Manual Rove 4.pdf	2026-06-12
1	CONC_FIXO	N/A	ficha tecnica	confirmado por ficha técni	NewLife® elite 5.pdf	2026-06-21
1	CONC_FIXO	N/A	ficha tecnica	confirmado por ficha técni	NewLife® Intensity® 10.pdf	2026-06-21
1	CONC_FIXO	N/A	manual utilizador	padrao mercado	Yuwell8F5AOxygenConcentrator(	2026-06-21
2	POC_cp	1	ficha tecnica	confirmado por ficha técni	Eclipse 5®.pdf	2026-06-21
2	LOX_port	0	ficha tecnica	confirmado por ficha técni	spirit 1200.pdf	2026-06-21

10.5. Integral logical matrix od the O2Match algorithm

Table 11- Deterministic exclusion rules

ID_Regra	Nivel	Tipo	Input_Doente	Variavel_Equipamento	Condicao_Logica	Acao	Justificacao_Operacional	Impacto_POC_cp
R00	Hard	Gatekeeper Clínico	Gasometria / Oximetria + Dano Orgânico	N/A	IF Contexto = "OLD" AND (PaO2 >= 60 OR (PaO2 BETWEEN 56 AND 59 AND Dano_Organico = "Não"))	Bloquear algoritmo (Mostrar Aviso: "Sem indicação clínica normativa para OLD")	Norma ATS / DGS: A prescrição de OLD exige $PaO_2 \leq 55$ mmHg, ou 56-59 mmHg com dano orgânico. A hipoxemia moderada isolada não tem indicação formal.	Não aplicável (bloqueia logo na entrada).
R01	Hard	Exclusão	Usa VNI = Sim	compati_tecnica_VNI + Categoria_eq	IF compati_tecnica_VNI = 0 OR ((Categoria_eq = "POC_p" OR Categoria_eq = "POC_cp") AND Deambulacao = "Não")	Excluir equipamento	Equipamento incompatível com circuito VNI, ou equipamento é portátil e o doente não tem deambulação (os POC nunca podem ser prescritos como a fonte VNI fixa principal).	POC_cp só sobrevive como complemento se o doente tiver deambulação validada associada à VNI.
R02	Hard	Exclusão	Traqueostomia = Sim	interface_compativel + Categoria_eq	IF interface_compativel = "Cânula nasal" OR interface_compativel = "Cânula nasal e Máscara" OR Categoria_eq = "Oxigénio Gasoso"	Excluir equipamento	Norma BTS: Traqueostomia exige humidificação. Botijas de gás fornecem oxigénio seco e equipamentos restritos a máscaras faciais/nasais não permitem acoplamento ao estoma.	POC_cp não sobrevive se a interface não permitir copo humidificador/adaptador.
R03	Hard	Exclusão	Necessita O2 no sono = Sim	Categoria_eq	IF Categoria_eq = "POC_p" OR Categoria_eq = "POC_cp" OR Categoria_eq = "LOX_port"	Excluir como fonte principal noturna	Norma BTS e Limitações Mecânicas: Equipamentos portáteis (pulsados, mistos e LOX portátil) não possuem autonomia e/ou resistência de compressor para garantir fluxo seguro e ininterrupto durante o sono. Situações de exceção exigem avaliação médica individual fora da recomendação automática.	**POC_cp excluído liminarmente de ser a fonte noturna (proteção do compressor).**
R04	Hard	Exclusão	Débito prescrito contínuo	debito_max_cont_Lmin	IF debito_prescrito > debito_max_cont_Lmin	Excluir equipamento	Débito máximo técnico insuficiente.	POC_cp sobrevive se débito contínuo máximo ≥ débito prescrito.
R05	Hard	Exclusão	Objetivo inclui deambulação	capacidade_portatilidade	IF capacidade_portatilidade = 0	Excluir para componente de deambulação	Equipamento não portátil não responde ao objetivo funcional.	POC_cp frequentemente sobrevive como portátil se autonomia/peso aceitáveis.
R06	Hard	Exclusão	Uso 24h = Sim	Adeq_uso_continuado_24h	IF Adeq_uso_continuado_24h = 0	Excluir como fonte principal	Equipamento não adequado a utilização contínua/prolongada.	POC_cp pode ser complemento, não fonte principal 24h, salvo validação específica.
R07	Hard	Exclusão	Viagem aérea = Sim	Aprovado_voo	IF Aprovado_voo = 0	Excluir para voo	Transporte aéreo exige certificação/aprovação.	POC_cp só sobrevive se aprovado para voo.
R08	Hard	Exclusão	Falha prévia de pulsado = Sim OR Correção na PM6M atual = Não	Categoria_eq	Condicao_Logica: IF (falha_pulsado_previa = "Sim" OR correcao_PM6M_no_setting_maximo = "Não") AND Categoria_eq = "POC_p"	Excluir POC apenas pulsado	Falha documentada do modo pulsado anula eficácia terapêutica.	Não excluir POC_cp automaticamente: avaliar modo contínuo.
R09	Hard	Bloqueio de recomendação	Hipoxemia noturna isolada sem indicação validada	modalidade_cenario	IF Grupo = G	Bloqueio Intencional: Requer avaliação especializada	Sem consenso/evidência suficiente para recomendação automática.	Não aplicar recomendação de POC_cp; encaminhar para avaliação especializada.
R10	Hard	Bloqueio de recomendação	Dados obrigatórios em falta	inputs_obrigatorios	IF input crítico em falta	Bloqueio Intencional: Informação clínica insuficiente	Evita recomendação sem informação mínima.	Não aplicável.
R11	Hard	Exclusão	O2 de deambulação + necessidade de fluxo contínuo	Categoria_eq	IF precisa_fluxo_continuo = "Sim" AND Categoria_eq = "POC_p"	Excluir POC apenas pulsado	Se foi documentada necessidade de fluxo contínuo, pulsado isolado é insuficiente.	POC_cp sobrevive se débito contínuo suficiente.
R12	Hard	Exclusão	Alarmes frequentes de ausência de respiração documentados	Categoria_eq	IF alarmes_trigger = "Frequentes" AND Categoria_eq = "POC_p"	Excluir/Não preferir POC apenas pulsado	Falha de ativação da válvula pode anular entrega de O2.	POC_cp sobrevive por permitir modo contínuo.
R13	Hard	Bloqueio de recomendação	Débito prescrito	N/A	IF debito_prescrito > 15	Bloquear algoritmo (Mostrar msg: Necessidade acima da capacidade domiciliária. Ponderar encaminhamento para Oxigenoterapia Nasal de Alto Fluxo (ONAF).	O limite máximo técnico dos equipamentos domiciliários atual é 15 L/min. Prescrições superiores não são exequíveis em ambulatório padrão, requerendo equipamentos específicos de Oxigenoterapia Nasal de Alto Fluxo (ONAF).	Não aplicável.
R14	Hard	Bloqueio de recomendação	Especialidade + Tipo de Prescrição + Contexto	N/A	IF Especialidade = MGF AND Tipo_Prescrição = Inicial AND Contexto IN (OLD, Deambulação, Adjuvante)	Bloquear algoritmo (Desativar as opções no menu e mostrar mensagem de Referenciação Hospitalar)	Norma DGS 018/2011: A prescrição inicial de oxigenoterapia domiciliária fica restrita a serviços especializados, exceto a oxigenoterapia paliativa e a de curta duração. Aos CSP reservam-se estas duas e as prescrições de continuidade.	Não aplicável. O bloqueio ocorre antes da seleção de equipamentos.
R15	Hard	Fallback / Tratamento Erro	Fumador + Alto Débito	N/A	IF lista_resultados = VAZIA AND Tabagismo = Sim	Emitir Output de Exceção: "Sem fonte portátil segura e compatível. O risco de incêndio (fumador ativo) impede o uso de Oxigénio Líquido/Gasoso, e a limitação técnica impede o uso de POC. Priorizar cessação tabágica e avaliação em consulta especializada."	Prevenção de erro silencioso ("dead end") quando as necessidades excedem os portáteis e o tabagismo corta as opções de alta capacidade.	Não aplicável.
R16	Hard	Exclusão	Débito ≤ 4 L/min + Sem Deambulação Regular	Categoria_eq	IF debito_prescrito <= 4 AND Deambulacao IN ("Não", "Pontual") AND (Categoria_eq = "LOX Base" OR Categoria_eq = "LOX Portátil")	Excluir Oxigénio Líquido	Norma DGS: O concentrador é a 1ª escolha até 4 L/min. LOX é exceção só justificável se o concentrador falhar a correção da SpO2, o que não se aplica numa prescrição inicial de baixo fluxo sem mobilidade.	Não aplicável.
R17	Hard	Exclusão Logística	Deambulação = Regular	Categoria_eq	IF Deambulacao = "Regular" AND Categoria_eq = "Oxigénio Gasoso"	Excluir Cilindros para deambulação	Caderno de Encargos CRD / Guias Práticos: Os cilindros pequenos estão limitados a um fornecimento máximo de 2/mês e o seu peso/autonomia desaconselham o uso frequente. Não devem ser recomendados como fonte de deambulação regular.	Não aplicável.
R18	Hard	Fallback / Tratamento Erro	VNI de Transporte = Sim AND Débito > 3 L/min	compati_tecnica_VNI / debito_max_cont_Lmin	IF VNI_Transporte = "Sim" AND debito_esforco > 3 AND (lista_resultados = VAZIA)	Aviso de Inexequibilidade Técnica: "Não existem portáteis compatíveis com VNI para débitos contínuos >3 L/min. Ponderar O2 autónomo (cânula separada) ou revisão clínica do débito."	Prevenção de erro silencioso ("dead-end"). O único POC VNI-compatível (Eclipse 5) satura aos 3 L/min contínuos. Evita prescrições impossíveis de instalar.	Mostra o limite exato do POC_cp mais potente do mercado.
R19	Exclusão Absoluta	Contexto = OLD 16h ou OLD 24h	Categoria_eq	IF Contexto IN ("OLD 16h", "OLD 24h") AND Categoria_eq = "Oxigénio Gasoso" -> THEN Excluir	Excluir como fonte principal domiciliária	Norma DGS 018/2011: O concentrador convencional é a fonte indicada para doentes em OLD (>15h/dia). Os cilindros de gás são estritamente fontes de recurso (emergência/backup) ou para deambulação pontual.		
R28	Exceção Clínica (Override)	Contexto = Curta Duração AND Reabilitação Ativa = Sim	Categoria_eq	IF Contexto = "Curta Duração" AND Reabilitacao_Ativa = "Sim" -> THEN Permitir POC (Override da regra de contenção de portáteis na curta duração)	Via Verde (Exceção): Desbloqueia a recomendação de portáteis (POC) na curta duração mediante justificação clínica.	Doentes em reabilitação ativa pós-alta beneficiam de portabilidade para recuperação funcional, justificando a exceção à regra de soluções temporárias simples.		
R29	Exceção Ética (Override)	Contexto = Paliativo AND Saída Pontual Conforto = Sim	Categoria_eq	IF Contexto = "Paliativo" AND Saida_Pontual_Conforto = "Sim" -> THEN Permitir POC_p / Cilindro Leve (Override do bloqueio logístico terminal)	Via Verde (Conforto): Permite a recomendação de portátil leve a doente terminal/acamado para saídas excecionais.	O conforto e a dignidade do doente terminal em saídas pontuais superam o fardo da complexidade técnica. O dispositivo serve a autonomia e a dignidade.		
R30	Exclusão	Contexto = Paliativo	Categoria_eq	IF Contexto = "Paliativo" AND Categoria_eq IN ("LOX_base", "LOX_port", "POC_p", "POC_cp")	Excluir por complexidade logística	Filtro de Humanização Paliativa: exclui equipamentos de alta complexidade técnica (LOX criogénico e POC a baterias) para proteger a família e o cuidador do fardo logístico no fim de vida.	Excluído por defeito para proteger o cuidador, salvo override da R27 (saídas pontuais de conforto).	

Table 12- Clinical preferences rules

ID_Preferencia	Cenario_ou_Condicao	Preferencia_Clinica	Racional	Efeito_no_Ranking	Impacto_POC_cp
P00	Red Flags de Segurança vs. Conveniência	Segurança sobrepõe-se a conforto (Arquitetura de Categorias)	Nenhuma vantagem logística ou de conforto pode compensar uma penalização da etapa de Red Flags.	Equipamentos com Red Flags descem obrigatoriamente para a categoria "Alternativas menos adequadas" (ou são excluídos), não podendo ser a Recomendação Principal.	Garante que um POC_cp ou LOX não vence no output se comprometer a segurança básica.
P01	OLD + deambulação regular	LOX preferencial	IF Contexto IN ("OLD 16h", "OLD 24h") AND Deambulacao = "Regular" -> THEN O Sistema LOX Integral assume a 1ª Linha	O LOX é a solução mais custo-efetiva para o SNS na deambulação regular prolongada. Esta preferência económica SOBREPÕE-SE expressamente à norma geral da DGS (que dita o concentrador como 1ª linha apenas no repouso).	Concentrador Fixo + Portátil passa para 2ª Linha (Alternativa), sugerida apenas se houver incapacidade de manuseamento do LOX.
P02	O_2 Deambulação + Débito Contínuo > 3 L/min no esforço	LOX/alto débito preferencial	Débito elevado reduz adequação prática dos POC, sobretudo pulsados.	Priorizar LOX; penalizar POC insuficientes.	POC_cp só se contínuo suficiente e validado.
P03	VNI + O2	Fluxo contínuo preferencial	Integração em circuito VNI exige fluxo contínuo estável e compatibilidade técnica.	Priorizar fixo/LOX compatível.	POC_cp apenas se tecnicamente compatível em contínuo.
P04	Sono	Fluxo contínuo preferencial	Sono não deve depender de trigger pulsado como fonte primária.	Excluir/penalizar pulsado como fonte noturna.	POC_cp pode sobreviver em modo contínuo.
P05	POC pulsado falhou previamente	Não recomendar pulse-only	Falha de correção ou de trigger é forte argumento contra pulsado isolado.	Excluir POC_p; priorizar contínuo/LOX.	POC_cp passa a opção relevante se contínuo funciona.
P06	Curta duração	Solução simples e temporária	Objetivo é resposta transitória, com reavaliação e baixa complexidade.	Priorizar fixo/botija/portátil simples conforme necessidade.	POC_cp apenas se deambulação temporária e necessidade variável.
P07	Paliativo	Priorizar conforto e baixa complexidade	Objetivo é alívio sintomático, não otimização técnica complexa.	Priorizar simplicidade, instalação rápida e conforto.	POC_cp se melhora mobilidade/dispneia sem complexidade excessiva.
P08	Viagem aérea	Equipamentos certificados para voo	Requisito regulatório/logístico.	Priorizar POC certificados e autonomia suficiente.	POC_cp se certificado para voo e autonomia adequada.
P09	Deambulação + risco moderado de falha de trigger	Portátil misto preferencial	Permite alternar pulsado/contínuo conforme sintomas, esforço ou trigger.	Bonificar POC_cp face a POC_p.	POC_cp torna-se recomendação principal/alternativa forte.
P10	Necessidades variáveis ao longo do dia	Portátil misto preferencial	Doente pode usar pulsado para poupar bateria e contínuo em maior dispneia/repouso pós-esforço.	Bonificar POC_cp.	Critério central de valorização do POC_cp.
P11	Alarmes frequentes no pulsado	Fluxo contínuo ou POC_cp	Alarmes de ausência de respiração sugerem falha de ativação.	Despromover POC_p; bonificar POC_cp/contínuo.	POC_cp recomendado se contínuo suficiente.
P12	Agravamento de dispneia com pulsado	Fluxo contínuo ou POC_cp	Sintomas podem refletir bólus insuficiente.	Despromover POC_p; considerar POC_cp ou LOX.	POC_cp como terceira via entre pulse-only e LOX.
P13	Débito Prescrito = 5 L/min	Priorizar Concentradores de Alto Débito (ex: 10 L/min)	Margem de Segurança: Evitar operar concentradores standard de 5L no seu limite mecânico absoluto para prevenir quebras na pureza do oxigénio (derating).	Bonificar equipamentos com debito_max_cont_Lmin > 5 (ex: 10 L/min). Despromover equipamentos limitados a 5 L/min para Alternativas.	Não aplicável. Em débitos de 5 L/min, todos os POC_cp já foram previamente excluídos pela regra R04 (limite máximo de 3 L/min contínuos).
P14	Equipamento de deambulação recomendado = LOX Portátil	O Sistema LOX Base assume a função de fonte fixa domiciliária, anulando o Concentrador Fixo.	Redundância: Evitar duplicação de fontes fixas no domicílio (violação do Caderno de Encargos do SNS).	Exclui o Concentrador Fixo do Output Final se o LOX for a recomendação principal para deambulação.	Não aplicável.
P15	Sobrevivência simultânea do Sistema Elétrico Combinado (Fixo + POC) e do Sistema LOX Integrado.	Agrupar os resultados em blocos estritamente mutuamente exclusivos (Opção A ou Opção B).	Segurança de Prescrição: Evitar que o médico selecione cruzadamente componentes de vias incompatíveis, gerando dupla prescrição.	O output visual separa as vias de forma estanque, indicando que não são cumuláveis.	Não aplicável.
P16	Recomendação combinada com níveis de confiança distintos (ex: Fonte Fixa Definitiva + Fonte Portátil Provisória)	Separar visualmente de forma inequívoca o estatuto de cada componente.	Design de Segurança (HCI): Prevenir que o prescritor confunda o estatuto da fonte validada com a fonte pendente de titulação.	O UI apresenta a prescrição em dois blocos de status com cores/ícones diferentes (ex: Confirmado vs. Pendente).	Não aplicável.
P17	Prescrição múltipla com diferentes requisitos de validação pendentes (ex: A12 na via ambulatória + A29 na via ventilatória).	Explicitar textualmente e de forma distinta, junto a cada componente, qual a validação clínica que falta realizar.	Design de Segurança (HCI): Prevenir "cegueira aos alertas". O prescritor tem de distinguir inequivocamente que a máquina da rua requer "Titulação por PM6M" e a máquina de casa requer "Oximetria com máscara de VNI acoplada".	Inclusão de blocos de Call-to-Action (Ação Requerida) com textos específicos debaixo de cada equipamento.	Não aplicável.

