NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTMENT OF PHYSICS

MAFALDA MOUSINHO BOFFA-MOLINAR

BSc in Sciences of Biomedical Engineering

ACTIVITY-BASED COSTING IN THE PEDIATRIC OTORHINOLARYNGOLOGY SURGERY VALUE MODEL

MASTER IN BIOMEDICAL ENGINEERING

NOVA University Lisbon
September, 2023

DEPARTMENT OF PHYSICS

ACTIVITY-BASED COSTING IN THE PEDIATRIC OTORHINOLARYNGOLOGY SURGERY VALUE MODEL

MAFALDA MOUSINHO BOFFA-MOLINAR

BSc in Sciences of Biomedical Engineering

Adviser: Doutor Luís Miguel Velez Lapão
Invited Professor in the Department of Physics and Researcher at UNIDEMI at the Faculty of Sciences and Technology, Nova University Lisbon

Examination Committee

Chair: Doutor Hugo Filipe Silveira Gamboa
Professor Associado com Agregação na Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

Rapporteur: Doutor João Pedro Bernardo Gregório
Investigador Auxiliar no Centro de Investigação em Biociências e Tecnologias da Saúde da Universidade Lusófona

Adviser: Doutor Luís Miguel Velez Lapão
Professor Convidado do Departamento de Física e Investigador na UNIDEMI na Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa

MASTER IN BIOMEDICAL ENGINEERING

NOVA University Lisbon
September, 2023

Activity-based Costing in the Pediatric Otorhinolaryngology Surgery Value Model

This document was created with the (pdf/Xe/Lua)LaTeX processor and the NOVAthesis template (v7.1.5) (Lourenço, 2021).

Dedico às minhas avós.

Acknowledgements

Gostaria de iniciar os meus agradecimentos com um enorme obrigada à FCT-NOVA por estes 5 anos de excelência, rigor e dedicação pela ciência e engenharia. Estendo o agradecimento a todo o Departamento de Física, às coordenadoras de curso Prof. Carla Quintão e Prof. Célia Henriques, e em particular, ao meu orientador Prof. Luís Lapão por todo o apoio, entusiasmo e atenção que dedicou ao longo do desenvolvimento da minha dissertação.

Dirijo a maior das gratidões ao Hospital, especificamente à Direção de Valor em Saúde, ao Filipe C., ao Pedro C. e em especial à Ana B., pelo apoio e orientação indispensáveis para a realização desta dissertação e a oportunidade de poder desenvolver este incrível projeto. Obrigada aos cirurgião do Hospital cuja perspetiva clínica e real foram cruciais para a validação e concretização da tese de mestrado.

Mil obrigadas a toda a minha família, à minha mãe Paula, ao meu pai Joaquim e ao meu irmão Francisco por estarem sempre presentes, nos momentos de impaciência e de revolta, mas também nos momentos de festejo, de conquistas e alegrias. Com o exemplo e vivência, ajudaram-me a crescer e ensinaram-me a dar sempre o melhor de mim, por mim e para os outros.

A toda a restante família, à minha avó Edite, tios/as e primos/as, e todos os que o Ceú guarda, obrigada por me inspirarem e serem modelos vivos de união, amor e preseverança.

A toda a família que a amizade me deu, os meus amigos, os de Santarém, a santa terrinha; os de Lisboa; os da faculdade; dos voluntariados e dos projectos católicos; obrigada por me acompanharem e partilharem comigo, lado a lado, todas as ocasiões, histórias, as minhas dores e alegrias.

A todos os que estiveram em projetos de Faculdade, de trabalho, babysitting, voluntariado, obrigada por presenciarem e viverem comigo os últimos 5 anos, por acreditarem em mim e nas minhas capacidades.

Obrigada, obrigada!

"The most important thing is to never stop questioning."

— **Albert Einstein**, Physicist
(en)

Abstract

In the last two decades, there has been an exponential increase in healthcare costs due to technological advances and innovations in the field. As a result, hospitals have had to implement management strategies to control costs while maintaining the quality of care provided.

In response to this challenge, the Value-Based Health methodology has emerged. This approach aims to achieve the best healthcare outcomes at an optimized cost. Given the complexity and variety of activities in hospitals, financing surgical procedures has become a significant challenge. Therefore, the primary objective of this dissertation is to assess the cost of the value chain in otorhinolaryngology surgery using the Activity-Based Costing methodology.

After processing and analyzing the provided data, we were able to establish and examine the clinical pathway of the selected group of patients. Subsequently, we calculated the costs associated with this pathway and conducted a detailed analysis.

The activity-based costing methodology allowed us to determine the costs associated with each patient's clinical pathway and surgery. It also helped us identify the resources and activities that contribute most significantly to the overall cost.

With the results obtained, the Hospital can standardize clinical practices, promote more sustainable resource utilization, negotiate value-based payment models, and enhance the quality of outcomes and cost-effectiveness in pediatric otorhinolaryngology surgery.

Keywords: Value based Healthcare, VBHC, Activity-based costing, ABC, Hospital management, Value chain costing

Saúde baseada em Valor, Custeio baseado em atividades, Gestão Hospital, Custeio da Cadeia de Valor

The research work described in this dissertation was carried out in accordance with the norms established in the ethics code of Universidade Nova de Lisboa. The work described and the material presented in this dissertation, with the exceptions clearly indicated, constitute original work carried out by the author.

Resumo

Nas últimas duas décadas, tem se vindo a observar um aumento exponencial dos custos nos cuidados de saúde devido aos avanços tecnológicos e a inovação na área. Como resultado, estratégias de gestão para controlar os custos, sem comprometer a qualidade dos cuidados prestados, tem vindo a ser aplicadas em meio hospitalar.

Como resposta a este desafio, surgiu a metodologia de Saúde Baseada em Valor. Esta abordagem visa alcançar os melhores resultados de saúde com um custo otimizado. Devido à complexidade e variedade de atividades hospitalares, o custeio dos procedimentos cirúrgicos revela-se um desafio. Deste modo, o objetivo principal de estudo desta dissertação é custear a cadeia de valor da cirurgia de otorrinolaringologia utilizando a metodologia de Custeio baseada em Atividades.

Após o processamento e análise dos dados fornecidos, foi possível estabelecer e examinar o percurso clínico do grupo de pacientes selecionados. Posteriormente, calculamos os custos associados a este percurso e conduzimos uma análise detalhada.

A metodologia de custeio baseado em atividades permitiu obter os custos associados ao caminho clínico e à cirurgia de cada paciente, bem como apurar os custos de cada uma das áreas assistenciais ao caminho clínico, identificando os recursos e as atividades que contribuem de uma forma mais significativa para o custo global.

Com os resultados obtidos o Hospital pode padronizar práticas clinicas, promover uma utilização de recursos mais sustentável, negociar modelos de pagamento baseados em valor e melhorar a qualidades dos resultados e a relação custo-eficácia na cirurgia de otorrinolaringologia em idade pediátrica.

Palavras-chave: Saúde baseada em Valor, Custeio baseado em atividades, Gestão Hospital, Custeio da Cadeia de Valor

O trabalho de investigação descrito nesta dissertação foi realizado de acordo com as normas estabelecidas no código de ética da Universidade Nova de Lisboa. O trabalho descrito e o material apresentado nesta dissertação, com as exceções claramente indicadas, constituem trabalho original realizado pelo/a autor/a.

Contents

List of Figures

List of Tables

Acronyms

ABC	Activity-based Costing
ADSE	Assistance in Sickness to Civil Servants of the Portuguese State
ANOVA	Analysis of Variance
CDTM	Complementary Diagnostic and Treatment Methods
CT	Computed Tomography
EC	External Consultation
EN	Episode Number
ENT	Ear, nose, and throat Specialty
GDP	Gross Domestic Product
HIS	Hospital Information Systems
IBM	International Business Machines Corporation
ICHOM	International Consortium for Health Outcomes Measurement
ICU	Intensive Care Unit
MRI	Magnetic Resonance Imaging
NHC	Patient Identification Number
OC	Outpatient Consultation
OME	Otitis media with effusion
Pcr	C-Reactive Protein
PROMS	Patient-Reported Outcome Measurements
TDABC	Time-driven Activity-based Costing
VBC	Volume-based Costing

VBHC Value Based Healthcare

Chapter 1

Introduction

This chapter presents an introduction to the dissertation in order to better understand the issues behind the topic ”Activity-based Costing in the Pediatric Otorhinolaryngology Surgery Value Model”.

1.1 Background

The Value-Based Healthcare (VBHC) methodology has emerged as the most recent and relevant approach in the future of healthcare management within the healthcare industry (Teisberg et al., 2020). Literature indicates that VBHC encourages healthcare providers to deliver patient-centred care of the highest quality, aligning with patient needs, at a certain cost (Porter & Lee, 2013).

In the realm of costing methodologies, several approaches are employed to assess costs in hospitals. This project marks the initial step in applying the VBHC methodology, focusing on the study of Activity-based Costing (ABC) as a value costing methodology. The primary objective is to explore this costing methodology as a means to calculate the costs associated with pediatric otorhinolaryngology surgery.

The collaboration of biomedical engineering and the ABC methodology offers a powerful toolset for enhancing patient outcomes, evident in the production and creation of devices, including tablets and wearables, for accurately measuring data related to the outcomes established by patients (Dueck et al., 2015). It entails analyzing the costs of medical devices, designing and developing cost-effective technologies, optimizing resource allocation, and elevating the overall quality of care. According to researchers, by integrating these methodologies into their practice, healthcare providers can deliver patient-centred care that is not only of the highest quality but also efficient, effective, and sustainable (Porter & Lee, 2013).

1.2 Context and Motivation

Over the past two decades, the world has witnessed an upward trend in healthcare costs. This upward trend can be attributed to a multitude of factors, including the ageing of the population, the introduction of expensive medical technologies, the growing incidence of chronic diseases such as diabetes, cancer, and heart disease, and the increased cost of medication (Dieleman et al., 2017).

In the European Union, healthcare costs as a percentage of Gross Domestic Product (GDP) increased by an average of 1.5% per year between 2000 and 2016. The European Commission reported that in 2016, the average expenditure on health in the European Union as a proportion of GDP was 9%. According to Eurostat, healthcare expenditure in Portugal as a proportion of GDP increased from 6.5% in 2000 to 9.5% in 2019, which represents an average annual increase of 0.33 percentage points over the 19-year period (Eurostat, 2023).

The evidence shows that an increase in costs necessitates a healthcare financing approach focused on outcomes, shifting from volume to value (Stamm et al., 2021). This requires the adoption of refined and up-to-date costing methodologies, which becomes imperative for enhancing resource efficiency and the overall quality of healthcare processes (Tarzibashi & Ozyapici, 2019).

When it comes to pediatric otorhinolaryngology, the field plays a vital role in addressing and improving a wide range of critical conditions affecting children. In the United States of America, about half a million children have a myringotomy, a procedure that relieves the pressure in the middle ear, when they suffer from repeated Otitis media with effusion (OME) (Rosenfeld et al., 2022). OME may result in hearing impairment, which can hinder the child's linguistic and behavioural growth (Cao et al., 2006).

Furthermore, the widespread occurrence of adenoid hypertrophy, affecting 34.5% of children in the United States (Z. Geiger, 2023), and tonsillitis, which is estimated to account for 5% of repeat visits to healthcare facilities in Portugal (Northwest Surgery Center, 2023), highlights the centrality of these pathologies in pediatric care. In instances of airway obstruction caused by enlarged adenoids or recurring tonsillitis, tonsillectomy and adenoidectomy procedures are carried out, with an estimated 400,000 of these surgeries being performed annually in the United States (Boston Children's Hospital, 2023).

According to the studied Hospital, a private hospital in Portugal, 350 pediatric otorhinolaryngology surgeries are performed annually, namely adenoidectomies, septoplasties, myringotomies, tympanomastoidectomies, turbinectomies and tonsillectomies. Not only does otorhinolaryngology address these acute conditions, but it also plays a crucial role in preserving, restoring, and improving hearing, voice, tasting, smelling, swallowing, and breathing, adding value in several crucial dimensions for the development of the child and its manifestation in the society (Robert J, 2003).

Given the high prevalence and significance of this speciality in child development, empirical evidence emphasizes that an advanced costing system not only yields greater precision in outcomes but also provides a robust foundation for informed decision-making (Tarzibashi & Ozyapici, 2019).

1.3 Objectives and Problems

The study of ABC as a costing methodology underscores the necessity for a precise and accurate cost analysis throughout the entirety of a patient's journey. It should also furnish pertinent information for assessing the quality and value delivered to the patient.

Thus, the goal of this master's thesis is to analyze the value chain of otorhinolaryngology surgery in the pediatric age group using the costing methodology based on the activities. Analyzing the costs associated with the various activities carried out through the pathway, namely, the costs of activities throughout the process is essential to understand at what cost we deliver certain results to patients.

Given the paramount significance and pertinence of process management in the speciality of otorhinolaryngology - ENT, particularly in the context of pediatric care, the selection of this topic for the master's thesis in biomedical engineering provides a significant contribution to the enhancement of healthcare delivery within a hospital environment. The thesis covers a range of critical aspects, including process analysis, data analysis, sustainable utilization of biomedical equipment, adherence to safety guidelines, and effective management of clinical guidelines. By addressing these crucial factors, the thesis aims to enhance the quality of care provided to pediatric patients in otorhinolaryngology, ultimately leading to better patient outcomes and improved overall health service delivery.

This assignment is intended to identify, calculate, and ensure that healthcare outcomes are delivered at a specific cost, following a specific care guideline. The development of this mechanism and process will allow the evaluation of the expense variation throughout the patient's journey, a fundamental process for implementing a VBHC model.

Chapter 2

State of the Art

This chapter, presents the methodological and conceptual underpinnings that constitute the basis upon which this dissertation is constructed. Begins with the Value-Based Healthcare (VBHC) model, dissecting its theoretical framework, practical applications, and significance within the healthcare landscape. Then an explanation of costing methods and activity-based costing methodology, with a primary focus on their adaptation and utilization in the context of healthcare systems. At the end of the chapter, the speciality of otorhinolaryngology is briefly presented.

2.1 Value-Based Healthcare

Due to rising health costs and the continued aspiration to deliver the best health outcomes, Porter and Teisberg have launched a new model centred around the ongoing improvement of patient outcomes. Value-based Healthcare (VBHC) intends to reorient the healthcare system, relating care costs to obtain a given outcome for the patient (Porter & Teisberg, 2006).

Research has exhibited that by correlating costs with outcomes across the various elements of the optimized patient care pathway, the VBHC determines the added value for the patient. By prioritizing value and focusing on results, it is possible to increase efficiency and quality of service, while reducing costs (Caleb Stowell & Akerman, 2015). According to the literature, in terms of the value added for the patient, i.e., faster recovery or lower costs, the model shifts its focus from the treatment itself to the outcomes that matter most to the patient in the healthcare process, in terms of capabilities and comfort (Teisberg et al., 2020).

In this way to implement VBHC, it is necessary to rigorously measure both costs and outcomes. This measurement should include the entire course of treatment for a specific medical condition, from diagnosis, treatment, and subsequent follow-up (Kaplan & Porter, 2011).

To obtain a better outcome measure, in addition to the clinical data collected by the hospital regarding patient outcomes, such as survival rates, treatment duration and complications, Patient-Reported Outcome Measurements (PROMS) are collected to provide valuable feedback to clinical, as well as an insight into the patient's perspective on their health status (Squitieri et al., 2017). PROMS include their ability to perform daily activities following the therapeutics, any discomfort experienced, and the durability of their recovery (Churruca et al., 2021). The function of abilities incorporates the ability to live independently or maintain the functional level and long-term consequences of therapy. Health status involves mortality rate, pain level achieved, functional level, ability to return to work, physical and psychological disorders during the treatment process (Cella et al., 2015).

The sustainability of recovery encompasses the patient's quality of life post-treatment, as well as their daily experience living with a chronic condition or long-term illness (Bele et al., 2019). The process of recovery also involves the time to begin treatment, return to physical activities, or time to return to work. It also includes the disutility of care, regarding diagnostic errors, ineffective care, discomfort, complications, delays, and anxiety (Cella et al., 2015). With a view to implementing VBHC, PROMS were collected from patients with lung cancer, and changes were subsequently applied to the process that allowed increasing the value of the patient's treatment chain (Bouazza et al., 2017).

The outcomes measurement in addition to being necessary to determine the value, needs to be standardized to obtain a solid and rigorous basis for comparison (Churruca et al., 2021). The criteria for outcome measurement can be defined by the hospital or the healthcare providers can resort to International Consortium for Health Outcomes Measurement (ICHOM) for the outcome set by a medical condition, and the best practices to outcome data collection and reporting (ICHOM, 2023).

Studies revealed that payment models stand as pivotal pillars within the realm of VBHC, wielding significant influence over how healthcare providers are remunerated for the delivery of care (Leao et al., 2023). Literature mentions that some payment models used nowadays are global capitation and fee-for-service, which incentivize cost containment or encourage healthcare professionals to amplify service volumes but do nott account for the value provided to the patient. Moreover, these reimbursement models lead to duplication, complex and inflated healthcare expenditures, limiting the flexibility of innovation, with new services and products (Wang et al., 2021).

Current research notes new reimbursement systems with bundled payments can incentivize providers to manage their costs more strictly and increase patient outcomes. The bundled payment covers the full care cycle for a specific medical condition or primary and preventive care for a defined patient population, linking the payment to the effective management of a patient's condition. Providers advantage from enhancing efficiency while preserving or improving outcomes (Navathe et al., 2021).

An example of a bundled payment applied in Sweden for hip and knee replacements, where 3.2% of the cost back and was paid only if the provider met the outcome goals, leading to added follow-up visits, education and earlier physical therapy, the decreased by 20% of complications and revisions, and the declined of 17% of the surgical procedure in 3 years (Mewara et al., 2023). These agreements impose financial accountability upon providers for the results achieved within the specified patient segment and medical condition, concurrently affording them greater autonomy in decision-making and the chance to partake in risk and reward arrangements (Mewara et al., 2023).

According to Kaplan and Porter (2011), the biggest problem in healthcare provision is that measurements have been taken for the wrong things and in the wrong manner. To calculate the costs for a given service, it is crucial to consider the level of organizational maturity to implement the costing method that best suits it and that allows an accurate cost measurement system.

Cost measurement is relevant to the complete cost measurement in the total cycle of treatment for a medical condition, including clinical and administrative human resources, medications, biomedical equipment, and facilities (Leusder et al., 2022). Several costing methodologies have been used to increase the value delivered in healthcare, including ABC.

2.2 Activity-based Costing Methodology

To correctly measure costs, hospitals need a practical and precise accounting system. The accounting system that is chosen depends on the maturity of the organization. Its implementation and continued optimization of costing methods, data collection, and systems must be balanced with the level of precision and cost measurement desired (International Federation of Accountants, 2013).

Due to the high costs of economic assessment, many health organizations still have a very rudimentary accounting system, the bare minimum of financial reporting requirements (Carroll & Lord, 2016). That said, the maturity of the accounting system is based on two primary principles. The first relates to the capacity of resources to produce outputs, products, services, and customers effectively reflecting the correlation between demand and supply. The second reflects the nature of the cost when resources are consumed. An accurate costing methodology allows us to understand how demand relates to supply, and how costs behave with consumer relationships and allows for better visualization, analysis, planning, and decision-making (World Health Organization, 2023).

Costing methods have two essential points:

- The degree of disaggregation, in which resources and cost components are measured: This can be micro-costing, where resources are very detailed cost centres (e.g., patient consumables), or macro-costing, where resources are viewed at a higher level of aggregation (e.g., energy costs) (Raftery, 2000).

- The method of evaluating resources and cost components: This can be top-down, in which overall expenses are distributed to a specific group of activity, or bottom-up, which first classifies the resources used by individual patients, and then evaluates, using unit costs to obtain the totals (Olsson, 2010).

Researchers mention that the most prevalent methods in healthcare studies are top-down micro-costing and top-down macro-costing. In the bottom-up approach, it is not possible to calculate all costs, as in general costs it is difficult to understand the amount spent by each patient (Špacírová et al., 2020).

In bottom-up costing, information on resources is gathered for every patient, whereas in the top-down costing method, data is collected at the level of the organization (Cunnama et al., 2016).

The Volume-based Costing (VBC), a top-down macro-costing approach, distribute indirect costs to cost objects (such as hospital services or units) using a single metric (such as working hours, prescriptions, or number of patients) (Špacírová et al., 2020). This is a popular and straightforward method to execute but produces unreliable results (Popesko et al., 2015).

The top-down approach calculates the mean expenses of a set of products and services in an organization over a given period (Mastrogianni et al., 2021). ABC, a top-down micro-costing method, accurately assigns indirect costs to final products based on the weight of resources used to obtain the products. Indirect costs are assigned to activity centres and then followed to cost objects by multiplying the rate of the activity driver by activity usage (Cooper & Kaplan, 1991).

ABC achieves a substantial enhancement in the precision of standard production, product, and service line costs by meticulously tracing both direct and indirect expenses to outputs, in accordance with the causality principle. This approach provides valuable insights into the actual cost practices, offering a clearer picture of cost realities (Alrashdan et al., 2012).

To implement the ABC method, two or more tasks or operations are defined for the specific cost centre or work centre, and accounting expenses are tracked directly to these work activities. Resource drivers, such as time, machine hours, or supplies, are used to allocate expenses to work activities. The added accuracy created with this method is primarily derived from the cost assignment consumption relationships (International Federation of Accountants, 2013).

In the ABC method, all activities or transactions that generate expenses are identified, and a particular cost driver is established for each activity. The cost activities are subsequently assigned to cost objects based on their corresponding cost driver. To calculate the total cost of each cost object, the total costs are first divided into direct and indirect costs (Cossio-Gil et al., 2022).

Direct expenses are the costs that a business directly bears in order to manufacture a product or offer a service, or to purchase a bulk product for the purpose of reselling it. An example of direct costs in hospitals includes medical supplies and equipment, laboratory tests, and surgical supplies. Indirect costs in hospitals include support expenses that are required to maintain the direct costs. For instance, expenses associated with technicians needed for equipment maintenance (such as diagnostic medical devices and patient beds), administrative and support staff, and utilities and facilities expenses (Azoulay et al., 2007). Overall, the ABC method offers an effective approach for hospitals to identify their costs with significant accuracy, which can lead to more informed financial decisions and efficient allocation of resources.

Based on Cao, Toyebe and Akasawa (2006), there are n indirect activities A_i (i=1,…n), that correspond to a total of cost X_i of activity A_i, and m cost objects O_j (j=1, …m). The indirect costs C_{ij} can be calculated by allocating a component of X_i to the object O_j based on the cost driver D_i. In this context, each activity corresponds to a cost driver. The complete amount of cost driver D_{ii_s} partitioned into a sub-volume for each cost object, d_{ij}.

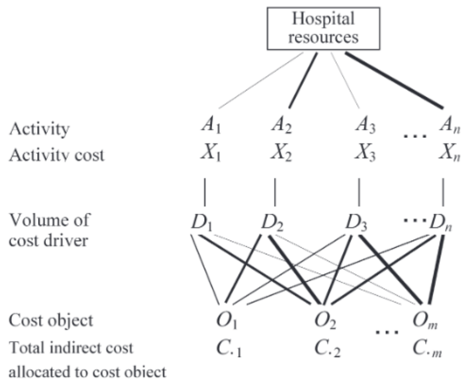

Figure 2.1: ABC Cost Accounting Method (Cao et al., 2006)

The indirect cost to be allocated to O_j from X_j, C_{ij}, is obtained the next equation:

$$C_ij = X_i * \frac{d_{ij}}{D_i} \tag{2.1}$$

And the total indirect cost $C_{(.}j)$, allocated to O_j, is:

$$C_{(.}j) = \sum_{i=1}^{n} C_{ij} \tag{2.2}$$

An example similar to the one given by Cao, Toyebe and Akasawa (2006), is to calculate an indirect cost of the medication administration unit O_j in the nursing department. It is assigned the activity "medications administration" A_1 and the driver "the number of medications administered" D_1. The, d_1j, which is part of D_1, is the number of medications administered by the nursing department.

The application of ABC cost accounting method has been providing a more precise understanding of the consumption of indirect and shared expenses and helps to identify activities that enhance the value of the end product or service (International Federation of Accountants, 2013).

2.2.1 VBHC and ABC in Healthcare

Value-based Healthcare (VBHC) has been increasingly applied in different specialities and procedures within the healthcare industry, resulting in improvements in efficiency and market competitiveness. Additionally, they uphold the ethical principle of utilizing healthcare resources in a responsible manner (Porter & Lee, 2013).

This model has been applied to various health conditions, such as heart failure, with a focus on illness and disease management and prevention (Joynt Maddox et al., 2020). In Switzerland, VBHC was studied in the treatment of sarcoma patients to improve the quality of patient care and services, as well as reduce costs and increase transparency for stakeholders.

A study conducted on hip joint replacement surgery in cases of osteoarthritis exemplifies the use of VBHC principles to calculate the added value in various treatments and costs, ultimately leading to an increase in the quality of healthcare (Gabriel et al., 2019).

Moreover, VBHC was applied in chronic disease management, with a study in diabetes showing its usefulness in monitoring glucose levels and providing a patient-centred approach (Wickramasinghe et al., 2019).

In the field of oncology, value-based healthcare has been applied to the treatment of breast cancer and lung cancer. In breast cancer treatment, the collection of PROMS was crucial in implementing the value-based approach. This method resulted in better treatment outcomes compared to routine clinical care (Van Egdom et al., 2019).

Despite its complexity in implementation, the ABC methodology has also been tested in the field of health, specifically in the area of radiotherapy. A study was conducted to evaluate the costs and found that the majority of expenses are attributed to human resources and equipment, with treatments being the primary consumption of costs. The ABC method has been deemed practical to implement, providing an effective way to examine the cost structure of the department and make necessary modifications (Lievens et al., 2003).

In Turkey, a study was conducted using the ABC costing methodology. This study aimed to enhance financial planning, improve the quality of pathology examinations, and enhance cost control (Yarikkaya et al., 2016).

In Kashani Hospital, a cross-sectional study was conducted utilizing the ABC method to determine the unit costs of medical services, the cost price of occupancy beds per day, and the cost per outpatient service. The ABC method demonstrated more precise data regarding the primary cost components, offering a valuable accounting system that grants genuine insight into the organizational costs of their department (Javid et al., 2015).

A study employing the ABC method to assess the costs associated with Schizophrenia has uncovered the total annual cost per patient and drawn conclusions regarding the factors contributing to cost escalation. The use of ABC has proven to be an effective approach for estimating costs compared to prevalence-based methods (Latorre et al., 2021).

An economic evaluation was conducted in the COVID-19 dedicated Intensive Care Unit (ICU), utilizing the ABC method. The findings revealed that the most significant factor contributing to direct costs was human resources, and the ICU experienced substantial losses during the COVID-19 pandemic. This study underscores the importance of hospital economic analysis and cost assessment as essential measures to mitigate costs, enhance productivity, and improve resource management (Rahimi et al., 2023).

A study examining the costs associated with testing in a clinical chemistry laboratory, utilizing ABC, has revealed that high-volume and automated tests have lower unit costs. This study concludes that ABC offers valuable insights for identifying tests with high average costs, thereby enabling optimization measures (Declerck et al., 2021).

Outcomes and ABC cost analysis have exhibited in robotic lung resection programs that total direct costs, including direct supply costs, median total operating costs, and total unit support costs, are closely correlated with the length of stay. This correlation suggests that process changes can lead to cost reductions while improving outcomes.(Coyan et al., 2022).

In Portugal, both traditional ABC and Time-driven Activity-based Costing (TDABC) methods have been employed in healthcare (Borges et al., 2010). A noteworthy example of TDABC, a simplified version of ABC, the application was the cost analysis of pharmaceutical services in community pharmacies. The findings revealed that TDABC was a powerful tool for identifying the costs of various activities linked to pharmaceutical services, such as medication dispensing, counselling, and communication with healthcare professionals. The research also indicated that a significant amount of time was spent on non-value-added activities, such as waiting times, which could be minimized through process improvements (Gregório et al., 2016).

In summary, the VBHC method and its application through ABC as a costing methodology have improved efficiency, productivity, and quality of patient care, and helped identify cost drivers and waste areas in healthcare delivery. They have also allowed for a more accurate measurement of costs and a patient-centred approach to healthcare.

2.3 Pediatric Otorhinolaryngology Surgery

Otorhinolaryngology is a medical speciality dedicated to the diagnosis and treatment of disorders affecting the ears (oto), nose (rhino), and throat (larynx) systems. This speciality encompasses evaluations of pediatric patients from newborns to, but not including, 18 years of age, as well a range of pathologies and procedures (Arnold Coran et al., 2002).

Among the numerous pathologies, the most frequent in pediatric patients include deafness, sleep problems, tonsillitis and recurrent otitis, hoarseness, and nasal obstruction (Teisberg et al., 2020). Deafness, induced by issues of the nasal and tonsils, is often the cause of difficulties in linguistic development, social interaction, environment engagement, and learning difficulties (Fernandes, 2021). Sleep disorders can range from simple snoring, typically caused by adenotonsillar hypertrophy (from adenoids and tonsils), to insomnia and sleep apnea, seen in up to 34.5% of children (Z. Geiger, 2023).

In children, the most frequent infectious pathology includes recurrent tonsillitis, affecting up to 15% to 30% of children every year (Stelter, 2014), and otitis media, with a prevalence of 80% in children (Danishyar & Ashurst, 2023), and which can have adverse effects on hearing and result in repeated doses of antibiotics and school absenteeism.

Hoarseness (dysphonia) is another problem that can affect children and young people and may be associated with vocal effort and changes in the vocal cords. Nasal obstruction, a common condition in children, can cause breathing difficulties and result in mouth breathing, which in some cases can lead to dental problems and facial malformations (Fernandes, 2021).

The most common surgical procedures in pediatric otorhinolaryngology include tonsillectomy (removal of tonsils), adenoidectomy (removal of adenoids), myringotomy (relief of pressure in the middle ear), septoplasty (straightening of the nasal septum), tympanoplasty (repair of eardrum holes), ossiculoplasty (reconstruction of the middle ear's ossicular chain), and mastoidectomy (removal of infections and growths in the mastoid bone) (Northwest Surgery Center, 2023).

These procedures are performed to address various conditions such as chronic or severe tonsillitis, hypertrophied adenoids, fluid accumulation in the middle ear, nasal breathing difficulties, eardrum holes, conductive hearing loss, and infections or growths in the mastoid bone (Clinic, 2022; WMCHealth, 2020).

According to the *Clinical Practice Guideline* (Rosenfeld et al., 2022), the surgeon or physician should examine the ears of a child within 90 days of the tympanostomy tube insertion and should obtain hearing evaluation if OME persists for 3 months longer or prior to the surgery. Children should also be reevaluated at 3 to 6 months intervals, with chronic OME, significant hearing loss or structural abnormalities of the tympanic membrane or middle ear are suspected.

The guideline also suggests that the surgeon examine the ears of the child within 3 months after the tube insertion to assess outcomes. After the tube extrusion (6-12 months), the guideline advises an additional follow-up appointment with an otorhinolaryngologist to ensure the ear's health and hearing function. Additionally, the most common sequela of tympanostomy tubes is otorrhea, observed in 16% of children within 4 weeks after surgery (Rosenfeld et al., 2022).

Chapter 3

Methodology

The implementation of an activity-based costing methodology within the context of VBHC in pediatric otorhinolaryngology surgery entails a series of steps. This chapter demonstrates the methodology applied based on a healthcare value model and the ABC costing methodology. The methodology begins with the collection and processing of data, the definition of the clinical path and the application of the costing methodology. After obtaining the results, the data underwent analysis, conclusions were drawn, and they were discussed with the hospital otorhinolaryngology peadriatic surgeon.

3.1 Subject

3.1.1 Healthcare Corporate Group and Hospital

The Corporate group was established in 2000 in the Portuguese healthcare market. The group provides its services through 29 units, including 14 private hospitals, 14 private clinics operating on an outpatient basis, and one senior residence.

In the realm of research, the Corporate Group has a Learning Department that aims to cultivate and do research efforts conducted within the Group. The study undertaken within the scope of this dissertation corresponds to a clinical study facilitated by the Hospital Learning Department and the Value-based Healthcare Department, duly approved by the Hospital's ethics committee.

The Hospital included in the study offers a comprehensive range of medical and surgical services. Services include extensive outpatient consultations in various medical and surgical specialities, clinical laboratory analyses, and medical imaging examinations.

It encompasses an Operating Unit designed for highly specialized surgeries. Inpatient care is distributed across units for acute care, intensive care, intermediate care, and a unit for continuous and palliative care. Urgent Care services are available for adults, paediatrics, and gynaecology-obstetrics.

Annually, the hospital attends to approximately one million individuals, conducting around 2.5 million consultations and urgent appointments, over 60,000 surgeries and deliveries, and 1.2 million diagnostic imaging examinations. The hospital is known for its stringent standards in hospital quality and safety, having been accredited by the Joint Commission International since 2018.

In the area of otorhinolaryngology (ENT), the Hospital comprises a team of 26 physicians. In terms of consultations, it offers a wide range of types, including ENT, ENT with swallowing; sleeping sickness; smell and taste; head and neck oncology; deafness screening; voice; vertigo and balance disorders. The medical exams available are acuphenometry, prosthetic audiogram, simple tone audiogram, vocal audiogram, high-frequency audiometry, pure tone audiometry - up to 5/8/10 years old, preschool assessment of vision and hearing, decay test, nasal endoscopy, otologic endoscopy, otoscopy, laryngeal stroboscopy, tympanometric study of the functioning of the eustachian tube, phonetogram glottography, impedance and admittance, laryngeal endoscopy, rehabilitative manoeuvres in vertigo and otoacoustic emissions.

The ENT service encompasses various areas of activity, including surgeries with CO2 Laser, procedures involving the mouth, pharynx, head, neck, and salivary glands, as well as laryngeal, endoscopic, computer-guided, nasal and sinus, otological, and radiofrequency surgeries. Additionally, the service covers diagnosis and treatment of balance disorders, phonology therapy, and ENT microsurgery. On average, the hospital performs 350 surgeries each year in the speciality of otorhinolaryngology.

3.2 Origin of the data

The Hospital has an electronic health record (established in 2007), and its database has been meticulously restored to a non-probabilistic convenience sample, to include data from 2020, 2021, and 2022, specifically focusing on the departments within the Lisbon Unit.

It included date from assistance areas encompassing a wide range of medical services, including emergency care, external consultations, otorhinolaryngology complementary diagnostic and treatment methods (CDTM), clinical pathology, hospitalization, otorhinolaryngology medical imaging, and surgery.

A cost matrix with direct and indirect costs associated with each cost object was also provided (Figure A.5). Due to the sensitivity inherent in the cost data, the information regarding costs presented in the graphics and the cost matrix has been suppressed. This precautionary measure, required by the private Hospital, is implemented to preserve the confidentiality of the information while maintaining the relationship between the data. This ensures the ability to draw consistent conclusions and perform a reliable analysis.

3.3 Data Treatment

The collected information in each of the existing areas, is presented in detail the information in Tables A.1, A.2, A.3. The data provides a comprehensive overview of each department's activities and patient records.

However, it is important to note that patients with and above the age of 18 from the department's databases were excluded from the sample. This selection criterion was implemented to align the thesis's primary focus, which centres exclusively on surgical procedures within the paediatric age group.

The first selection of patients was done through the Surgery file, excluding all surgeries that are not part of the ENT speciality. Subsequently, the patients were included in each surgery procedure category, regardless of the surgery method performed.

720 patients were collected from the provided file, and they were sought and identified in the remaining department's files. Out of these 720 patients, 27 underwent two or three surgeries for clinical reasons during the three years of analysis. Since each clinical path is supposed to include only one surgery, 748 different clinical paths were defined for analysis.

The cost matrix provided presented the cost objects in each of the assistance areas (example in Figure A.5). For each of the items, it provides a breakdown of the number of individual elements, consumable expenses, medication costs, professional fees, both direct and indirect personnel expenditures, maintenance expenses, laboratory charges, and other costs. Consumable expenses encompass the material resources utilized in a procedure, while medication costs pertain to the drugs administered to the patient. Regarding professional fees, these are attributed to healthcare practitioners (such as doctors, surgeons, and anaesthetists, among others) participating in the activity; however, nursing services are excluded from this consideration. The nursing services detailed have a nominal cost, as the nurses operate under a predetermined employment agreement, which is not contingent on the tasks performed. The quantity and corresponding costs have been normalized in the cost matrix.

Direct personnel costs are linked to professionals involved in the execution of the clinical procedure. Indirect personnel costs are associated with human resources indirectly engaged in clinical procedures, including individuals responsible for facility cleanliness, administrative tasks, patient assistance, and similar functions. Maintenance expenses account for the costs incurred to uphold the condition of spaces, machinery, and instruments used in the outlined clinical procedures. The remaining costs represent various costs that could not be allocated to any specific category.

3.4 Activity Cost Pathway Methodology

The first step in measuring costs according to a value-based healthcare methodology is to identify the key activities performed throughout the patient's treatment that can contribute value to the care cycle. This initial stage enables the establishment of crucial phases in the cycle for result measurement and process mapping, as referenced in previous studies (Cossio-Gil et al., 2022; Kaplan & Porter, 2011). The selection of these activities was determined by applying specific criteria, drawing from insights found in the guidelines, information provided by a surgeon from the Hospital, and data collected from the Hospital Information Systems (HIS).

The criteria for the activities were as follows: a diagnosis and follow-up period applied before and after all types of surgeries, extending to 40 days an event in every area; 200 days when it pertains to an otorhinolaryngology event or is requested by or for otorhinolaryngology; and 365 days when it involves otorhinolaryngology exams, CDTM, and imaging, whether before or after the surgery.

Starting with Emergency Care, a meticulous selection process was undertaken to curate episodes within the speciality of otorhinolaryngology and paediatrics.

As stated in the guidelines, the clinicians should evaluate the increased risk of developmental difficulties, for example, speech, language or learning problems from otitis media (Rosenfeld et al., 2022). So a comprehensive approach was employed for external consultations, encompassing pediatric, developmental paediatrics, immunoalergology, clinical psychology, speech therapy and neuro-pediatric and otorhinolaryngology.

In terms of otorhinolaryngology CDTM and Imagiology exams were included from one year before and to one year after surgery.

Regarding hospitalizations, the initial focus was placed on selecting solely surgical admissions. Subsequently, non-surgical hospitalizations with a following episode in otorhinolaryngology speciality or 40 days before or after the surgery.

For clinical pathology, specific indications of the episode were selected for each patient, focusing on clinical pathology, immunology, and clinical chemistry. This selection was made for all services that requested an episode. However, haematology exams and COVID-19 tests were excluded from the analysis.

To facilitate the pathway analysis, the following information was extracted: the episode number, date of the episode, requested service for the episode, speciality of the procedure, and, in the case of surgeries, medical imaging and CDTM, the descriptions of the related medical procedures (Figure A.4). This data retrieval process enables a comprehensive examination of the patient pathway and facilitates a thorough analysis of the healthcare journey.

Regarding the clinical pathway, the episodes were grouped into three groups: in diagnosis, before the date of surgery; surgery, on the day of surgery; and follow-up, after the surgery date. Concerning the 28 patients with more than 1 surgery within the space of

3 years, each surgery was divided into different pathways. For this, the same limits presented above were applied. In case of overlapping, because the surgery was very close to the previous one, it was considered a follow-up from the first surgery 40 days after surgery and 40 days after diagnosis for the second surgery.

The episodes were then sorted by patient identifier Patient Identification Number (NHC) and in chronological order, from oldest to most recent. Next, the episode identifier number was sorted in ascending order, and in cases where it was the same, hospitalization was considered to occur after surgery, while emergency care took place before both surgery and hospitalization.

3.4.1 Pathway Process Mining Visualization

In order to apply the costing methodology, it was necessary to define, based on the value chain, the patient clinical pathway. An activity cost pathway, defined as a clinical pathway, is described as a management care methodology, that defines the overall structure of decision-making for treating a specific medical condition of a group of patients during a well-defined period of time (Elbattah et al., 2018).

The clinical pathway will allow a more precise cost analysis, as well as an evaluation of risk care outcomes, increase patient satisfaction and optimize resources (Elbattah et al., 2018). The clinical pathway starts with the gathering of data and organizing important and relevant information for the case study. The data from the hospital healthcare systems of information gatherers the information according to the patient's number and then an episode number is generated according to the several entries in the HIS by the staff, giving the possibility to track the sequence of activities executed, when they were performed, by whom and for whom (Munoz-Gama et al., 2022).

For the purpose of better visualization of the pathway, it was used process mining techniques to analyze the clinical pathway (Munoz-Gama et al., 2022). According to International Business Machines Corporation (IBM), process mining applies data science, combining data mining and process analytics, in order to create a process model through data, or process graphs ("IBM Process Mining", 2023; Munoz-Gama et al., 2022).

In order to streamline the pragmatic deployment of process mining, an array of sophisticated software tools has been meticulously crafted. Among these tools, commercial solutions like Disco stand out for their capacity to adeptly handle voluminous event logs and intricate models, rendering the tasks of conversion and filtering decidedly effortless. Notably, this software furnishes a comprehensive presentation of performance metrics in a lucid and straightforward manner. Furthermore, it empowers the visualization of historical progress through dynamic animations seamlessly superimposed onto the model's framework (Fluxicon, 2023).

For this, each patient pathway includes the patient identification NHC (*Case_ID*), the activities that each patient executes are identified as *Number_of_Episode* (*Activity*) and are associated with the date that they were performed (*Timestamp*). Each activity was associated also to the person, physician/surgeon or other, that carried the activity (*STAFF_ID*) (Munoz-Gama et al., 2022).

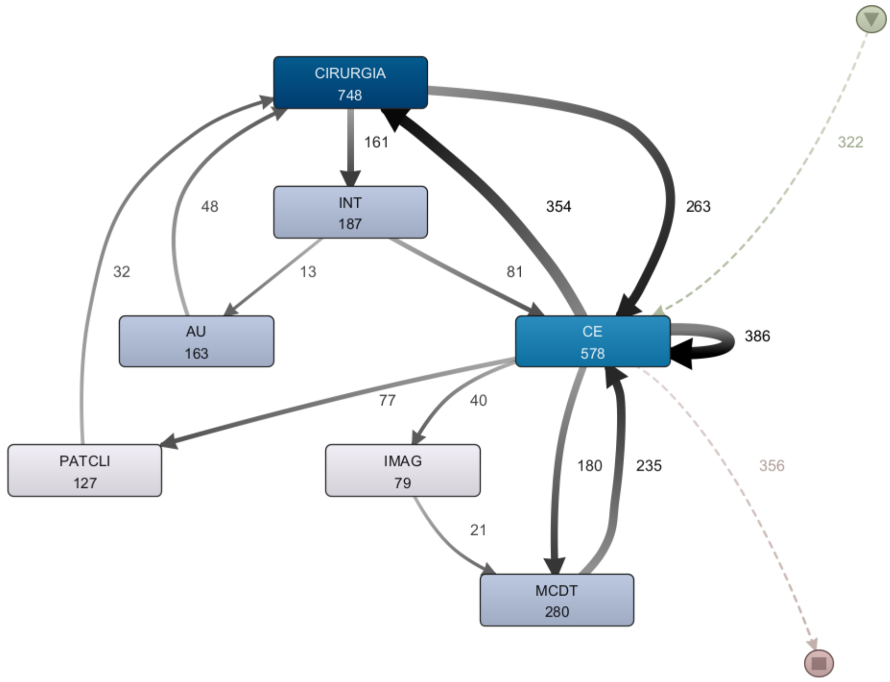

Figure 3.1: Activity cost pathway visualization using process mining (*DISCO*)

Using the *DISCO* application, it quickly and easily visualizes the activity cost pathway (Figure 3.1), but also gathers information about various aspects of care areas, such as the percentage of case coverage (Figure A.8), the number of patients who start and finish the path in each area, and the maximum number of repetitions.

Furthermore, *DISCO* allows for the analysis of activity frequencies and performance between each of the activities on the path, including total, average, median, maximum, and minimum durations between events (Figure A.7). Simultaneously, it is possible to individually monitor the clinical pathways followed by patients (Figure A.9).

3.5 ABC - Costing Methodology

After acquiring the complete patient pathway, the cost engineering model known as Activity-Based Costing was applied to calculate the cost of the value chain.

Through the clinical pathway, the activities relevant to each of the clinical pathways were obtained. These activities are identified by the *Episode Number (EN)*. With EN, cost objects were removed from each of the existential areas, that is, all the acts performed associated with the activity.

These cost objects were identified with a *Article_Act_Code* associated with the cost matrix (Figure A.5). The cost matrix displays the hospital expenses associated with performing the aforementioned procedures. Therefore, the cost driver is the billing for procedures performed on the patient. Thus, for each cost object, the cost was calculated by multiplying the number of objects realized by the cost driver. For every single cost object, it was acquired the cost of consumables, drugs, fees, direct and indirect personnel costs, maintenance costs and other costs.

By adding the consumables, drugs, fees, direct personnel, and maintenance costs we obtained the direct cost for each of the objects, and by adding the indirect personnel and other costs, it resulted in the indirect costs.

The cost matrix presents the allocation of indirect costs in a manner determined by the Hospital, employing a ratio that considers the direct costs billed for each respective act or department. It is important to acknowledge that this methodology, while useful, may potentially lead to a variance in the distribution of overhead costs, resulting in either overestimated or underestimated indirect costs depending on the circumstances (Azoulay et al., 2007). For these reasons, indirect costs will not be included in the cost of the clinical path, as they do not represent a real and reliable estimate of the indirect costs associated with each activity, using only the direct costs.

Also, indirect costs are associated with overhead areas, such as administration, housekeeping, and other similar (Azoulay et al., 2007). Although the calculation of indirect costs is relevant to the reduction of the general costs of medical treatment, estimating the losses that result from work loss, work replacement, and low productivity, all aspects regarding the efficiency of processes and not with the medical results obtained with the treatment and care provided (Boccuzzi, 2003).

The direct cost of the objects was added for each of the activities through the *Episode_ Number*. Thus, it was possible to add up the direct costs of the activities for every care area of each of the patients by adding the direct cost of each NHC (Figure A.6).

3.6 Surgeons's Activity Pathway Validation

Following the applied methodology and analysis of the results, in alignment with the methodology inherent to value-based healthcare (Gabriel et al., 2019), a meeting was conducted with a pediatric otorhinolaryngology surgeon. The purpose of this meeting was to evaluate the validity of the data and results obtained and to explore the relationship between the cost activity pathway and the clinical practices.

Chapter 4

Results

The application of the presented methodology encompasses a series of significant discoveries. This chapter reveals the results achieved through the implementation of the ABC methodology within a value-based healthcare model. The outcome analysis begins with an examination of the data obtained from the activity pathway, followed by an analysis of the cost of care areas, the patient's journey, and surgical procedures.

4.1 Activity Cost Pathway

According to the rules applied to the data regarding the patient's pathway, 720 patients were identified. Considering that each clinical path will have only one surgery, 748 activity paths were defined for analysis.

Table 4.1: Surgeries combinations performed in ENT pedriatic

Surgery Combinations	Percentage of Surgery
Adenoidectomy + Myringotomy	26.1%
Adenoidectomy + Tonsillectomy	17.3%
Adenoidectomy + Tonsillectomy + Miringotmy	14.4%
Tonsillectomy	6.9%
Foreign Body Extraction	6.4%
Myringotomy	3.9%
Tympanoplasty	2.5%
Adenoidectomy	2.4%
Tympanomastoidectomy	2.0%
Tonsillectomy + Myringotomy	1.6%

In terms of types of surgery, the most performed during the three years were adenoidectomy with 34.5%, myringotomy with 24.9% and tonsillectomy with 22.8% (Table B.1). The surgeries performed sometimes involve a combination of surgery types (Table B.1), resulting in a total of 58 different combinations. Regarding the most common combinations performed by the surgeons, they include combined adenoidectomy with myringotomy, observed in 26.1% of patients, as well as adenoidectomy and tonsillectomy, seen in 17.3% of cases, and adenoidectomy with tonsillectomy and myringotomy, accounting for 14.4% (Table 4.1).

Considering the external consultations in the three years, 1934 were carried out, 59% for diagnosis and 41% for follow-up. Representing 77.3% of patients with an outpatient consultation, with 75% of the patients having consultations in the otorhinolaryngology speciality. Out of the total number of patients, 70% have at least one consultation event during the diagnosis phase, and 59% do so during the follow-up phase (Table B.2). It was observed, considering only patients with outpatient consultations, that on average each patient has 4 consultations, namely an average of 2 for diagnosis and 2 for follow-up (Table B.3).

In the case of emergency care, approximately 21.8% of patients present at least one episode, with 13.5% of patients resorting to emergencies in the pre-surgery phase, 10.9% in the post-surgery phase, and 1.3% on the day of surgery. In post-surgery, about 8% of patients resort to the emergency room in less than 30 days after surgery, a period identified as a period of complications associated with the operation (Table B.4).

Hospitalization included both non-surgical and surgical hospitalization, where 25% of patients had at least one episode. About 24.3% of the patients had post-surgery hospitalization, which means that the remaining 75.7% of the surgeries were performed in an ambulatory surgery (Table B.5).

When evaluating the surgery schedules, it was observed that the largest number of surgeries were performed between 8:00 and 12:00, around 80.2% (Table B.6). Through Table B.6, it is observed that the percentage of hospitalization increases throughout the day, starting with 12% of hospitalizations in the morning (8h-12h), 42% in the late afternoon (16h-20h) and 57% at night (20h-00h).

In Table B.2, it is possible to observe the surgeries and the percentage of surgical hospitalization and outpatient surgeries. Regarding the most performed surgeries in adenoidectomy 83% of the cases are performed in ambulatory, in myringotomy with 97% and tonsillectomy with 63%. In the remaining surgeries most practised, which are combinations of those presented previously, the percentage of outpatients remains above 65%, this being 95% in adenoidectomy with myringotomy, 83% in adenoidectomy and tonsillectomy, 75% in tonsillectomy and myringotomy, and 69% in adenoidectomy with tonsillectomy and myringotomy (Table B.2).

Considering clinical pathology, 17% of patients have at least one episode in this area. Since 15.2% of patients are in the diagnosis phase, 1.2% in follow-up and 0.9% in surgery (Table B.7).

Regarding Imagiology, 10.6% of patients have imaging exams, namely 9.9% in the diagnostic phase and 0.7% in the post-surgery phase (Table B.8). A range of imaging procedures was identified, including thyroid biopsy, orthopantomography, cranial morphological examination, eco complementary study, ultrasound soft tissues, Magnetic Resonance Imaging (MRI) spectroscopy, MRI study, MRI orbit, MRI ears, Cavum x-ray, in transportable X-rays, chest X-rays, Computed Tomography (CT) contrast, CT Sinuses, CT skull, CT face, CT larynx, CT ears, CT neck, CT spn low dose, and CT chest. The most frequent imagiology exams are the cavum x-ray, with about 37% of the imaging exams performed, sinus CT with 15%, 10% of chest x-ray and 6% neck CT (Table B.9).

As for otorhinolaryngology CDTM, 37.4% had episodes, 30.2% were in the diagnostic phase, and 15.2% were in follow-up. Of these, 8.7% underwent diagnostic and follow-up tests (Table B.10). The average number of exams per patient in diagnosis is 2 and in follow-up surgery 2 exams (Table B.11). In CDTM it was identified the following exams: pure tone audiogram, protein audiogram, vocal audiogram, pure tone audiometry, oropharyngeal biopsy, impedance study, tympanometric study, microlaryngoscopy, otoemissions, auditory EV potentials, central processing hearing, rhinoscopy, speech therapy, tympanogram, polygraphic Record of Night Sleep. The exam with the highest percentage of performance is the tonal audiometry with 33%, followed by the impedance study with 27.6%, and the tympanogram with 21.2% (Table B.12).

Through the Disco Platform, it was obtained that about 34.4% of the patients start their journey in surgery, without presenting any diagnostic activity at Lisbon Hospital. About 43.0% start with an outpatient consultation, 8.6% with CDTM and 7.1% with urgent care. In the post-surgery phase, identified as follow-up, about 32.6% of patients do not have any post-surgery episodes. 47.6% of patients end up with an outpatient visit and 8.2% with an inpatient appointment (Table B.13).

Using the Disco application, we could calculate the percentage of case coverage for each of the care areas (Table B.14) and identify the various clinical paths followed by patients. There is a notable lack of uniformity in clinical paths, as evident in the table where the top 10 of 436 paths with the highest completion percentages only account for approximately 32% of the clinical paths (Table B.15). The same analysis was conducted for a set of three surgeries adenoidectomy, tonsillectomy, and myringotomy, and in 15 of 328 clinical paths, they account for roughly 38% of the cases (Table B.16).

4.2 Activity-based Costing

4.2.1 Assistance Areas Cost Distribution

Applying the ABC costing method, a meticulous examination of cost allocation within each distinct care sector was undertaken. It is possible to obtain, with the ABC method, the decomposition of the costs of each elementary costing object.