Table 13- Alerts

Part 1

ID_Alerta	Categoria	Condicao	Mensagem_Output	Aplicabilidade	Referencia_para_Tese
A01	Segurança	Fumador ativo	Alerta de segurança: reforçar risco de incêndio/queimadura e educação do doente.	Red Flag de Segurança (Camada 2): Penalização máxima/Bloqueio para Oxigénio Líquido (LOX) e Cilindros Gasosos devido a risco extremo de deflagração. Restringir recomendação a concentradores elétricos.	Alerta transversal de segurança.
A02	POC pulsado	POC pulsado listado ou recomendado	Os settings dos concentradores pulsados não equivalem a L/min contínuos. Validar a adequação por PM6M com o equipamento selecionado.	Sempre que POC_p ou modo pulsado de POC_cp for considerado	ATS/BTS: avaliação funcional/titulação em esforço.
A03	Validação funcional	O2 de deambulação	Recomenda-se PM6M com o equipamento selecionado para confirmar correção da dessaturação e adequação do débito.	Todos os cenários de deambulação	BTS ambulatory oxygen assessment; ATS home oxygen guideline.
A04	Alto débito	Débito >4 L/min em deambulação	Débito elevado: considerar preferencialmente oxigénio líquido ou solução de fluxo contínuo/alto débito.	Deambulação e OLD + deambulação	ATS sugere LOX em doentes móveis com fluxo contínuo elevado.
A05	Red flag pulsado	DPI/fibrose pulmonar	Doença intersticial/fibrótica pode associar-se a maior exigência de O2 no esforço; validar cuidadosamente sistemas pulsados.	Deambulação	Plausibilidade fisiológica + guideline ATS ILD.
A06	Red flag pulsado	Hipertensão pulmonar	Hipertensão pulmonar pode associar-se a dessaturação marcada no esforço; confirmar eficácia do sistema portátil.	Deambulação	Plausibilidade clínica.
A07	Red flag pulsado	Taquipneia importante	Taquipneia pode comprometer a eficácia de sistemas por bólus/trigger; considerar modo contínuo se sintomas/alarmes.	Deambulação	Regra técnica/consenso; validar por PM6M.
A08	Red flag pulsado	Respiração oral predominante	Respiração oral ou superficial pode impedir a ativação adequada da válvula do pulsado.	Deambulação	Insights CRD + mecanismo de trigger.
A09	Logística	Escadas/barreiras arquitetónicas	Avaliar peso, trolley/mochila, autonomia e risco de quedas/transporte.	Portáteis/LOX	Soft rule futura.
A10	Funcional	Fragilidade física	Fragilidade física: ponderar peso do equipamento, complexidade e necessidade de cuidador.	Portáteis/LOX	Soft rule futura.
A11	Cuidador	Sem cuidador	Sem cuidador: penalizar equipamentos com recarga/manuseamento complexo.	LOX/portáteis complexos	Soft rule futura.
A12	Dados incompletos	PM6M não realizada	Recomendação provisória: validar por PM6M antes de confirmar equipamento de deambulação.	Deambulação inicial	Alerta de prescrição inicial.
A13	Sintomas com pulsado	Maior dispneia/cansaço ao usar portátil pulsado em repouso ou após esforço	Aumento de dispneia/cansaço ao transitar de fixo/contínuo para portátil pulsado pode indicar ineficácia do bólus. Considerar fluxo contínuo ou portátil misto.	Follow-up e output quando POC_p/POC_cp em modo pulsado	Insight de entrevista CRD; regra clínica de segurança.
A14	Alarmes de trigger	Alarmes frequentes de 'ausência de respiração'	Alarmes frequentes de ausência de respiração sugerem falha na ativação da válvula. Orientar o doente a contactar a equipa; considerar modo contínuo/POC_cp.	Follow-up e output quando POC_p/POC_cp em modo pulsado	Insight de entrevista CRD; regra técnica de trigger.
A15	Portátil misto	Necessidades variáveis ou risco moderado de falha do pulsado	Portátil misto pode permitir pulsado para autonomia e fluxo contínuo quando há dispneia, falha de trigger ou maior necessidade de débito.	Deambulação com necessidades variáveis	Integração prática do POC_cp no algoritmo.
A16	Viagem Aérea (Logística)	Viagem aérea programada	Atenção: O doente deve transportar baterias para cobrir, no mínimo, 150% do tempo total de jornada (porta-a-porta, incluindo escalas e esperas), e não apenas o tempo de voo. O cálculo de autonomia da bateria deve utilizar o débito de voo (titulado), e não o débito de repouso em terra.	Cenário de Viagem Aérea	Manuais dos POC (regra dos 150% FAA) + Acoplamento logístico.
A17	Viagem Aérea (Fisiológico)	Viagem aérea programada	Risco de hipóxia de altitude (pressão de cabina até 8000 pés). É obrigatória a realização de Teste de Simulação de Hipóxia (HCT) pré-voo para titular o débito exato necessário em altitude e recalcular as autonomias.	Cenário de Viagem Aérea	BTS recommendations for air travel.
A18	Viagem Aérea (Burocrático)	Viagem aérea programada	É obrigatório o preenchimento de Declaração Médica para a companhia aérea atestando a necessidade e a certificação do dispositivo (FAA).	Cenário de Viagem Aérea	Regras da aviação civil (FAA).
A19	Técnico / Segurança	Débito Prescrito = debito_max_cont_Lmin (ex: 5 L/min)	Alerta de Margem de Segurança: O débito prescrito atinge o limite máximo contínuo deste equipamento, o que a longo prazo pode comprometer a pureza do oxigénio entregue. Recomenda-se ponderar um Concentrador de Alto Débito (ex: 10 L/min).	Sempre que um Concentrador Fixo standard for a opção recomendada e for forçado a operar no seu teto máximo absoluto.	Manuais técnicos dos concentradores (ex: manual do Drive DeVilbiss 525) que alertam para a possível queda da concentração de oxigénio no débito limite; princípio de derating em engenharia clínica.
A20	Logística / Segurança	Categoria_eq = "LOX Portátil" AND Débito > 2 L/min contínuos	Atenção: A autonomia do deambulador de LOX diminui drasticamente em altos débitos face ao tabelado nominal. Recalcular a autonomia esperada para o débito prescrito.	Sempre que o LOX Portátil for a recomendação para débitos > 2 L/min.	Manuais técnicos dos deambuladores LOX (ex: Companion 1000) detalhando a queda não-linear de autonomia.
A21	Segurança / Logística	Recomendação = Concentrador Fixo AND VNI/CPAP = Não	Plano de Contingência (Backup): O doente fica dependente de uma fonte elétrica. É obrigatório associar um Cilindro de Oxigénio Gasoso de emergência para falhas de energia. [Exceções de Segurança Absoluta: 1) Traqueostomia: o cilindro tem de incluir copo humidificador acoplado; 2) Tabagismo Ativo: é estritamente proibido prescrever cilindro gasoso; a contingência para falha elétrica deve ser assegurada por baterias/UPS ou suspensão da recomendação até cessação tabágica].	Sempre que um Concentrador Fixo for selecionado como fonte domiciliária principal.	BTS Guidelines for home oxygen (necessidade de back-up) e Avisos de Segurança dos Manuais.

(Continued on the next page)

ID_Alerta	Categoria	Condicao	Mensagem_Output	Aplicabilidade	Referencia_para_Tese
A22	Logística / Usabilidade	Recomendação = Concentrador Fixo + POC + Cilindro de Backup	Atenção à Carga Logística: A solução elétrica combinada implica a gestão de 3 equipamentos distintos no domicílio. Validar com o doente/cuidador a capacidade de gestão técnica e o espaço físico disponível.	Sempre que a via combinada elétrica for a recomendada para um doente OLD 24h com deambulação.	Princípio clínico de Burden of Treatment (Carga do Tratamento): impacto do excesso de tecnologia no domicílio na adesão à terapêutica.
A23	Normativo / Burocrático	Recomendação = LOX Base AND Deambu	Exceção Normativa (DGS): O Oxigénio Líquido apenas pode ser selecionado como fonte de OLD domiciliária se for clinicamente documentado que o Concentrador Fixo não atinge saturações (SpO2) superiores a 90% neste débito.	Sempre que o LOX Base figurar como Alternativa face a um Concentrador Fixo num cenário de OLD SEM deambulação regular. (Se houver deambulação regular, a regra P01 de sustentabilidade do SNS prevalece e este alerta não é ativado).	Norma DGS nº 018/2011 (Critérios de escalonamento para LOX em OLD).
A24	Segurança / Logística	Recomendação = LOX Base E Uso 24h = Sim	Plano de Contingência (Abastecimento LOX): O doente está dependente de Oxigénio Líquido 24h/dia. Para precaver atrasos na entrega domiciliária ou o esgotamento rápido do reservatório devido ao alto débito, é obrigatório prever uma reserva de segurança (ex: 2ª reservatório Base ou cilindros gasosos de emergência de alta capacidade).	Sempre que o Sistema LOX for a recomendação principal para uso contínuo de 24 horas.	Logística de CRD; gestão de risco de falha de abastecimento e perdas por taxa de evaporação (boil-off) do oxigénio líquido.
A25	Clínica / Follow-up	Objetivo inclui deambulação AND OLD = Não	Nota de Follow-up: Sendo uma componente ambulatória exclusiva de esforço, programar reavaliação periódica. A progressão para dessaturação em repouso/noturna exigirá a transição para critérios de OLD e a revisão imperativa da adequação do equipamento.	Sempre que O_2 for prescrito para deambulação a doentes sem critérios de OLD.	Boas práticas de monitorização da progressão da hipoxemia na DPOC/DPI.
A26	Logística / Segurança	Categoria_eq = "POC_cp" AND Modo de Utilização = Contínuo	Atenção à Autonomia (Modo Contínuo): A autonomia da bateria dos concentradores portáteis mistos cai drasticamente (frequentemente para ≤ 1,5 horas) quando operam em fluxo contínuo face ao tabelado para o modo pulsado. Validar se a autonomia real no débito prescrito é compatível com o padrão e duração de deambulação do doente.	Sempre que um Concentrador Portátil Misto (POC_cp) for recomendado ou listado para uso em modo de fluxo contínuo.	Manuais técnicos de equipamentos POC mistos (ex: SimplyGo, Zen-O) e princípios de segurança na prescrição de deambulação regular.
A27	Segurança / Eficácia Clínica	Categoria_eq = "POC_cp" AND debito_max_cont_Lmin = débito prescrito	Margem de Segurança Nula (POC): O concentrador portátil misto recomendado atingirá o limite absoluto da sua capacidade mecânica contínua. Não existe folga terapêutica para eventual agravamento clínico no esforço. Ponderar fortemente a transição para Oxigénio Líquido (LOX) em caso de deambulação regular.	Sempre que um POC Misto operar no seu limite máximo nominal de fluxo contínuo.	Princípio de folga de prescrição e limitações mecânicas em alto rendimento.
A28	Logística / Informação	Recomendação inclui "LOX Base" AND Cenário = "Deambulação Isolada"	Nota Logística: A Unidade Base de Oxigénio Líquido é instalada no domicílio estritamente como reservatório de reabastecimento para a unidade portátil. O doente não possui indicação clínica para oxigenoterapia de repouso.	Sempre que o LOX for prescrito a um doente sem critérios de OLD.	Prevenção de perceção de sobreprescrição e clarificação do papel do equipamento estacionário no ambulatório isolado
A29	Segurança / Titulação	Contexto = Adjuvante VNI/CPAP	Validação de SpO2 no Circuito: A FiO2 (fração inspirada de oxigénio) efetiva no circuito não é linear e depende da pressão do ventilador e da fuga da máscara. É obrigatório validar a correção da hipoxemia (SpO2) com o ventilador a funcionar e o débito de O2 acoplado.	Sempre que for prescrito oxigénio acoplado a VNI ou CPAP.	Prática clínica de ventiloterapia domiciliar.
A30	Segurança / Logística	Contexto = Adjuvante VNI/CPAP AND Uso 24h = Não	Contingência Elétrica Múltipla: Em caso de falha de energia, o doente perde simultaneamente o concentrador de O2 e o suporte ventilatório (VNI/CPAP). O cilindro de reserva não substitui o ventilador. Garantir plano de emergência ajustado à dependência do doente.	Sempre que o O2 estiver associado a ventilador/CPAP domiciliário.	Gestão de risco de life-support domiciliário.
A31	Segurança de Vida (Crítico)	Contexto = Adjuvante VNI/CPAP AND Uso 24h = Sim	Risco Crítico em Suporte de Vida (VNI 24h): Numa falha elétrica, ocorre a perda simultânea do suporte ventilatório e da oxigenoterapia. Torna-se obrigatória a alocação de uma fonte de energia de emergência (ex: UPS ou bateria externa) para o ventilador (domiciliário e de transporte). Do ponto de vista clínico, sugere-se ponderar a prescrição excecional de Oxigénio Líquido (LOX) para garantir uma fonte de oxigénio eletricamente autónoma, mitigando assim o risco de falha partilhada do sistema.	Sempre que houver dependência total (24h) de VNI associada a O2.	Princípio de redundância em engenharia clínica de life-support domiciliário.
A32	Eficácia Clínica / Titulação	Recomendação inclui POC_p ou POC_cp (modo pulsado) AND Débito de Esforço = 3 L/min	Limiar de Eficácia do Modo Pulsado: A 3 L/min, o equipamento encontra-se no limiar superior de eficácia da tecnologia por bólus. A probabilidade de o volume entregue ser insuficiente para corrigir a dessaturação é elevada. Caso a PM6M falhe, prever a necessidade de escalada imediata para fluxo contínuo (POC misto contínuo ou Oxigénio Líquido).	Sempre que o débito estimado para um portátil pulsado for de 3 L/min.	Limitações fisiológicas do bólus pulsado a débitos moderados face à taquipneia.
A33	Validação Funcional / Titulação	Uso no sono = Sim AND Uso de VNI/CPAP = Não	Titulação Noturna Obrigatória: À semelhança da PM6M no esforço, a eficácia do débito de O2 prescrito para o sono deve ser validada através de oximetria/poligrafia noturna, para garantir a correção da dessaturação e despistar agravamentos.	Qualquer prescrição de oxigénio que inclua o período de sono sem ventilação.	Norma BTS: Necessidade de monitorização da adequação do débito noturno.
A34	Segurança Clínica (Crítico)	Objetivo Clínico = O2 Noturno Exclusivo	Risco de Hipoventilação/Hipercapnia: A hipoxemia noturna isolada é frequentemente secundária a hipoventilação (ex: Obesidade-Hipoventilação, Doença Neuromuscular, DPOC avançada). A administração isolada de O2 mascara e agrava a retenção de CO2. Confirmar ausência de hipercapnia por gasometria; se presente, a indicação é para VNI e não O2 isolado.	Sempre que o O2 for pedido em regime exclusivamente noturno.	Norma BTS: Contraindicação do O2 noturno isolado em SOH, apneia e doenças neuromusculares.
35	Segurança Clínica / Acessórios	Traqueostomia = Sim	Humidificação Ativa Obrigatória: A presença de traqueostomia exige a prescrição explícita de um sistema de humidificação (preferencialmente aquecida) acoplado à fonte principal de oxigénio, para prevenir o ressecamento da mucosa e a formação de rolhões de secreções.	Sempre que o doente for traqueostomizado.	Norma BTS: Doentes com traqueostomia exigem humidificação no circuito.
A36	Cuidados Paliativos	Contexto = Paliativa	Medidas Não-O2: A evidência demonstra que a dispneia terminal sem hipoxemia grave responde frequentemente melhor a opióides, fluxo de ar facial (ventoinha) e posicionamento do que à administração isolada de O2. Ponderar a otimização destas medidas de conforto.	Sempre que a Porta P for selecionada.	BTS Guidelines for Home Oxygen (Palliative Care).

10.6. Suite of 38 Clinical scenarios (blocks A-H)

Clinical_scenarios_general

- Clinical scenario_Blocks A
- Clinical scenario_Blocks B
- Clinical scenario_Blocks C
- Clinical scenario_Blocks D
- Clinical scenario_Blocks E
- Clinical scenario_Blocks F
- Clinical scenario_Blocks G
- Clinical scenario_Blocks H

10.7. Verification and audit reports: Python oracle, regression and stress tests

- Audit_reports _Bloks A
- Audit_reports Blocks B
- Audit_reports Blocks C
- Audit_reports Blocks D
- Audit_reports Blocks E
- Audit_reports Blocks F
- Audit_reports Blocks G
- Audit_reports Blocks H
- Audit_reports Other

10.8. Interface mockups (low-and medium fidelity: login -> PEM)

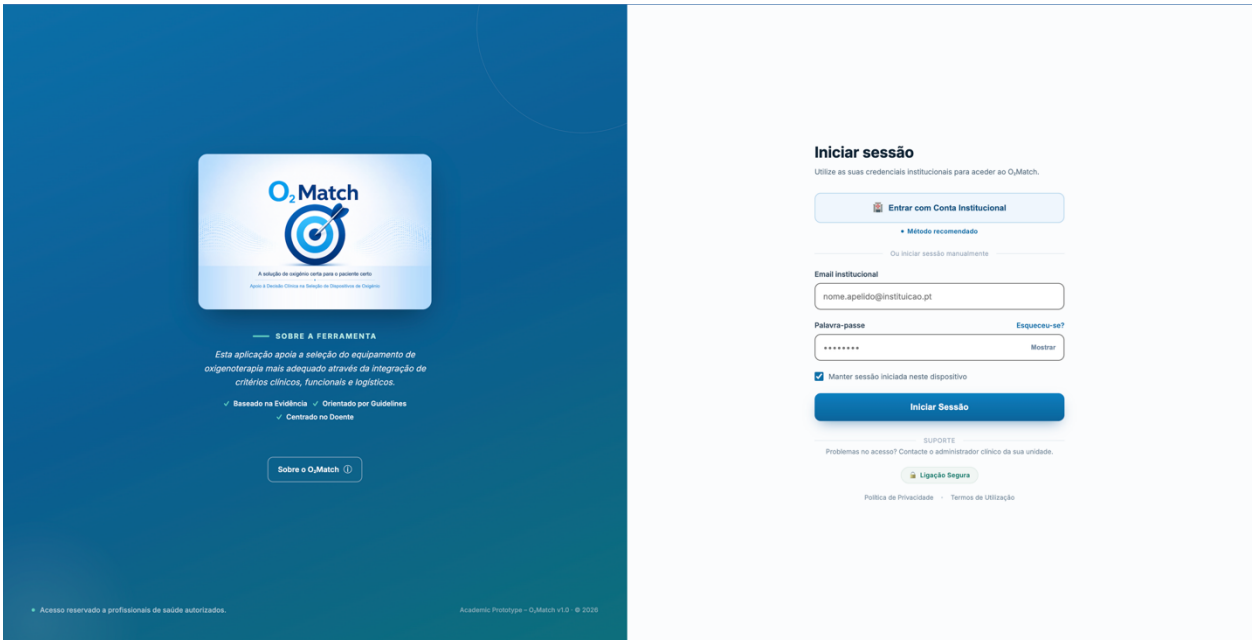


Figure 37- Login screen with institutional single sign-on, email/password fields, password recovery and an 'About O_2Match' panel.

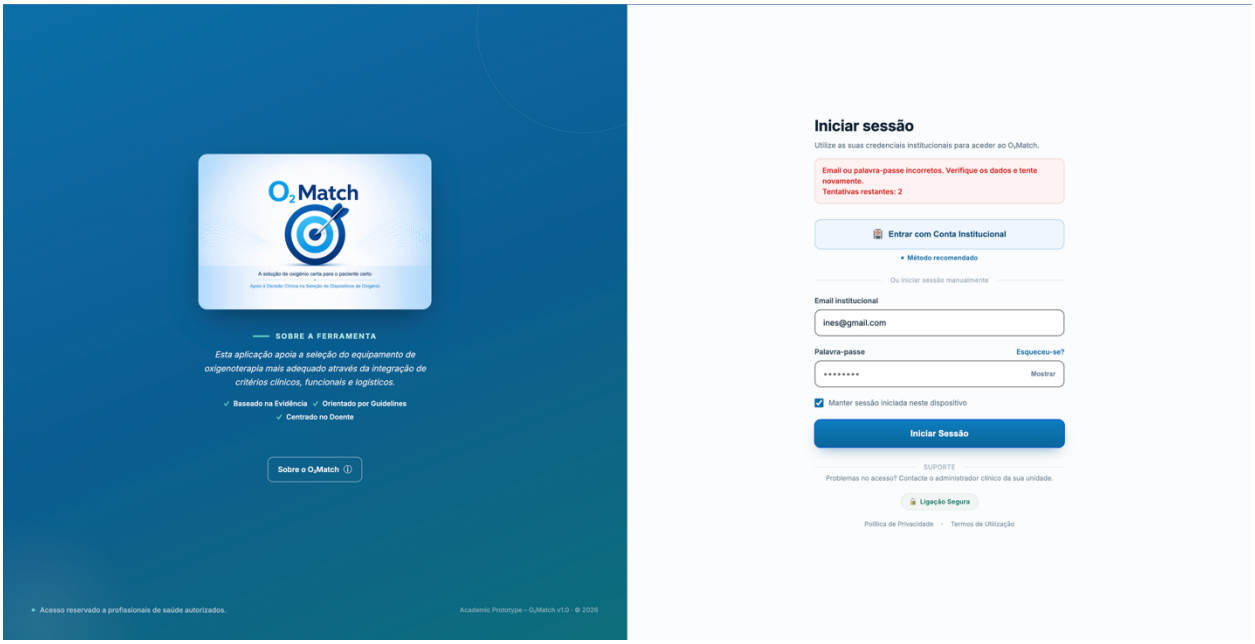


Figure 38- Login screen showing an incorrect-credentials error with a counter of the remaining attempts.

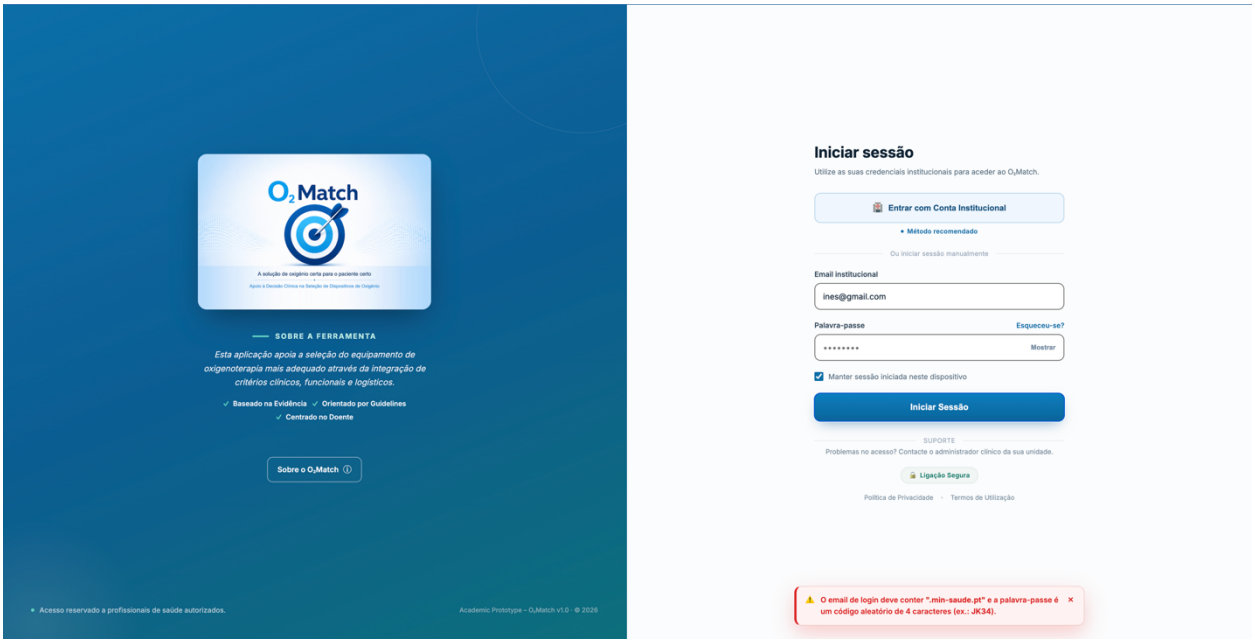


Figure 39- Login screen after the attempts are exhausted, showing the demo-version hint about the required email domain and access code.

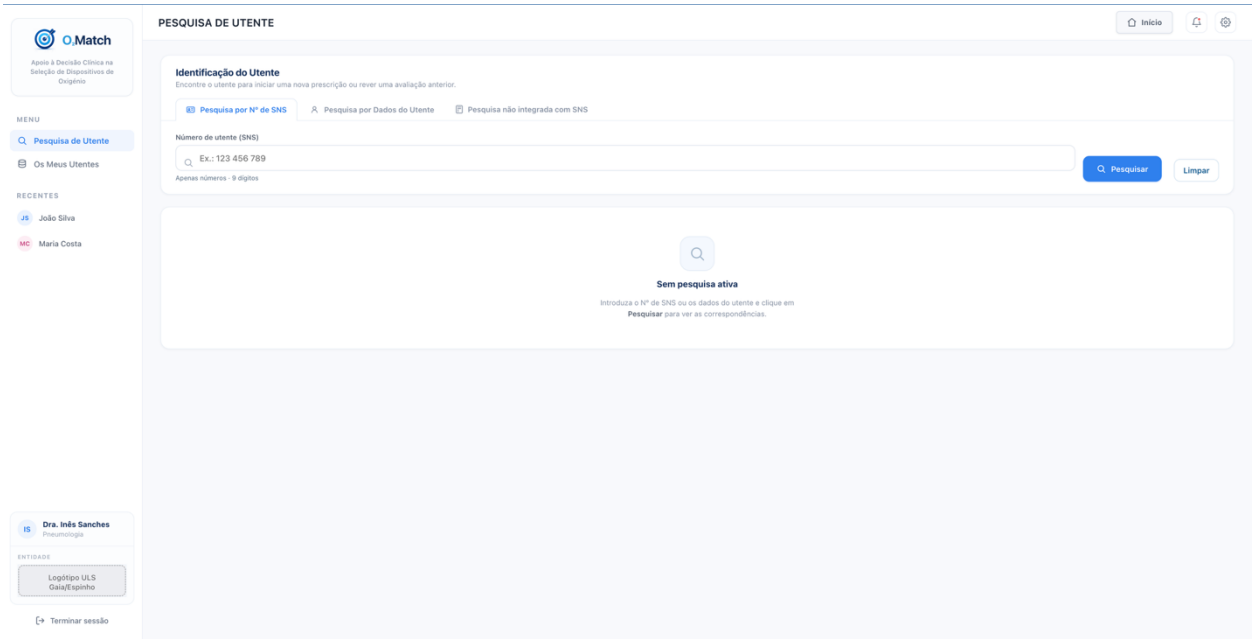


Figure 40- Patient search screen with the empty 'Search by SNS number' tab active (no active query).

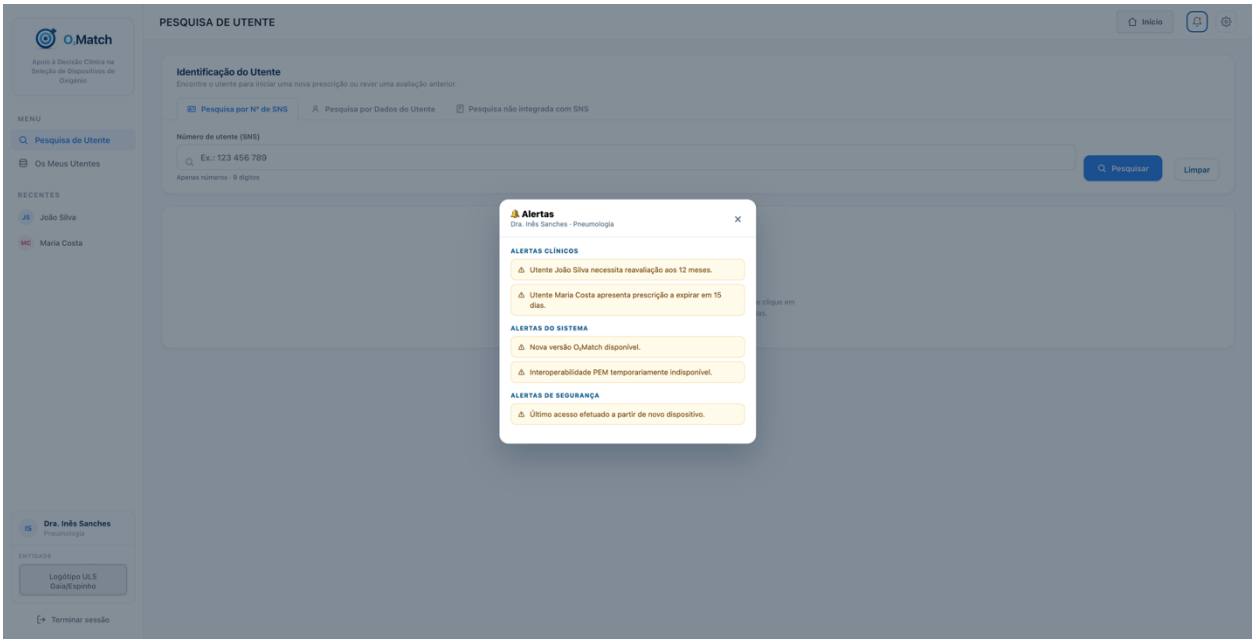


Figure 41- Patient search screen with the Alerts panel open (clinical, system and security notifications).

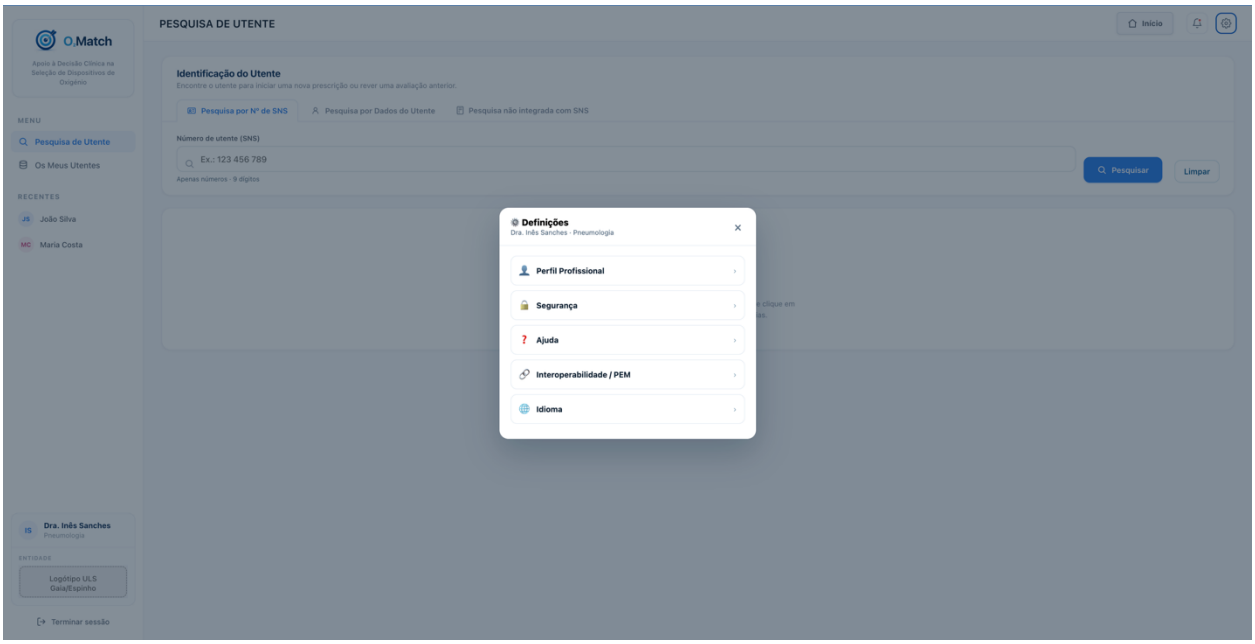


Figure 42- Configuration panels: professional profile, security, help, PEM interoperability and language selection.

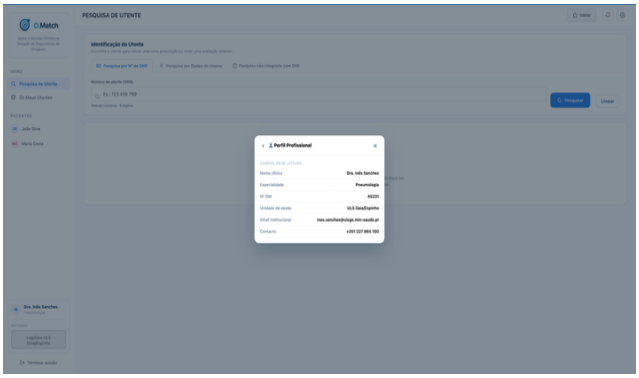


Figure 43- Settings — Professional Profile: clinician name, specialty, licence number, health unit and contacts.

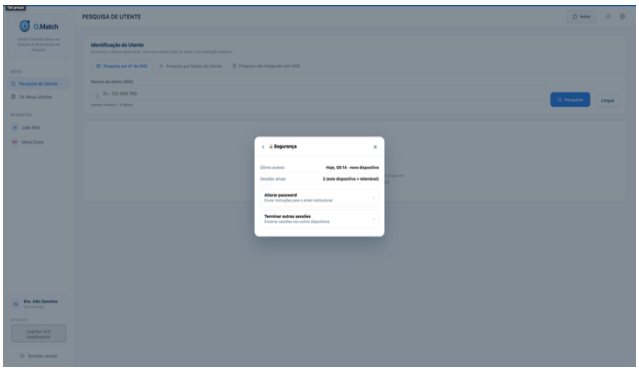


Figure 44- Settings — Security: last access, active sessions, change password and sign out of other sessions.

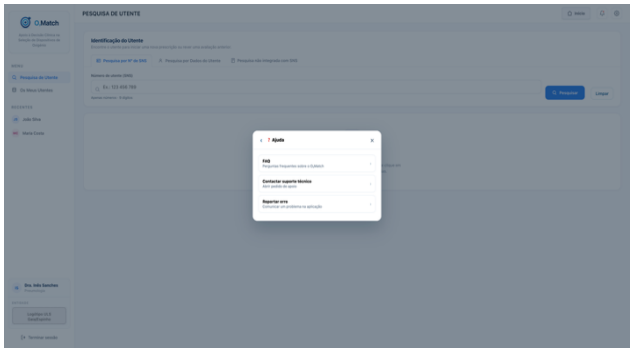


Figure 45- Settings — Help: FAQ, contact technical support and report an error.

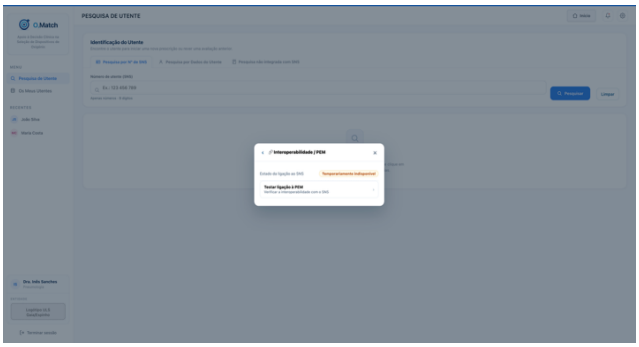


Figure 46- Settings — Interoperability/PEM: SNS connection status and a test-connection option.

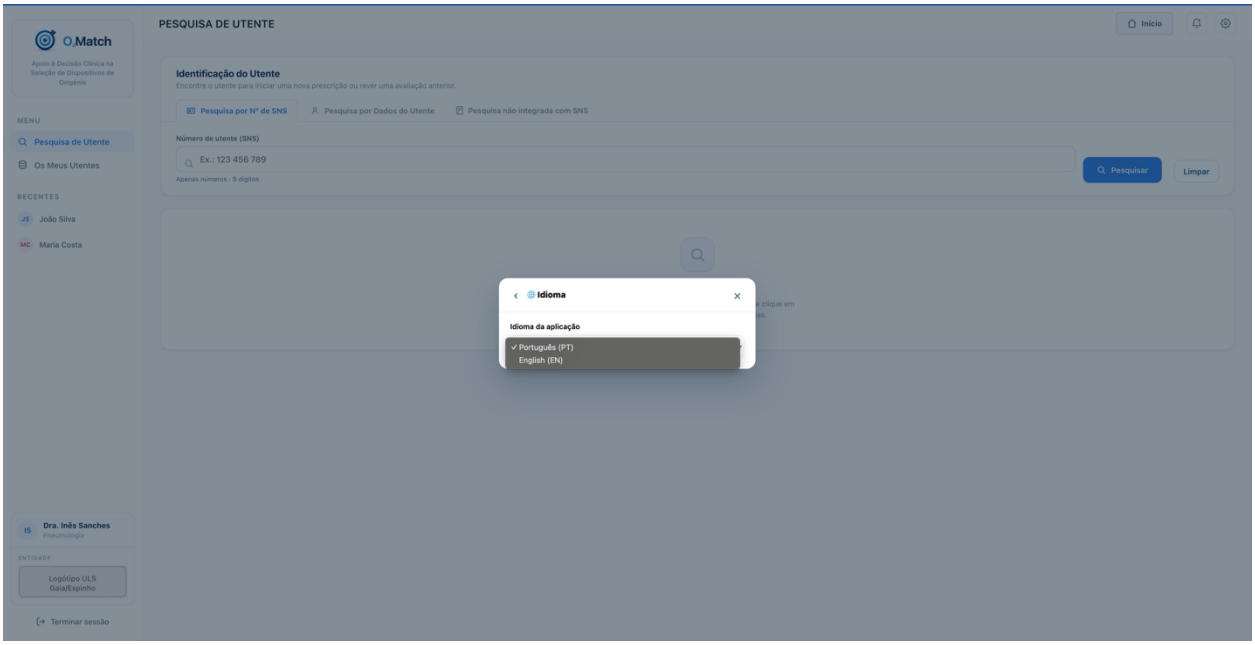


Figure 47- Settings — Language: Portuguese selected, English available

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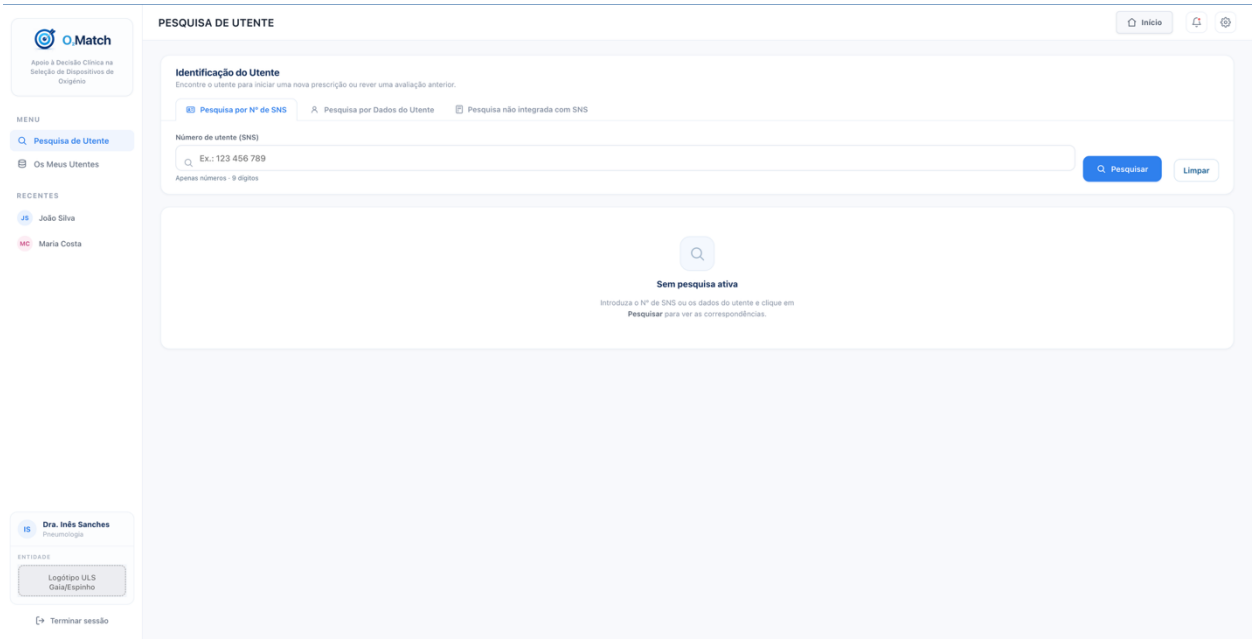


Figure 48- Patient search screen with the empty 'Search by SNS number' tab active (no active query).