In the context of emergency medical services, it is noteworthy that the preponderance of costs can be traced back to personnel engagement, accounting for 92.9% of the aggregate expenses. Specifically, a significant portion of these personnel-related costs, amounting to 88.9% is linked to pediatric Permanent Care. In parallel, concerning the allocation of resources, the cost allocated to pharmaceuticals and consumables is quantified at 7.0% (Figure C.2).

Within the outpatient consultations, a large proportion of costs falls on medical personnel, constituting a substantial 99.9% of the total cost, as the central part is the consultation itself. This distribution encompasses 83.1% for specialized otorhinolaryngology consultations and 3.6% for paediatric consultations. Remarkably, even though its proportional weight is a mere 0.1%, the maintenance cost is directed towards the preservation of the healthcare personnel office (Figure C.3).

Within the delineated spectrum of cost objects within the domain of hospitalization, a substantial proportion of 22.9% of direct costs correspond to resources, namely, 5.9% to consumables, 4% to laboratory and 11.7% to medication. In the case of personnel, 43.8% are direct costs associated with surgical hospital stay and 14.3% with intensive care unit daily (Figure C.4). It should be noted that only 11.3% of hospitalization cases correspond to intensive care. Although the percentage of occurrence is low, it should be noted that intensive care has a very high direct cost.

In the assistance area of imaging, the cost object with the highest percentage of direct cost corresponds to personnel with 88.3%, specifically with fees for CT sinuses (19.6%), CT Neck (8.7%), CT Ears (6.2%). About 24.4% of the costs are applied to direct personnel and 11.7% to resources, with 10.6% of these corresponding to the maintenance of the instruments/machines used for the exams (Figure C.5).

When looking at the direct costs related to CDTM, 97.1% correspond to medical personnel, with 15.6% of direct personnel. As for the tests performed, the direct costs in fees are distributed with 42.1% in pure tone and vocal audiometry, 13.7% in impedance study, 8.7% in tympanogram and 7.8% in auditory potentials. The remaining 2.9% is allocated to consumables, medication and maintenance (Figure C.6).

In clinical pathology, costs are mostly found in laboratory tests (87.3%), specifically, 13.2% in hemogram platelets, 6.0% in D-dimers and 4.3% in C-Reactive Protein (Pcr). About 12.7% of the direct costs of clinical pathology are allocated to direct human resources (Figure C.7).

In the operating room, costs are mostly allocated to health professionals who perform the surgical procedure, namely the surgeon fees with 29.5% of costs, assistant surgeons with 20.8%, anesthesiologists with 15.9% and instrumentalists with 10.1%. Although surgical procedures involve the use of various resources, from surgical instruments to anaesthesia, resources represent only 16.3% of the total direct cost of surgery, with 11.7% referring to consumables and 3.2% to medications (Table 4.2 and Figure C.8).

Table 4.2: Surgery Objects of Cost and Cost Distribution

Surgery Object of Cost	Percentage of Total Direct Cost
Resources	16.3%
Consumables	11.7%
Medicines	3.2%
Other (maintenance and laboratory)	1.4%
Personnel	83.7%
Surgeon Fee	29.5%
Helper Fee	20.8%
Anesthesiologist Fee	15.9%
Instrumentalist Fee	10.1%
Direct Human Resources	7.4%

It is possible to derive not only the cost distribution for each of the care areas from ABC, but also to analyze the resources used and their associated costs for each of the activities conducted. Given that the surgery constitutes the largest percentage of the overall activity pathway cost, we also examined the expenses related to consumables and medications utilized during surgical procedures (respectively Table C.9 and Table C.10).

Regarding consumables, the most substantial cost contribution arises from cochlear implants, accounting for 26.9% of consumables expenses, despite being utilized in only 0.1% of the surgeries performed over the three-year study period. Other resources with a significant cost percentage include ventilation tubes, turbinate probes, tonsillectomy and celon tips, and surgical gowns (Table C.9).

When considering the pharmacy used, it is noteworthy that 23.1% corresponds to sevoflurane, a volatile anesthetic, which was employed 649 times. This demonstrates that despite accounting for a significant percentage of the cost, it is utilized in 87% of the surgeries conducted (Table C.10).

When analyzing the cost distribution among the total activity path's cost objects, 84.2% of the costs are attributed to personnel, 3.3% to pharmaceuticals, 10.7% to consumables, with the remaining 1.8% allocated to laboratory tests and maintenance (respectively Figure C.1,C.2, C.3).

4.2.2 Activity Pathway and Surgery Cost Analysis

To evaluate direct costs, *Box and Whisker* charts were created for observation and analysis of results. These graphs allow obtaining the distribution of a continuous variable, with information on quartiles, median, identification of outliers, mean and standard deviation (Figure I.1). It also allows observing the spread and skewness of the data sample, the symmetry, and the length of the distribution (Kotu & Deshpande, 2019).

The graph is divided into quartiles, where the box corresponds to the interquartile range, where 50% of the data is found. The horizontal line that splits the box in two is the median, and the mean is also indicated by a cross on the box plot. The whiskers are the two lines outside the box, that go from the minimum to the lower quartile (the start of the box) and then from the upper quartile (the end of the box) to the maximum (Kotu & Deshpande, 2019).

Figure 4.1 shows the direct cost of the total number of complete activity cost pathways. It is possible to confirm that the distribution is slightly skewed to the left and that the first quartile is smaller than the last quartile. The existence of outliers after the maximum can be explained by some expensive procedures, such as cochlear implants, or because the payment is made at private prices, that is, without health insurance or Assistance in Sickness to Civil Servants of the Portuguese State (ADSE).

Through Figure 4.1 it is possible to see that the median cost presented by a line and that the average is slightly higher presented as a cross.

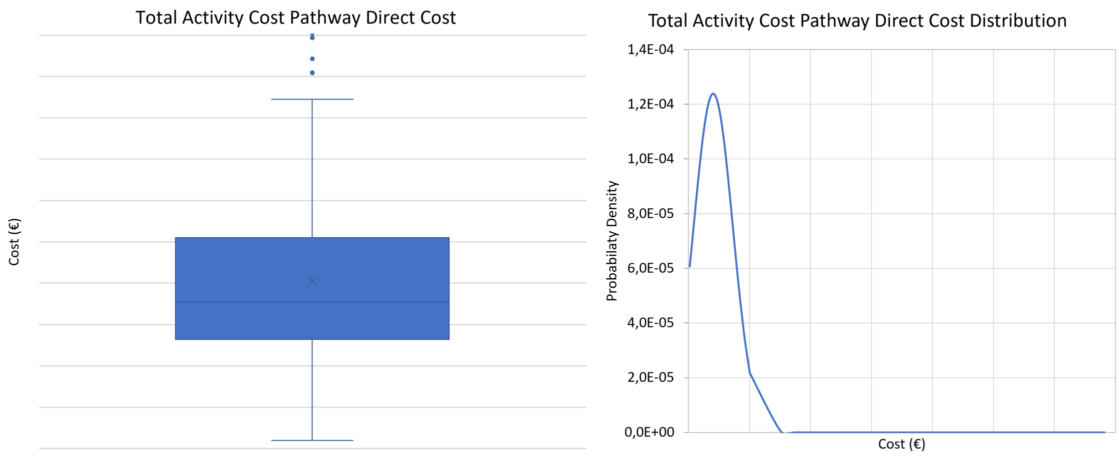

Figure 4.1: Activity cost pathway direct cost distribution graphic

Through the direct cost distribution graphic and the direct costs histogram (Figure 4.1 and Figure C.11), it is possible to observe in more detail the cost variation. Combining the two graphs, it is possible to demonstrate that the highest proportion of costs is found within the interquartile range - equivalent to 50% of the total costs. Additionally, two other significant sets of costs can be observed in the upper and lower whisker, just before the first quartile and just after the third quartile.

In order to study the population of patients, through Figure C.12 it is possible to observe the age distribution of the patients, where 67% of the patients are between 1 and 5 years old. With the aim of studying whether age could influence the cost of the activity pathway, with Figure C.13 it is possible to verify that despite slight variations in the median and the slight increase in the average at 5 years of age, the total cost is very uniform. The margins of the 1st and the fourth quartile are within the same values.

With the aim of enhancing comprehension regarding the genesis of costs and the identified fluctuations, a box and whiskers graphic of the direct cost was created for the total activity cost pathway for the procedures with the highest percentage of completion (Table 4.1). Using Graphic C.14, It is possible to observe that the mean and median increase with the number of procedures performed. For simple procedures with lower costs, myringotomy comes first, followed by tonsillectomy, and then adenoidectomy, in ascending order. When combining two surgeries, there is an approximate 24% increase in the cost for the surgeries adenoidectomy with tonsillectomy and tonsillectomy with myringotomy, and an approximate increase of 46% for the surgery of adenoidectomy with myringotomy. For the procedure that combines all three types of surgery, the mean deviates more from the others, increasing by 69% from the single-procedure surgeries and between 13-36% for the double-procedure surgeries (Figure C.14).

Foreign body extraction has a low mean and high compliance cost when compared to the total cost of all activity pathways. It is followed by the surgeries of septoplasty and turbinectomy with an increasing average, followed by tympanoplasty with a deviated average, and then tympanomastoidectomy (Figure C.15).

To better understand the influence of each of the care areas on the total cost of each surgery, the contribution of each of the areas to the total cost was performed. Thus, it is possible to observe that the greatest contribution to the cost comes from the surgical procedure, corresponding to 90% of the total cost. Next with 3% is inpatient care and 4% is outpatient consultation. With contributions of less than 1%, CDTM, emergency care, medical imaging and clinical pathology are presented (Figure C.1).

As surgery corresponds to the greatest contribution to the total direct cost of the activity pathway (Figure C.1), only the variation and compliance of the cost for the surgical procedure were studied individually.

As such, a box and whiskers plot was performed, as well as a histogram and the distribution with probability density for the costs of surgery. It is possible to observe that the mean continues to be greater than the median. In terms of distribution, it shows a slight left skew, but with a higher probability density value and a decrease in the average by 9% compared to the one presented in the total activity pathway (Figure C.16).

The variation in costs among surgeries is evident in the average cost table for each procedure (Table C.21). This allows us to identify variations in the average cost among different surgical procedures, which result from the differences in the procedures or their combinations.

4.2.3 Adenoidectomy, Myringotomy, Tonsillectomy Surgeries

Due to the difference in degrees of complexity of surgery, as well as the high variance between costs, a more particular study was carried out, evaluating only the costs of adenoidectomy, tonsillectomy, and myringotomy. The set of these surgeries, as well as their combinations, represent 72.7% of the surgeries performed in the three years of the study.

This study thus includes a sample of 544 activity pathways of the 748 paths.

By observing Figure 4.2, It is possible to demonstrate that there is greater uniformity in the costs of the total activity pathway. We can observe that the average cost is approximately 8% higher than the median. It also indicates the existence of only two outliers and a smaller range of costs. From the distribution graphic, a slight left skew in the cost values is observed. When compared with the graphic for all surgeries, there is not a significant increase in the average cost for these surgeries (less than 0.1%).

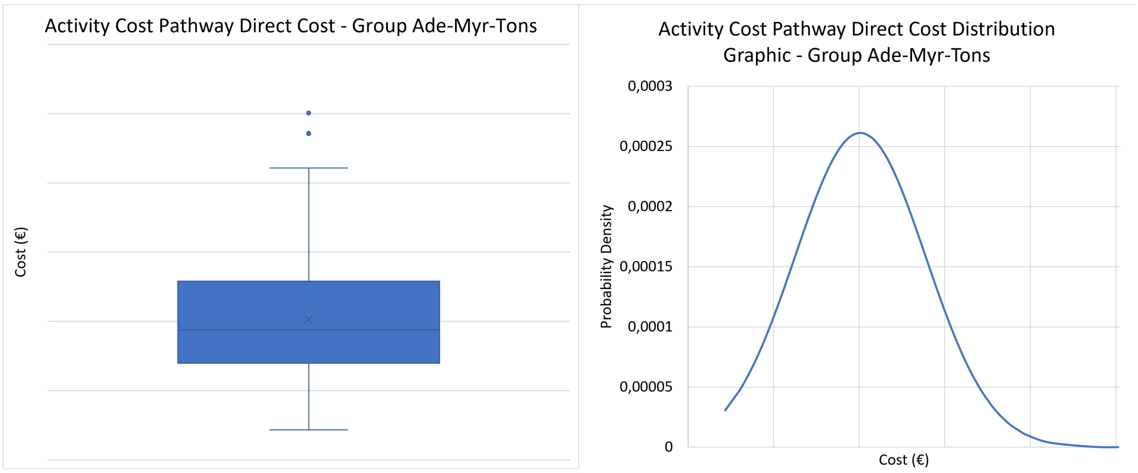

Figure 4.2: Activity cost pathway direct cost of the group of surgeries: adenoidectomy, myringotomy and tonsillectomy

Also for this group of surgeries, the contribution of the cost of care areas to the total cost of activity pathways was studied. It was obtained that for the surgery the contribution corresponds to 92.7% of the total cost, followed by 4.1% for the outpatient consultation. Next to 1.1% are CDTM and to 1.32% hospitalization. With a contribution of less than 1% are the areas of emergency care, clinical pathology and imaging (Figure C.17).

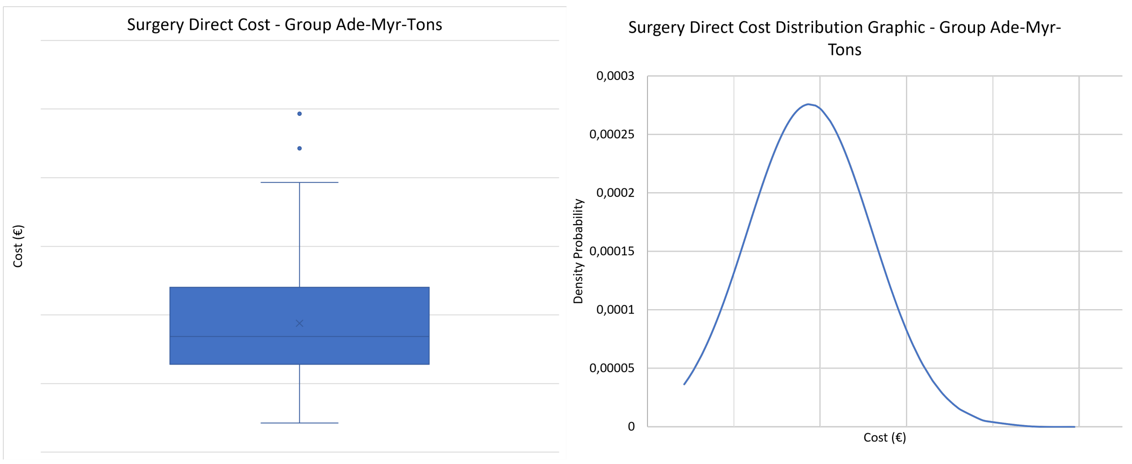

Figure 4.3: Surgery direct cost of the group of surgeries: adenoidectomy, myringotomy and tonsillectomy

In terms of surgical procedures, the average cost is 7% lower when compared to the average cost of the complete pathway. It also shows a slight left skew in the distribution graphic of costs, with high probability density (Figure 4.3).

4.2.4 Surgeons Cost Analysis - Adenoidectomy, Myringotomy, Tonsillectomy

To verify the presence of cost variations among surgeons for the same set of surgeries, Figure 4.4 shows the direct cost of surgeries (from the set of three surgeries) for each surgeon. It can be observed that among surgeons A, B, C, E, and F, there is a higher average cost and a wider range of costs. In contrast, surgeons D and G exhibit a lower average and a smaller range of costs.

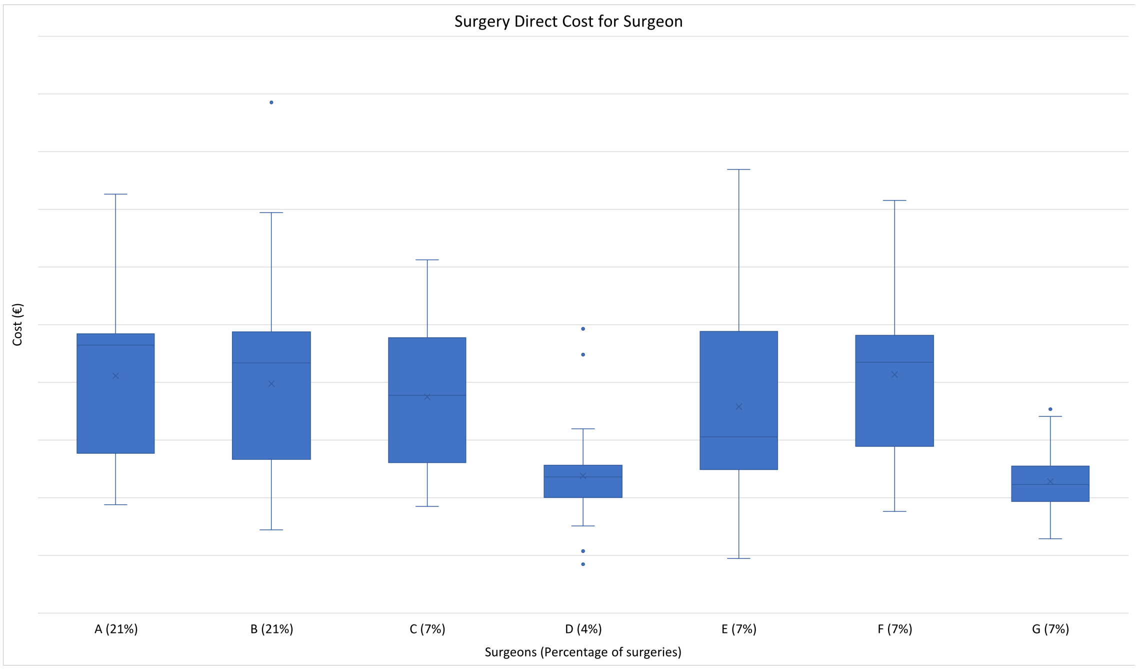

Figure 4.4: Surgery direct cost of the group of three surgeries for surgeon

In the distribution graph in Figure 4.5, it can be seen that in the case of surgeons A, B, and F, the skew is slightly inclined to the right, and in surgeon E, oriented to the left, and in the case of surgeon C slightly more symmetrical. All of these have a height in the same probability density zone between 0.00025 and 0.0003. In the case of surgeons D and G, the distribution has a high probability density as well and the range of costs is smaller, that is, the distribution is less wide.

By observing the distribution of surgeries performed by each surgeon (Figure C.19), it is possible to demonstrate that surgeons D and G perform more simple surgeries, which correspond to a lower cost (Figure C.20). In the case of the remaining surgeons, there is greater uniformity in the distribution of procedures performed, which is also evidenced by the uniformity in the distribution of costs.

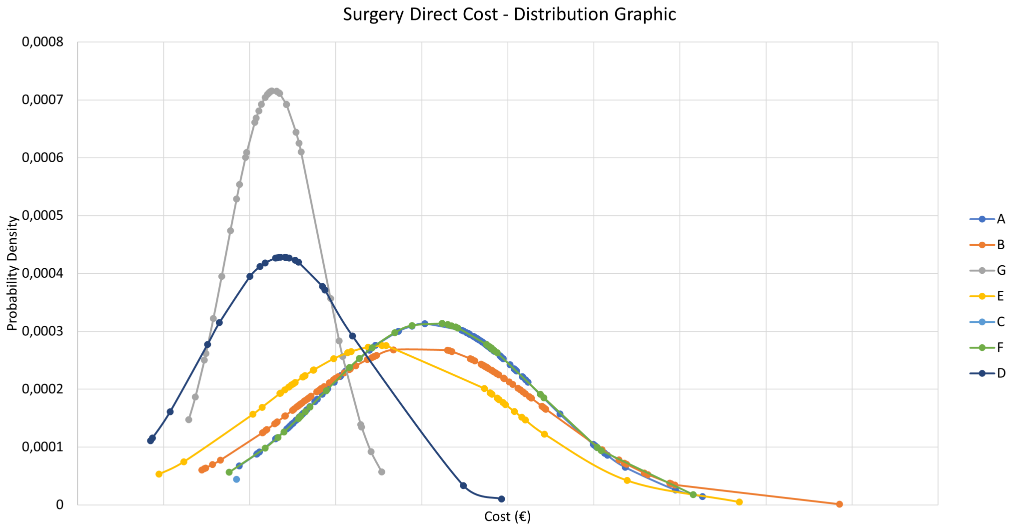

Figure 4.5: Surgery direct cost distribution graphic of the group of three surgeries for surgeon

4.2.5 Pathway Statistics Analysis

Due to the high variability of the activity cost pathways, it was made 9 paths according to the most common pathways were chosen in the set of three surgeries, corresponding to 83% of these cases (63% of the total cases). It was carried out only for this group of surgeries, as they present a higher percentage of total cases, greater conformity in costs and a smaller number of outliers (Figure 4.3), the study will present a more reliable and more informative result.

It started with the simplest route, corresponding to 19% of cases where only the surgical procedure is performed at the health unit in Lisbon. Followed by 16% where only the surgery and the External Consultation (EC) were included, in three different ways: only EC before surgery, only after, and those that present before and after surgery (Figure C.22). Then, in addition to surgery and external consultation, there was an event in clinical pathology, corresponding to 4%, and another with clinical pathology and hospitalization with 5% of cases (Figure C.22).

In the remaining cases, EC and clinical pathology are always included, since most of the cases with CDTM or urgent care also have an outpatient consultation. In cases that presented emergency care, they corresponded to 11%, a CDTM event, diagnostic and/or postoperative, present a percentage of presence of 20% (Figure C.22).

For this distribution of pathways, a statistical study was carried out to perceive the difference in pathways and the implication for the variations in the total costs. For this, the Analysis of Variance (ANOVA) statistical method was used, a method used to compare the variances between the means of different groups (Bertinetto et al., 2020; Sawyer, 2009). A significant difference between the means of the groups suggests a significantly larger variation within groups.

ANOVA assumes a null hypothesis which indicates that the means of the different groups are similar, so there is no significant difference between them. If the calculated F-statistic is greater than the F-critical (for a specific α/significance level - 5%, 0.05), then the null hypothesis is rejected, and it can be stated that the means of the groups are significantly different (Sawyer, 2009).

It is possible to observe the table in Figure C.23, where the statistical study ANOVA is presented, the F-statistic is superior to the critical value and the p-value is inferior to the alpha of 0.05 selected. It is possible to reject the null hypothesis and conclude that there is a significant difference between the means of the groups, proving a statistically relevant difference in the data.

Because ANOVA does not provide which groups are different, it was necessary to run a post-hoc test, with the Bonferroni method, to tell exactly which groups differ in means (Lee & Lee, 2018; Sawyer, 2009).

As shown in the table in Figure C.25, the averages are significant when comparing path 1, where only surgery is performed, with paths 4,7,8, and 9, these being respectively the groups where external consultation before and after included, emergency care, CDTM, and combination of hospitalization and CDTM. A relevant difference is also presented between pathways 1 and 2, 6, these being respectively the ones that present only diagnostic appointments and the ones that presents hospitalization episodes. Through this study, it is possible to conclude that an activity pathway with only surgery is statistically different in terms of cost from the remaining pathways.

ANOVA statistical test was performed again, excluding the pathway with only surgery. It is shown that the F-statistical is now lower than the F-critical, and the p-value higher than the selected alpha, thus being able to conclude the veracity of the null hypothesis, which expresses that there are no statistically relevant differences between the costs of the evaluated groups (Figure C.24).

By examining the costs associated with each patient's activities, they could be categorized into distinct temporal phases. These phases consist of the diagnostic phase, encompassing events before surgery; the surgical phase, which includes all events occurring on the day of surgery; the post-operative phase, comprising elements occurring after the surgery, including hospitalization; and the follow-up phase, covering all events occurring after surgery that did not initiate on the day of surgery.

In each segment of the activity pathway, it was feasible to compute both the average cost within each phase and the cost distribution. As evident from Table C.26, the average cost in the diagnosis, post-op, and follow-up phases constitutes a total of 15% of the average total cost of the pathway. In the case of surgery, the cost amounts to 85% of the total cost (Table 4.1).

The same study was exclusively conducted for adenoidectomy, myringotomy, and tonsillectomy surgeries (Table C.27). As depicted in the figure, surgery carries a higher cost accounting for 87% of the total, while follow-up has a lower cost contributing just 4% to the overall average cost.

Chapter 5

Discussion

In this chapter, the results obtained throughout this dissertation are discussed in correlation with the theoretical concepts and the previous implementation.

5.1 Activity Cost Pathway

In order to establish a cost model founded on a value-based healthcare framework, it was imperative to delineate the activities exerting influence upon the patient's value chain. This was undertaken to elucidate the entities subject to costing analysis. In this regard, specific activities were discerned, those that relate to patients advised or eligible to undergo otorhinolaryngology surgery.

Consequently, the activity cost trajectories of patients at the Lisbon Unit were expounded upon, revealing a noteworthy diversity in the processes pursued by each individual. Illustrated in Figure A.9, the sample of paths under examination yielded a total of 436 distinct trajectories across the entirety of surgical cases. This diversity can be attributed to varying patient preferences and characteristics, in addition to the practices of healthcare professionals (Pera, 2017). Patients may seek alternative establishments for consultations and medical examinations, inside or outside Corporate Group services, resorting to the Lisbon Unit exclusively for surgical intervention or only some of the assistance areas.

This variability in patient trajectories potentially bears implications in VBHC perspective. Conversely, the absence of comprehensive data concerning the complete patient care journey impedes the thorough analysis of healthcare service outcomes. Such analysis is indispensable for evaluating the value conferred by the service to the patients. To execute a value-based healthcare methodology, an all-encompassing scrutiny of the patient's clinical trajectory is essential. The completed trajectory is needed for costing assessments and the evaluation of pertinent patient outcomes (Porter & Lee, 2013).

Upon scrutinizing the cost of surgeries (adenoidectomy, myringotomy, and tonsillectomy) conducted by different surgeons, it has been observed that disparities exist in the costs incurred for these procedures (Figure 4.4). These disparities might stem from distinct clinical approaches to the same type of pathology or personal preferences of diverse healthcare professionals (Pera, 2017).

These discrepancies can be rationalized by considering that surgeons with a lower average cost per surgery and a narrower cost range tend to perform a higher percentage of surgeries involving a smaller number of procedures (Table C.19). This results in a significant difference of 36% to 44% in average costs when compared to other surgeons. Conversely, other surgeons, namely those with the highest proportion of surgeries (63%), predominantly undertake surgeries involving two or three procedures within a single intervention (Figure C.19). Conducting two procedures simultaneously proves to be more cost-effective than performing each procedure individually when it is necessary to perform both procedures (Table C.20 and Graphic C.14).