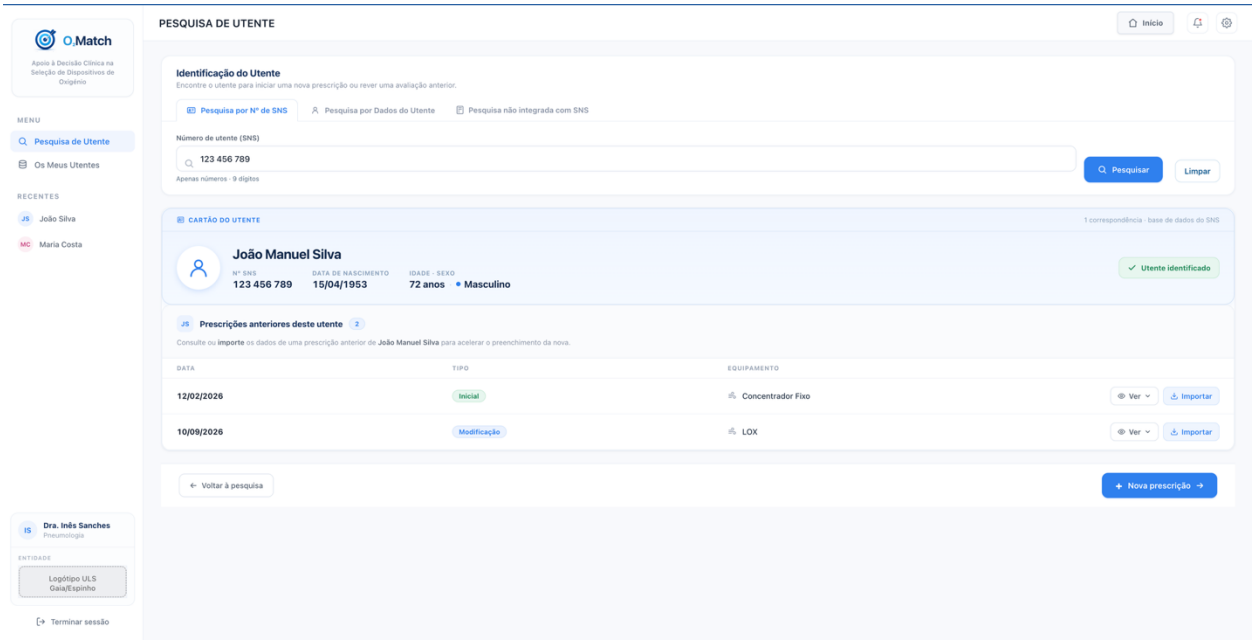


Figure 49- Patient search by SNS number returning a matched patient card with demographics and previous prescriptions.

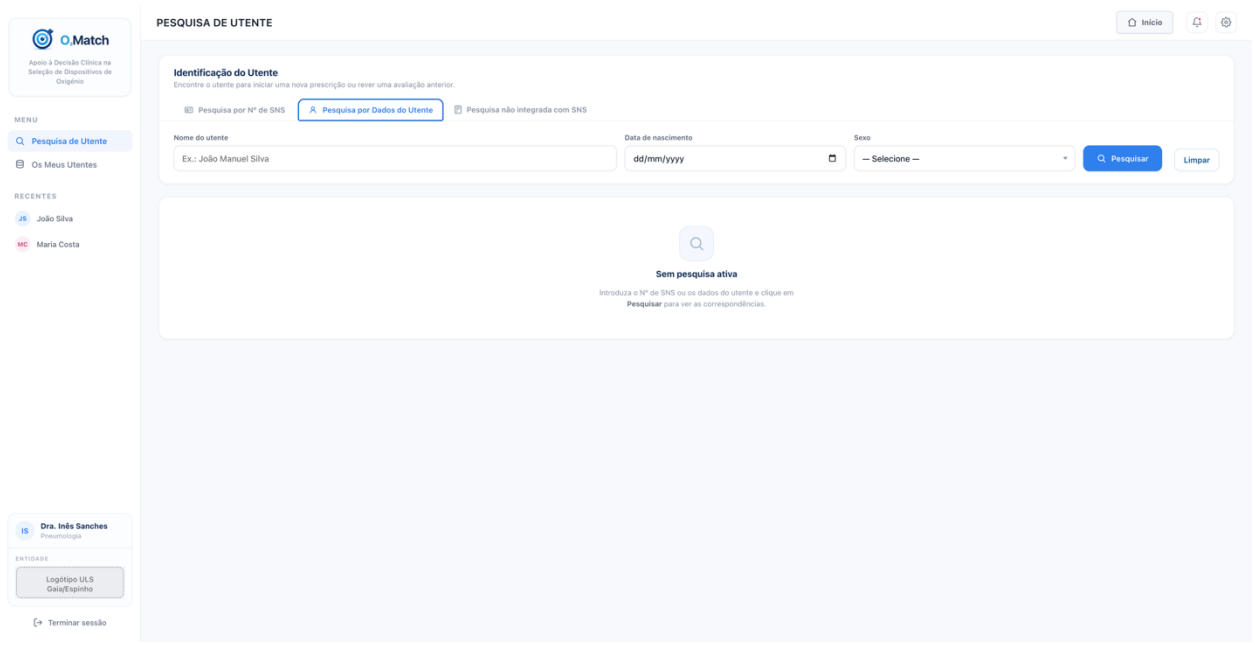


Figure 50- Patient search by patient data (name, date of birth, sex), with an empty 'no active search' state.

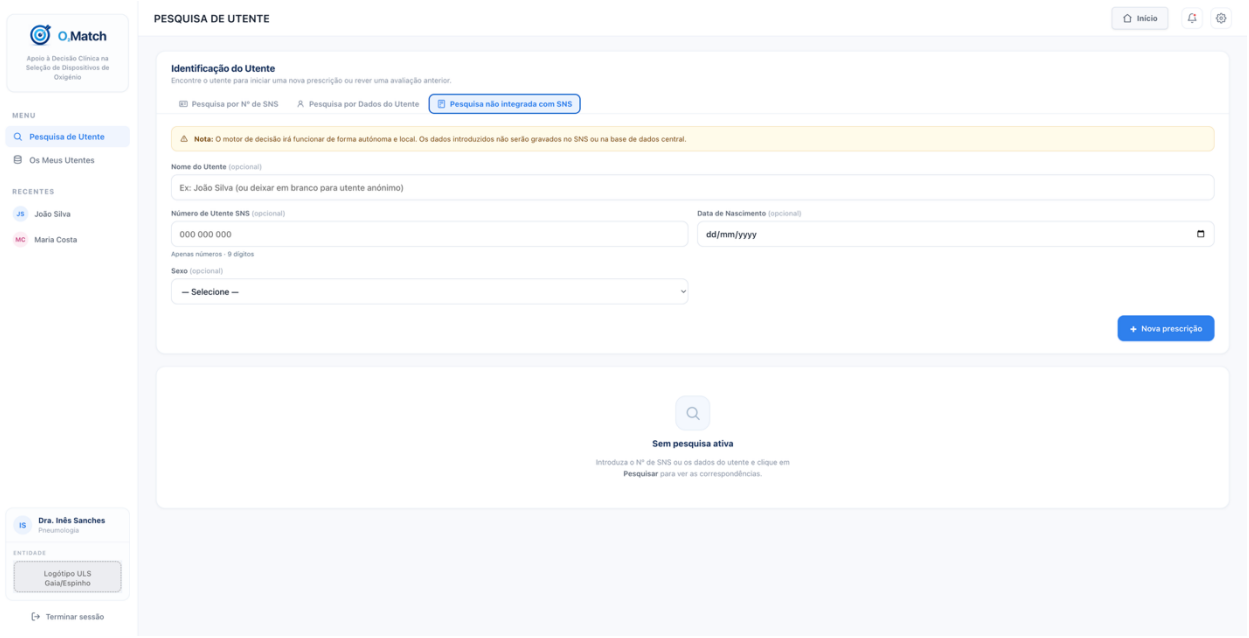


Figure 51- Patient search in non-integrated mode with optional name, SNS number, date of birth and sex fields, and an empty results panel.

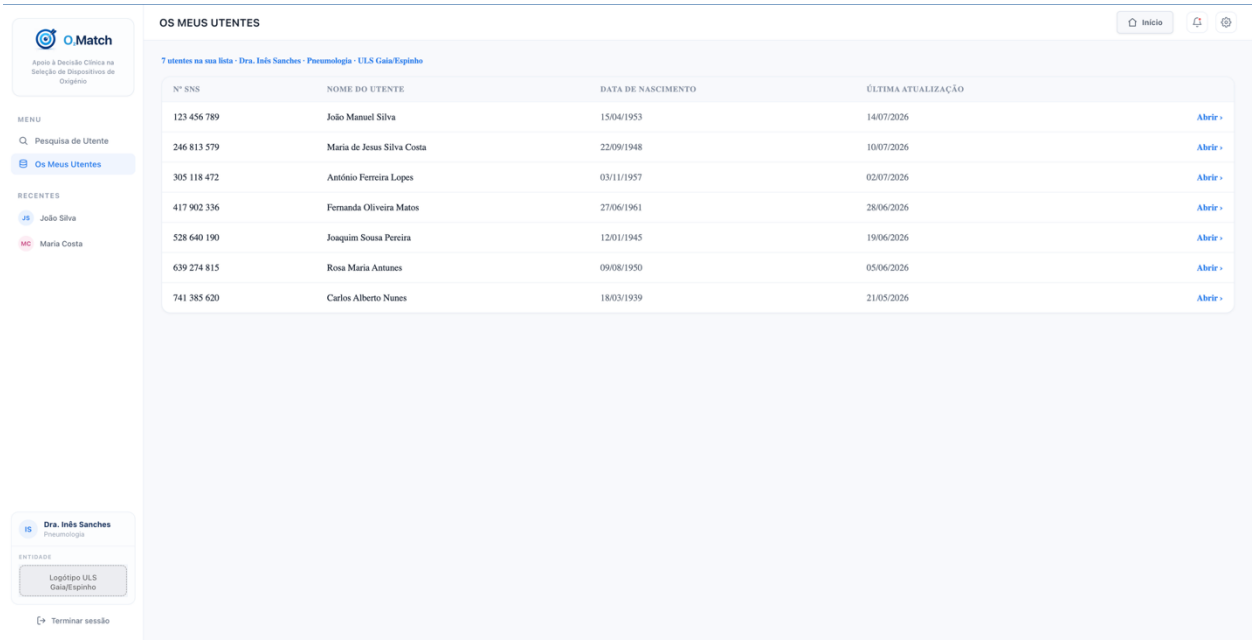


Figure 52- — 'My patients' screen listing the prescriber's patients with SNS number, name, date of birth and last update.

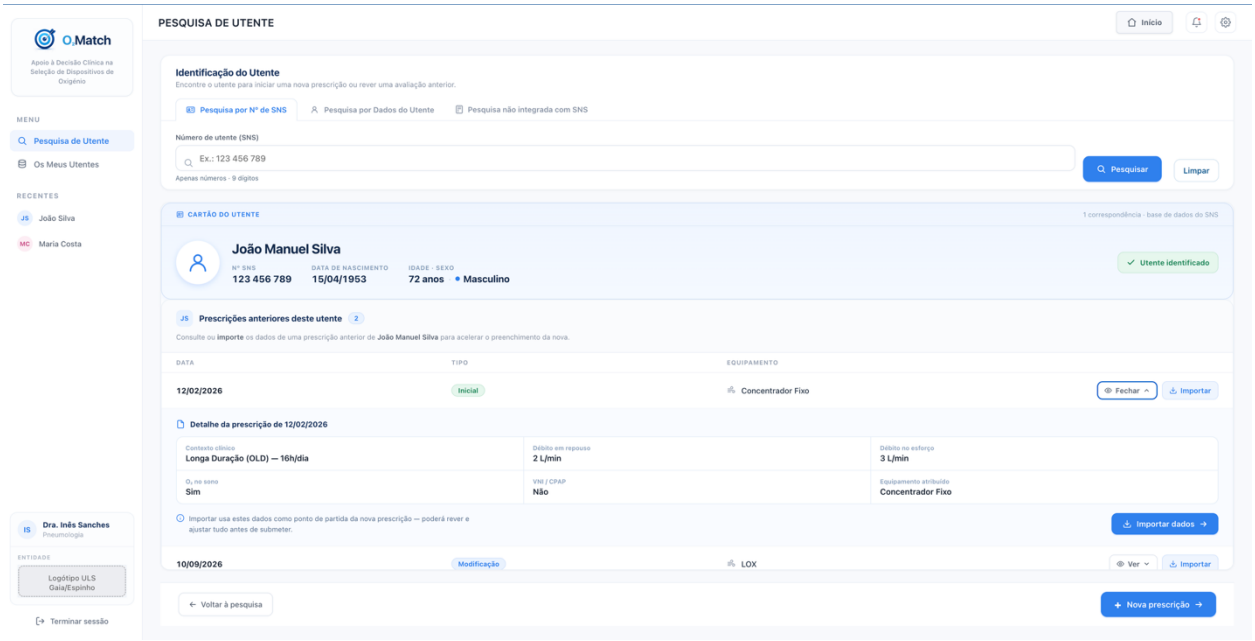


Figure 53 Patient search by SNS number returning a patient's identity card, with a previous prescription expanded and options to view or import.

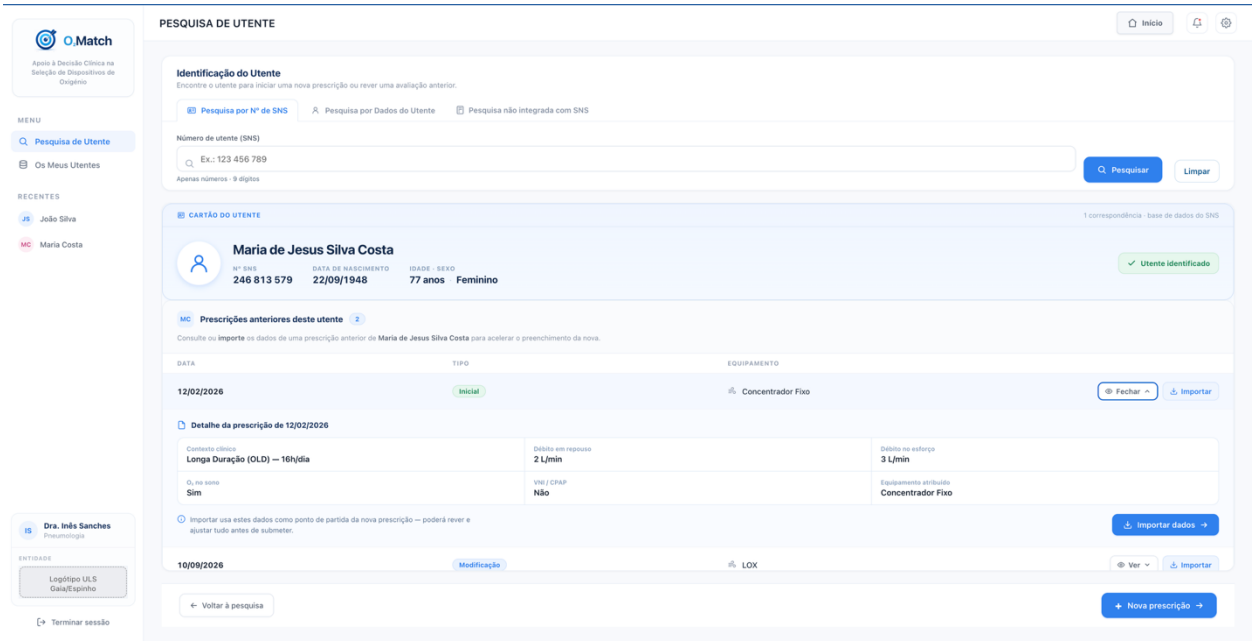


Figure 54- Patient search by SNS number for another patient, with an expanded previous prescription and options to import prior data into a new prescription.

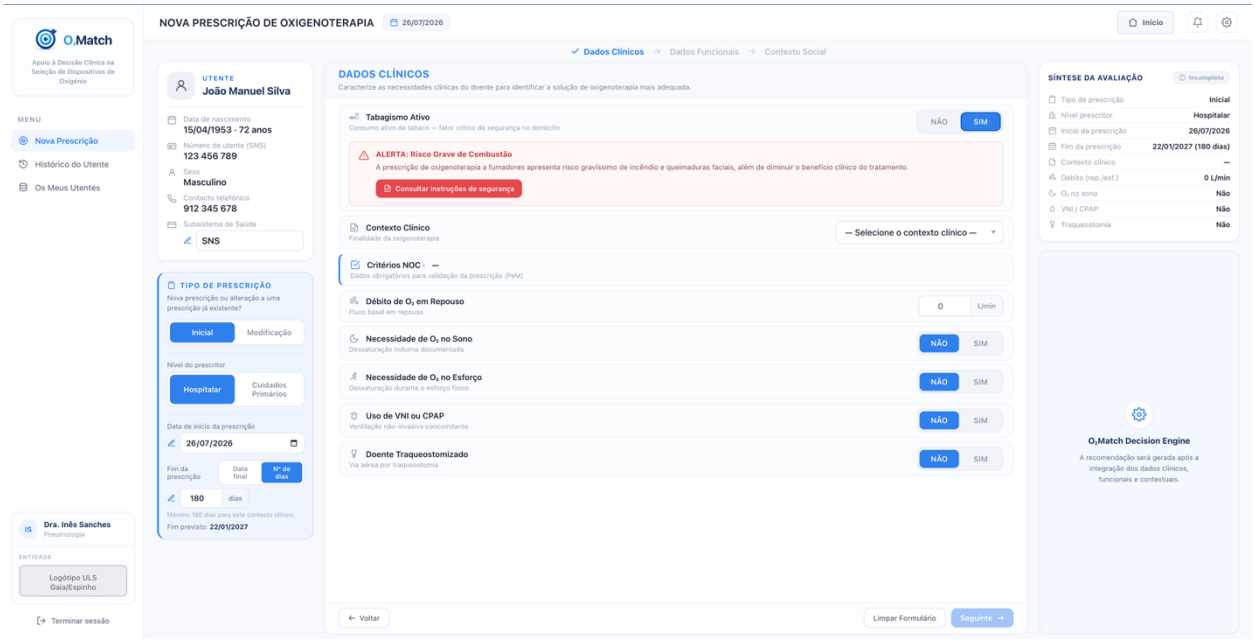


Figure 55- Clinical Data step with Active Smoking set to 'Yes', triggering a severe-combustion-risk alert and a link to safety instructions.