By individually costing each activity and attributing costs to each surgeon, it becomes possible to analyze the cost as well as the efficacy and personal preference of each surgeon (Pera, 2017).

Incorporating healthcare practitioners into the value-based model, particularly within the activity costing department, enables the evaluation of clinical practices within the Lisbon Hospital Unit. When validating the criteria with the surgeon at the Hospital, the outcomes of the cost analysis for activities within the surgical care cycle were presented. The surgeon commended the significance of the study in comprehending the expenses associated with surgeries and various departments. Furthermore, the surgeon appreciated the potential for examining consumables and medications used in the operating room, aiming for a more sustainable utilization of resources.

Literature mentions this medical professionals' participation and awareness of the prevailing costs, enhance a heightened sense of responsibility concerning cost management and equitable distribution. It promotes the exploration of new technologies and therapies that are or could potentially be, integrated into the diagnostic and treatment procedures (Mewara et al., 2023).

Due to the considerable variability in activity cost pathways, an investigation was conducted for the three most frequently performed surgeries, assessing the fluctuation of average costs through a statistical analysis ANOVA (Figure C.23 and C.24). This analysis enables the examination of variations in the mean costs and the determination of whether significant differences exist among them.

It was demonstrated that the clinical pathway solely involving surgery exhibits a noteworthy disparity in its average cost when compared to other clinical pathways (Figure C.23 and C.25). In the remaining scenarios, irrespective of whether they encompass outpatient consultations, hospitalization, CDTM, clinical pathology, or urgent care, the average cost is not significantly different (Figure C.24), which prevents the characterization of cost variation based on the presence of one or another intervention within the diverse care areas.

Performing only surgery in the Lisbon hospital unit has a lower cost, 18% to 37% less expensive when compared to the presence of other care areas in the clinical pathway. These values align with the average cost of the entire clinical pathway. As illustrated in the table containing average values for each stage of the treatment cycle, considering only instances when activities take place, it reveals that surgery constitutes approximately 85% of the total cost, with the remaining 15% allocated to diagnosis, post-operative care, and follow-up (Figures C.26 and C.27).

However, considering from a perspective of value for the patient and the need for diagnostic and follow-up elements, with this analysis, it is possible to conclude that exams, consultations or hospitalization in the pre- and postoperative period do not significantly change the cost of the total clinical pathway. This allows us to admit that depending on the outcomes and what brings more value to the patient, the variation in the number of exams, consultations, and hospitalizations does not translate into a significant increase in direct costs in the total clinical path.

5.2 Distribution of Direct Cost

Through the application of an ABC methodology, we have been able to discern the distribution of costs across various sectors of care, the cost of every activity and identify a set of costing pathways. The examination of cost distribution in the care areas affords us the opportunity to investigate resource utilization and to pinpoint the primary contributors to expenses. This, in turn, enables a comprehensive understanding of the origins of direct costs associated with clinical procedures, describing in detail for each of the activities the respective weight in the total cost of the object, as can be seen in Figures C.2, C.3, C.4, C.5, C.6, C.7, C.8.

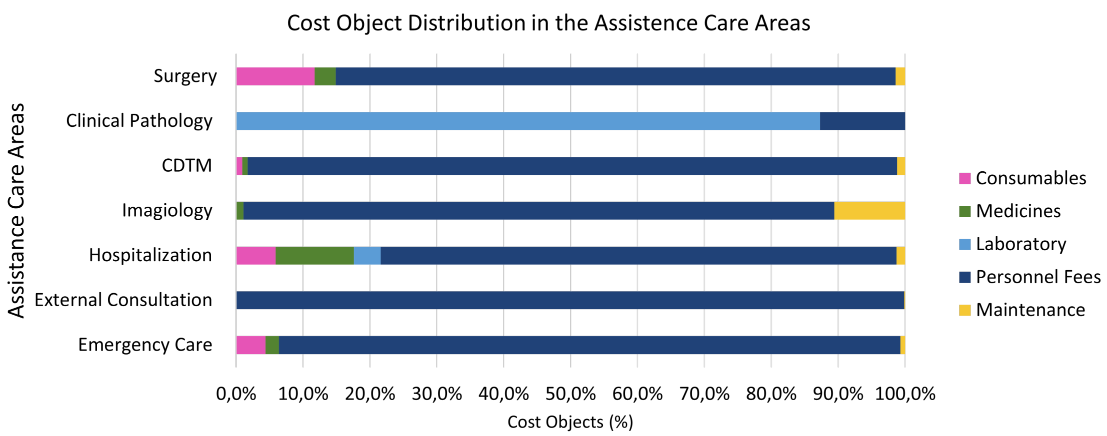

Figure 5.1: Summary of cost object distribution in the assistance care areas

The results derived from this analysis demonstrate that with the exception of clinical pathology, the preponderance of costs within all sectors is ascribed to medical personnel direct costs (Figure 5.1), representing 84.2% total of the activity cost pathway, pinpointing opportunities to reduce the costs associated with unused capacity could, in theory, enhance the hospital's contribution margin (Milewicz et al., 2018). The subsequent most substantial contributor to costs is allocating resources and medicine, respectively 10.7% and 3.3%. This information can help healthcare providers identify areas where costs can be reduced or eliminated, leading to more efficient and effective care delivery (Rahimi et al., 2023).

In addition to the distribution of costs, it is possible to study, within each resource and medication, which are most used in each of the care areas, study usage patterns and professional preferences, for example, the consumables and medications used in surgery (Figures C.9 and C.10). By employing micro-costing methods, where patient-specific resources are meticulously identified and costed, it is possible to "standardize" the use of resources and medicines, for less variability of products from different suppliers, enhance contract negotiations, and study a more efficient and sustainable use of resources (Ricci De Araújo et al., 2019).

By costing the areas for each clinical act carried out for a given pathology, it allows a solid hospital internal budget projection to be made, relating the number of acts carried out with the costs. Thus, ABC also becomes a tool that promotes efficiency in a hospital strategy view, promoting the profitability of resources.

5.3 Clinical Pathway and Surgery Direct Cost

As a result of ABC methodology, it is possible to easily analyze the distribution of costs within the defined comprehensive clinical pathway as well as the distribution of costs associated with surgical procedures. Given the diversity inherent in surgical interventions conducted within the range of pediatric otorhinolaryngology, a broad spectrum of costs has been observed across the two conducted evaluations, one for all types of surgeries and one for the group of 3 of the most performed surgeries: tonsillectomy, adenoidectomy, and myringotomy, along with their combinations.

In an initial analysis of the patient's age distribution based on patient age, it was revealed that the majority of otorhinolaryngology surgeries occur in the age range of 1 to 5 years old (67%), consistent with research (Children's National Hospital, 2023; Schupper et al., 2018). Upon scrutinizing the cost distribution within this age group, it was noted that, despite variations in the mean and median, the cost range remains unchanged, signifying that age does not contribute to cost variations along the activity pathway (C.13).

While examining the cost contribution to the overall clinical pathway for each of the care areas, it was substantiated that surgery accounts for 91% of the total costs (Graph C.1). As a result of this observation, the cost distribution of surgery was analysed for direct costs (Graph C.16), revealing a similar slight leftward skewness in costs, comparable to that observed in the total clinical pathway cost (Graph 4.1). Furthermore, this analysis demonstrated analogous scope and identical outliers. The cost distribution high range and outliers can be explained due to the existence of less complex procedures such as foreign body extraction, presenting a lower cost, to more resource-intensive interventions like the placement of cochlear implants, or more complex procedures, such as Endonasal Microsurgery, which exhibits a superior average costs (Table C.21).

As depicted in the graphs 4.1 and C.16, given the wide range of costs and significant variability in surgeries, a more specific study was conducted for the three most frequently performed surgeries to achieve a more precise cost. When observing the cost of the total activity cost pathway for the group of the three surgeries it was noted that as the number of procedures performed increases, the average cost of the surgery also increases. This increase is approximately 20 to 30% with the addition of one procedure (Graph C.14). As mentioned before, this small increase shows that doing two procedures simultaneously is more cost-effective than performing each procedure individually when it is necessary to perform both procedures.

In this scenario, the cost distribution in the total clinical pathway, despite a mean deviation of 8% from the median, exhibits a small left-ward skew and a smaller range of cost (Figure 4.2). When analyzing the leftward slope and the presence of a median lower than the average, it becomes evident that over 50% of the costs are below the average value. In other words, a majority of surgeries have costs lower than the average. This situation presents an opportunity to explore cost optimization due to the variance in values. On another hand, there is a reduced presence of outliers compared to the equivalent analysis conducted for all surgeries.

As displayed in Table B.6, the rate of hospitalization rises as the day progresses. While surgeries, particularly tonsillectomies, adenoidectomies, and myringotomies, are typically low risk for outpatient settings, the surgeon has attributed these data to factors such as the timing of the surgery. The proximity to nighttime, the patient's distance from their residence, and the administration of medication at that hour lead to the practical decision for patients to stay overnight. Approximately 75% of surgeries are conducted as outpatient procedures and the cost associated with post-operative hospitalization accounts for just 1 to 3% (Figure C.1 and C.17). Also, the low risk of surgery is corroborated by the low rate of post-operative problems (urgent care within 30 days post-surgery), which stands at just 8%.

The distribution of costs for these surgical procedures within this group shows a slight leftward skew, a greater disparity between the mean and the median, and a more restricted range of costs compared to that of all surgeries (Figure 4.3). This scope is elucidated by the combinations performed with these three procedures, which elevate the cost of surgery and consequently the clinical pathway, through an escalation in the number of processes conducted within a single surgery.

A rationale behind the demonstrated cost range could be attributed to the diverse payment methods. When utilizing insurers, public payers or full payment, the costs of surgical procedures and all other clinical interventions are charged at distinct values. Payment through insurance also varies among different insurance providers, contingent on the coverage offered by the insurance and agreements established with the hospital. This leads to the conclusion that the cost range is normal and is attributable to the various payment methods, highlighting that the average cost is an accurate and representative value for these surgeries.

When comparing the analyses conducted for all surgeries and the subset of three surgeries, both in terms of surgical procedures and cost activity pathways, it is noticeable that both the mean and median for the set of three surgeries are higher than those for all surgeries. This observation may be attributed to the prevalence of a substantial percentage of low-cost surgeries, such as foreign body extraction, accounting for 6.4% (Table B.1 and C.21). The presence of these lower-cost surgeries justifies the lower value for the overall surgery costs in the distribution of costs for all surgeries.

In another analysis focused on cost distribution, the three surgeries exhibit 2% less hospitalization and a marginal increase of 0.1% in CDTM (Figure C.1 and C.17). It is important to highlight that even though this latter increase is minor, it holds significance as only 37% of patients, in total, experience at least one episode of CDTM (Table B.10).

Through the implementation of an ABC system, it becomes feasible to gain insight into the practices prevailing within the hospital setting, thereby enabling the projection of not only the actual costs of surgeries but also the total clinical pathway for these medical conditions.

On account of ABC, comprehensive and transparent cost data is generated for all parties involved, this could enable stakeholders to gain insights into the actual costs associated with hospital activities (Fuchs et al., 2021).

5.4 Costing methodology in a Value-based Model

Considering that the intended model for application is a value-based healthcare model, which relies not only on costing but also on patient-relevant outcomes of the full cycle of care, concluding on value enhancement necessitates not only conducted costing but also the evaluation of PROMS (Squitieri et al., 2017). This evaluation aims to delineate parameters that contribute value to the pediatric otorhinolaryngology surgery pathway. To accomplish this, it is imperative to administer questionnaires tailored to the Portuguese population. These questionnaires aid in defining criteria that extend beyond surgical success, elucidating whether the procedures and various clinical interventions have added value for the patient (ICHOM, 2023).

Activity-based costing allows for the costing of the entire patient journey, especially in situations where the patient is directed toward surgery due to a specific pathology, as literature suggests in a value-based healthcare model (Kaplan & Porter, 2011). However, solely through costing, it is inadequate to determine which interventions and processes genuinely deliver value to the patient. Therefore, implementing cost-optimization changes requires prior establishment of what is deemed valuable for the patient (Teisberg et al., 2020).

Clinicians and administrators can then work together to improve the value of care, with the cost information provided and the outcomes that will be studied (Porter & Lee, 2013). This fact was emphasized and confirmed by the surgeon while reviewing the cost study of the surgical value chain. It became evident that the data provided by ABC costing, the connection with the cost activity pathway, and clinical practices serve as an excellent starting point for a value-based healthcare approach. With great enthusiasm, the surgeon demonstrated this to be necessary and fundamental for pediatric otorhinolaryngology surgery, and that could potentially lead to more efficient, patient-centred treatment, and the standardization of clinical practices.

When comparing the ABC method to TDABC in terms of the value of the costing methodology, ABC appears to be more impartial. This is because when using TDABC, it is assumed that the time cost driver will bring greater value to the patient (Etges et al., 2020). However, time is a subjective variable that varies from person to person, depending on their individual schedules and how busy they are (Špacírová et al., 2020). ABC enables costing before establishing the value for the patient by utilizing cost drivers such as the hospital expenses associated with performing the procedures. Hence, ABC, encompassing the costs associated with all facets of pediatric otorhinolaryngology surgery, enables a comprehensive assessment of costs before determining outcomes that are pertinent to patients.

Chapter 6

Conclusions

6.1 Business Implications and Recomendations

As emphasized throughout this discussion, the ABC methodology serves as a costing tool that facilitates insights into resource costs, treatment areas, and the average cost per patient within the pediatric otorhinolaryngology clinical pathway.

Equipped with this information, the Hospital can leverage the obtained results, alongside PROMS data collection, to support decision-making at both the hospital and clinical levels, payment methods and budgetary allocations.

A more comprehensive understanding of costs in this surgical field will enable the hospital to scrutinize resource utilization and establish more sustainable practices. With the acquired data, the hospital can investigate the clinical pathways in use and explore opportunities for optimizing and standardizing procedures among clinical staff. Furthermore, it can identify investment prospects in technological innovation.

By concurrently implementing VBHC, the hospital will enhance the value delivered to pediatric ENT pathology patients, focusing on both outcomes and associated costs.

6.2 Limitations

When applying a costing methodology, various estimates and assumptions are made, often involving trade-offs or compromises between theory and practicality (Špacírová et al., 2020). While the ABC methodology allows for the inclusion of indirect costs through the use of cost drivers associating activity costs with their objects, it was chosen to consider only the direct costs of the activities when measuring the costs of the surgeries under study.

As outlined in the methodology, these direct costs are closely tied to the quality of the clinical services provided. Nevertheless, the pricing structure for Hospital services billed to patients encompasses both direct and indirect costs. From a broader cost-reduction perspective, it would be beneficial to also account for the indirect costs associated with the pathology to optimize the overall cost efficiency (Chapman et al., 2016).

On the other hand, since payments to nurses are governed by contractual agreements, their performance was not included in this study. The work of nurses directly influences patient flow management, contributing to enhanced patient care quality and reduced healthcare expenses (Benjamin & Jacelon, 2021). To accurately assess patient outcomes and the efficiency of their work, a separate parallel study employing either the ABC or TDABC methodology would be necessary.

Another limitation of the conducted study is that the costing is performed retrospectively and does not encompass cost estimates for potential new therapies that may be integrated into clinical practice in the future (Špacírová et al., 2020).

6.3 Future Work

As previously emphasized, to implement a VBHC methodology, it is imperative not only to evaluate the costs inherent in the patient's entire clinical pathway but also to consider the pertinent outcomes that hold significance for the patient throughout is journey.

To achieve this, as part of future endeavours, it will be essential to collect PROMS data. This data collection aims to gain insight into what aspects are most relevant and deliver the highest value in terms of treatment and the overall healthcare experience for patients. With this information at our disposal, it becomes feasible to formulate a patient-centred strategy that factors in the crucial outcomes for patients and the costs required to attain these same outcomes.

Simultaneously, parallel studies can be conducted to design a value-based payment model. This model will take into account the insights gained from the implementation of VBHC, enabling the Hospital to incentivize payment models that enhance the quality of treatment while maintaining cost-effectiveness (Teisberg et al., 2020).

Currently, payment is contingent upon contracts defined among paying entities, and providers. These payment structures and contracts hinge on the volume of procedures conducted, leading to an expansion of services and complexity that ultimately contribute less value to the patient, alongside a notable escalation in costs. With the integration of a value-based model, it becomes feasible to establish equitable remuneration with paying entities for a predefined clinical pathway, encompassing the pertinent pathology and care areas delivering the highest value to the patient (Mewara et al., 2023).

In the design of a payment model, it is necessary to measure and assess outcomes that are relevant to pediatric patients undergoing otorhinolaryngology surgery. This involves defining patient segment criteria, implementing risk adjustment measures, setting outcome targets, and establishing reporting and cost parameters (Mewara et al., 2023). Value-based payment models facilitate larger payment sums, thereby motivating providers to emphasize prevention, early diagnosis, and proactive treatment with the goal of minimizing overall costs to the healthcare system (Horner et al., 2019).

Due to the utilization of the ABC methodology, a top-down micro-costing method, we have access to data regarding the average cost per patient for surgery and the clinical pathway, the average cost and cost distribution within each treatment area, and the average cost for each phase of the treatment. This information serves as a foundation for hospital reimbursement and enables us to develop and substantiate a value-based payment approach, such as a bundle payment model. This model encompasses the entire treatment cycle for a specific medical condition or preventive treatment for a defined population, such as pediatric otorhinolaryngology pathologies (Navathe et al., 2021).

6.4 Research Conslusions

The ABC methodology, a top-down micro-costing method, enables the allocation of activity costs to individual cost objects within them through the use of cost drivers. This dissertation applied the activity-based costing method to the otorhinolaryngology surgery value chain, accomplishing the primary goal of attaining detailed and precise cost data for the entire patient journey.

In summary, considering the results and discussions within the dissertation, ABC methodology facilitated the computation of healthcare costs, including the average cost per patient for both the clinical pathway and surgeries. It not only allowed us to ascertain the actual expenses incurred across all surgeries but also, more specifically, in the case of the most frequently performed procedures: adenoidectomy, tonsillectomy, and myringotomy.

By measuring the average costs per patient, it is evident that the costs incurred in both the clinical pathway and surgery albeit with a slight leftward skew in the distribution graphic. The notable dispersion of costs, accompanied by several outliers, can be attributed to surgery, as it accounts for approximately 90% of the total costs of the clinical pathway, especially due to the considerable number of procedures, each varying in complexity and resource intensity. When specifically examining the three surgeries—adenoidectomy, tonsillectomy, and myringotomy— distribution with a leftward skew was observed. This distribution exhibited a narrower range of costs and a reduced number of outliers.

ABC also enabled the identification of cost distribution within each treatment area, clearly highlighting labour costs as the primary cost driver. This identification of resources and their respective contributions to costs paved the way for a detailed study of opportunities for more sustainable resource utilization and the reduction of excessive and unnecessary resource consumption across all activities.

Due to the complexity and the multitude of activities within the clinical pathway, ABC has proven to be a straightforward and practical methodology that accommodates the allocation of a substantial number of activities and patients.

ABC facilitated the assessment of costs incurred by healthcare professionals, highlighting variations in clinical practices. In the context of VBHC, ABC costing plays a pivotal role in justifying and supporting decision-making. With a deeper understanding of hospital activity cost accounting, managers and healthcare professionals can collaborate across disciplines to develop measures for optimizing costs and reengineering processes.

Given the substantial variability in clinical pathways, ABC costing allowed for statistical analysis of average costs within distinct sets of clinical paths. This analysis revealed that the utilization of healthcare areas like CDTM, clinical pathology, external consultation, imaging, and urgent care did not significantly alter or increase the clinical pathway average costs.

Furthermore, in addition to cost per activity, this methodology enables the measurement of costs per treatment phase, encompassing expenses related to diagnosis, surgery, post-operative care, and patient follow-up.

Additionally, the ABC methodology, by identifying and studying the activities undertaken by each patient along the clinical pathway, has revealed opportunities for enhancing quality, particularly in outpatient and inpatient surgical cases, as well as in addressing the severity of the treated conditions. It enables the identification of cost-effective treatment strategies, standardization, and technological innovations while preserving quality. Involving healthcare professionals in this process fosters greater awareness of incurred costs.

In conclusion, as a cost engineering method, ABC enables precise cost calculations, facilitating the application of the VBHC methodology. This, in turn, leads to improved outcomes in pediatric otorhinolaryngology surgery and the implementation of value-based payment models.

Bibliography

Alrashdan, A., Momani, A., & Ababneh, T. (2012). Activities identification for activity-based cost/management applications of the diagnostics outpatient procedures. *Journal for Healthcare Quality*, *34*(1), 35–43. https://doi.org/10.1111/j.1945-1474.2011.00139.x (cit. on p. 7).

Arnold Coran, C., Aronsson, D. D., Denslow, G. T., & Hotaling, A. J. (2002). Guidelines for referral to pediatric surgical specialists. *AAP, American Academy of Pediatrics*, *110*(1), 187–191. https://doi.org/10.1542/peds.110.1.187 (cit. on p. 10).

Azoulay, A., Doris, N. M., Filion, K. B., Caron, J., Pilote, L., & Eisenberg, M. J. (2007). The use of the transition cost accounting system in health services research. *Cost Effectiveness and Resource Allocation*, *5*(1), 11. https://doi.org/10.1186/1478-7547-5-11 (cit. on pp. 8, 18).

Bele, S., Mohamed, B., Chugh, A., Haverman, L., & Santana, M.-J. (2019). Impact of using patient-reported outcome measures in routine clinical care of paediatric patients with chronic conditions: A systematic review protocol. *BMJ Open*, *9*(3), e027354. https://doi.org/10.1136/bmjopen-2018-027354 (cit. on p. 5).

Benjamin, E., & Jacelon, C. (2021). An analysis of the concept of patient flow management. *Nursing Forum*, *57*(3), 429–436. https://doi.org/10.1111/nuf.12681 (cit. on p. 38).

Bertinetto, C., Engel, J., & Jansen, J. (2020). Anova simultaneous component analysis: A tutorial review. *Analytica Chimica Acta: X*, *6*, 100061. https://doi.org/https://doi.org/10.1016/j.acax.2020.100061 (cit. on p. 28).

Boccuzzi, S. J. (2003). Indirect health care costs. In W. S. Weintraub (Ed.), *Cardiovascular health care economics*. Humana Press. https://doi.org/10.1007/978-1-59259-398-9_5 (cit. on p. 18).

Borges, C. M., Ramalho, R., Bajanca, M., Oliveira, T., Major, M. J., Diz, P., & Rodrigues, V. (2010). Implementação de um sistema de custeio por actividades nos hospitais do SNS. *REVISTA PORTUGUESA DE SAÚDE PÚBLICA* (cit. on p. 10).

Boston Children's Hospital. (2023). Tonsillectomy and Adenoidectomy — childrenshospital.org. https://www.childrenshospital.org/treatments/tonsillectomy-and-adenoidectomy (cit. on p. 2).

Bouazza, Y. B., Chiairi, I., Kharbouchi, O. E., Backer, L. D., Vanhoutte, G., Janssens, A., & Meerbeeck, J. P. V. (2017). Patient-reported outcome measures (PROMs) in the management of lung cancer: A systematic review. *Lung Cancer*, *113*, 140–151. https://doi.org/10.1016/j.lungcan.2017.09.011 (cit. on p. 5).

Caleb Stowell, M., & Akerman, C. (2015). Better value in health care requires focusing on outcomes. *Harvard Business Review* (cit. on p. 4).

Cao, P., Toyabe, S.-I., & Akazawa, K. (2006). Development of a Practical Costing Method for Hospitals. *The Tohoku Journal of Experimental Medicine*, *208*(3), 213–224. https://doi.org/10.1620/tjem.208.213 (cit. on pp. ix, 2, 8).

Carroll, N., & Lord, J. C. (2016). The growing importance of cost accounting for hospitals. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6910125/ (cit. on p. 6).

Cella, D., Hahn, E., & Jensen, S. (2015). *Patient-reported outcomes in performance measurement*. RTI Press. https://www.ncbi.nlm.nih.gov/books/NBK424381/ (cit. on p. 5).

Chapman, C. S., Kern, A., Laguecir, A., et al. (2016). Management accounting and efficiency in health services: The foundational role of cost analysis [Available from: https://www.ncbi.nlm.nih.gov/books/NBK436887/]. In J. Cylus, I. Papanicolas, & P. C. Smith (Eds.), *Health system efficiency: How to make measurement matter for policy and management*. European Observatory on Health Systems; Policies. (Cit. on p. 38).

Children's National Hospital. (2023). Pediatric Myringotomy Tubes (Ear Tubes) - Conditions and Treatments | Children's National Hospital — childrensnational.org [[Accessed 11-10-2023]]. (Cit. on p. 33).

Churruca, K., Pomare, C., Ellis, L. A., Long, J. C., Henderson, S. B., Murphy, L. E. D., Leahy, C. J., & Braithwaite, J. (2021). Patient-reported outcome measures (PROMs): A review of generic and condition-specific measures and a discussion of trends and issues. *Health Expectations*, *24*(4), 1015–1024. https://doi.org/10.1111/hex.13254 (cit. on p. 5).

Clinic, M. (2022). Tonsillectomy - Mayo Clinic — HTTPS. https://WWW.MAYOCLINIC.ORG/TESTS-PROCEDURES/TONSILLECTOMY/ABOUT/PAC-20395141 (cit. on p. 11).

Cooper, R., & Kaplan, R. S. (1991). Profit priorities from activity-based costing. *Harvard Business Review* (cit. on p. 7).

Cossio-Gil, Y., Omara, M., Watson, C., Casey, J., Chakhunashvili, A., Gutiérrez-San Miguel, M., Kahlem, P., Keuchkerian, S., Kirchberger, V., Luce-Garnier, V., Michiels, D., Moro, M., Philipp-Jaschek, B., Sancini, S., Hazelzet, J., & Stamm, T. (2022). The Roadmap for Implementing Value-Based Healthcare in European University Hospitals—Consensus Report and Recommendations. *Value in Health*, *25*(7), 1148–1156. https://doi.org/10.1016/j.jval.2021.11.1355 (cit. on pp. 7, 15).

Coyan, G. N., Lu, M., Ruppert, K. M., Baker, N., Levy, R. M., Luketich, J. D., Schuchert, M. J., & Sarkaria, I. S. (2022). Activity-based cost analysis of robotic anatomic lung resection during program implementation. *The Annals of Thoracic Surgery*, *113*(1), 244–249. https://doi.org/10.1016/j.athoracsur.2021.01.053 (cit. on p. 10).