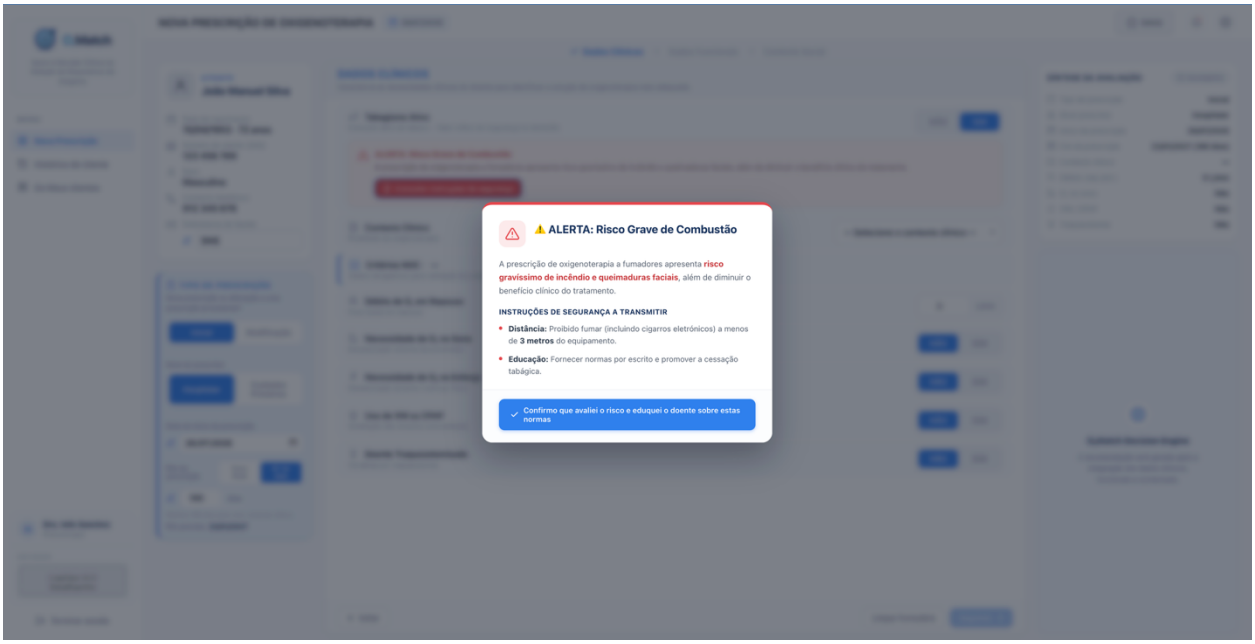


Figure 56- 'Severe combustion risk' modal with safety instructions for smokers and a checkbox confirming the risk was assessed and the patient educated.

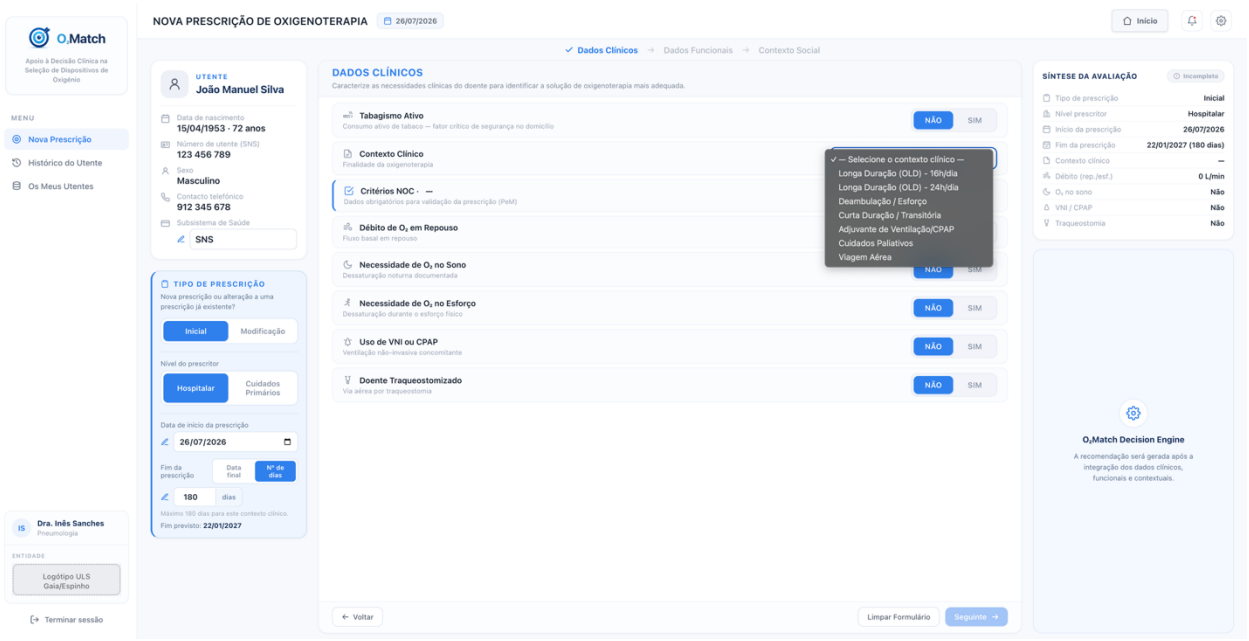


Figure 57- Clinical Data step with the Clinical Context dropdown open (OLD 16h/24h, ambulatory, short-term, ventilation adjunct, palliative care, air travel).

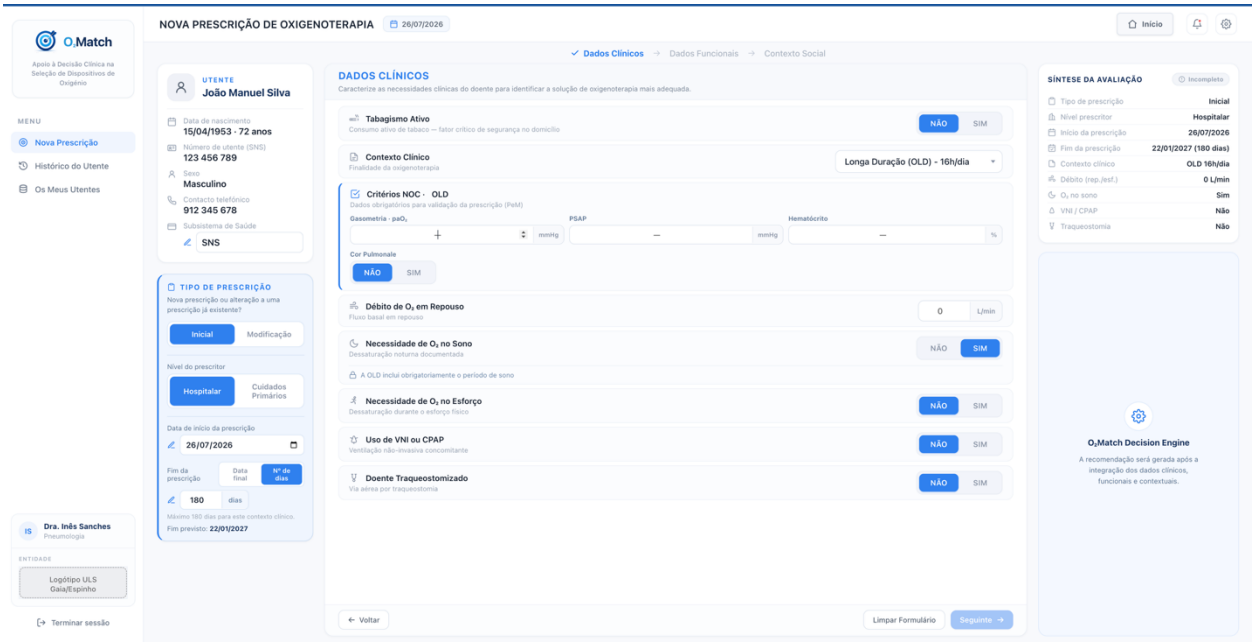


Figure 58- Clinical Data step set to long-term oxygen (OLD) 16h/day, showing the regulatory (NOC) criteria fields, with sleep oxygen auto-set to 'Yes'.

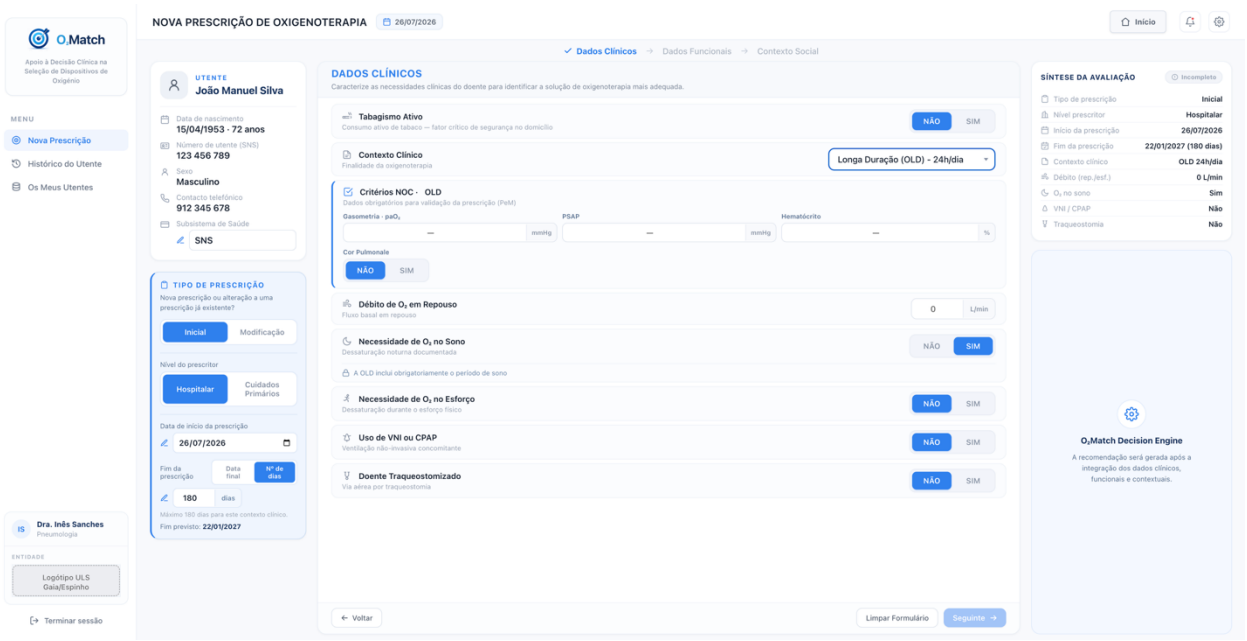


Figure 59- Clinical Data step set to long-term oxygen (OLD) 24h/day, showing the regulatory criteria fields, with sleep oxygen auto-set to 'Yes'.

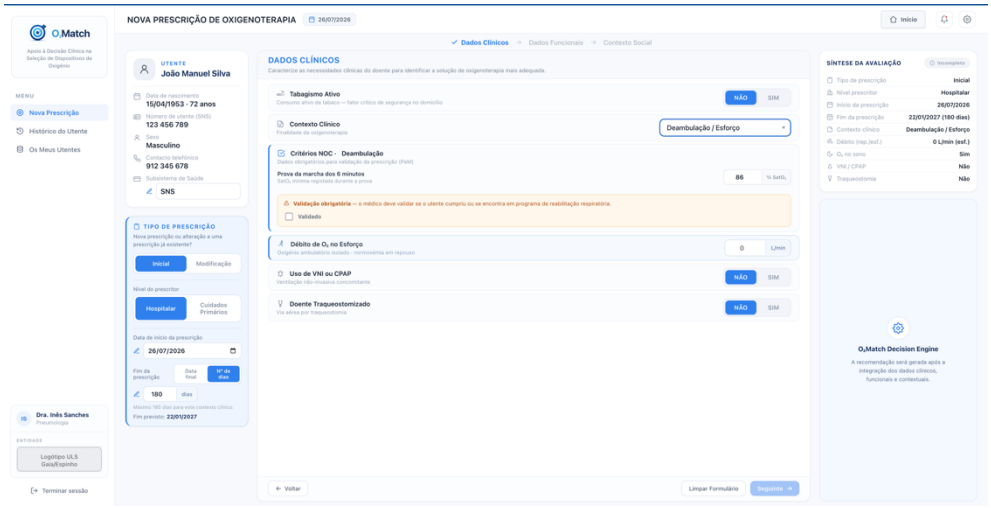


Figure 60- Clinical Data step set to ambulatory oxygen, showing the six-minute walk test criterion, a mandatory validation checkbox and an exertional oxygen flow field.

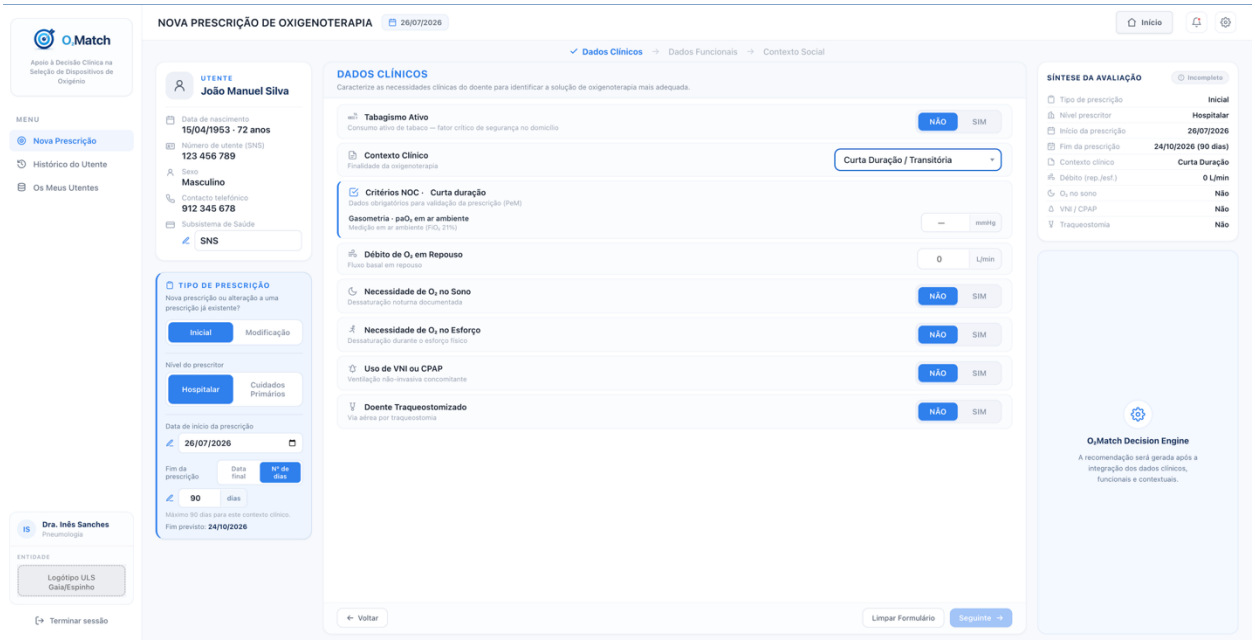


Figure 61- Clinical Data step set to short-term oxygen, showing the room-air blood-gas criterion and a 90-day maximum prescription period.

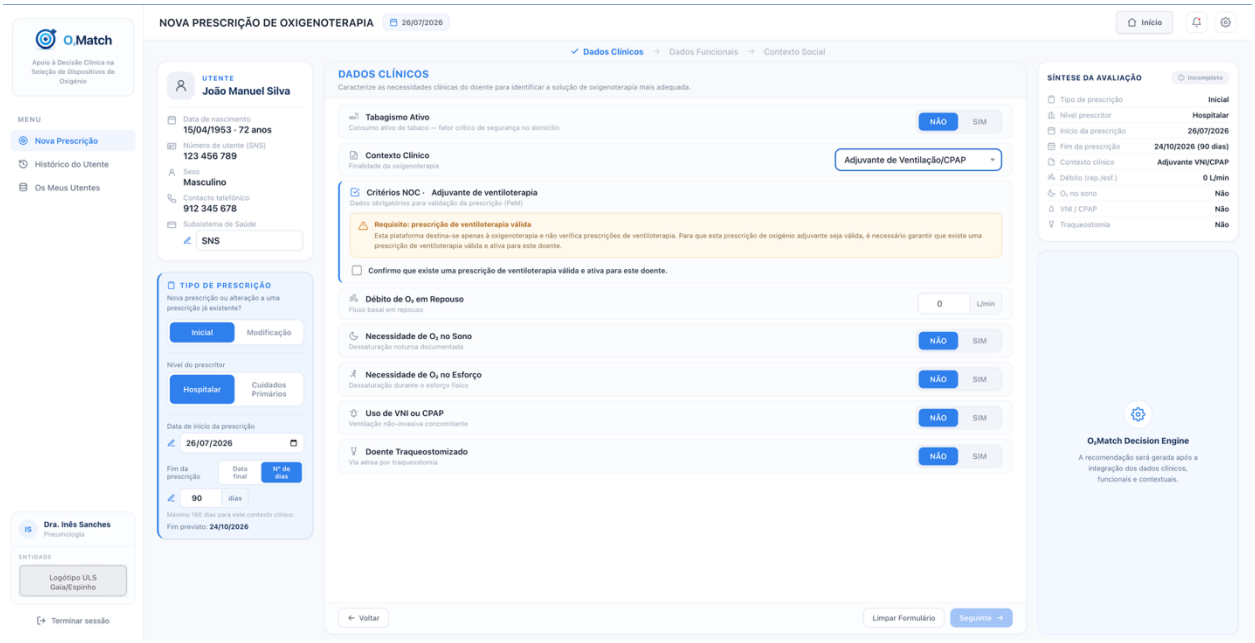


Figure 62- Clinical Data step set to adjunct-to-ventilation (NIV/CPAP), requiring confirmation of a valid active ventilation prescription before validation.