Cunnama, L., Sinanovic, E., Ramma, L., Foster, N., Berrie, L., Stevens, W., Molapo, S., Marokane, P., McCarthy, K., Churchyard, G., & Vassall, A. (2016). Using top-down and bottom-up costing approaches in LMICs: The case for using both to assess the incremental costs of new technologies at scale. *Health Economics*, *25*(S1), 53–66. https://doi.org/10.1002/hec.3295 (cit. on p. 7).

Danishyar, A., & Ashurst, J. (2023). Acute otitis media [PMID: 29262176]. https://pubmed.ncbi.nlm.nih.gov/29262176/ (cit. on p. 11).

Declerck, B., Swaak, M., Martin, M., & Kesteloot, K. (2021). Activity-based cost analysis of laboratory tests in clinical chemistry. *Clinical Chemistry and Laboratory Medicine (CCLM)*, *59*(8), 1369–1375. https://doi.org/10.1515/cclm-2020-1849 (cit. on p. 10).

Dieleman, J., Squires, E., Bui, A., Campbell, M., Chapin, A., Hamavid, H., Horst, C., Li, Z., Matyasz, T., Reynolds, A., Sadat, N., Schneider, M., & Murray, C. (2017). Factors associated with increases in us health care spending- 1996-2013. https://doi.org/10.1001/jama.2017.15927. (cit. on p. 2).

Dueck, A. C., Mendoza, T. R., Mitchell, S. A., Reeve, B. B., Castro, K. M., Rogak, L. J., Atkinson, T. M., Bennett, A. V., Denicoff, A. M., O'Mara, A. M., Li, Y., Clauser, S. B., Bryant, D. M., Bearden, J. D. I., Gillis, T. A., Harness, J. K., Siegel, R. D., Paul, D. B., Cleeland, C. S., … Group, N. C. I. P.-C. S. (2015). Validity and reliability of the us national cancer institute's patient-reported outcomes version of the common terminology criteria for adverse events (pro-ctcae) [Erratum in: JAMA Oncol. 2016 Jan;2(1):146]. *JAMA Oncology*, *1*(8), 1051–1059. https://doi.org/10.1001/jamaoncol.2015.2639 (cit. on p. 1).

Elbattah, M., Molloy, O., & Zeigler, B. P. (2018). DESIGNING CARE PATHWAYS USING SIMULATION MODELING AND MACHINE LEARNING. *2018 Winter Simulation Conference (WSC)*, 1452–1463. https://doi.org/10.1109/WSC.2018.8632360 (cit. on p. 16).

Etges, A. P. B. D. S., Polanczyk, C. A., & Urman, R. D. (2020). A standardized framework to evaluate the quality of studies using TDABC in healthcare: The TDABC in Healthcare Consortium Consensus Statement. *BMC Health Services Research*, *20*(1), 1107. https://doi.org/10.1186/s12913-020-05869-0 (cit. on p. 36).

Eurostat. (2023). Healthcare expenditure statistics — ec.europa.eu. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Healthcare_expenditure_statistics#Healthcare_expenditure (cit. on p. 2).

Fernandes, A. (2021). Otorrinolaringologia nas crianças e jovens | Hospital da Luz. Https://www.hospitaldaluz.pt/pt/saude-e-bem-estar/otorrinolaringologia-criancas-jovens (cit. on p. 11).

Ferreira, J., Pinheiro, M., Santos, W., & Maia, R. (2016). Graphical representation of chemical periodicity of main elements through boxplot. *Educación Química*, *27*. https://doi.org/10.1016/j.eq.2016.04.007 (cit. on pp. x, 80).

Fluxicon. (2023). Process Mining and Automated Process Discovery Software for Professionals - Fluxicon Disco. https://fluxicon.com/disco/ (cit. on p. 16).

Fuchs, B., Studer, G., Bode, B., Wellauer, H., Frei, A., Theus, C., Schüpfer, G., Plock, J., Windegger, H., & Breitenstein, S. (2021). Development of a value-based healthcare delivery model for sarcoma patients. *Swiss Medical Weekly*, *151*(5152), w30047. https://doi.org/10.4414/SMW.2021.w30047 (cit. on p. 35).

Gabriel, L., Casey, J., Gee, M., Palmer, C., Sinha, J., Moxham, J., & Colegate-Stone, T. J. (2019). Value-based healthcare analysis of joint replacement surgery for patients with primary hip osteoarthritis. *BMJ Open Quality*, *8*(2), e000549. https://doi.org/10.1136/bmjoq-2018-000549 (cit. on pp. 9, 18).

Gregório, J., Russo, G., & Lapão, L. V. (2016). Pharmaceutical services cost analysis using time-driven activity-based costing: A contribution to improve community pharmacies' management. *Research in Social and Administrative Pharmacy*, *12*(3), 475–485. https://doi.org/10.1016/j.sapharm.2015.08.004 (cit. on p. 10).

Horner, B., van Leeuwen, W., Larkin, M., Baker, J., & Larsson, S. (2019). Paying for value in health care. (cit. on p. 39).

IBM Process Mining. (2023). Retrieved 2023-09-11, from https://www.ibm.com/topics/process-mining (cit. on p. 16).

ICHOM. (2023). Why measure outcomes? — ichom.org [[Accessed 02-10-2023]]. (Cit. on pp. 5, 35).

International Federation of Accountants. (2013). Evaluating the costing journey: A costing levels continuum maturity framework 2.0. https://www.ifac.org/_flysystem/azure-private/publications/files/IFAC-Evaluating-the-Costing-Journey_0.pdf (cit. on pp. 6, 7, 9).

Javid, M., Hadian, M., Ghaderi, H., Ghaffari, S., & Salehi, M. (2015). Application of the activity-based costing method for unit-cost calculation in a hospital. *Global Journal of Health Science*, *8*(1), 165. https://doi.org/10.5539/gjhs.v8n1p165 (cit. on p. 9).

Joynt Maddox, K., Bleser, W. K., Crook, H. L., Nelson, A. J., Hamilton Lopez, M., Saunders, R. S., McClellan, M. B., Brown, N., & the American Heart Association Value-Based Models Learning Collaborative. (2020). Advancing Value-Based Models for Heart Failure: A Call to Action From the Value in Healthcare Initiative's Value-Based Models Learning Collaborative. *Circulation: Cardiovascular Quality and Outcomes*, *13*(5), e006483. https://doi.org/10.1161/CIRCOUTCOMES.120.006483 (cit. on p. 9).

Kaplan, R. S., & Porter, M. E. (2011). The big idea: How to solve the cost crisis in health care. *Harvard Business Review* (cit. on pp. 5, 15, 35).

Kotu, V., & Deshpande, B. (2019). Chapter 3 - data exploration. In V. Kotu & B. Deshpande (Eds.), *Data science (second edition)* (pp. 39–64). Morgan Kaufmann. https://doi.org/10.1016/B978-0-12-814761-0.00003-4 (cit. on pp. 23, 24).

Latorre, V., Petruzzelli, A. M., Uva, A. E., Ranaudo, C., & Semisa, D. (2021). Unveiling the actual cost of schizophrenia: An activity-based costing (ABC) approach. *The*

International Journal of Health Planning and Management, *37*(3), 1366–1380. https://doi.org/10.1002/hpm.3405 (cit. on p. 10).

Leao, D. L. L., Cremers, H.-P., van Veghel, D., Pavlova, M., & Groot, W. (2023). The impact of value-based payment models for networks of care and transmural care: A systematic literature review. *Applied Health Economics and Health Policy*, *21*(3), 441–466. https://doi.org/10.1007/s40258-023-00790-z (cit. on p. 5).

Lee, S., & Lee, D. K. (2018). What is the proper way to apply the multiple comparison test? https://doi.org/10.4097/kja.d.18.00242 (cit. on p. 29).

Leusder, M., Porte, P., Ahaus, K., & van Elten, H. (2022). Cost measurement in value-based healthcare: A systematic review. *BMJ Open*, *12*(12), e066568. https://doi.org/10.1136/bmjopen-2022-066568 (cit. on p. 6).

Lievens, Y., Van Den Bogaert, W., & Kesteloot, K. (2003). Activity-based costing: A practical model for cost calculation in radiotherapy. *International Journal of Radiation Oncology*Biology*Physics*, *57*(2). https://doi.org/10.1016/S0360-3016(03)00579-0 (cit. on p. 9).

Lourenço, J. M. (2021). *The NOVAthesis LaTeX Template User's Manual*. NOVA University Lisbon. https://github.com/joaomlourenco/novathesis/raw/main/template.pdf (cit. on p. i).

Mastrogianni, M., Galanis, P., Kaitelidou, D., Konstantinou, E., Fildissis, G., & Katsoulas, T. (2021). Factors affecting adult intensive care units costs by using the bottom-up and top-down costing methodology in oecd countries: A systematic review. *Intensive and Critical Care Nursing*, *66*, 103080. https://doi.org/https://doi.org/10.1016/j.iccn.2021.103080 (cit. on p. 7).

Mewara, S., Anderson, K., Guichot, Y. D., McCain, K., & Witkowski, M. (2023). The moment of truth for healthcare spending: How payment models can transform healthcare systems. https://www3.weforum.org/docs/WEF_The_Moment_of_Truth_for_Healthcare_Spending_2023.pdf (cit. on pp. 6, 31, 38).

Milewicz, A., Jalalabadi, F., Shah, S., Hollier, L., & Reece, E. (2018). Activity-based costing. *Seminars in Plastic Surgery*, *32*(04), 182–186. https://doi.org/10.1055/s-0038-1672208 (cit. on p. 33).

Munoz-Gama, J., Martin, N., Fernandez-Llatas, C., Johnson, O. A., Sepúlveda, M., Helm, E., Galvez-Yanjari, V., Rojas, E., Martinez-Millana, A., Aloini, D., Amantea, I. A., Andrews, R., Arias, M., Beerepoot, I., Benevento, E., Burattin, A., Capurro, D., Carmona, J., Comuzzi, M., … Zerbato, F. (2022). Process mining for healthcare: Characteristics and challenges. *Journal of Biomedical Informatics*, *127*, 103994. https://doi.org/10.1016/j.jbi.2022.103994 (cit. on pp. 16, 17).

Navathe, A. S., Liao, J. M., Wang, E., Isidro, U., Zhu, J., Cousins, D. S., & Werner, R. M. (2021). Association of patient outcomes with bundled payments among hospitalized patients attributed to accountable care organizations. *JAMA Health Forum*, *2*(8), e212131. https://doi.org/10.1001/jamahealthforum.2021.2131 (cit. on pp. 6, 39).

Northwest Surgery Center. (2023). ENT Surgical Procedures | NW-ENT Surgery Center — nwentsurgerycenter.com. https://www.nwentsurgerycenter.com/our-procedures/ (cit. on pp. 2, 11).

Olsson, T. M. (2010). Comparing top-down and bottom-up costing approaches for economic evaluation within social welfare. *The European Journal of Health Economics*, *12*(5), 445–453. https://doi.org/10.1007/s10198-010-0257-z (cit. on p. 7).

Pera, M. (2017). Variability in surgical practice. an unresolved problem. *Cirugía Española (English Edition)*, *95*(2), 59–61. https://doi.org/10.1016/j.cireng.2017.03.010 (cit. on pp. 30, 31).

Popesko, B., Papadaki, Š., & Novák, P. (2015). Cost and reimbursement analysis of selected hospital diagnoses via activity-based costing. *EM Ekonomie a Management*, *18*(3), 50–61. https://doi.org/10.15240/tul/001/2015-3-005 (cit. on p. 7).

Porter, M. E., & Lee, T. H. (2013). Https://hbr.org/2013/10/the-strategy-that-will-fix-health-care (cit. on pp. 1, 9, 31, 36).

Porter, M. E., & Teisberg, E. (2006). Redefining health care: Creating value-based competition on results. *Harvard Business Review* (cit. on p. 4).

Raftery, J. (2000). Economics notes: Costing in economic evaluation. *BMJ*, *320*(7249), 1597–1597. https://doi.org/10.1136/bmj.320.7249.1597 (cit. on p. 7).

Rahimi, H., Goudarzi, R., Markazi-Moghaddam, N., Nezami-Asl, A., & Jame, S. Z. B. (2023). Cost-benefit analysis of intensive care unit with activity-based costing approach in the era COVID-19 pandemic: A case study from iran (M. A. N. M. Nazir, Ed.). *PLOS ONE*, *18*(5), e0285792. https://doi.org/10.1371/journal.pone.0285792 (cit. on pp. 10, 33).

Ricci De Araújo, T., Papathanassoglou, E., Gonçalves Menegueti, M., Auxiliadora-Martins, M., Grespan Bonacim, C. A., Lessa Do Valle, M. E., & Laus, A. M. (2019). Urgent need for standardised guidelines for reporting healthcare costs in ICUs – Results of an integrative review of costing methodologies. *Intensive and Critical Care Nursing*, *54*, 39–45. https://doi.org/10.1016/j.iccn.2019.07.005 (cit. on p. 33).

Robert J, R. (2003). Valedictory—why pediatric otorhinolaryngology is important. *International Journal of Pediatric Otorhinolaryngology*, *67*, S53–S61. https://doi.org/10.1016/j.ijporl.2003.09.001 (cit. on p. 2).

Rosenfeld, R. M., Tunkel, D. E., Schwartz, S. R., Anne, S., Bishop, C. E., Chelius, D. C., Hackell, J., Hunter, L. L., Keppel, K. L., Kim, A. H., Kim, T. W., Levine, J. M., Maksimoski, M. T., Moore, D. J., Preciado, D. A., Raol, N. P., Vaughan, W. K., Walker, E. A., & Monjur, T. M. (2022). Clinical practice guideline: Tympanostomy tubes in children (update). *Otolaryngology–Head and Neck Surgery*, *166*(S1). https://doi.org/10.1177/01945998211065662 (cit. on pp. 2, 11, 15).

Sawyer, S. F. (2009). Analysis of variance: The fundamental concepts. *Journal of Manual & Manipulative Therapy*, *17*(2), 27E–38E. https://doi.org/10.1179/jmt.2009.17.2.27E (cit. on pp. 28, 29).

Schupper, A. J., Nation, J., & Pransky, S. (2018). Adenoidectomy in children: What is the evidence and what is its role? *Current Otorhinolaryngology Reports*, *6*(1), 64–73. https://doi.org/10.1007/s40136-018-0190-8 (cit. on p. 33).

Špacírová, Z., Epstein, D., García-Mochón, L., Rovira, J., Olry De Labry Lima, A., & Espín, J. (2020). A general framework for classifying costing methods for economic evaluation of health care. *The European Journal of Health Economics*, *21*(4), 529–542. https://doi.org/10.1007/s10198-019-01157-9 (cit. on pp. 7, 36–38).

Squitieri, L., Bozic, K. J., & Pusic, A. L. (2017). The role of patient-reported outcome measures in value-based payment reform. *Value in Health*, *20*(6), 834–836. https://doi.org/10.1016/j.jval.2017.02.003 (cit. on pp. 5, 35).

Stamm, T., Bott, N., Thwaites, R., Mosor, E., Andrews, M. R., Borgdorff, J., Cossio-Gil, Y., de Portu, S., Ferrante, M., Fischer, F., Hameed, F., Hazelzet, J., Hopkins, D., Kalra, D., Metcalfe, T., Molero, E., Newson, R., Patalano, F., Prasser, F., … Styliadou, M. (2021). Building a value-based care infrastructure in europe: The health outcomes observatory. *Catalyst non-issue content*, *2*(3). https://doi.org/10.1056/CAT.21.0146 (cit. on p. 2).

Stelter, K. (2014). Tonsillitis and sore throat in children. *GMS Curr Top Otorhinolaryngol Head Neck Surg*, *13*, Doc07 (cit. on p. 11).

Tarzibashi, O., & Ozyapici, H. (2019). The impact of the magnitude of overhead costs on the difference between abc and tdabc systems. *Foundations of Management*, *11*, 81–92. https://doi.org/10.2478/fman-2019-0007 (cit. on pp. 2, 3).

Teisberg, E., Wallace, S., & O'Hara, S. (2020). Defining and Implementing Value-Based Health Care: A Strategic Framework. *Academic Medicine*, *95*(5), 682–685. https://doi.org/10.1097/ACM.0000000000003122 (cit. on pp. 1, 4, 11, 36, 38).

Van Egdom, L., Lagendijk, M., Van Der Kemp, M., Van Dam, J., Mureau, M., Hazelzet, J., & Koppert, L. (2019). Implementation of Value Based Breast Cancer Care. *European Journal of Surgical Oncology*, *45*(7), 1163–1170. https://doi.org/10.1016/j.ejso.2019.01.007 (cit. on p. 9).

Wang, Y., Hou, W., Wang, X., Zhang, H., & Wang, J. (2021). Bad to all? a novel way to analyze the effects of fee-for-service on multiple grades hospitals operation outcomes. *International Journal of Environmental Research and Public Health*, *18*(23), 12723. https://doi.org/10.3390/ijerph182312723 (cit. on p. 5).

Wickramasinghe, N., John, B., George, J., & Vogel, D. (2019). Achieving Value-Based Care in Chronic Disease Management: Intervention Study. *JMIR Diabetes*, *4*(2), e10368. https://doi.org/10.2196/10368 (cit. on p. 9).

WMCHealth. (2020). Ear, Nose and Throat (ENT) Care for Children — wmchealthaps.com. https://www.wmchealthaps.com/ear-nose-and-throat-ent-care-for-children (cit. on p. 11).

World Health Organization. (2023). Health accounts — who.int. https://www.who.int/health-topics/health-accounts#tab=tab_1 (cit. on p. 6).

Yarikkaya, E., Ozekinci, S., Sargan, A., Durmus, S. E., & Yildiz, F. R. (2016). A comparative study of activity-based costing vs. current pricing system for pathology examinations at okmeydani training and research hospital, turkey. *Turkish Journal of Pathology*. https://doi.org/10.5146/tjpath.2016.01372 (cit. on p. 9).

Z. Geiger, G. N. (2023). Adenoid Hypertrophy — ncbi.nlm.nih.gov. https://www.ncbi.nlm.nih.gov/books/NBK536984/ (cit. on pp. 2, 11).

Appendix A

Methodology and Data Treatment

This appendix contains figures and tables related to the data provided by the hospital's information system, data processing, and the methodology employed in the study.

Common Element	Description
UNIDADE	Hospital unit where the episode occurs
DATA	Day, month and year at which the episode happened
DIA_DA_SEMANA	Week day which the episode happened
NUM_DE_EPISÓDIO	Identification number of the episode
NHC	Client identification number
MPI	Patient identification number
IDADE	The length of an existence extending from the beginning to the time of the episode
GÉNERO	Refers to the biological characteristics that define humans as female or male.
NACIONALIDADE	Nationality refers to the patient's status of belonging to a particular nation, whether by birth or naturalization.
DISTRITO	Administrative or judicial territorial division, in charge of a certain authority where the patient resides.
CONCELHO	A municipality is a set of parishes close to each other where the patient resides
SERVIÇO_SOLICITANTE_EPISÓDIO	Hospital Service that requested the episode.
SERVIÇO_DO_EPISÓDIO	Hospital service where the episode took place.
SERVIÇO_SOLICITANTE_DO_ACTO	Hospital Service that requested the act.
SERVIÇO	Hospital service where the act took place.
STAFF_ID	Identification number of the staff who performed the act
ESPECIALIDADE	Particular branch of medicine in which a doctor has more complete and in-depth knowledge, acquiring a special competence where the episode takes place.
EFR	Responsible Financial Entity, the entity responsible for the payment or reimbursement of prescription drugs.
AGRUPADOR_EFR	Responsible Financial Entity Grouper
SUBAGRUPADOR_EFR	Responsible Financial Entity Sub grouper
PLANO	Plan of Responsible Financial Entity
CLASSE_GRUPO_ACTO	Class of act groups, namely: consumables, drugs, nursing, among others.
TIPO_DE_ACTO	Type of act performed, for example, surgical, non-surgical, materials, drugs, administrative..
CÓDIGO_ACTO_ARTIGO	Identifier code of the type of act performed
DESCRIÇÃO_ACTO_ARTIGO	Description of the type of act performed
CÓDIGO_DICIONÁRIO	Dictionary code
DESCRIÇÃO_DICIONÁRIO	Description of the act in the dictionary
FAMÍLIA	Material family: clinical, pharmaceutical, hotel consumption
SUBFAMÍLIA	Material sub-family
TIPO_DE_EPISÓDIO	Episode type
CLASSIFICAÇÃO_BI	Classifier BI
CÓDIGO_CLASSIFICADOR_BI	Classifier BI Code
ESTADO	Episode Status: valid or not billable
MOTIVO_DE_NÃO_FACTURAÇÃO	Description of the reason why there is no billing: according to the contract or definition of the service
ELEG_CÁLCULO_QUANTIDADES_S_N	Internal management information - IT and billing processes
QUANTIDADE_DE_ATOS	Number of acts performed
QUANTIDADE	Number of acts performed for each article
CÓDIGO_SI	Internal management information - IT and billing processes

Figure A.1: Table with the data provided for each patient common in all care areas

Existential Areas	Element	Description
Clinical Pathology	CÓDIGO_DA_PRESTAÇÃO	Internal management information - IT and billing processes
	ELEG_CÁLC_QUANTIDADES_TOTAL	Eligible Total amount
	QUANTIDADE_DE_ATOS_TOTAL	Total number of acts
Hospital Stay	TIPO_DE_INTERNAMENTO_NÍVEL_1	Type of hospitalization level 1: surgical or non-surgical.
	TIPO_DE_INTERNAMENTO_NÍVEL_2	Type of hospitalization level 2: general care, intensive care, continuous and palliative care, intermediate care
	CÓDIGO_DA_PRESTAÇÃO	Internal management information - IT and billing processes
	DATA_E_HORA_DE_ADMISSÃO	Date and time of admission in Hospital Stay
	DATA_E_HORA_DE_ALTA	Date and time of discharge from Hospital Stay
	DURAÇÃO_DO_EPISÓDIO	Episode duration
	ALTA_ANTES_DAS_11_S_N	Checks if the discharge took place before 11 am
Operating room	TIPO_DE_CIRURGIA	Type of surgery performed: outpatient or inpatient
	CÓDIGOS_PROCEDIMENTOS	Surgical procedure identifier code
	PROCEDIMENTOS	Performed surgical procedure
	CIRURGIÃO_PRINCIPAL_STAFF_ID	Lead Surgeon Identifier Code
	CIRURGIÃO_AJUDANTE_STAFF_ID	Assistant surgeon identifier code
	ANESTESISTA_STAFF_ID	Anesthetist Identifier Code
	INSTRUMENTISTA_STAFF_ID	Instrumentalist Identifier Code
	ESTADO_DA_CIRURGIA	Surgery status: closed or open
	SALA	Room where the operation takes place
	DATA_HORA_DE_MARCAÇÃO	Date and time of surgery appointment
	DATA_HORA_DE_AGENDAMENTO	Date and time of surgery appointment
	DATA_HORA_ADMISSÃO_AO_BLOCO	Date and time of admission to the operating room
	HORA_INÍCIO_DE_OCUPAÇÃO	Operating room occupancy start time
	HORA_FIM_DE_OCUPAÇÃO	Operating room occupancy end time
	HORA_INÍCIO_DE_INTERVENÇÃO	Surgical intervention start time
	HORA_FIM_DE_INTERVENÇÃO	Surgical intervention end time
	HORA_INÍCIO_DE_ANESTESIA	Anesthesia start time
	HORA_FIM_DE_ANESTESIA	Anesthesia end time
	TIPO_DE_ANESTESIA	Type of anesthesia applied to the patient
	DATA_HORA_TRANSFERÊNCIA_UCPA	Date and time of transfer to Post-Anesthetic Care Unit
	DATA_HORA_SAÍDA_UCPA	Date and time of departure from the Post-Anesthetic Care Unit
	DATA_HORA_ENTRADA_RECOBRO	Date and time of entry into recovery
	DATA_HORA_SAÍDA_RECOBRO	Date and time of departure from recovery
	DATA_HORA_INÍCIO_DO_EPISÓDIO	Episode start date and time
	DATA_HORA_FIM_DO_EPISÓDIO	Episode end date and time
	DURAÇÃO_DA_ANESTESIA	Duration of anesthesia
	DURAÇÃO_DA_OCUPAÇÃO	Duration of room occupancy
	DURAÇÃO_DA_OCUPAÇÃO_CORRIGIDA	Duration of correct room occupancy
	DURAÇÃO_DA_INTERVENÇÃO	Intervention duration
	AMBULATÓRIO_S_N	Outpatient episode classification: yes or no
	PRIORIDADE_DA_CIRURGIA	Surgery priority: elective, urgent or emergent.
	PRIMEIRA_CIRURGIA_DIA_SALA_S_N	Verification whether or not it is the first surgery in the room
	TEMPO_DE_ATRASO	Surgery start delay time
	TEMPO_DE_ESPERA	Waiting time
	DURAÇÃO_PREVISTA_DA_CIRURGIA	Expected duration of surgery
	CONSENTIMENTO_INFORMADO_S_N	Verification of informed consent
	ORIGEM_DA_REFERENCIAÇÃO	Hospital unit of origin of referral

Figure A.2: Table with the data provided for each patient in the following care areas: clinical pathology, hospital stay, operating room.

Existential Areas	Element	Description
External Appointment	CONSULTÓRIO	Office room where the episode takes place
	CÓDIGO_DA_PRESTAÇÃO	Internal management information - IT and billing processes
	DATA_HORA_AGENDAMENTO	Date and time of external appointment
	DATA_E_HORA_DE_ADMISSÃO	Date and time of admission of external appoiment
	DATA_HORA_ENTRADA_TRIAGEM	Screening start date and time
	DATA_HORA_SAÍDA_TRIAGEM	Screening end date and time
	DATA_HORA_INÍCIO_REALIZAÇÃO	Date and time of start of external appoiment
	DATA_HORA_FINAL_REALIZAÇÃO	Date and time of end of external appoiment
	DATA_E_HORA_DE_ALTA	Date and time of discharge from external appoiment
	PRIMEIRA_CONSULTA_OU_SUB	Verification if it is the first consultation of the specialty or the subsequent one
	PRIMEIRA_CONSULTA_DO_DIA_S_N	Check if it's the first appointment of the day
	ELEGÍVEL_S_N	Internal management information - IT and billing processes
	NÃO_CONFORMIDADES	Presence of nonconformities, for example delays
	DURAÇÃO_DA_CONSULTA	External Appoiment Duration
	DURAÇÃO_DA_CONSULTA_CORRIGIDA	Query duration correction
	ATRASO_DO_INÍCIO_DA_CONSULTA	Delay start of query
	TEMPO_ATRASO_MÉDICO	Delay time performed by the doctor
	ELEG_ATRASO_MÉDICO	Eligible delay time performed by the doctor
	ACTIVIDADE_PK	Internal management information - IT and billing processes
Imagiology	STAFF_ID_PRESCRITOR	Examination prescriber identification number
	CONSULTÓRIO	Room or center where the exam is performed
	CÓDIGO_DA_PRESTAÇÃO	Internal management information - IT and billing processes
	ORIGEM_DO_EXAME	Origin of the exam: outpatient or inpatient
	TIPO_DE_EXAME	Type of examination performed, such as CAT scan, X-ray, ectomography, MRI
	ELEG_CÁLC_QUANTIDADES_TOTAL	Eligible Total amount
	QUANTIDADE_DE_ATOS_TOTAL	Eligible Total of Acts
Urgent Care	CÓDIGO_DA_PRESTAÇÃO	
	DATA_E_HORA_DE_ADMISSÃO	Date and time of admission to urgent care
	DATA_HORA_INÍCIO_REALIZAÇÃO	Date and time of admission to urgent care
	DATA_HORA_FINAL_REALIZAÇÃO	Date and time of start of urgent care
	DATA_E_HORA_DE_ALTA	Date and time of discharge from urgent care
	DURAÇÃO_DO_EPISÓDIO	Episode Duration
	ELEG_NÚM_MÉD_ATEND_URG_HORA	Eligible urgent care duration
	DURAÇÃO_DO_ATENDIMENTO	Duration of urgent care
	ELEG_DUR_MÉD_EPISÓDIO_DE_URG	Eligible urgent care episode duration
	GERA_CIRURGIA_S_N	Urgent care leads to surgery: yes or no
	GERA_INTERNAMENTO_S_N	Urgent care leads to hospitalization: yes or no
	DATA_HORA_INÍCIO_TRIAGEM	Screening start date and time
	GRAU_PRIORIDADE_TRIAGEM	Triage priority grade: 2 - very urgent, 3 - urgent, 4 - not very urgent
	DESTINO_ALTA	Discharge destination: home, hospitalization, outpatient consultation
	TEMPO_MÉDIO_ESPERA_TRIAGEM	Average screening waiting time
	ELEG_TEMPO_MÉD_ESPERA_TRIAGEM	Eligible average screening waiting time
	TEMPO_MÉD_ESPERA_1_CHAMADA	Average waiting time after 1st call
	ELEG_TEMPO_MÉD_ESPERA_1_CHAM	Eligible average waiting time after 1st call
MCDT	STAFF_ID_PRESCRITOR	Examination prescriber identification number
	CÓDIGO_DA_PRESTAÇÃO	Internal management information - IT and billing processes

Figure A.3: Table with the data provided for each patient in the following care areas: external appointment, imagiology, urgent care, CDTM.

Code	Patient	Department	Date	Service_Requester_of_Episode	Specialty/Act	Type of Surgery	Pathway	Days To Surgery
1	Patient 1	EC	27/10/2021	External	Otorhinolaryngology		DIAG	-47
2	Patient 1	SURGERY	13/12/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Endonasal Microsurgery + Septoplasty	SURGERY	0
3	Patient 1	EC	15/12/2021		Otorhinolaryngology		FOLLOW	2
4	Patient 1	EC	22/12/2021		Otorhinolaryngology		FOLLOW	9
5	Patient 1	EC	10/03/2022	Otorhinolaryngology LIS (CE)	Development Peadriatic		FOLLOW	87
1	Patient 2	SURGERY	22/01/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Septoplasty + Turbinectomy	SURGERY	0
2	Patient 2	HOSPITALIZATION	22/01/2020	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0
1	Patient 3	EC	14/07/2020	External	Otorhinolaryngology		DIAG	-84
2	Patient 3	CDTM	15/09/2020	Otorhinolaryngology LIS (CE)	Tone Audiogram		DIAG	-21
3	Patient 3	CDTM	15/09/2020	Otorhinolaryngology LIS (CE)	Tympanogram		DIAG	-21
4	Patient 3	EC	15/09/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		DIAG	-21
5	Patient 3	PATCLI	24/09/2020	Otorhinolaryngology LIS (CE)	Clinical Pathology		DIAG	-12
6	Patient 3	SURGERY	06/10/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Tympanoplasty	SURGERY	0
7	Patient 3	HOSPITALIZATION	06/10/2020	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0
8	Patient 3	EC	12/10/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology		FOLLOW	6
9	Patient 3	EC	22/10/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	16
10	Patient 3	EC	05/11/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	30
11	Patient 3	EC	03/12/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	58
1	Patient 4	SURGERY	13/04/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Tympanomastoidectomy	SURGERY	0
2	Patient 4	HOSPITALIZATION	13/04/2021	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0
3	Patient 4	EC	21/04/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology		FOLLOW	8
4	Patient 4	EC	14/05/2021	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	31
5	Patient 4	EC	21/05/2021	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	38
6	Patient 4	EC	11/06/2021	External	Otorhinolaryngology		FOLLOW	59
1	Patient 5	EC	07/11/2022	External	Peadriatic		DIAG	-36
2	Patient 5	EC	11/11/2022	External	Otorhinolaryngology		DIAG	-32
3	Patient 5	SURGERY	13/12/2022		Otorhinolaryngology	Tympanomastoidectomy	SURGERY	0
4	Patient 5	HOSPITALIZATION	13/12/2022		Surgery Hospitalization		SURGERY	0

Figure A.4: Example of Clinical Pathway defined for five patients

ARTICLE_ACT_CODE	ARTICLE_ACT_DESCRIPTION	QUANTITY	CONSUMABLES_COST	DRUGS_COST	HONORARY_COST	DIRECT_PERSONNEL_COST	INDIRECT_PERSONNEL_COST	LABORATORY_COST	MAINTENANCE_COST	OTHER_COST
100	Hemograma com Plaquetas	1	0,00	0,00	0,00	-	-	-	0,00	-
106	Hemograma sem Formula	1	0,00	0,00	0,00	-	-	-	0,00	-
107	Estudo Morfologico do Sangue Periferico	1	0,00	0,00	0,00	-	-	-	0,00	-
109	Reticulocitos	1	0,00	0,00	0,00	-	-	-	0,00	-
110	Vs, Velocidade de Sedimentaçao	1	0,00	0,00	0,00	-	-	-	0,00	-
126	Electroforese das Hemoglobinas	1	0,00	0,00	0,00	-	-	-	0,00	-
128	Glucose-6-P-Desidrogenase (G6pd)	1	0,00	0,00	0,00	-	-	-	0,00	-
131	Tempo de Protrombina - Inr	1	0,00	0,00	0,00	-	-	-	0,00	-
132	Aptt, Tempo de Tromboplastina Parcial Activado	1	0,00	0,00	0,00	-	-	-	0,00	-
133	Fibrinogenio	1	0,00	0,00	0,00	-	-	-	0,00	-
139	Factor VIII da Coagulaçao	1	0,00	0,00	0,00	-	-	-	0,00	-
140	Factor VII da Coagulaçao	1	0,00	0,00	0,00	-	-	-	0,00	-
145	Plasmodium Sp, Pesquisa	1	0,00	0,00	0,00	-	-	-	0,00	-
146	Dimeros D (Dd/Pdf)	1	0,00	0,00	0,00	-	-	-	0,00	-
150	Tipagem Ab0 e Rh (D)	1	0,00	0,00	0,00	-	-	-	0,00	-
152	Coombs Directo	1	0,00	0,00	0,00	-	-	-	0,00	-
153	Coombs Indirecto	1	0,00	0,00	0,00	-	-	-	0,00	-
162	Fenotipo Rh	1	0,00	0,00	0,00	-	-	-	0,00	-
192	Fenotipagem Eritrocitaria Alargada	1	0,00	0,00	0,00	-	-	-	0,00	-
201	Proteinograma, Electroforese de Proteinas	1	0,00	0,00	0,00	-	-	-	0,00	-

Figure A.5: Example of the cost matrix provided by the Hospital

Code	Patient	Department	Date	Service_Requester_of_Episode	Specialty/Act	Type of Surgery	Pathway	Days To Surgery	Emergency Care Cost	Surgery Cost	CDTM Cost	Hospitalization Cost	External Consultation Cost	Imagiology	Clinical Pathology Cost
1	Patient 1	EC	27/10/2021	External	Otorhinolaryngology		DIAG	-47	0,00	0,00	0,00	0,00	-	0,00	-
2	Patient 1	SURGERY	13/12/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Endonasal Microsurgery + Septoplasty	SURGERY	0	0,00	-	0,00	0,00	0,00	0,00	0,00
3	Patient 1	EC	15/12/2021		Otorhinolaryngology		FOLLOW	2	0,00	0,00	0,00	0,00	-	0,00	0,00
4	Patient 1	EC	22/12/2021		Otorhinolaryngology		FOLLOW	9	0,00	0,00	0,00	0,00	-	0,00	0,00
5	Patient 1	EC	10/03/2022	Otorhinolaryngology LIS (CE)	Development Peadriatic		FOLLOW	87	0,00	0,00	0,00	0,00	-	0,00	0,00
1	Patient 2	SURGERY	22/01/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Septoplasty + Turbinectomy	SURGERY	0	0,00	-	0,00	0,00	0,00	0,00	0,00
2	Patient 2	HOSPITALIZATION	22/01/2020	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0	0,00	0,00	0,00	-	0,00	0,00	0,00
1	Patient 3	EC	14/07/2020	External	Otorhinolaryngology		DIAG	-84	0,00	0,00	0,00	0,00	-	0,00	0,00
2	Patient 3	CDTM	15/09/2020	Otorhinolaryngology LIS (CE)	Tone Audiogram		DIAG	-21	0,00	0,00	-	0,00	0,00	0,00	0,00
3	Patient 3	CDTM	15/09/2020	Otorhinolaryngology LIS (CE)	Tympanogram		DIAG	-21	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4	Patient 3	EC	15/09/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		DIAG	-21	0,00	0,00	0,00	0,00	-	0,00	0,00
5	Patient 3	PATCLI	24/09/2020	Otorhinolaryngology LIS (CE)	Clinical Pathology		DIAG	-12	0,00	0,00	0,00	0,00	0,00	0,00	-
6	Patient 3	SURGERY	06/10/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Tympanoplasty	SURGERY	0	0,00	-	0,00	0,00	0,00	0,00	0,00
7	Patient 3	HOSPITALIZATION	06/10/2020	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0	0,00	0,00	0,00	-	0,00	0,00	0,00
8	Patient 3	EC	12/10/2020	Otorhinolaryngology LIS (INT)	Otorhinolaryngology		FOLLOW	6	0,00	0,00	0,00	0,00	-	0,00	0,00
9	Patient 3	EC	22/10/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	16	0,00	0,00	0,00	0,00	-	0,00	0,00
10	Patient 3	EC	05/11/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	30	0,00	0,00	0,00	0,00	-	0,00	0,00
11	Patient 3	EC	03/12/2020	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	58	0,00	0,00	0,00	0,00	-	0,00	0,00
1	Patient 4	SURGERY	13/04/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology	Tympanomastoidectomy	SURGERY	0	0,00	-	0,00	0,00	0,00	0,00	0,00
2	Patient 4	HOSPITALIZATION	13/04/2021	Otorhinolaryngology LIS (INT)	Surgery Hospitalization		SURGERY	0	0,00	0,00	0,00	-	0,00	0,00	0,00
3	Patient 4	EC	21/04/2021	Otorhinolaryngology LIS (INT)	Otorhinolaryngology		FOLLOW	8	0,00	0,00	0,00	0,00	-	0,00	0,00
4	Patient 4	EC	14/05/2021	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	31	0,00	0,00	0,00	0,00	-	0,00	0,00
5	Patient 4	EC	21/05/2021	Otorhinolaryngology LIS (CE)	Otorhinolaryngology		FOLLOW	38	0,00	0,00	0,00	0,00	-	0,00	0,00
6	Patient 4	EC	11/06/2021	External	Otorhinolaryngology		FOLLOW	59	0,00	0,00	0,00	0,00	-	0,00	0,00
1	Patient 5	EC	07/11/2022	External	Peadriatic		DIAG	-36	0,00	0,00	0,00	0,00	-	0,00	0,00
2	Patient 5	EC	11/11/2022	External	Otorhinolaryngology		DIAG	-32	0,00	0,00	0,00	0,00	-	0,00	0,00
3	Patient 5	SURGERY	13/12/2022		Otorhinolaryngology	Tympanomastoidectomy	SURGERY	0	0,00	-	0,00	0,00	0,00	0,00	0,00
4	Patient 5	HOSPITALIZATION	13/12/2022		Surgery Hospitalization		SURGERY	0	0,00	0,00	0,00	-	0,00	0,00	0,00

Figure A.6: Example of Clinical Pathway defined for five patients with the cost for care area

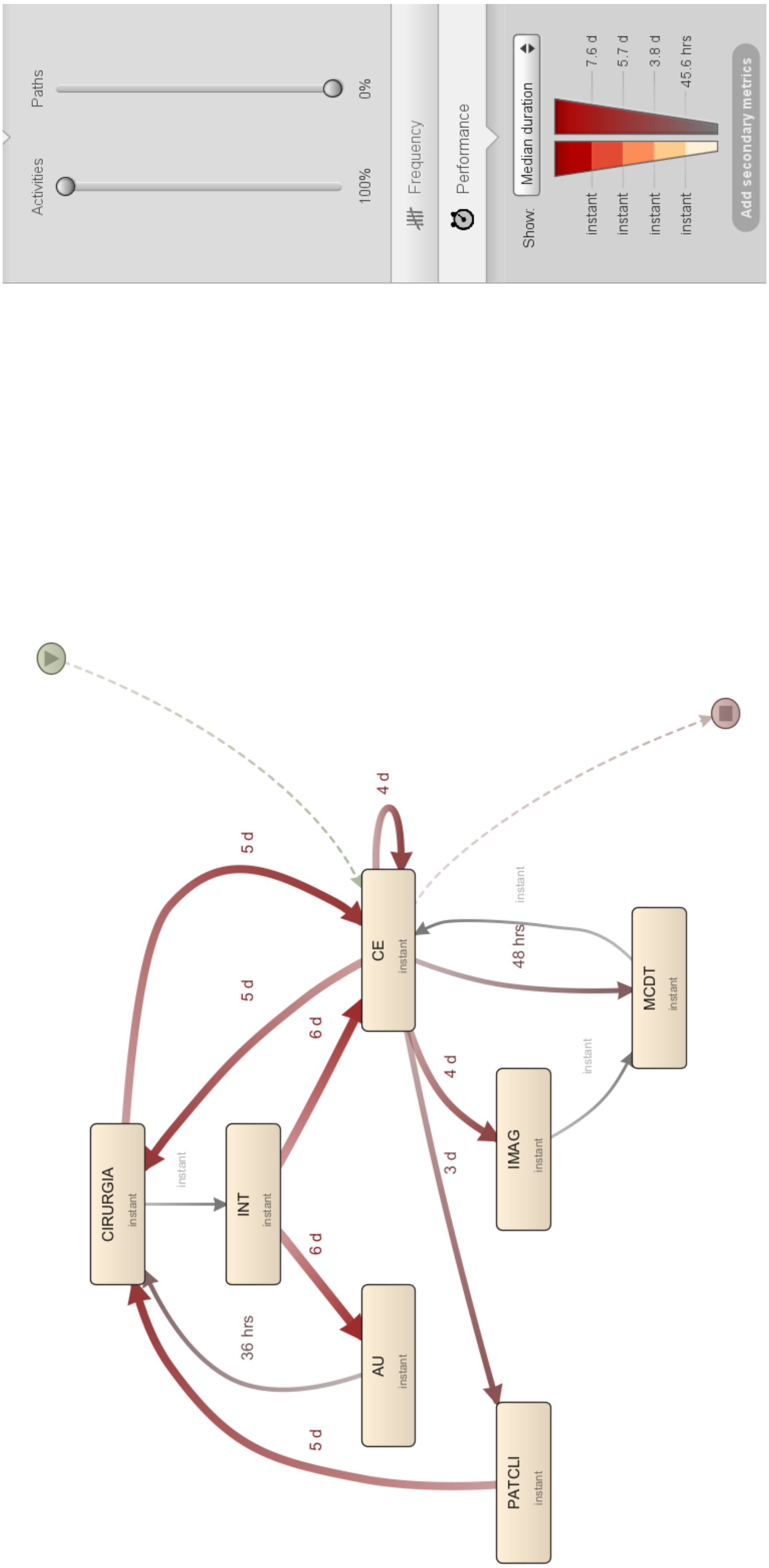

Figure A.7: Visualization of the clinical pathway performance regarding the median duration between events (made in *DISCO*)

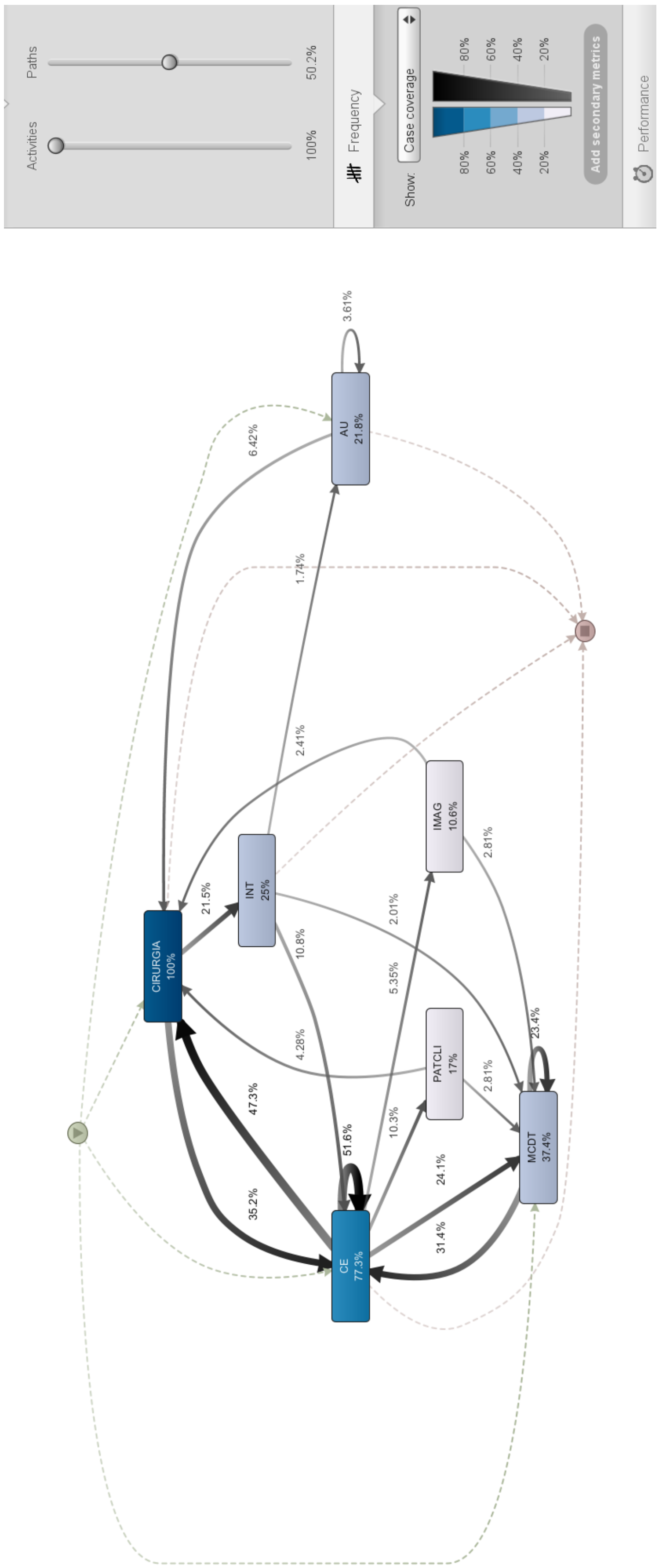

Figure A.8: Visualization of the clinical pathway case coverage between events including 50.2% of the total paths (made in *DISCO*)

Figure A.9: Visualization of the different pathways practiced by patients (made in *DISCO*)

Appendix B

Results activity pathway

This appendix contains figures and tables related to the results obtained from the study of the patients' activity pathway.

Table B.1: Most performed types of surgeries in ENT pediatric

Surgery Type	Percentage of Surgery
Adenoidectomy	34.5%
Myringotomy	24.9%
Tonsillectomy	22.8%
Foreign Body Extraction	3.8%
Turbinectomy	3.3%
Endonasal Microsurgery	2.0%
Septoplasty	1.7%
Tympanoplasty	1.5%
Mastoidectomy	1.3%
Tympanomastoidectomy	1.2%

Table B.2: External activity pathway analysis

External Consultation	No of Patients	% of Patients
Episode	578	77%
Episode in Diagnosis	523	70%
Episode in Follow-up	439	59%
ENT Episode	561	75%

No of Consultations	1934	100%
No Appointments in Diagnosis	1142	59%
No Appointments in Follow-Up	794	41%

Table B.3: Average external consultation for patient

External Consultation	Average
Appointment for Patient	4
Diagnosis Appointment for Patient	2
Follow-up Appointment for Patient	2

Table B.4: Emergency Care activity pathway analysis

Emergency Care	No of Patients	% of Patients
Episode	163	22%
Episode in Diagnosis	101	14%
Episode in Follow-up	82	11%
Episode in Follow-up <30 days	60	8%
Episode in Surgery	10	1%

Table B.5: Hospitalization activity pathway analysis

Hospitalization	No of Patients	% of Patients
Episode	187	25.0%
Surgery Hospitalization Episode	182	24.3%
Average Duration	1.5 (days)	

Table B.6: Number of Surgeries for scheduled time and hospitalization rate

Surgery Scheduled Time	No of Surgery	% of Hospitalization
Morning (08h-12h)	334	12%
Afternoon (12h-16h)	266	29%
Late Afternoon (16h-20h)	130	42%
Night (20h-00h)	14	57%

Dawn (>00h)	2	100%
Without Hour	2	50%

Table B.7: Clinical Pathology - activity pathway analysis

Clinical Pathology	No of Patients	% of Patients
Episode	127	17%
Diagnosis Episode	114	15%
Follow-up Episode	9	1%
Surgery Episode	7	1%

Table B.8: Imagiology - activity pathway analysis

Imagiology	No of Patients	% of Patients
Episode	78	11%
Diagnosis Episode	74	10%
Follow-up Episode	5	1%

Table B.9: Imaging Exams performed in ENT pedriatic

Surgery Combinations	Percentage of Surgery
Cavum X-ray	37%
CT Sinuses	16%
Torax X-ray	10%
CT Neck	6%
Transportable X-ray	6%
CT Ears	5%
CT Face	3%
CT Contrast	3%
CT Spn	3%
CT Chest	2%
MRI Ears	1%
Eco Complementary Study	1%
MRI Spesctroscopy	1%
Cranial Morphological	1%
MRI Orbit	1%
CT Larynx	1%

Orthopantomography	1%
Thyroid Biopsy	1%
Ultrasound Soft Tissues	1%

Table B.10: Othorynolaryngoly CDTM- activity pathway analysis

Othorynolaryngoly CDTM	No of Patients	% of Patients
Episode	280	37%
Diagnosis Episode	226	30%
Follow-up Episode	114	15%
Diagnosis and Follow-Up Episode	65	9%

Table B.11: Average Othorynolaryngoly CDTM for patient

Othorynolaryngoly CDTM	Average
Appointment for Patient	2
Diagnosis Appointment for Patient	2

Table B.12: CDTM Exams performed in ENT pedriatic

CDTM Combinations	Percentage of CDTM
Pure Tone Audiometry	33.0%
Impedance Study	27.6%
Tympanogram	21.2%
Pure Tone Audiogram	6.9%
Otoemissions	5.8%
Auditory EV Potentials	2.4%
Tympanometric Study	1.0%
Speech Therapy	0.8%
Vocal Audiograms	0.7%
Central Processing Hearing	0.1%
Protein Audiogram	0.1%
Microlaryngoscopy	0.1%
Rhinoscopy	0.1%
Oropharyngeal Biopsy	0.1%
Polygraphic Record of Night Sleep	0.1%

Surgery Combinations	% of Surgeries
Adenoidectomy	2,4%
Adenoidectomy + Tonsillectomy	17,3%
Adenoidectomy + Tonsillectomy + Foreign Body Extraction + Lingual Brake	0,1%
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery	0,1%
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery + Myringotomy	0,1%
Adenoidectomy + Tonsillectomy + Myringotomy	14,4%
Adenoidectomy + Tonsillectomy + Myringotomy + Lingual Brake Plasty	0,3%
Adenoidectomy + Tonsillectomy + Myringotomy + Turbinectomy	0,3%
Adenoidectomy + Tonsillectomy + Turbinectomy	1,1%
Adenoidectomy + Endonasal Microsurgery	1,0%
Adenoidectomy + Microcirurgia Endonasal + Myringotomy + Septoplasty	0,1%
Adenoidectomy + Endonasal Microsurgery + Septoplasty	0,4%
Adenoidectomy + Myringotomy	26,1%
Adenoidectomy + Myringotomy + Lingual Brake Plasty	0,1%
Adenoidectomy + Myringotomy + Turbinectomy	0,5%
Adenoidectomy + Lingual Brake Plasty	0,1%
Adenoidectomy + Septoplasty	0,1%
Adenoidectomy + Turbinectomy	1,5%
Tonsillectomy	6,9%
Tonsillectomy + Abscess Drainage	0,1%
Tonsillectomy + Foreign Body Extraction	0,1%
Tonsillectomy + Endonasal Microsurgery	0,1%
Tonsillectomy + Endonasal Microsurgery + Septoplasty	0,1%
Tonsillectomy + Myringotomy	1,6%
Tonsillectomy + Otoplasty	0,1%
Tonsillectomy + Palate Suture Laceration	0,1%
Tonsillectomy + Turbinectomy	0,5%
Caldwell-Luc	0,1%
Abscess Drainage	0,8%

Surgery Combinations	% of Surgeries
Abscess Drainage + Endonasal Microsurgery	0,1%
Septum Nasal Drainage	0,1%
Cyst Excision	0,8%
Sublingual Gland Excision	0,1%
Foreign Body Extraction	6,4%
Foreign Body Extraction + Tympanoplasty	0,1%
Foreign Body Extraction Nasal	0,5%
Lingual Frenectomy	0,1%
Cochlear Implant	0,5%
Mastoidectomy	0,1%
Endonasal Microsurgery	0,8%
Endonasal Microsurgery + Myringotomy	0,1%
Endonasal Microsurgery + Septoplasty	0,7%
Endonasal Microsurgery + Septoplasty + Turbinectomy	0,1%
Laryngeal Microsurgery	0,1%
Microlaryngoscopy in suspension	0,1%
Myringotomy	3,9%
Myringotomy + Tympanomastoidectomy	0,3%
Palatoplasty	0,1%
Lingual Brake Plasty	0,3%
Ret.Tecid.Adjac.Reg.Frontal Face/Boca/Pesc/Axila/Gen/Mãos/Pés-10 Cm2	0,1%
Rhinoplasty	0,5%
Septoplasty	0,1%
Septoplasty + Turbinectomy	1,5%
Tympanomastoidectomy	2,0%
Tympanoplasty	2,5%
Tympanoplasty + Turbinectomy	0,1%
Nose Fracture Treatment	0,5%
Turbinectomy	0,9%