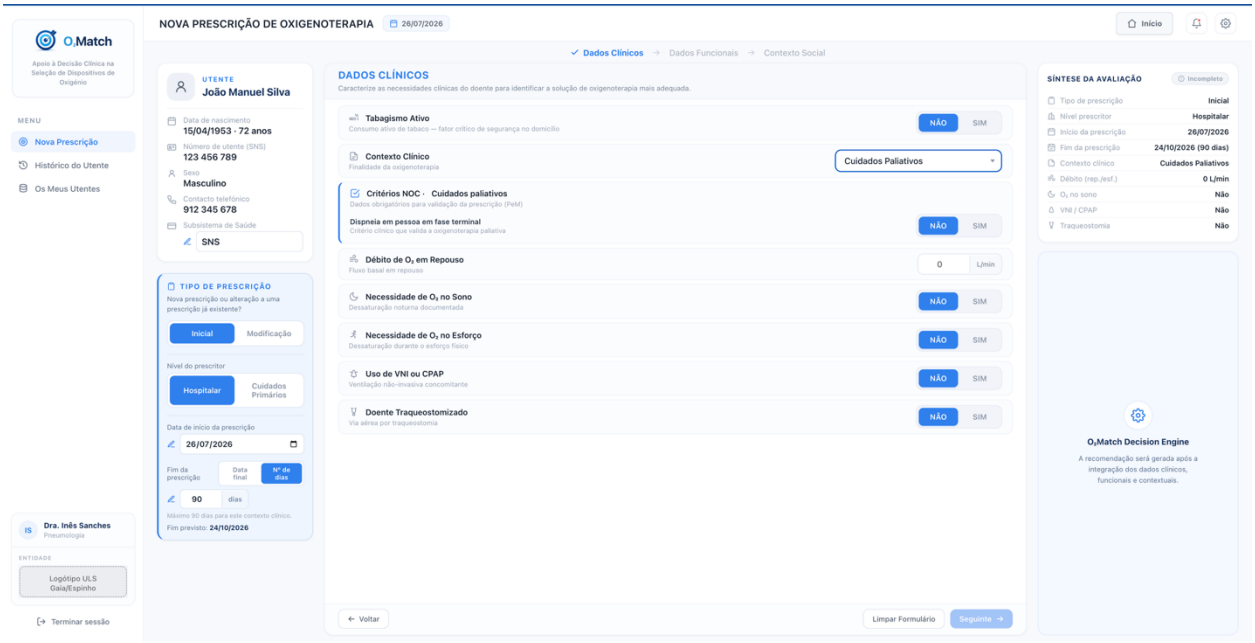


Figure 63- Clinical Data step set to palliative care, whose single criterion is dyspnoea in a terminally ill patient.

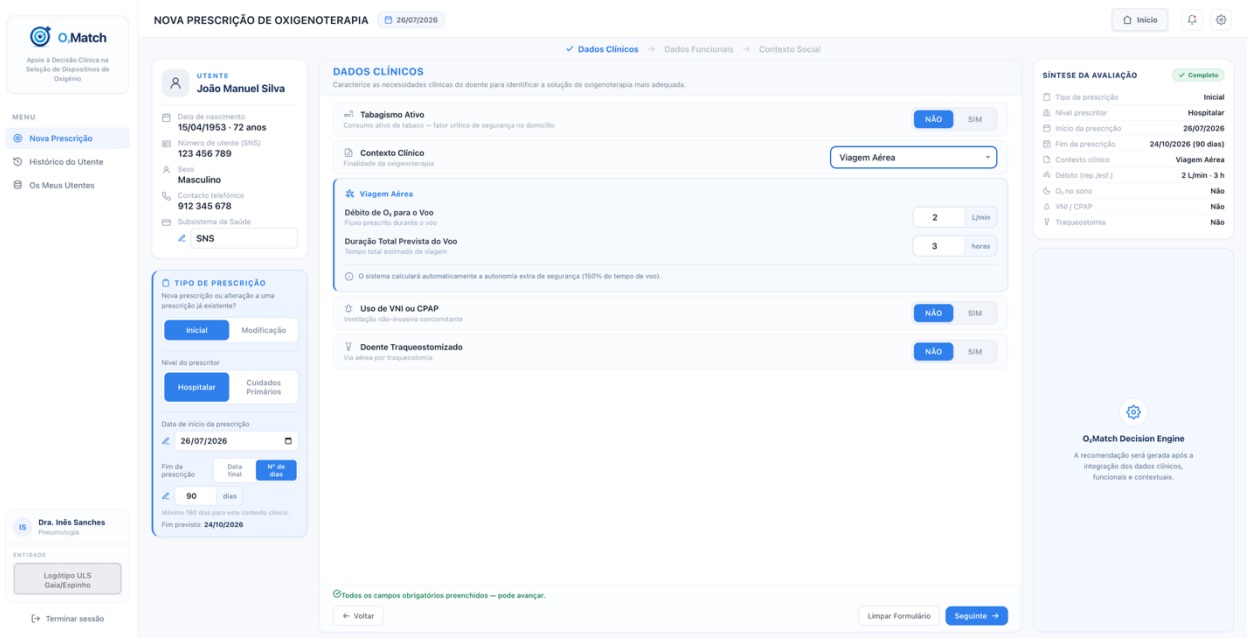


Figure 64- Clinical Data step set to air travel, capturing in-flight oxygen flow and flight duration, with an automatic 150% safety-autonomy margin.

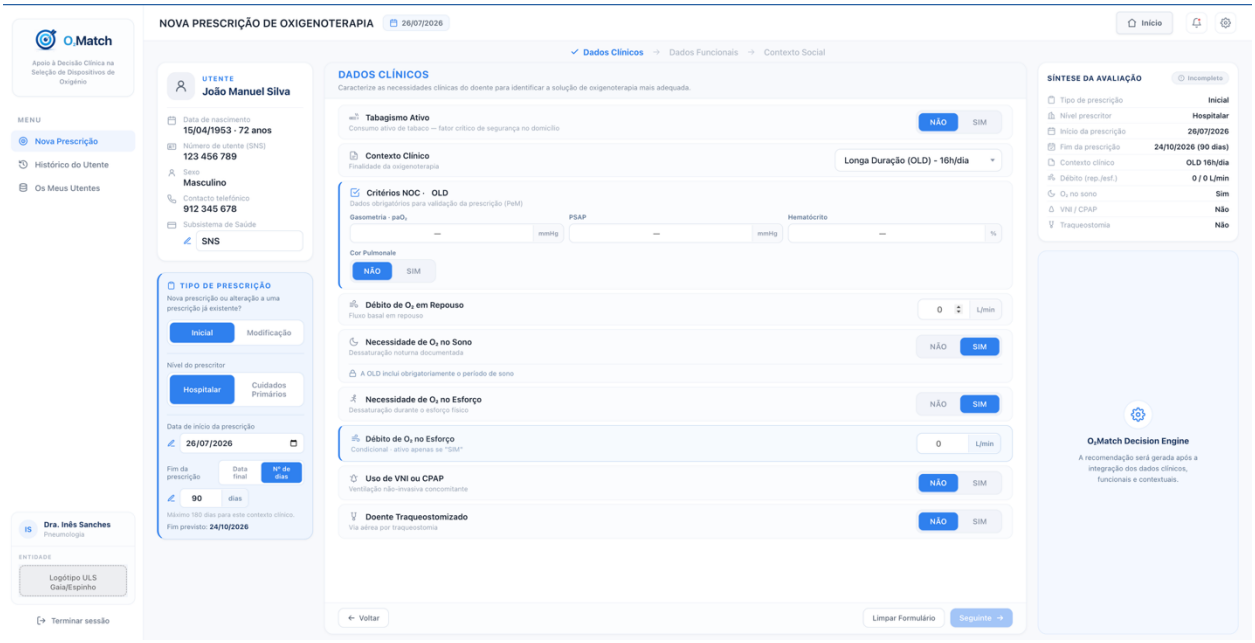


Figure 65- Clinical Data step set to long-term oxygen at rest plus ambulatory, showing the regulatory fields with both rest and exertional oxygen needs.

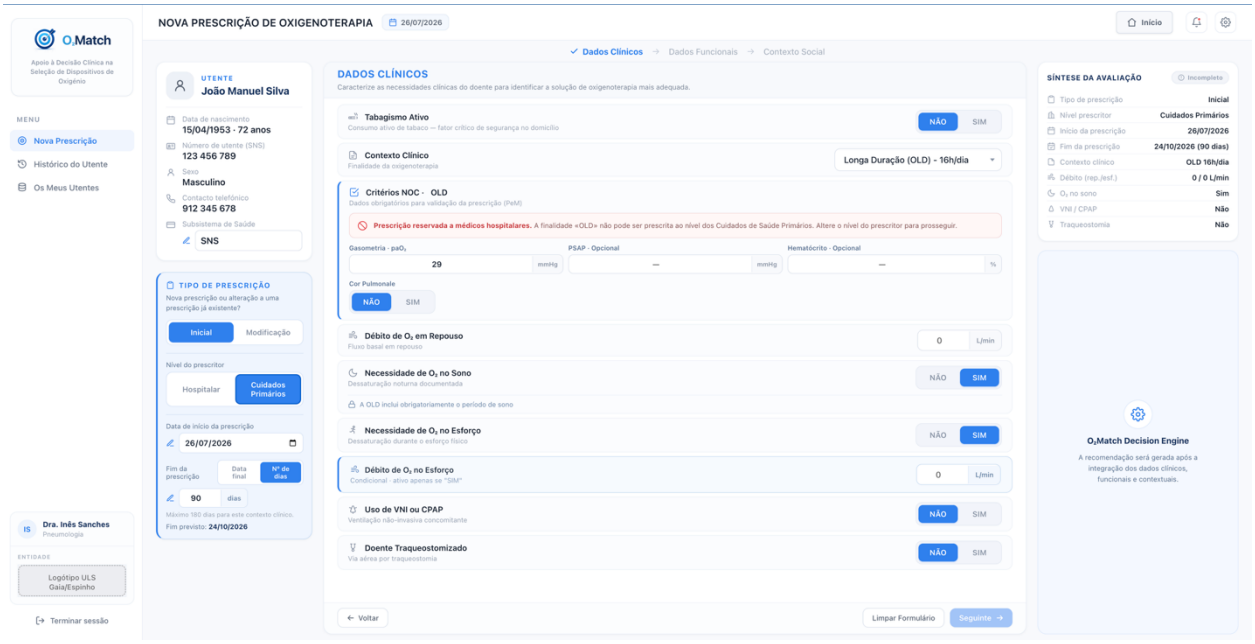


Figure 66- Blocked prescription: with prescriber level set to primary care, a red alert states the OLD modality is reserved for hospital physicians.

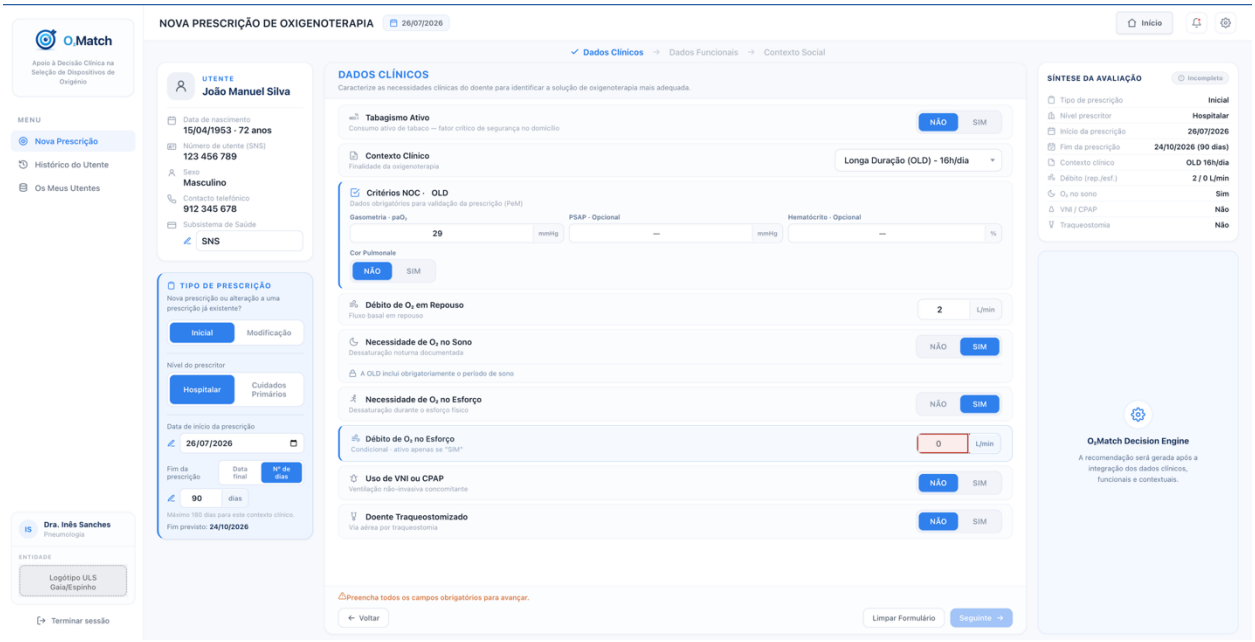


Figure 67- Mandatory-field validation: the empty exertional-oxygen flow field is outlined in red and a footer warns that all required fields must be completed before advancing.

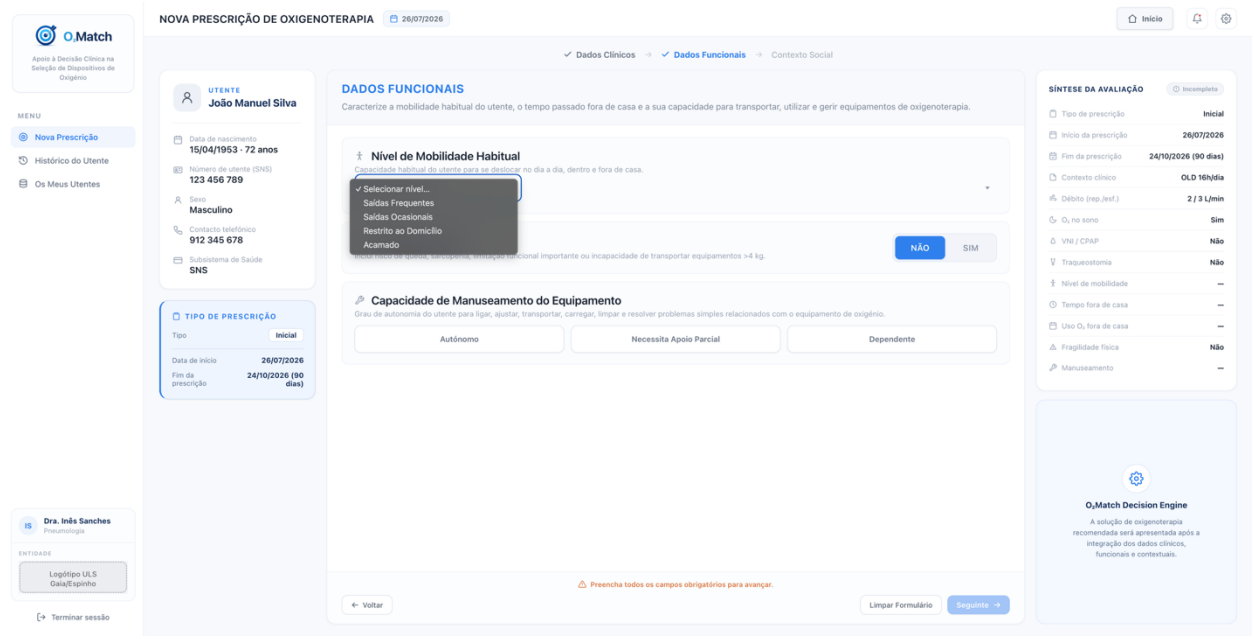


Figure 68- Functional Data step with the Habitual Mobility Level dropdown open (frequent outings, occasional, home-restricted, bedbound).

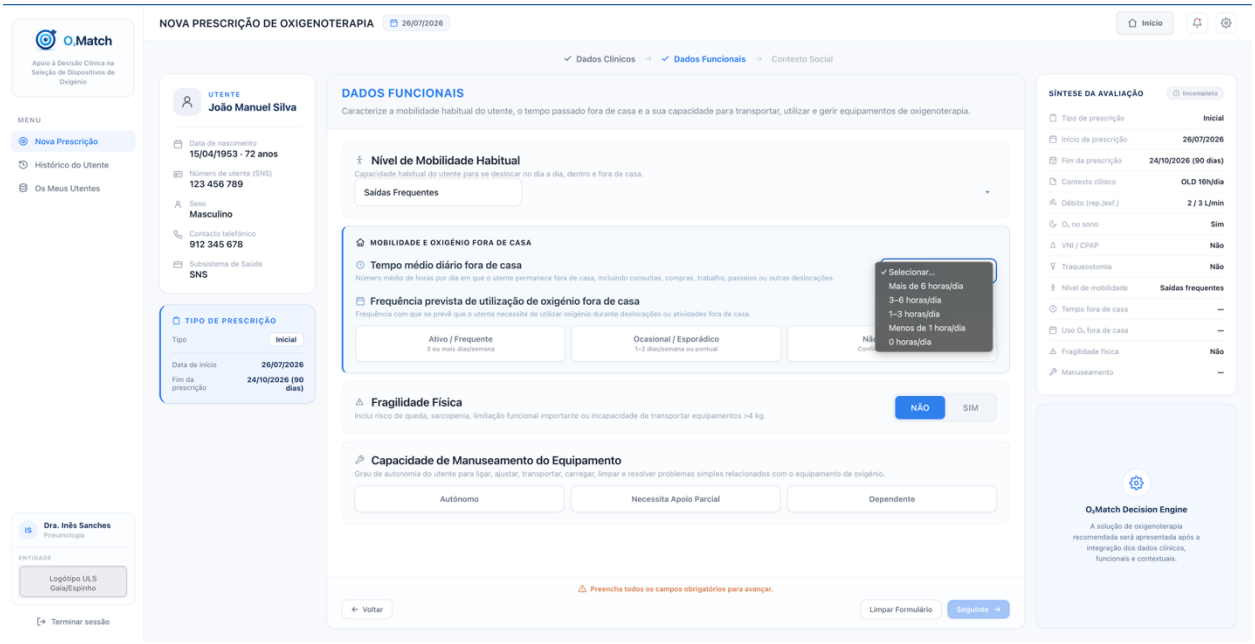


Figure 69- Functional Data step with the average daily time-outside-home dropdown open, alongside the frequency-of-out-of-home-oxygen-use options.

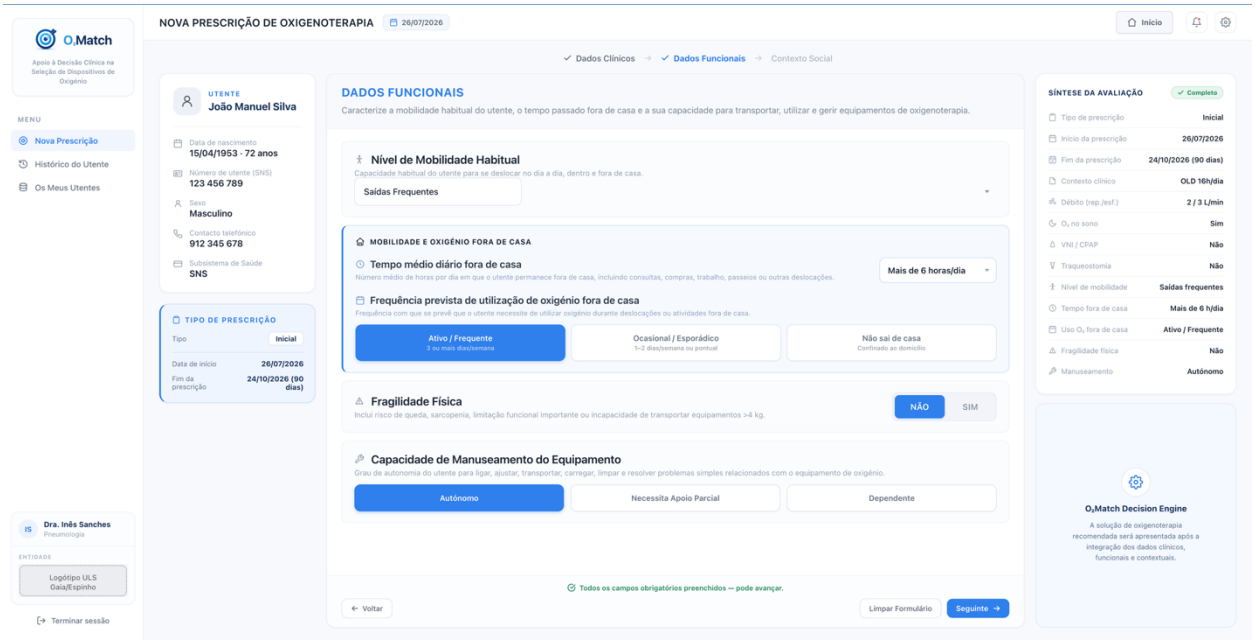


Figure 70- Social and Logistical Context step with the Home Support dropdown open (isolated, guaranteed support, institutionalised).

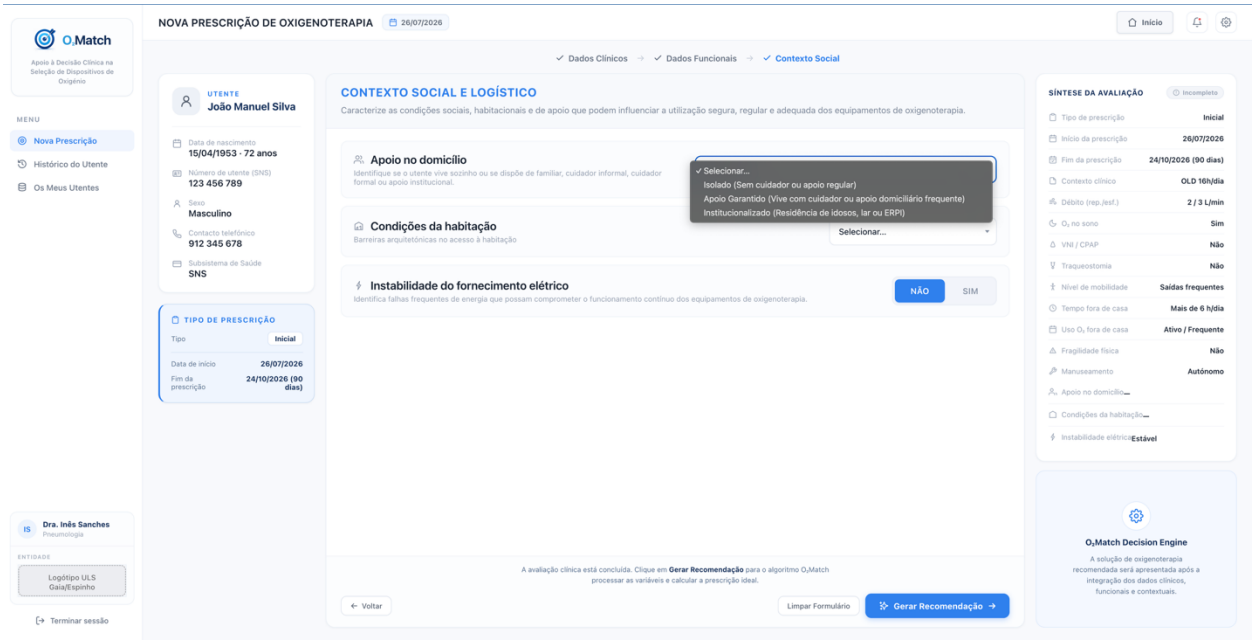


Figure 71- Social and Logistical Context step with home support set to 'Isolated' and the Housing Conditions dropdown open (no barriers, stairs with lift, stairs without lift).

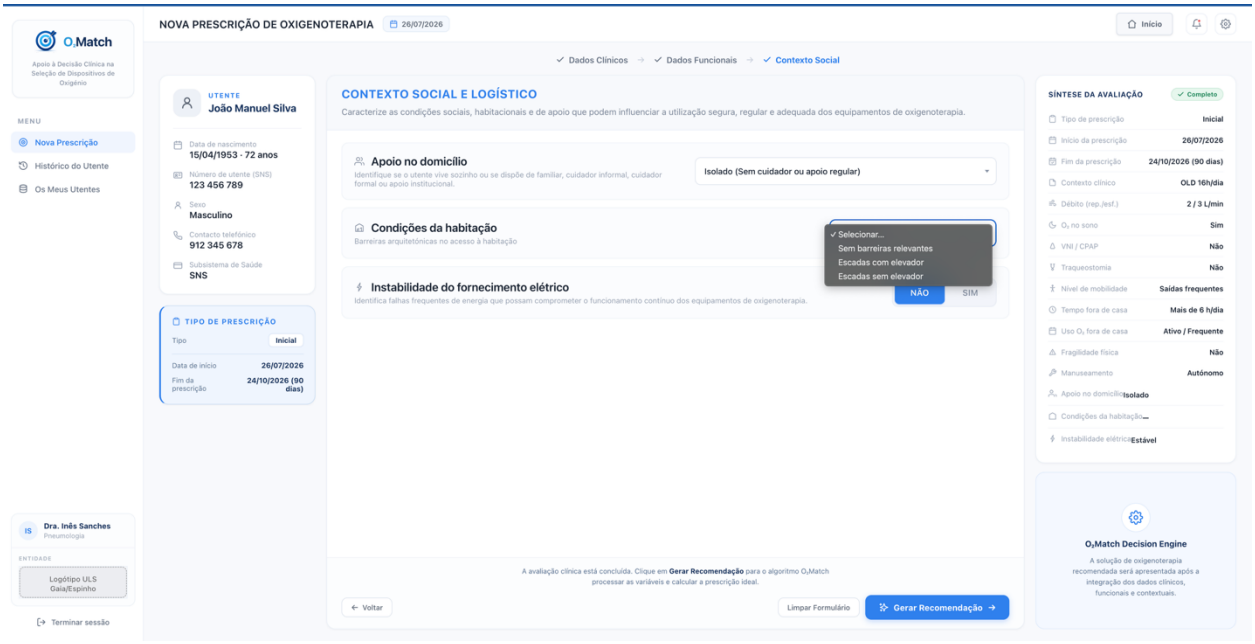


Figure 72- Completed Social and Logistical Context step, with housing conditions shown, the assessment marked complete and the 'Generate recommendation' action enabled.

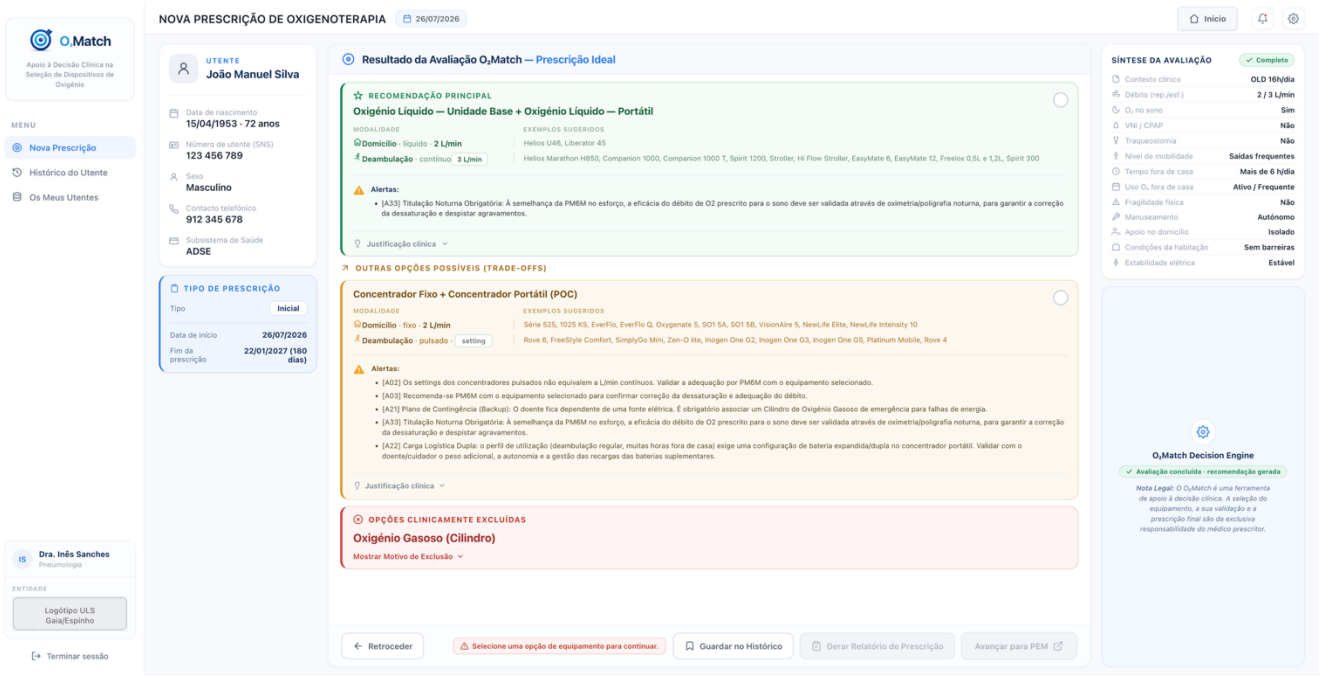


Figure 73- Assessment result screen listing the primary recommendation (liquid oxygen base plus portable), alternative trade-off options and clinically excluded options, with no device yet selected.

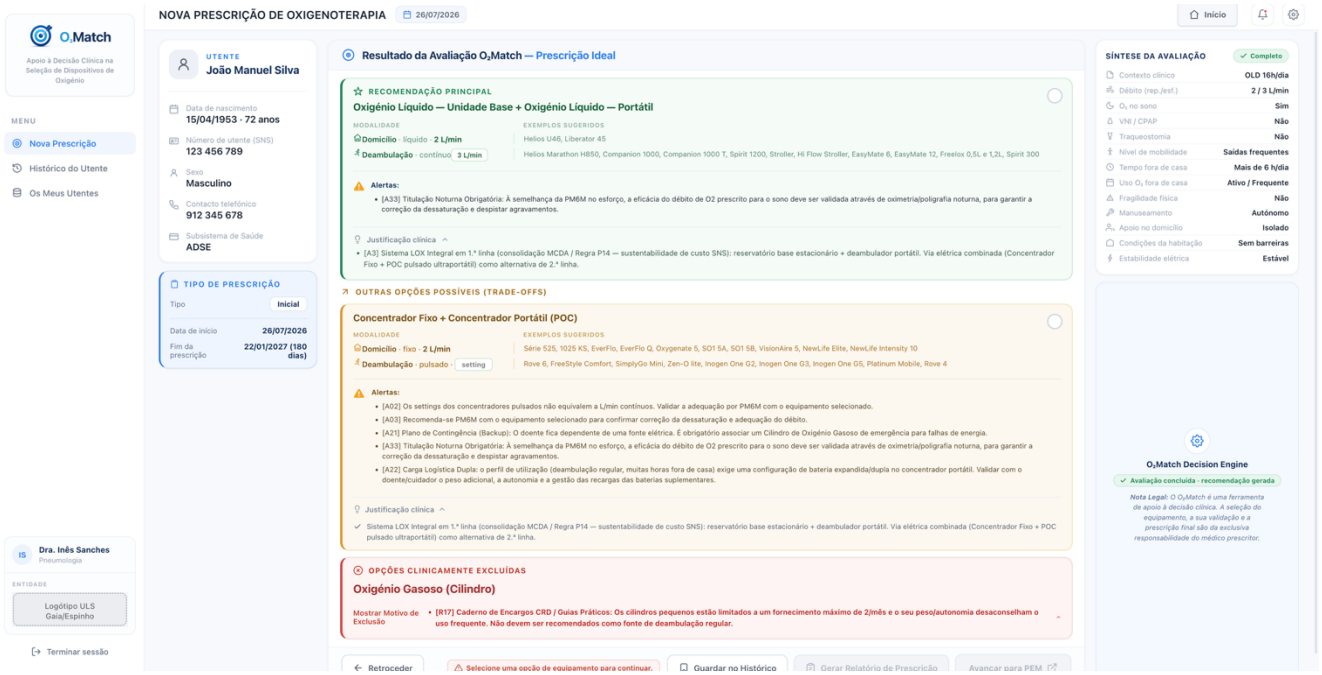


Figure 74- Assessment result screen with the primary recommendation selected, enabling the save, generate-report and export-to-PEM actions.

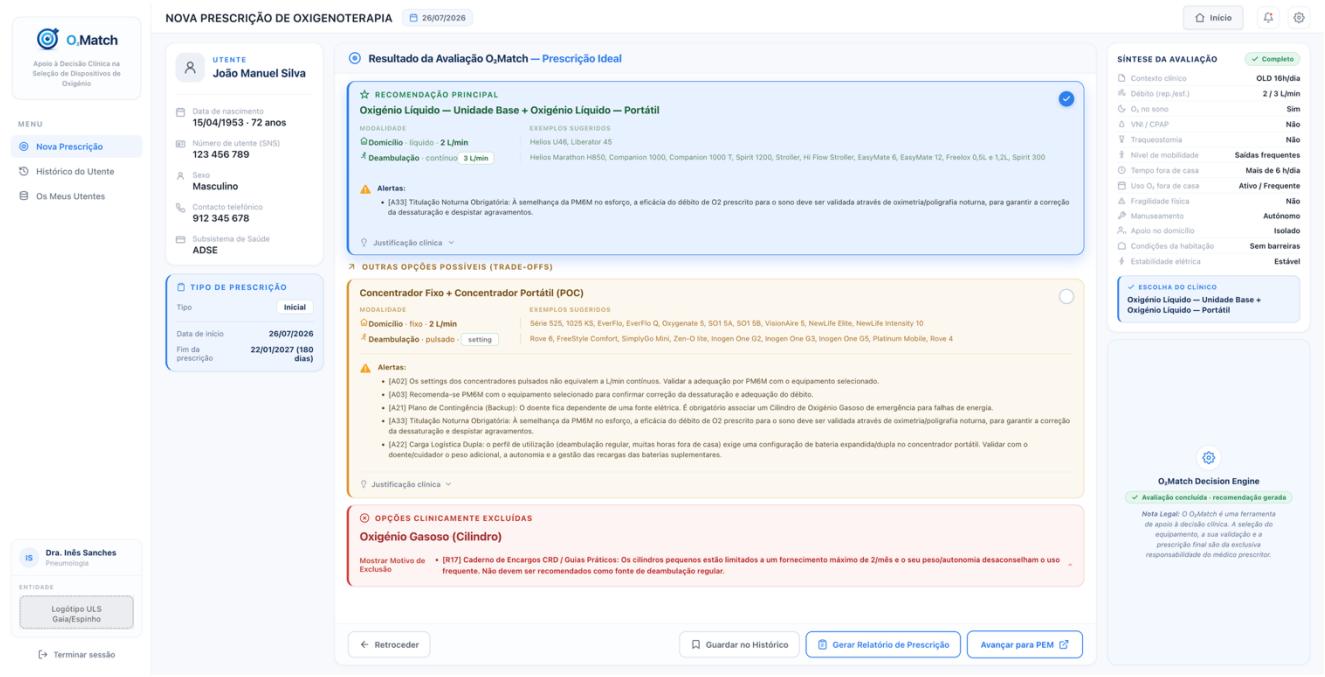


Figure 75- Generated PDF clinical recommendation report (page 1): institutional header, decision summary, patient identification, recommendation and clinical alerts.

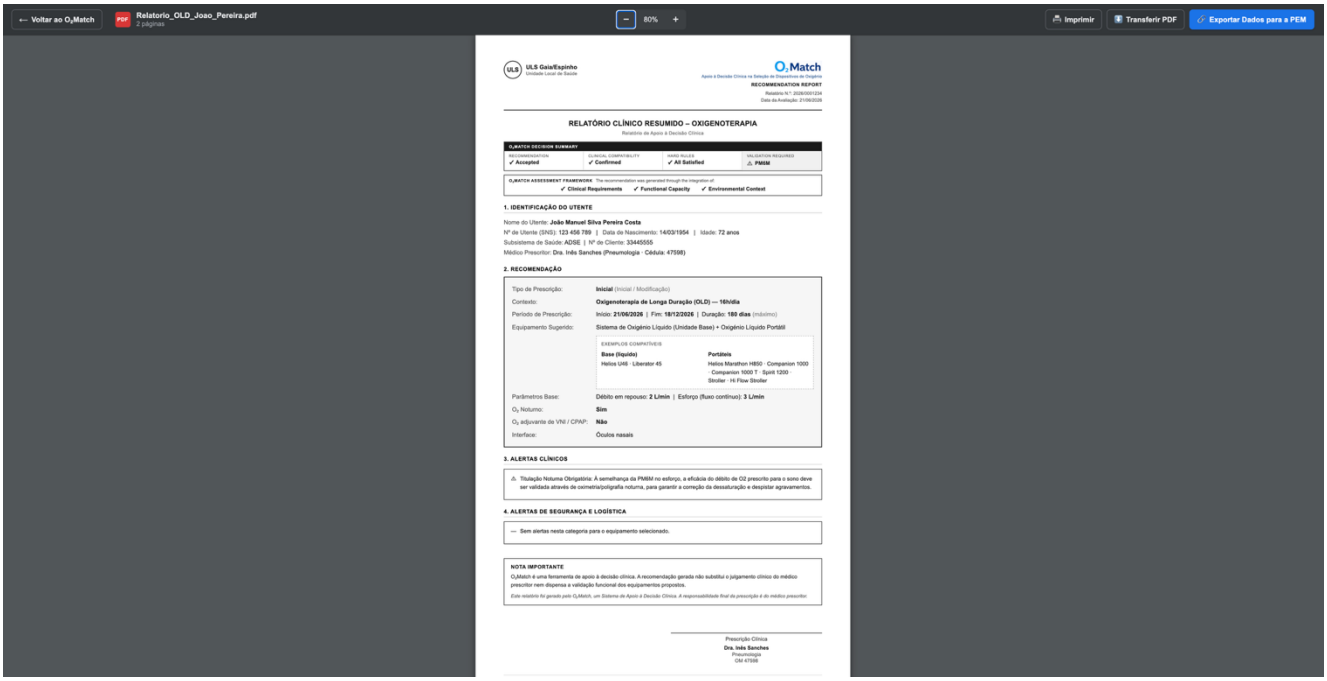


Figure 76- Generated PDF clinical recommendation report (page 1): institutional header, decision summary, patient identification, recommendation and clinical alerts.