Figure B.1: Surgeries combinations performed in ENT pedriatic

Table B.13: Patient percentage of each assistance area in the activity pathway

Assistance Area	% Start of Clinical Path	% End of Clinical Path
Surgery	34.6%	32.6%

Outpatient Consultation	43.1%	47.6%
Emergency Care	7.1%	3.9%
Hospitalization	2.0%	8.2%
Clinical Pathology	2.7%	2.7%
Imaging Exams	1.9%	1.3%
CDTM	8.7%	3.7%

Table B.14: Case coverage percentage for each assistance area

Assistance Area	% Case Coverage
Surgery	100.0%
Outpatient Consultation	77.3%
Emergency Care	21.8%
Hospitalization	25.0%
Clinical Pathology	17.0%
Imaging Exams	10.6%
CDTM	37.4%

Table B.15: 10 activity pathways comprising 436 variations of paths for all types of surgeries (data provided by *DISCO*)

activity pathway	% Case Coverage
Surgery	15.5%
Surgery -> OC	2.9%
OC -> Surgery -> OC	2.4%
Surgery -> Hospitalization	2.3%
OC -> OC -> Surgery	2.3%
OC -> Surgery	2.3%
Surgery -> OC -> OC	1.6%
OC -> OC -> Surgery -> OC	1.3%
Surgery -> OC -> OC -> OC	0.9%
Emergency Care -> Surgery	0.9%

Table B.16: 15 activity pathways comprising 328 variations of paths for the group of surgeries: adenoidectomy, myringotomy and tonsillectomy (data provided by *DISCO*

activity pathway	% Case Coverage
Surgery	18.7%
Surgery -> OC	3.5%
OC -> OC -> Surgery	2.4%
OC -> Surgery -> OC	2.4%
OC -> Surgery	2.2%
OC -> OC -> Surgery -> OC	1.5%
Surgery -> Hospitalization	1.3%
Surgery -> OC -> OC	1.3%
Surgery -> OC -> OC -> OC	1.1%
Emergency Care -> Surgery	0.7%
OC -> OC -> OC -> Surgery	0.7%
OC -> Surgery -> Hospitalization	0.7%
OC -> Surgery -> OC -> CDTM -> OC	0.7%
Surgery -> OC -> OC ->OC -> OC -> OC	0.6%
CDTM -> CDTM -> OC -> OC -> Surgery	0.6%

Surgery	% Hospitalization	% Ambulatory
Adenoidectomy	17%	83%
Adenoidectomy + Tonsillectomy	17%	83%
Adenoidectomy + Tonsillectomy + Foreign Body Extraction + Lingual Brake Plasty	0%	100%
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery	100%	0%
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery + Myringotomy	0%	100%
Adenoidectomy + Tonsillectomy + Myringotomy	31%	69%
Adenoidectomy + Tonsillectomy + Myringotomy + Lingual Brake Plasty	0%	100%
Adenoidectomy + Tonsillectomy + Myringotomy + Turbinectomy	50%	50%
Adenoidectomy + Tonsillectomy + Turbinectomy	38%	63%
Adenoidectomy + Endonasal Microsurgery	71%	29%
Adenoidectomy + Microcirurgia Endonasal + Myringotomy + Septoplasty	100%	0%
Adenoidectomy + Endonasal Microsurgery + Septoplasty	100%	0%
Adenoidectomy + Myringotomy	5%	95%
Adenoidectomy + Myringotomy + Lingual Brake Plasty	0%	100%
Adenoidectomy + Myringotomy + Turbinectomy	0%	100%
Adenoidectomy + Lingual Brake Plasty	100%	0%
Adenoidectomy + Septoplasty	0%	100%
Adenoidectomy + Turbinectomy	9%	91%
Tonsillectomy	37%	63%
Tonsillectomy + Abscess Drainage	100%	0%
Tonsillectomy + Foreign Body Extraction	0%	100%
Tonsillectomy + Endonasal Microsurgery	100%	0%
Tonsillectomy + Endonasal Microsurgery + Septoplasty	100%	0%
Tonsillectomy + Myringotomy	25%	75%
Tonsillectomy + Otoplasty	100%	0%
Tonsillectomy + Palate Suture Laceration	100%	0%
Tonsillectomy + Turbinectomy	25%	75%
Caldwell-Luc	0%	100%
Abscess Drainage	100%	0%
Abscess Drainage + Endonasal Microsurgery	100%	0%
Septum Nasal Drainage	100%	0%
Cyst Excision	33%	67%
Sublingual Gland Excision	100%	0%
Foreign Body Extraction	0%	100%
Foreign Body Extraction + Tympanoplasty	0%	100%
Foreign Body Extraction Nasal	0%	100%
Lingual Frenectomy	0%	100%
Cochlear Implant	100%	0%
Mastoidectomy	100%	0%
Endonasal Microsurgery	50%	50%
Endonasal Microsurgery + Myringotomy	100%	0%
Endonasal Microsurgery + Septoplasty	80%	20%
Endonasal Microsurgery + Septoplasty + Turbinectomy	100%	0%
Laryngeal Microsurgery	100%	0%
Microlaryngoscopy in suspension	0%	100%
Myringotomy	3%	97%
Myringotomy + Tympanomastoidectomy	100%	0%
Palatoplasty	0%	100%
Lingual Brake Plasty	0%	100%
Ret.Tecid.Adjac.Reg.Frontal Face/Boca/Pesc/Axila/Gen/Mãos/Pés-10 Cm2	0%	100%
Rhinoplasty	67%	33%
Septoplasty	100%	0%
Septoplasty + Turbinectomy	82%	18%
Tympanomastoidectomy	100%	0%
Tympanoplasty	63%	37%
Tympanoplasty + Turbinectomy	100%	0%
Nose Fracture Treatment	33%	67%
Turbinectomy	0%	100%

Figure B.2: Surgery percentage of hospitalization and ambulatory procedures

Appendix C

Results Costing Methodology

This appendix contains figures and tables related to the results obtained from the study of the costing methodology.

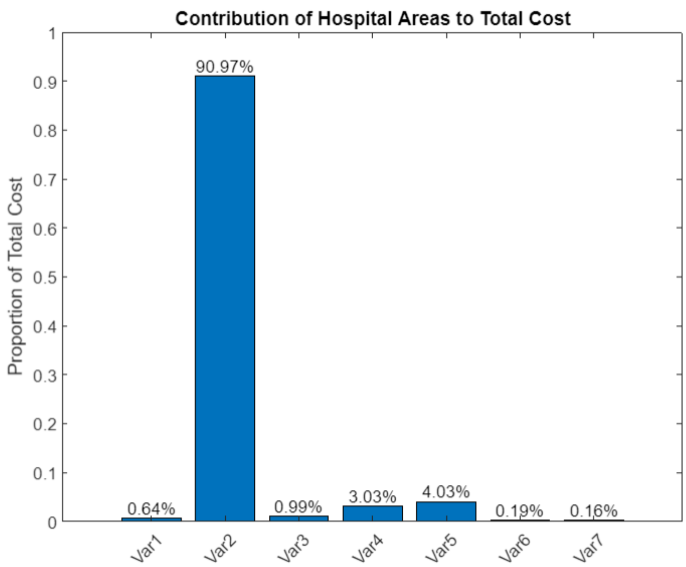

Figure C.1: Proportion of total cost distribution for Hospital Areas - Var1:Emergency care, Var2: Surgery, Var3: CDTM, Var4: Hospitalization, Var5: External Consultation, Var6: Imagiology, Var7: Clinical Pathology.

Emergency Care Objects of Cost	% Direct Total Cost
Resources	7,0%
Consumables	4,2%
Medicines	2,0%
Other	0,8%
Personnel	92,9 %
Pediatric Permanent Care	88,9%
Otorhinolaryngology Permanent Care	1,2%
Other	2,8%
CMDT	0,1%

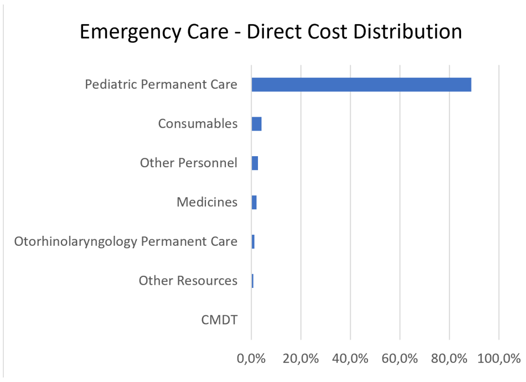

Figure C.2: Emergency care objects of cost and cost distribution

External Consultation Objects of Cost	% Direct Total Cost
Resources	0,1%
Office Maintenance	0,1%
Personnel	99,9%
2nd ENT Consultation Honorary	65,2%
1st ENT Consultation Honorary	17,9%
1st Pediatric Consultation Honorary	2,0%
2nd Pediatric Consultation Honorary	1,6%
Other Consultation Honorary Cost	1,8%
Direct Personnel	11,4%

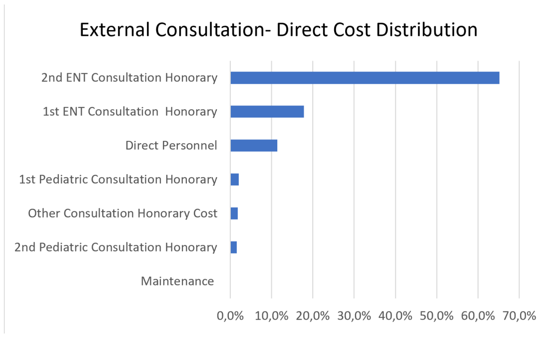

Figure C.3: External consultation objects of cost and cost distribution

Hospitalization Objects of Cost	% Direct Total Cost
Resources	22,9%
Consumables	5,9%
Laboratory	4,0%
Medicines	11,7%
Other (maintenance)	1,3%
Personnel	77,1%
Surgery Hospitalization	43,8%
ICU Diary	14,3%
Intermedium Care Unit Diary	1,5%
Other Direct Personnel	17,5%

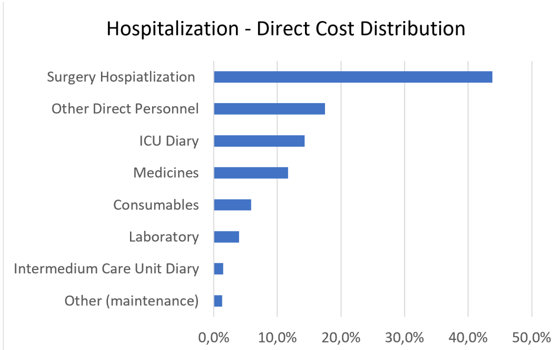

Figure C.4: Hospitalization objects of cost and cost distribution

Imagiology Objects of Cost	% Direct Total Cost
Resources	11,7%
Medicines	1,1%
Maintenance	10,60%
Personnel	88,3%
CT Sinuses Honorary	19,6%
CT Neck Honorary	8,7%
CT Ears Honorary	6,2%
CT Spn (low dose protocol) Honorary	4,5%
MRI Ears Honorary	4,2%
MRI Cavum Honorary	4,2%
Other Exams	16,6%
Direct Personnel	24,4%

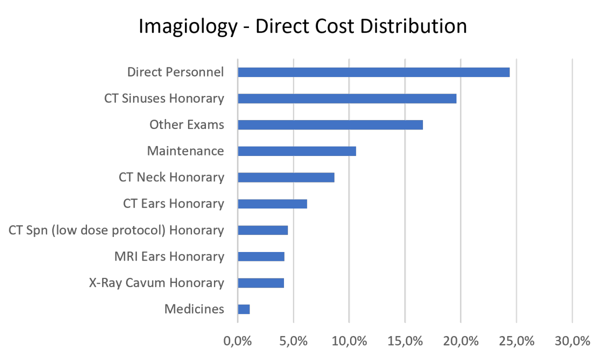

Figure C.5: Imagiology objects of cost and cost distribution

CDTM Objects of Cost	% Direct Total Cost
Resources	2,9%
Consumables	0,9%
Medicines	0,7%
Other (maintenance and laboratory)	1,2%
Personnel	97,1%
Tone and Vocal Audiometry Honorary	42,1%
Impedance Study Honorary	13,7%
Tympanogram Honorary	8,7%
Auditory EV Potentials Honorary	7,8%
Other Exams Honorary Cost	9,3%
Direct Personnel	15,6%

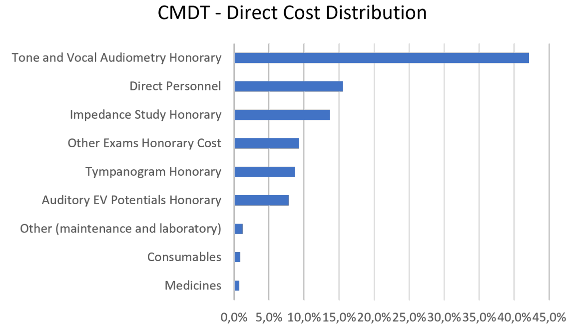

Figure C.6: CDTM objects of cost and cost distribution

Clinical Pathology Objects of Cost	% Direct Total Cost
Resources	87,3%
Platelets Hemogram	13,2%
D-Dimers (Dd/Pdf)	6,0%
Pcr (C-Reactive Protein)	4,3%
Ionogram (Na, K, Cl)	3,1%
Serum Ionogram	2,9%
Fibrinogen	2,6%
T. Prothrombin	2,6%
Other laboratory tests	52,5%
Personnel	12,7%
Direct Personnel	12,7%

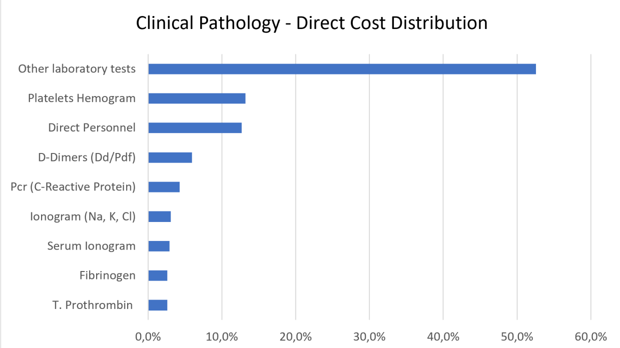

Figure C.7: Clinical Pathology objects of cost and cost distribution

Surgery Objects of Cost	% Direct Total Cost
Resources	16,3%
Consumables	11,7%
Medicines	3,2%
Other (maintenance and laboratory)	1,4%
Personnel	83,7%
Surgeon Fee	29,5%
Helper Fee	20,8%
Instrumentalist Fee	10,1%
Anesthesiologist Fee	15,9%
Direct Human Resourses	7,4%

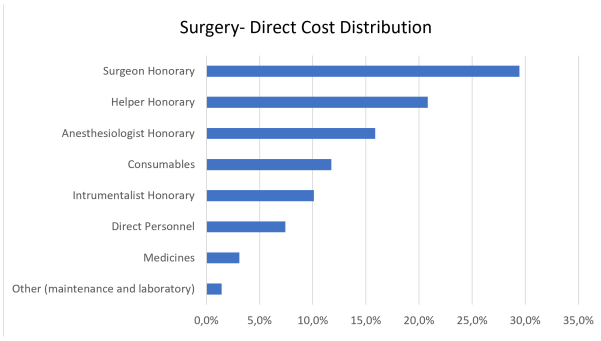

Figure C.8: Surgery objects of cost and cost distribution

Table C.1: Total personnel cost weighted percentage in the activity cost pathway

Assistance Area	% Personnel Cost	% Total Cost	% Personnel Cost Weighted
Surgery	83.7%	90.97%	76.1%
Outpatient Consultation	99.9%	4.03%	4.0%
Emergency Care	92.9%	0.64%	0.6%
Hospitalization	77.1%	3.03%	2.3%
Clinical Pathology	12.7%	0.16%	0.02%
Imaging Exams	88.3%	0.19%	0.2%
CDTM	97.1%	0.99%	1.0%
Total		100%	84.2%

Consumable	Cost of Unit	Cost Distribution	Quantity
Adaptador P/ Canula de Aspiração Ouvido/Nasal	-	0,6%	373
Agulha Colorado Recta, 3cm	-	3,3%	59
Bata N/Esteril Descartavel Impermeavel	-	1,3%	571
Bata Standard L	-	3,0%	1155
Bata Standard Xl	-	1,7%	629
Campo C/Orifício 200x280	-	1,6%	272
Campo Cirurgico C/Orificio 120x150	-	1,5%	494
Canula Aspiração Ouvido 2x80mm	-	0,7%	363
Cobertura de Mesa de Mayo Reforçada 77x145 Cm	-	1,5%	722
Compressa Esteril Tnt Radiopaca 10x40cm 70gr Pact 5	-	1,2%	798
Dispositivo Cateter Balão 6x18mm	-	0,7%	1
Filtro Bacteriano Anestesia Pediatrico	-	0,6%	597
Implante Coclear c/ Electrodo Fino e Recto	-	12,0%	2
Implante Coclear c/ Eletrodo Avanço de Contorno	-	5,8%	1
Kit Cateter Balão 5x8mm	-	0,6%	1
Manta Pediatrica	-	1,7%	178
Ponta Comprida P/ Canivete Eléctrico	-	2,1%	145
Ponteira Celon 1.3mm Bisel	-	3,3%	35
Ponteira de Amigdalectomia 70º	-	4,5%	38
Processador de Implante Coclear Castanho	-	6,3%	2
Processador Implante Coclear c/ Eletrodo	-	2,8%	1
Protector Auricular Externo	-	0,6%	28
Regulador de Gotas	-	0,6%	564
Sensor Bis Monitor Infinity	-	1,0%	86
Sensor Bis Pediatrico	-	0,6%	52
Sensor Oximetria Pediátrico	-	1,7%	376
Sist. Anestesia C/Balão e Válvulas Pediatrico Comp	-	0,6%	37
Sist. Anestesia Completo Pediatrico 1,6m	-	2,4%	355
Sistema Completo Anestesia c/ Balão 2 Lts	-	0,5%	94
Sonda P/Cornetos	-	6,8%	94
Sonda P/Palato	-	0,6%	8
Tubo Capnografia	-	0,5%	154
Tubo de Aspiração P/ Aspirador/Irrigador de Laparoscopia	-	1,8%	635
Tubo de Ligação Sonda Yankauer	-	0,6%	518
Tubo Ventilação Shepard s/ Fio 1.14mm	-	3,6%	681

Figure C.9: Surgery objects of cost and cost distribution - Consumables

Table C.2: Total consumables weighted percentage in the activity cost pathway

Assistance Area	% Personnel Cost	% Total Cost	% Personnel Cost Weighted
Surgery	11.7%	90.97%	10.6%
Outpatient Consultation	0.0%	4.03%	0.0%
Emergency Care	4.2%	0.64%	0.02%
Hospitalization	5.9%	3.03%	0.1%
Clinical Pathology	0.0%	0.16%	0.0%
Imaging Exams	0.0%	0.19%	0.0%
CDTM	0.9%	0.99%	0.0%
Total		100%	10.7%

Medication	Unit Cost	Cost Distribution	Quantity
Acetonido de Triamcinolona 40mg/Ml	[illegible]	0,3%	2
Água Para Preparações Injectáveis Sol Inj Fr 10 ml Nesp	-	0,3%	326
Atropina 0.5 Mg/1 ml Sol Inj Fr 1 ml Im IV Sc	-	2,7%	785
Brometo de Rocurónio 10 Mg/Ml Sol Inj Fr 5 ml Iv	-	1,1%	222
Cetamina 500 Mg/10 ml Sol Inj Fr 10 ml Im Iv	-	0,5%	7
Cetorolac 10 Mg/1 ml Sol Inj Fr 1 ml Im Iv	-	2,4%	532
Cetorolac 30 Mg/1 ml Sol Inj Fr 1 ml Im Iv	-	0,5%	113
Cloreto de Sodio 9 Mg/Ml IV Amp 10 ml	-	1,2%	1754
Cloreto de Sodio 9 Mg/Ml Lavagem 500 ml	-	2,2%	464
Cloreto de Sodio 9 Mg/Ml Sol Inj Fr 100 ml Iv	-	1,4%	806
Dexametasona 4 Mg/1 ml Sol Inj Fr 1 ml	-	1,2%	321
Dexametasona 5 Mg/1 ml Sol Inj Fr 1 ml Im IV Sc	-	1,4%	357
Efedrina 50 Mg/1 ml Sol Inj Fr 1 ml Im IV Sc	-	1,7%	98
Esomeprazol 40 mg Pó Sol Inj Fr Iv	-	0,3%	33
Esponja de Gelatina Hemostática Standard	-	0,4%	51
Fentanilo 0.05 Mg/Ml Sol Inj Fr 2 ml Iv	-	1,2%	341
Frac. 1ml Sevoflurano Liq. Inal. Vaporizador	-	23,1%	649
Frac. 5 ml Clorohexidina 2% + Álcool Isopropílico 70%	-	0,3%	615
Frac. 5 Removedor de Adesivo Silicone	-	0,3%	192
Frac. 50 ml Clorohexdina 2% + Álcool Isopropilico 70% Sol Co	-	0,5%	295
Gel Lubrificante Unidose 5g (Ky)	-	0,4%	220
Glucose 50 Mg/Ml + Cloreto de Sódio 9 Mg/Ml Sol Inj Fr 500 M	-	0,7%	167
Hidrocortisona 100 mg Pó Sol Inj Fr Im Iv	-	1,1%	235
Lidocaína 20 Mg/G + Cloro-Hexidina 0.5 Mg/G Gel Uret Ser 11m	-	0,5%	52
Lidocaína 25 Mg/G + Prilocaína 25 Mg/G Pens Impreg Saq	-	1,0%	256
Midazolam 15 Mg/3 ml Sol Inj Fr 3 ml Im IV Rectal	-	0,8%	466
Morfina 10 Mg/1 ml Sol Inj Fr 1 ml Epidural Im It IV Sc	-	1,3%	193
Ondansetrom 2 Mg/Ml Sol Inj Fr 2 ml Iv	-	0,3%	282
Paracetamol 10 Mg/Ml Sol Inj Fr 100 ml Iv	-	1,3%	659
Parecoxib 40 mg Po Sol Inj Fr Im Iv	-	0,3%	16
Penso/Película Silicone N Aderente 9x10cm	-	0,8%	72
Polielectrol Sol Inj Fr 500 ml Iv	-	1,8%	462
Propofol 10 Mg/Ml Emul Inj Fr 20 ml Iv	-	1,7%	550
Propofol 20 Mg/Ml Emul. Injectável Seringa 50ml Iv	-	1,9%	66
Propofol 20mg/Ml Emul Inj Fr.50ml Iv	-	1,7%	109
Proteínas Coagulantes Cola Tecido Seringa 4 ml	-	6,6%	11
Remifentanilo 1 mg Pó Sol Inj Fr Iv	-	0,7%	130
Remifentanilo 2 mg Po Sol Inj Fr Iv	-	0,3%	70
Ropivacaina 7,5mg/Ml IV Amp 20 ml	-	0,4%	38
Sacarose, Solução 24% , Copo 11ml	-	1,2%	501
Sugamadex 100mg/Ml Sol Inj Frsc 2ml	-	27,8%	184

Figure C.10: Surgery objects of cost and cost distribution - Medicines

Table C.3: Total medicines weighted percentage in the activity cost pathway

Assistance Area	% Personnel Cost	% Total Cost	% Personnel Cost Weighted
Surgery	3.2%	90.97%	2.9%
Outpatient Consultation	0.0%	4.03%	0.0%
Emergency Care	2.0%	0.64%	0.01%
Hospitalization	11.7%	3.03%	0.4%
Clinical Pathology	0.0%	0.16%	0.0%
Imaging Exams	1.1%	0.19%	0.0%
CDTM	0.7%	0.99%	0.0%
Total		100%	3.3%