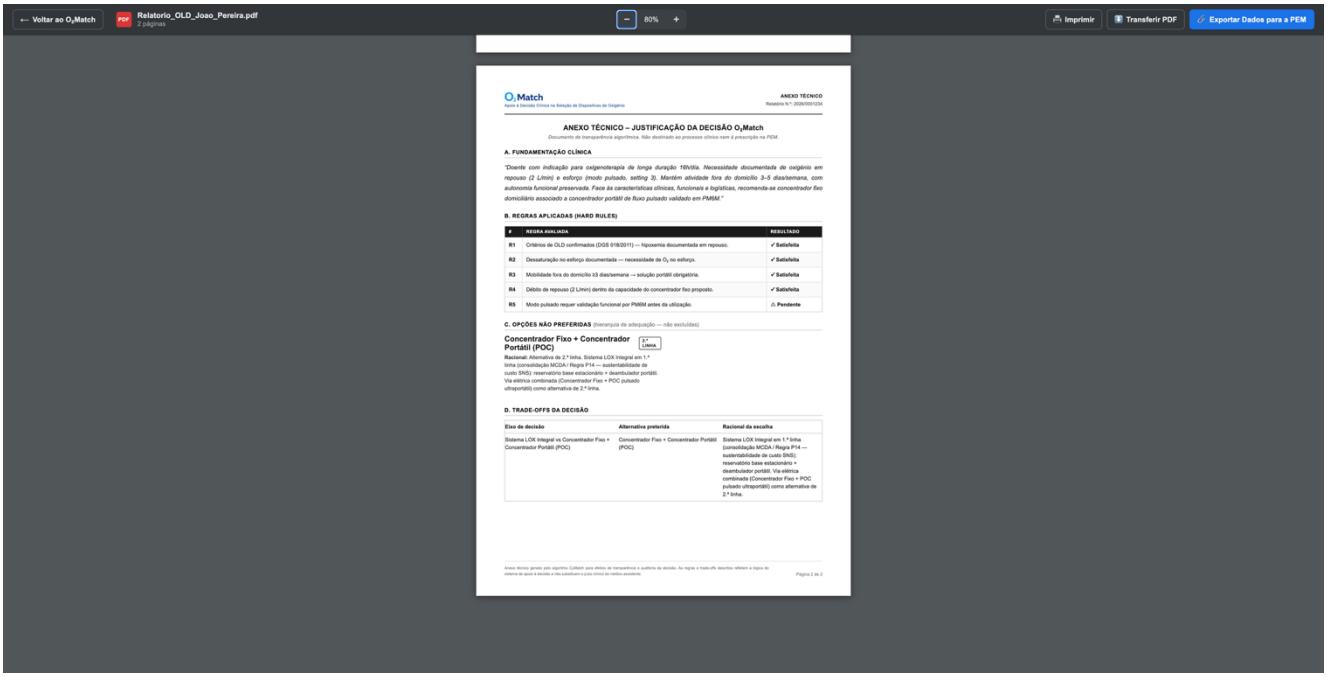


Figure 77- Generated PDF clinical recommendation report (page 1): institutional header, decision summary, patient identification, recommendation and clinical alerts.

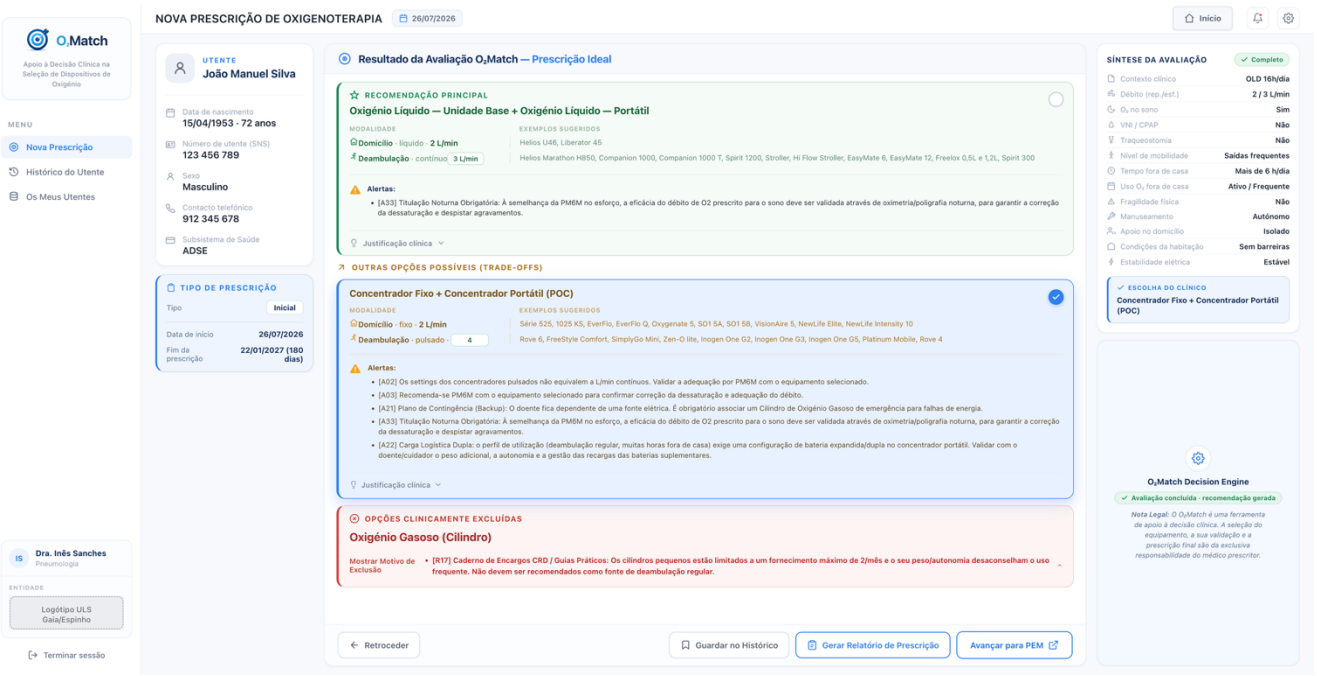


Figure 78- Assessment result screen with the other options selected, enabling the save, generate-report and export-to-PEM actions.

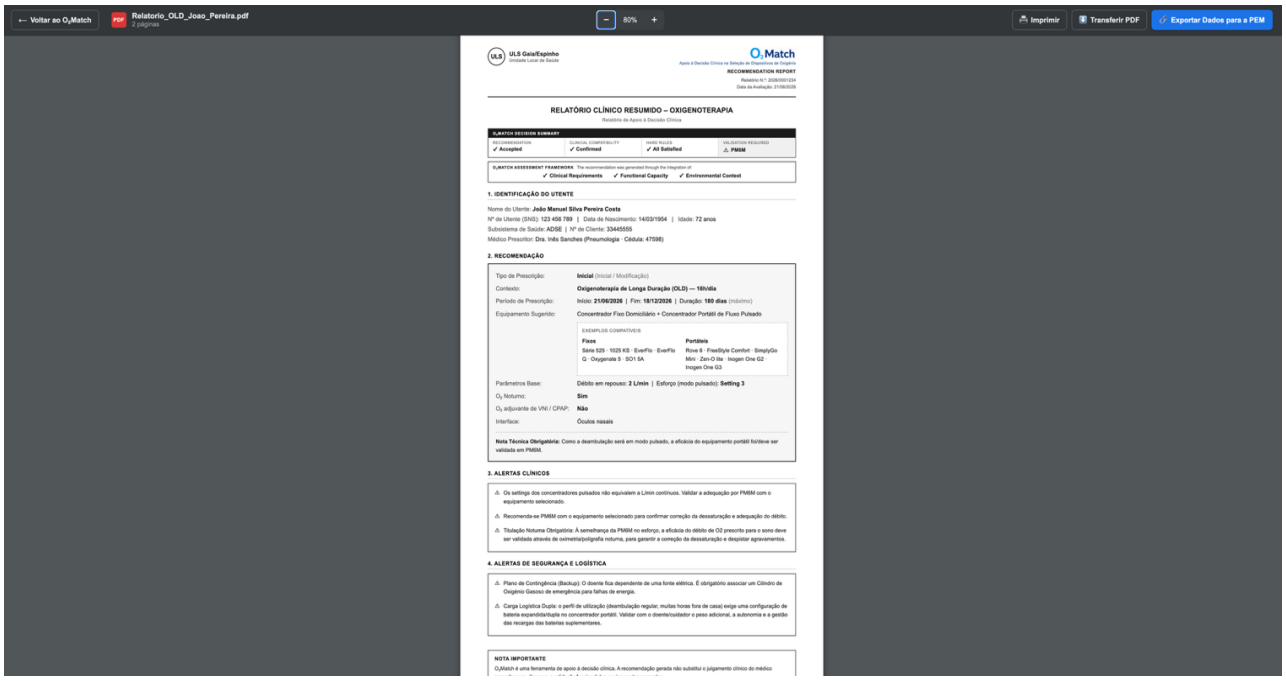


Figure 79- Generated PDF other options report (page 1): institutional header, decision summary, patient identification, recommendation and clinical alerts.

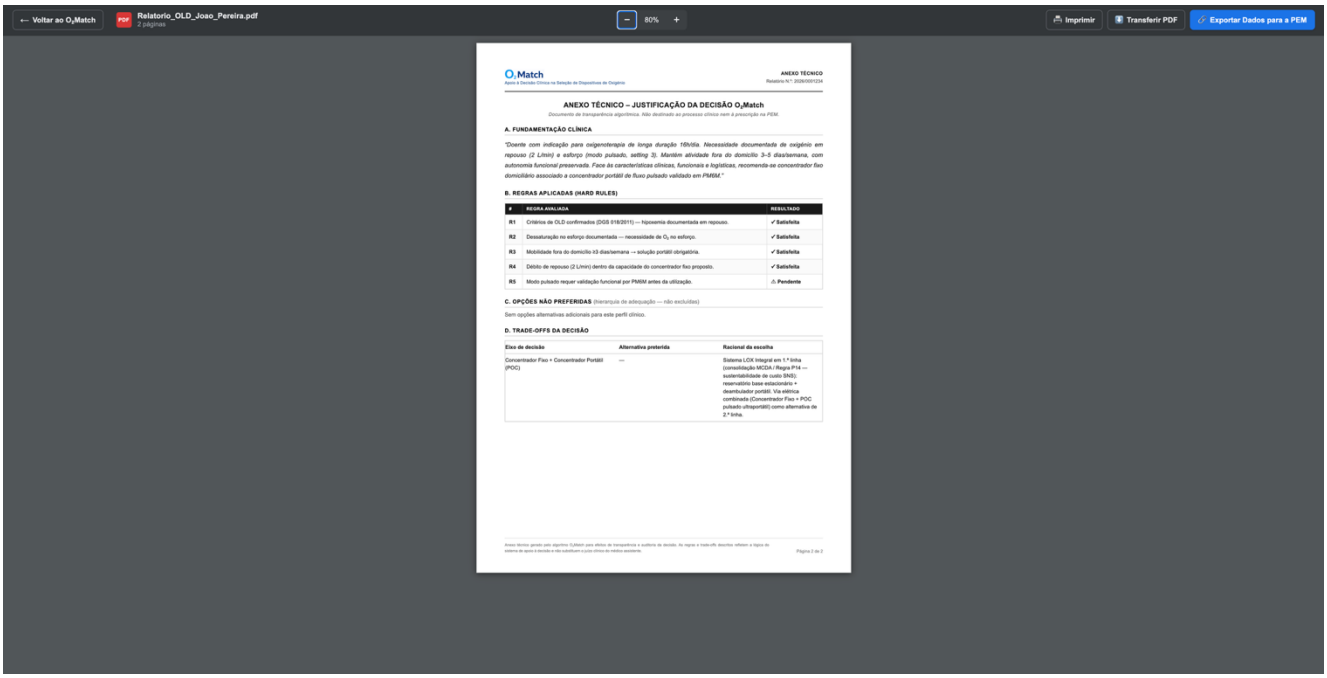


Figure 80- Generated PDF technical annex (page 2): the decision justification, applied rules, non-preferred options and trade-offs.

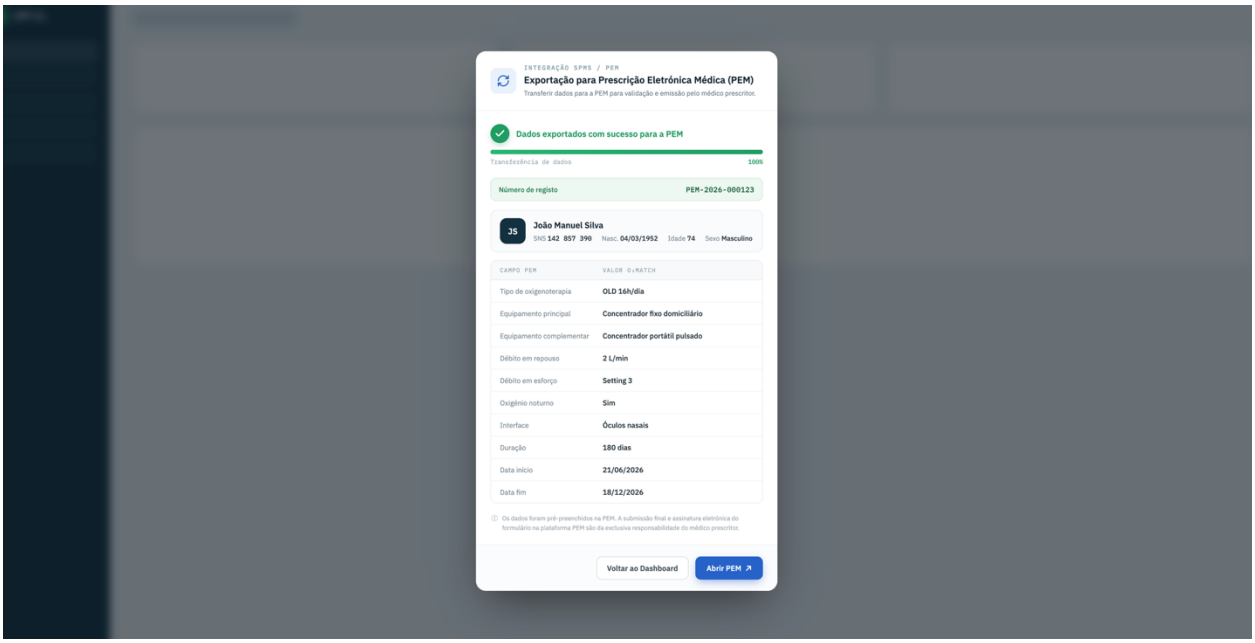


Figure 81- Success dialog confirming export to the Electronic Medical Prescription (PEM) system, showing the registration number and mapped prescription fields.

10.9. SPA state mapping and code architectur

CODE ARCHITECTUR

10.10. Usability evaluation

Grelha de Registo Dinâmico e Observação Direta

Utilizar esta tabela para classificar em direto cada uma das ações efetuadas pelo participante:

ID	Ação / Tarefa na APP-O_2	Grau de Conclusão 🟢 🟡 🔴			Dificuldades, Hesitações e Comentários
1	**Efetuar Login:** Testar introduzir password errada para verificar fluxo de segurança.				
2	**Recuperação de Conta:** Interagir com a opção de "Esqueceu-se da password".				
3	**Pesquisa de Utente:** Procurar doente pelo número de SNS ou dados locais.				
4	**Navegação nas Definições:** Percorrer Perfil Profissional, Segurança, Ajuda, Interoperabilidade e Idioma.				
5	**Preenchimento Clínico:** Selecionar objetivo, débito, sono e VNI.				
6	**Preenchimento Funcional:** Introduzir nível de mobilidade, manuseamento e fragilidade.				
7	**Preenchimento Logístico:** Definir cuidador, escadas e eletricidade.				
8	**Gerar Recomendação:** Acionar o processamento clínico e tolerar o tempo de espera.				
9	**Interpretação do Output:** Ler e interpretar os cartões Verde (Principal), Amarelo (Alternativas) e Vermelho (Exclusões).				
10	**Exportação e Interoperabilidade:** Gravar no Histórico, Gerar Relatório PDF e simular Integração na PEM.				
11	**Terminar Sessão:** Encontrar e acionar o botão de Logout com segurança.				

🟢 **Verde:** Concluiu de forma autónoma e imediata.

🟡 **Amarelo:** Concluiu com hesitação, dificuldade ou após uma dica verbal do investigador.

🔴 **Vermelho:** Não conseguiu concluir a tarefa, desistiu ou gerou um erro de sistema intransponível.

3. Questionário de Avaliação Heurística e Qualitativa da Interface (HCI)

Imediatamente após a conclusão das tarefas, peça ao médico participante que avalie formalmente os seguintes parâmetros de design e interação (Escala Likert de 1 a 5, onde 1 = Muito Difícil/Inadequado e 5 = Muito Fácil/Excelente):

A. Distribuição e Organização do Ecrã (Layout)

Pergunta: *Como avalia a distribuição dos elementos visuais no ecrã de preenchimento (inputs divididos em 3 blocos claros: Clínicos, Funcionais e Logísticos/Sociais)?*

Escala: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Comentário do Médico: _____

B. O Quadro de Resumo das Variáveis (Sidebar Direita)

Pergunta: *Durante o preenchimento, o quadro de resumo dinâmico no canto superior direito (que reflete os dados introduzidos em tempo real) foi útil? Sentiu que ajudou a diminuir a sua carga mental/esforço de memória?*

Escala: (Muito difícil/inadequado) 1☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (Muito fácil/excelente)

Comentário do Médico: _____

C. Facilidade de Seleção das Opções

Pergunta: *Quão fácil e intuitivo foi selecionar as opções nos formulários (utilização de toggles, botões segmentados Sim/Não e menus de seleção em vez de escrita livre)?*

Escala: (Muito difícil/inadequado) 1☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (Muito fácil/excelente)

Comentário do Médico: _____

D. Facilidade de Navegação Entre Ecrãs

Pergunta: *Quão intuitivo foi navegar entre os sucessivos ecrãs do processo de prescrição (avançar com "Seguinte", retroceder com "Voltar" ou saltar através do assistente por passos)?*

Escala: (Muito difícil/inadequado) 1☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (Muito fácil/excelente)

Comentário do Médico: _____

E. Facilidade de Gerar Funções Avançadas (Output e Burocracia)

Pergunta: *Como classifica a facilidade de gerar a recomendação final, analisar as justificações clínicas e acionar as funções de exportação (Guardar no Histórico, Gerar PDF e Avançar para a PEM)?*

Escala: (Muito difícil/inadequado) 1☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ (Muito fácil/excelente)

Comentário do Médico: _____

5. Entrevista Qualitativa Final e Feedback de Impacto

Para fechar a sessão de usabilidade, realize estas duas perguntas abertas de resposta livre ao clínico:

Questão 1: Simplificação do Trabalho Clínico

> **"Tendo em conta a sua prática diária na urgência ou na consulta, considera que uma aplicação deste tipo (que processa variáveis funcionais, logísticas e clínicas e dá justificações automáticas) simplificaria o seu trabalho na escolha dos dispositivos de oxigenoterapia para o doente?"**

Notas de Registo do Investigador:

Questão 2: Recomendação Final e Sugestões de Melhoria

> **"Qual é a sua recomendação final ou sugestão crítica de melhoria sobre o design, lógica ou terminologia da APP-O_2 para que esta possa vir a ser implementada com sucesso no SNS / PEM?"**

Notas de Registo do Investigador:

_____

Comentários Adicionais: Tem outras observações ou sugestões de melhoria para o O_2Match?

_____

Fim do Protocolo de Teste de Usabilidade. Muito Obrigado

SEDE ADMINISTRATIVA

FACULDADE DE **MEDICINA**

FACULDADE DE **CIÊNCIAS**