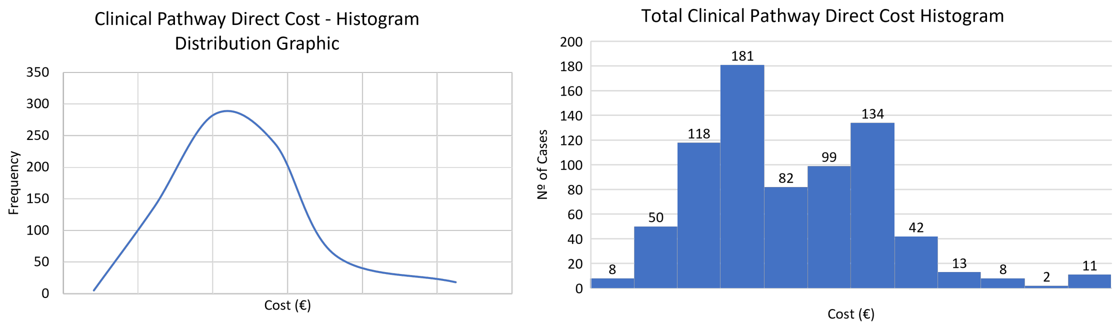

Figure C.11: Histogram cost distribution of the total clinical pathway

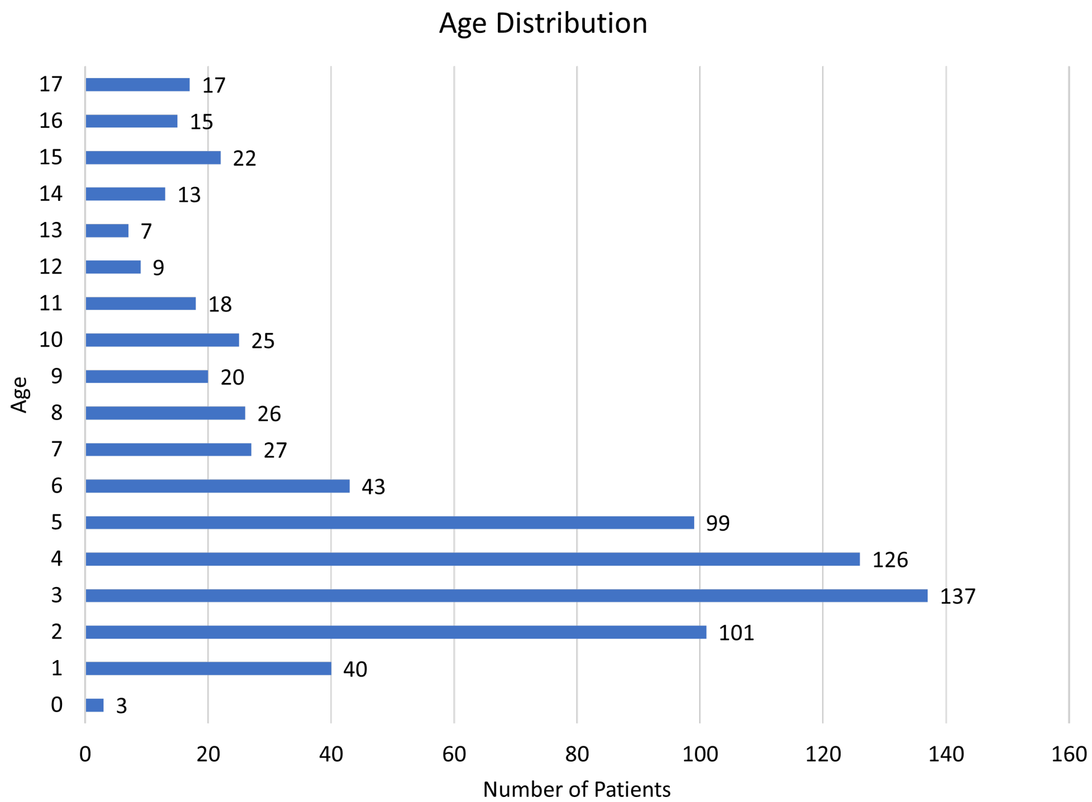

Figure C.12: Patients age distribution

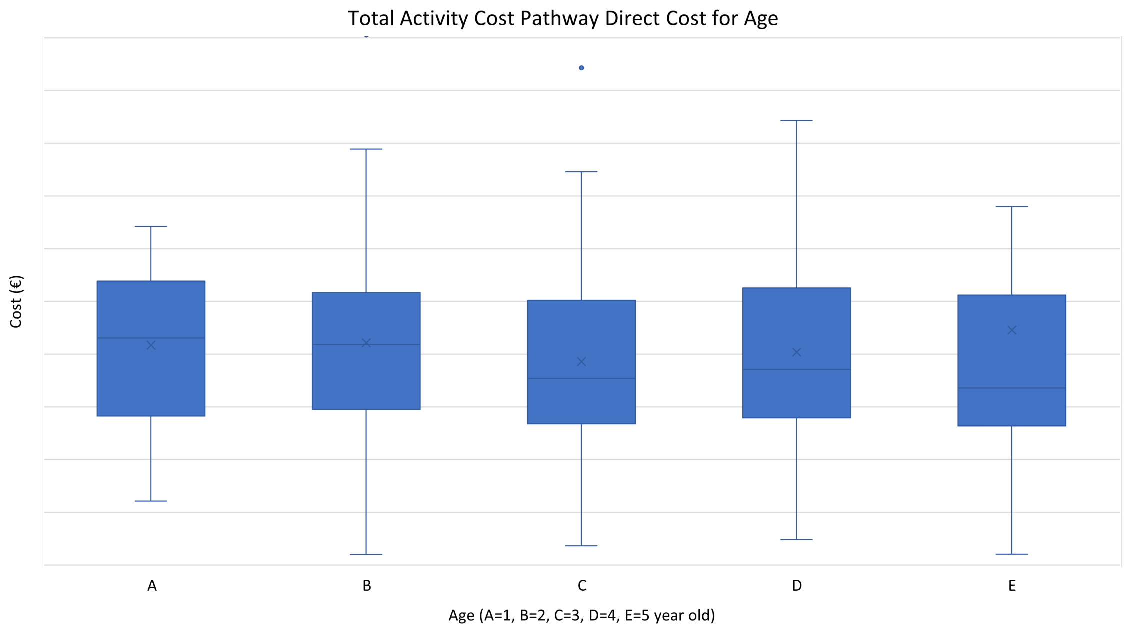

Figure C.13: Direct cost of the total activity cost pathway for age

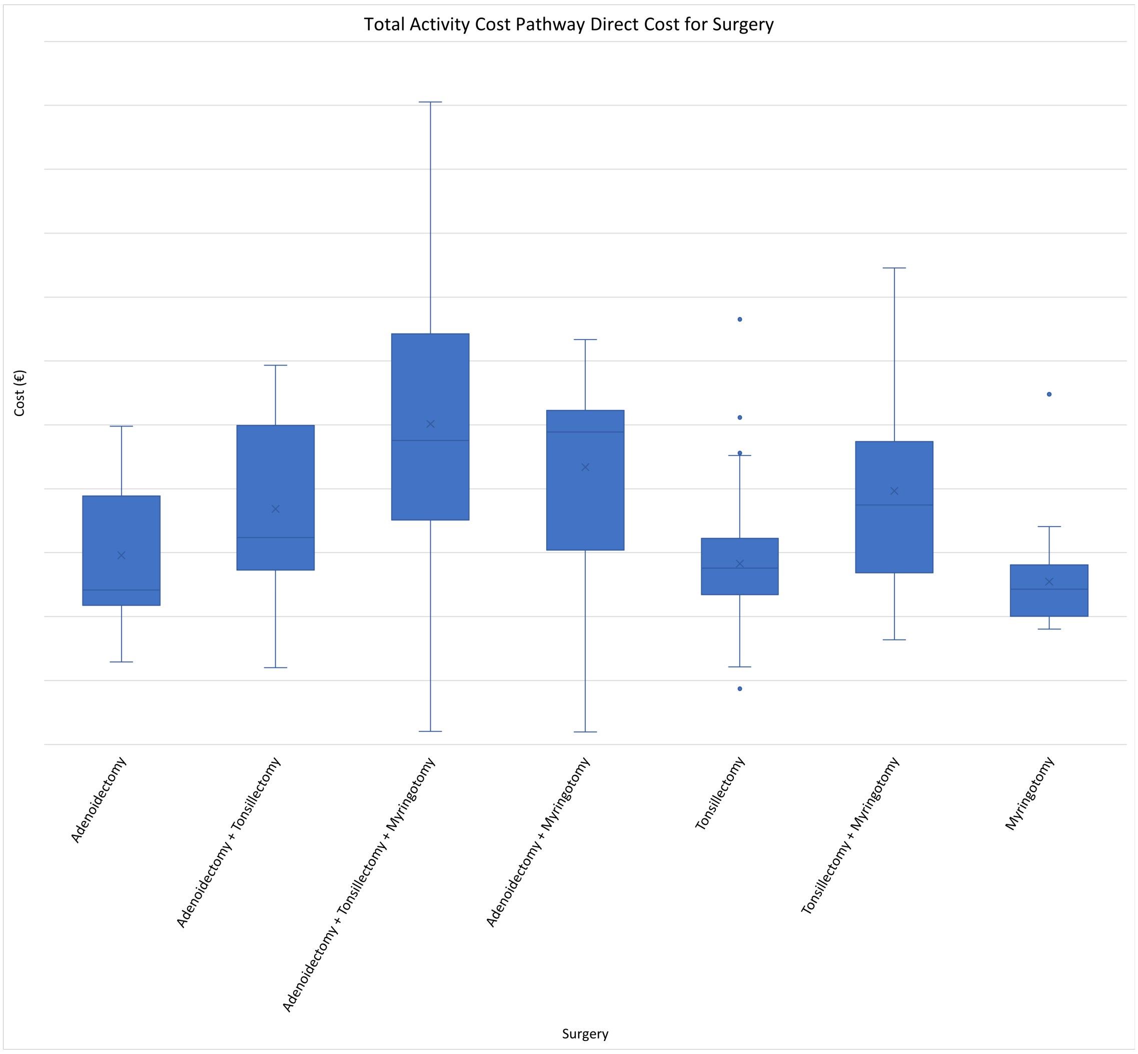

Figure C.14: Direct cost of the total activity cost pathway for the most five performed surgeries

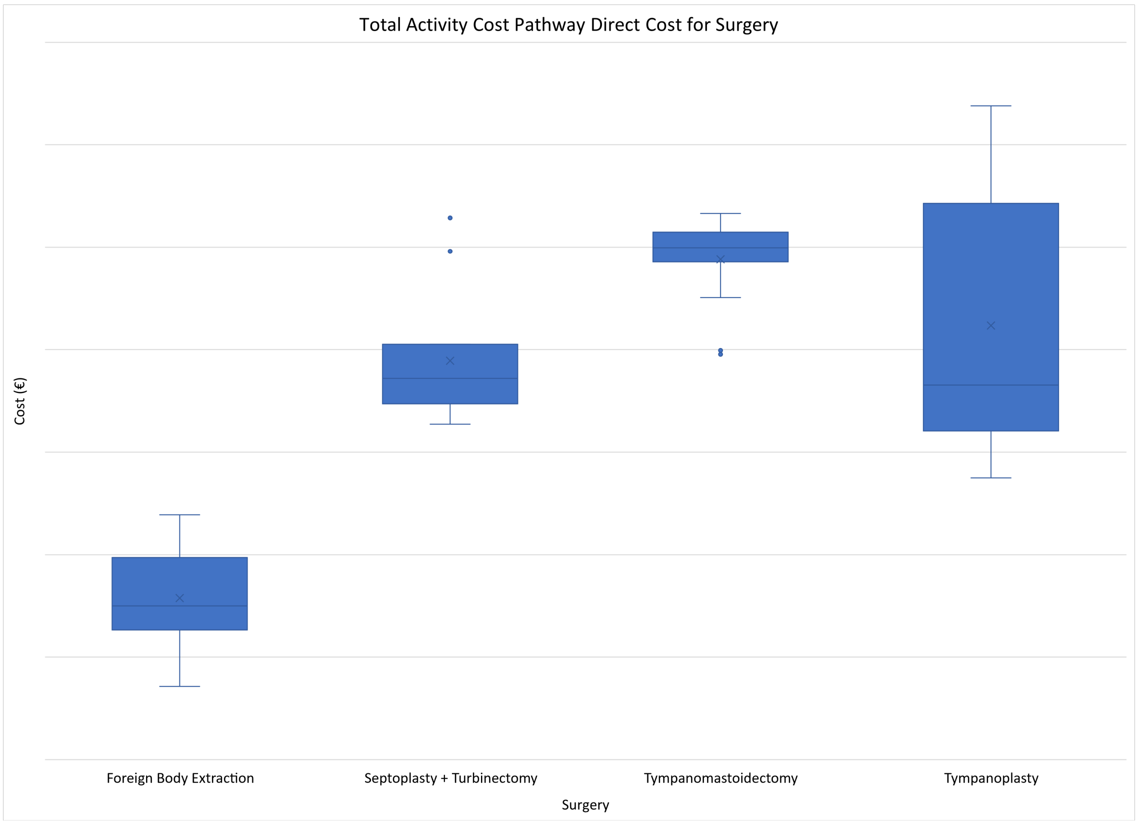

Figure C.15: Direct cost of the total activity cost pathway for the most performed surgeries

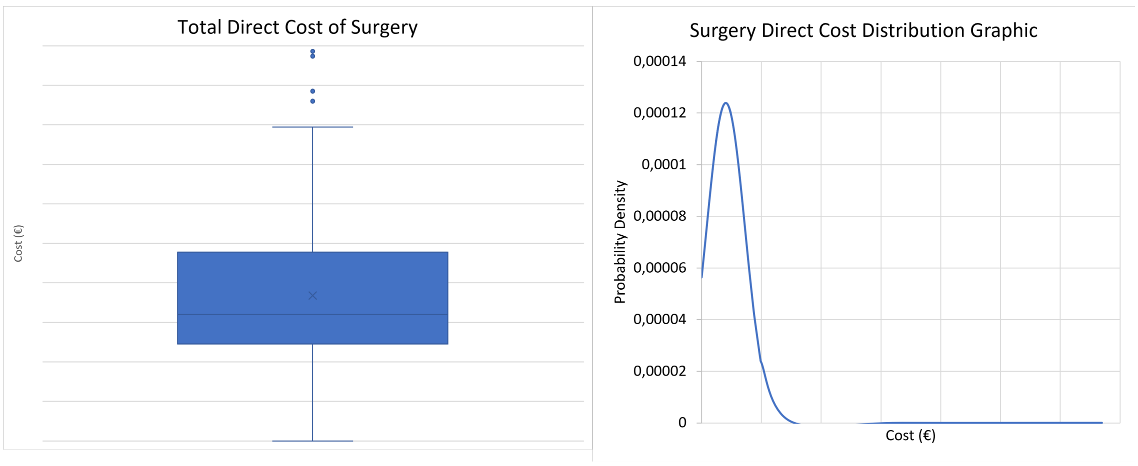

Figure C.16: Surgery total direct cost and distribution graphic

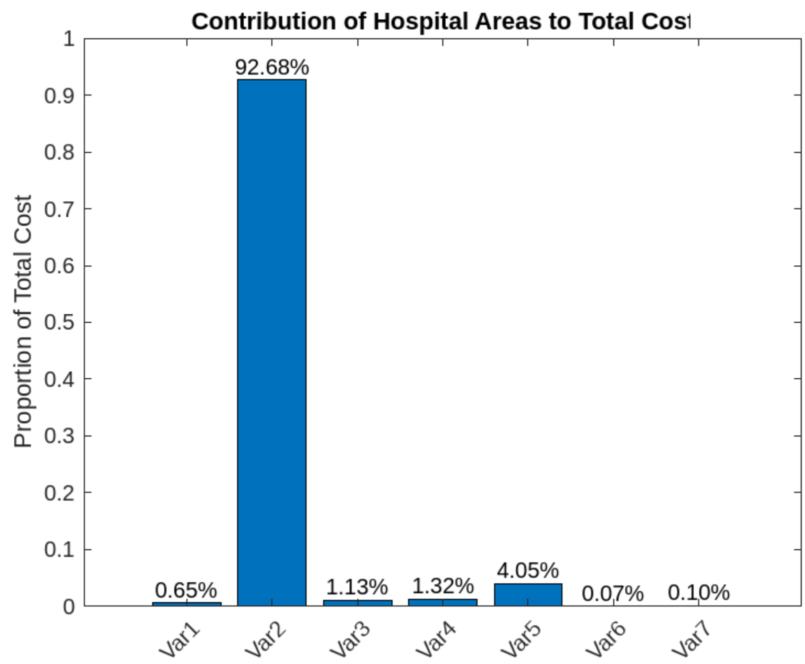

Figure C.17: Hospital Areas proportion of total cost distribution for the group of the three surgeries - Var1:Emergency care, Var2: Surgery, Var3: CDTM, Var4: Hospitalization, Var5: External Consultation, Var6: Imagiology, Var7: Clinical Pathology.

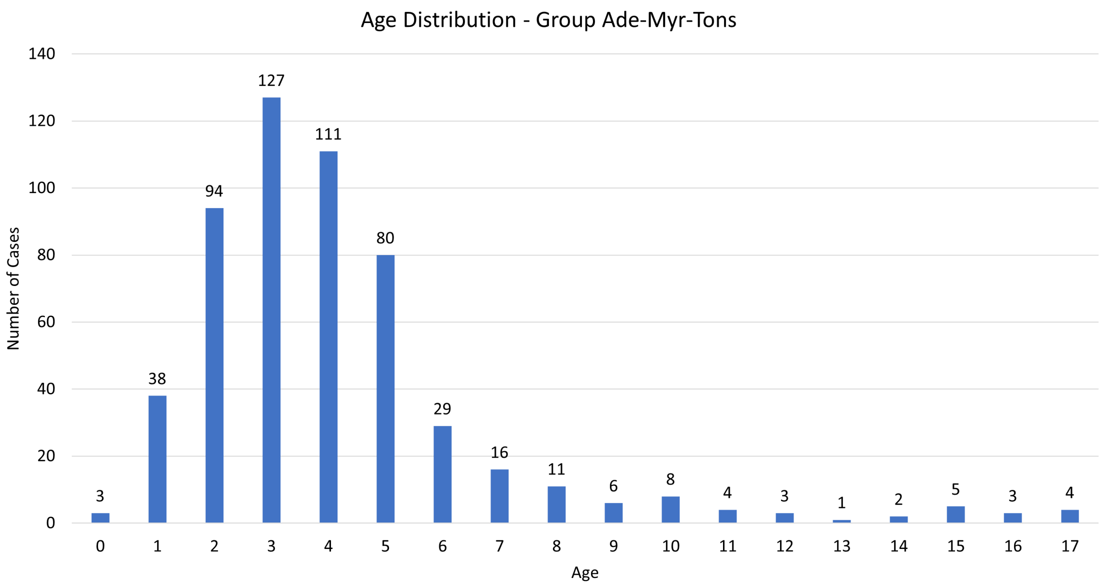

Figure C.18: Patients age distribution for the group of the three surgeries

Surgery Procedure	A	B	C	D	E	F	G
Adenoidectomy	0%	1%	3%	9%	3%	3%	13%
Adenoidectomy + Tonsillectomy	30%	25%	18%	9%	40%	11%	26%
Adenoidectomy + Tonsillectomy + Myringotomy	17%	21%	21%	4%	23%	19%	3%
Adenoidectomy + Myringotomy	46%	38%	47%	0%	33%	51%	18%
Tonsillectomy	5%	6%	8%	48%	3%	3%	26%
Tonsillectomy + Myringotomy	0%	1%	0%	4%	0%	8%	5%
Myringotomy	2%	8%	3%	26%	0%	5%	8%

Figure C.19: Surgery procedure distribution for surgeon

Surgery Procedure	Average Cost (€)
Adenoidectomy	--72,6
Adenoidectomy + Tonsillectomy	--44,6
Adenoidectomy + Tonsillectomy + Myringotomy	--67,3
Adenoidectomy + Myringotomy	--44,7
Tonsillectomy	--24,6
Tonsillectomy + Myringotomy	--86,1
Myringotomy	--19,9

Figure C.20: Average cost for surgery procedure: adenoidectomy, myringotomy and tonsillectomy

Surgery Combination	Surgery Average Cost (€)
Drainage	**68,7
Abscess Drainage + Endonasal Microsurgery	**86,3
ectomy	**72,6
Adenoidectomy + Lingual Brake Plasty	**60,8
ectomy + Tonsillectomy	**44,6
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery	**22,6
Adenoidectomy + Tonsillectomy + Myringotomy	**67,3
ectomy + Turbinectomy	**65,5
Adenoidectomy + Endonasal Microsurgery	**63,0
Adenoidectomy + Endonasal Microsurgery + Septoplasty	**57,1
Adenoidectomy + Microcirurgia Endonasal + Myringotomy + Septoplasty	**63,5
ectomy + Myringotomy	**44,7
Adenoidectomy + Myringotomy + Turbinectomy	``96,6
Adenoidectomy + Myringotomy + Lingual Brake Plasty	**29,1
ectomy + Septoplasty	**85,1
Adenoidectomy + Tonsillectomy + Foreign Body Extraction + Lingual Brake Plasty	**88,6
Adenoidectomy + Tonsillectomy + Endonasal Microsurgery + Myringotomy	**32,6
Adenoidectomy + Tonsillectomy + Myringotomy + Lingual Brake Plasty	**93,1
Adenoidectomy + Tonsillectomy + Myringotomy + Turbinectomy	**29,6
Adenoidectomy + Tonsillectomy + Turbinectomy	**08,8
r Implant	**298,1
ision	**50,8
al Microsurgery	**20,8
Endonasal Microsurgery + Myringotomy	**40,5
Endonasal Microsurgery + Septoplasty	**16,2
Endonasal Microsurgery + Septoplasty + Turbinectomy	**97,3
3ody Extraction	**45,8
Foreign Body Extraction + Tympanoplasty	**58,8
3ody Extraction Nasal	**34,9

Surgery Combination	Surgery Average Cost (€)
Laryngeal Microsurgery	**26,6
Lingual Brake Plasty	**19,0
Lingual Frenectomy	**3,2
Mastoidectomy	**00,4
Microlaryngoscopy in suspension	**21,4
Myringotomy	**19,9
Myringotomy + Tympanomastoidectomy	**45,7
Nose Fracture Treatment	**41,1
Palatoplasty	**39,1
Ret.Tecid.Adjac.Reg.Frontal Face/Boca/Pesc/Axila/Gen/Mãos/Pés-10 Cm2	**16,6
Rhinoplasty	**73,0
Septoplasty	**75,4
Septoplasty + Turbinectomy	**89,8
Septum Nasal Drainage	**,9
Sublingual Gland Excision	**10,1
Tonsillectomy	**24,6
Tonsillectomy + Abscess Drainage	**06,4
Tonsillectomy + Endonasal Microsurgery	**49,9
Tonsillectomy + Endonasal Microsurgery + Septoplasty	**63,6
Tonsillectomy + Foreign Body Extraction	**71,1
Tonsillectomy + Myringotomy	**86,1
Tonsillectomy + Otoplasty	**68,3
Tonsillectomy + Palate Suture Laceration	**,3
Tonsillectomy + Turbinectomy	**54,9
Turbinectomy	**74,0
Tympanomastoidectomy	**62,6
Tympanoplasty	**21,6
Tympanoplasty + Turbinectomy	**88,8

Figure C.21: Average cost for surgery procedure

Type of Pathway	Percentage of Cases
1. Only Surgery	19%
2. External Consultation (EC) Before Surgery	6%
3. External Consultation (EC) After Surgery	3%
4. External Consultation After and Before Surgery	10%
5. Clinical Pathology (CP) (included external consultation)	4%
6. Hospitalization (including EC and CP)	5%
7. Emergency Care (including EC and CP)	11%
8. CDTM (including EC and CP)	20%
9. Hospitalization and CDTM (including EC, CP, Imagiology)	6%
Total Percentage of Pathways Studied	83%

Figure C.22: Clinical pathways percentage of case coverage

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	102	---498,6	--85,28	1322098
Column 2	31	---859,9	--98,707	1729510
Column 3	15	---00,56	--20,037	4169834
Column 4	54	---131,9	--87,629	1794240
Column 5	22	---61,39	--66,427	2374346
Column 6	28	---421,6	--07,913	3560886
Column 7	59	---821,3	--66,463	1751474
Column 8	109	---938,8	--67,329	2063102
Column 9	32	---008,4	--50,262	3225082

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1,52E+08	8	19040262	9,276462	7,52E-12	1,959303
Within Groups	9,09E+08	443	2052535			
Total	1,06E+09	451				

Figure C.23: ANOVA statistical test for the nine most common pathways

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	31	---859,9	--98,707	1729510
Column 2	15	---00,56	--20,037	4169834
Column 3	54	---131,9	--87,629	1794240
Column 4	22	---61,39	--66,427	2374346
Column 5	28	---421,6	--07,913	3560886
Column 6	59	---821,3	--66,463	1751474
Column 7	109	---938,8	--67,329	2063102
Column 8	32	---008,4	--50,262	3225082

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	29871801	7	4267400	1,881364	0,071713	2,036384
Within Groups	7,76E+08	342	2268249			
Total	8,06E+08	349				

Figure C.24: ANOVA statistical test for the most common pathways (without the only surgery path)

Group	x2	x3	x4	x5	x6	x7	x8	x9
x1	913.43	934.76	1202.35	681.15	922.63	1181.18	1482.05	1764.98
x2	0	21.33	288.92	232.28	9.21	267.76	568.62	851.56
x3	21.33	0	267.59	253.61	12.12	246.43	547.29	830.22
x4	288.92	267.59	0	521.2	279.72	21.17	279.7	562.63
x5	232.28	253.61	521.2	0	241.49	500.04	800.9	1083.84
x6	9.21	12.12	279.72	241.49	0	258.55	559.42	842.35
x7	267.76	246.43	21.17	500.04	258.55	0	300.87	583.8
x8	568.62	547.29	279.7	800.9	559.42	300.87	0	282.93

Figure C.25: Turkey statistical test for the nine most common pathways

Clinical Pathway Part	Average Cost (€)	Cost Distribution
Diagnosis Total Direct Cost	----	5%
Surgery Total Direct Cost	----	85%
Post-Op Total Direct Cost	----	5%
Follow-Up Total Direct Cost	----	5%
Total	----	100%

Figure C.26: Activity cost pathway components average cost

Clinical Pathway Part	Average Cost (€)	Cost Distribution
Diagnosis Total Direct Cost	----	5%
Surgery Total Direct Cost	----	87%
Post-Op Total Direct Cost	----	5%
Follow-Up Total Direct Cost	----	4%
Total	----	100%

Figure C.27: Activity cost pathway components average cost - adenoidectomy, myringotomy and tonsillectomy

ANNEX I

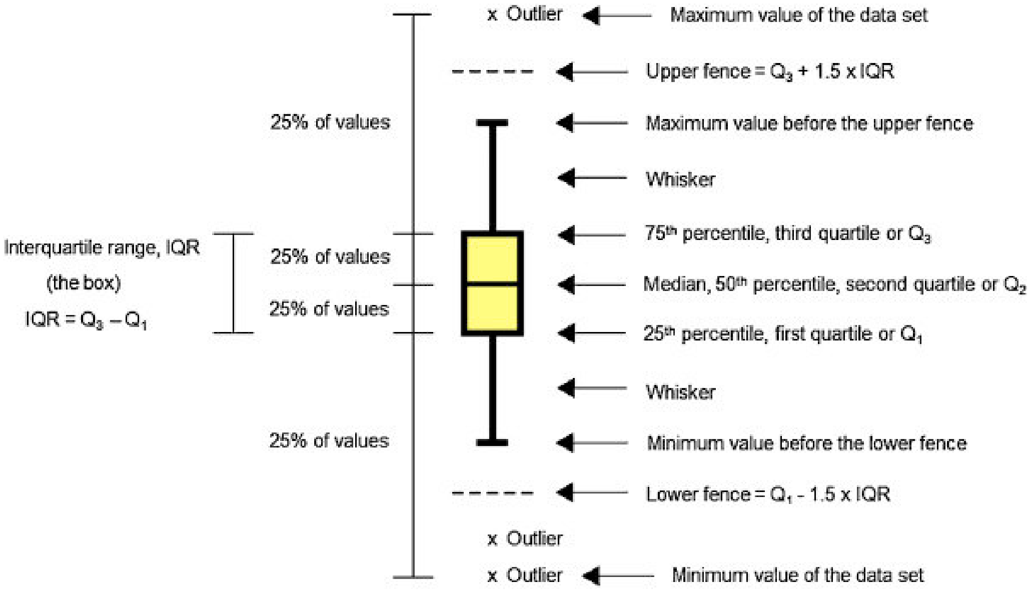

Figure I.1: Box and Whisker Charts illustration (Ferreira et al., 2016)